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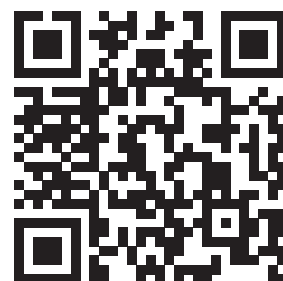
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Tuber Crop based Integrated Farming for Augmenting Livelihoods of Marginal Farmers in Meghalaya: A Success Story

Hammylliende Talang, Kamni P. Biam, M. B. Devi, H. Rymbai and S. Hazarika

Introduction

Tuber crops viz. colocasia, cassava, sweet potato, yam and elephant foot yam are the third most important food crops, after cereals and grain legumes. These crops are rich source of carbohydrate, proteins, minerals, vitamins, cellulose, antioxidants and dietary fibres and can help to mitigate hidden hunger through diet diversification. These crops do not require much care as there is little or no serious disease or insect damages and hence they are being preferred as risk aversion crops in the conventional farming system followed by tribal farmers. Besides tuber crops have wider adaptability to adverse soil and climatic conditions. Tuber crops are an integral part of dietary system of tribal of the region and are grown abundantly in their jhum land or kitchen garden as mixed cropping. Due to wider adaptability of these crops, they can be grown in the marginal soil on the hill slopes under the Jhum areas. It has been reported that crop diversification through cultivation of tuber crops viz. colocasia, cassava, sweet potato, elephant foot yam, taro etc. are very economic and sustainable in improvement of jhum land under Mizoram condition.

Problems: In north eastern hills region including Meghalaya, shifting cultivation or slash and burn agriculture is the most prevalent form of agricultural

practice of the ethnic people. However, recently with increase pressure on land resources, the jhum cycle is reduced (3-4 years only against suggested 15-20 years for sustainable land use practice), resulted in decline crop productivity, degradation of natural vegetation and drying of perennial water resources. Besides the land use issue, most of the farmers (about 85%) are small and marginal with land holding size, ranged between 0.32 to 0.57 ha. Undulating slope of small land hold by farmers, harsh climate and use of traditional implements and farm practices result in low productivity. This has become a major concern and calls for immediate attention in development of sustainable farming alternatives.

Interventions: Under the All India Coordinated Research Project (AICRP) tuber crops, tuber crops based integrated farming system model integrating tuber crops with other horticultural crops and animal components was initiated as demonstration unit in the land owned by Mr. Evarist Myrsing during 2020 to 2022. Vital inputs like planting materials of tuber crops (taro, sweet potato, cassava, elephant foot yam etc), piglets, vegetable seeds (summer and winter vegetables), fruit plants, agriculture lime, bio-pesticides, bio-fungicides, tools and implements (knapsack sprayer, water can and spade) were provided. Implementation of the tuber crops based

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Table 1: Cropping system economic return prior to intervention including farm revenue

Crops	Area (ha)	Yield (Kg)	Selling rate (Rs. kg ⁻¹)	Gross Income (Rs.)	Expenditure (Rs.)	Net Income (Rs.)	B:C
Cassava	0.04	500	25	12500	6845	5655	1.83
Soybean	0.03	200	20	4000	1500	2500	1.60
Ginger	0.02	500	20	10000	5542	4458	1.80
French Bean	0.01	150	20	3000	1645	1355	1.82
Cabbage	0.01	350	15	5250	1640	3610	3.20
Lemon	0.04	600	10	6000	3053	2947	1.97
Total	0.15	-	-	36750	18725	20525	1.79

Table 2: Economic return after intervention from different components at Nongrim Nongladaw

Particular	Area planted (ha)	Yield (kg)	Selling price kg ⁻¹ (Rs)	Gross income (Rs)	Expenditure (Rs)	Net Income	B:C
Colocasia	0.1	2315	20	46300	15000	31300	3.09
Sweet Potato	0.1	4210	10	42100	8000	34100	5.26
Tapioca	0.1	2472	10	24720	3500	21220	7.06
Soybean	0.01	154	20	3080	1200	1880	2.57
Ginger	0.03	520	20	10400	3500	6900	2.97
Brinjal	0.08	135	30	4050	1200	2850	3.38
Tomato	0.08	168	30	5040	2000	3040	2.52
Lemon	0.04	500	10	5000	2500	2500	2.00
Piggery	0.008	16 nos.	4000	64000	12000	52000	5.33
Total	0.58	-	-	222940	54390	168550	4.10

farming system model was carried out in close supervision by the team of scientists from ICAR Research Complex for NEH Region, Umiam. All the improved production technology of the different crops and animals were followed including field visit from time to time by the scientist team throughout the intervention period.



Fig. 1: Interventions introduced at the farmers field

Result: The land area available was divided into separate plot and tuber crops along with vegetables were grown successfully. Fruit viz., Assam lemon and litchi were grown near the fences and at the corner of the land piggery unit was established. With the intervention it was observed that net income from the farm increased to ₹ 1,68,550/- from the initial net income of ₹ 20,525/- with B.C ratio of 4.10 (Table 2) as against 1.79 (Table 1).



Advances in Breeding Techniques for Disease Resistant Fruit Varieties

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Abstract

The advancement of breeding techniques for disease-resistant fruit varieties has become one of the cornerstones of modern agriculture, helping to address the rising challenges of crop diseases and pest infestations that threaten fruit production worldwide. With growing concerns over food security, the environmental impact of pesticide use, and the economic consequences of crop losses, the need for disease-resistant fruit varieties is more pressing than ever. Traditional breeding methods, coupled with modern biotechnological tools, have paved the way for innovative approaches in the development of disease-resistant fruit crops. This article explores the various advancements in breeding techniques, including molecular breeding, genetic modification, and CRISPR/Cas9 gene editing, that have been instrumental in producing fruit varieties with improved disease resistance. The article also highlights the benefits and challenges associated with these techniques and their potential to revolutionize the future of fruit production.

Introduction

The global demand for fruits has been steadily increasing due to population growth, urbanization, and a heightened awareness of the health benefits of consuming fruits. However, fruit production is continuously threatened by numerous diseases caused by pathogens, fungi, bacteria, and viruses. Traditional pest and disease control methods often involve the use of chemical pesticides, which, while effective, raise concerns regarding environmental sustainability, human health, and economic costs. To overcome these challenges, breeding for disease resistance has become an essential strategy in

ensuring fruit crop sustainability and reducing dependency on harmful pesticides. Traditional breeding techniques, which have been used for decades, involve the selection of parent plants with desirable disease resistance traits. However, with advancements in molecular biology and genetic engineering, new approaches have emerged, offering more precise, faster, and more efficient methods for developing disease-resistant fruit varieties. This article delves into the recent advances in fruit breeding techniques, focusing on the role of molecular breeding, genetic modification, and CRISPR/Cas9 gene editing in enhancing disease resistance in

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fruits.

Traditional Breeding Techniques for Disease Resistance

Historically, disease-resistant fruit varieties have been developed through conventional breeding methods. This process involves selecting parent plants that exhibit resistance to particular diseases and cross-breeding them to create offspring with enhanced resistance. Over time, this approach has led to the development of several disease-resistant fruit varieties, including resistant cultivars of apples, grapes, and citrus. However, traditional breeding has limitations, particularly when it comes to introducing resistance to new or complex diseases, as well as the long time frame required for developing new varieties. Furthermore, the transfer of desirable disease-resistant traits can be hampered by genetic incompatibilities between species or varieties. Despite these limitations, traditional breeding remains a critical foundation upon which modern breeding techniques are built.

Molecular Breeding: A Modern Approach

Molecular breeding, also known as marker-assisted selection (MAS), has significantly advanced the development of disease-resistant fruit varieties. Unlike traditional breeding, which relies on the physical traits of plants, molecular breeding uses molecular markers to identify specific genes associated with disease resistance. By identifying these genetic markers, breeders can select plants with the desired disease-resistant traits more efficiently, without having to rely on phenotypic selection.

One of the major breakthroughs in molecular breeding was the identification of resistance genes for various pathogens, such as Powdery Mildew in grapes, Citrus Greening Disease (HLB) in citrus, and Fire Blight in apples. Marker-assisted selection has significantly shortened the breeding cycle and increased the precision of trait selection. For example, in apples, researchers have successfully identified genetic markers associated with resistance to apple scab, a major fungal disease. Using these markers, breeders can more quickly and accurately develop apple varieties with inherent resistance to this disease, reducing the need for chemical treatments and improving yield stability.

Genetic Modification (GM) for Enhanced Disease Resistance

Genetic modification (GM), also referred to as genetic engineering, involves the introduction of foreign genes into a plant's genome to confer specific traits, such as disease resistance. Unlike traditional breeding, which relies on the natural genetic variation within a species, GM allows for the targeted addition of genes that confer resistance to particular diseases. This technique offers the potential to introduce disease resistance from non-related plant species, providing access to a broader pool of genetic resources. One notable example of GM in fruit crops is the development of Papaya varieties resistant to the Papaya Ringspot Virus (PRSV). The introduction of a viral coat protein gene into the papaya genome has made it possible to develop varieties that can resist the devastating effe-

cts of PRSV, which had previously caused significant losses in papaya production. Similarly, genetically modified tomatoes with resistance to bacterial wilt and genetically engineered apples with resistance to Fire Blight have also been developed. These advances have not only improved crop resilience but also minimized the need for chemical pesticide applications, resulting in environmental and economic benefits. Despite its promise, genetic modification in fruit crops remains a controversial subject, with concerns over food safety, ethical considerations, and the potential for cross-species gene transfer. Regulatory frameworks in many countries are strict regarding the approval of GM crops, which has slowed their widespread adoption.

CRISPR/Cas9 Gene Editing for Precision Disease Resistance

In recent years, the CRISPR/Cas9 gene editing technology has revolutionized plant breeding, including in the development of disease-resistant fruit varieties. Unlike traditional genetic modification, which involves the insertion of foreign DNA, CRISPR/Cas9 allows for precise editing of the plant's own DNA. This means that genes responsible for disease susceptibility can be edited or knocked out without the introduction of foreign genes, thus reducing public concerns about genetic modification. CRISPR/Cas9 has been successfully used to edit the genomes of various fruit crops to enhance disease resistance. For example, researchers have utilized CRISPR/Cas9 to develop Citrus varieties resistant to Citrus Greening Disease, a bacterial disease that has

severely impacted the citrus industry worldwide. By editing genes involved in the disease's susceptibility, CRISPR/Cas9 has opened up new possibilities for creating disease-resistant varieties with higher precision and fewer unintended consequences. Another promising application of CRISPR/Cas9 in fruit breeding is the development of Grapes resistant to Powdery Mildew by targeting specific genes that control plant immune responses. The ability to edit genes in a highly targeted manner promises to accelerate the development of disease-resistant fruit crops, while also addressing some of the regulatory challenges associated with genetic modification.

Challenges and Ethical Considerations

While the advances in breeding techniques for disease-resistant fruit varieties offer immense potential, there are several challenges that need to be addressed. First, there is the issue of genetic diversity. Over-reliance on a small number of resistant varieties could lead to the development of new diseases or strains that overcome existing resistance. Therefore, it is essential to maintain genetic diversity in fruit crops to ensure long-term sustainability. Second, public perception and regulatory frameworks remain significant hurdles. Despite scientific evidence supporting the safety of genetically modified and gene-edited crops, many consumers and environmental groups are skeptical. Regulatory bodies in different countries have stringent approval processes for GM and CRISPR-modified crops, which can delay their commercial release. Lastly, the cost and accessibility of advanced

breeding technologies may limit their adoption, particularly in developing countries where farmers may not have the resources or expertise to adopt these techniques.

Conclusion

Advances in breeding techniques for disease-resistant fruit varieties, including molecular breeding, genetic modification, and CRISPR/Cas9 gene editing, hold tremendous promise for the future of fruit production. These technologies offer the potential to create more resilient crops that require fewer pesticides, thus reducing environmental impact and ensuring food security in the face of increasing global demand for fruits. However, these advancements must be approached carefully, considering both the benefits and the challenges involved. As research continues to progress, it is crucial to ensure that these techniques are used responsibly, taking into account ecological, economic and ethical considerations. The future of disease-resistant fruit breeding will likely involve a combination of traditional and modern techniques, leading to the development of more sustainable and resilient fruit varieties that can thrive in a changing agricultural landscape.

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Little Wild Gourd, *Momordica cymbalaria* at a Glance

Jegadeeswari V., P. Yasodha and K. R. Vijayalatha

Abstract

Karchikai (*Momordica cymbalaria*), the underexploited tuber belongs to the family cucurbitaceae with the habitat to Western and Eastern Ghats of India. The fruits and tubers are used in the traditional medicine and used as vegetable by the tribal farmers. Attacked by hadda beetle, cotton aphid, cucurbit fruit fly and yellow mosaic virus. This species is being conserved by farmers at the home province for ethnic usage as traditional knowledge.

Introduction

It is originated from tropical regions of India and South East Asia. It is found at Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra and Tamil Nadu. It is a trailing plant with large turnip shaped tuberous rootstock with slender, scandent, branched, striate stem. Plants exhibit monoecious sex form, bears white flower, anthesis between 11 and 12 am and produces symmetrical anthers. The plant is a perennial climber available only during the *kharif* and *rabi* season and at Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, and Tamil Nadu. It is reported as medicinal plant in India and various parts of plant are useful for treating the common ailments. Leaves can also be used as a leafy vegetable. Leaves are deeply cordate at the base, orbicular-reniform in outline and are obtusely lobed having five to seven lobes. Fruits measure 20 to 25 mm long and is pyriform having 8 sharp ridges and with base narrowed into curved peduncle which is dark green,

shaped and is about 4.6 mm long. Male flower is filiform, ebracteate, puberulous, about 5-30 mm long with pale yellow corolla and two stamens. Female flower is solitary on a peduncle of 28 mm length. Roots are perennial, woody and tuberous. It is dicotyledonous cross pollinated vegetable.

Nutritional properties

The nutritional and economic significance of this species is unexplored due to the lack of its popularity. It is the rich source of minerals mainly potassium (505.92 mg/100 g), calcium (73.57 mg/100 g), sodium (41.58 mg/100 g), zinc (2.76 mg/100g), iron (1.71 mg/100 g) and ascorbic acid (299.12 mg/100 g), total carotenoids (2.81 mg/100 g) and lycopene (1.86 mg/100 g). Tubers and leaves are also used for therapeutic uses as these contain flavonoids, steroids, triterpenes, saponins. Tubers have been reported to contain sterols, triterpenes, cardiac glycosides, and saponins. This can act as a weapon against malnutrition and hunger.

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Bioactive properties: Tubers and leaves are also used for therapeutic uses as these contain flavonoids, steroids, triterpenes, saponins. Tubers have been reported to contain sterols, triterpenes, cardiac glycosides, and saponins. This can act as a weapon against malnutrition & hunger. Fruit pulp, leaf juice and seeds possess antihelminthic activity. The roots of *M. cymbalaria*, shown antidiabetic activity in presence of an oleanane type triterpenoid saponin. Plant is having the pharmacological activities like Antidiabetic, hypolipidemic, antidiarrhoeal, anti-ulcer, protective effect, anticancer, anticonvulsant, antiinflammatory, antiovaratory, abortifacient, antimicrobial and antioxidant properties. The ascorbic acid content of *M. cymbalaria* two times higher than that of bitter melon, this is of interest, where there is shortage in Vitamin C consumption. The content of potassium in *M. cymbalaria* is also two times higher than in *M. charantia*. Plants belonging to *Momordica* species have been used as therapeutic agents for the treatment of diabetes mellitus. The other species of this genus, *Momordica charantia* and *Momordica foetida* have been reported to have hypoglycaemic effects.

Health benefits: *M. cymbalaria* fruits were considered as tonic, stomachic, stimulant, laxative and alterative. The fruits are useful in treating gout, rheumatism and sub-acute cases of the spleen and liver disease. It has also been shown to have hypoglycaemic properties in animal studies. The fruits juice and leaf tea of *M. cymbalaria* is employed for diabetes, malaria, colic, sores and wounds,

infections, worms and parasites as an emmenagogue, and for measles, hepatitis, and fevers. Root is astringent, abortifacient, aphrodisiac and also used to treat constipation, indigestion, diabetes, diarrhoea and rheumatism. *Momordica cymbalaria* prevent alterations in marker enzymes of myocardial infection and oxidative stress with uric acid. *M. cymbalaria* displayed normal myofibrillar structure with striations and exhibited marked protection by an extract against myocardial necrotic damage. Isoproterenol increases LDL cholesterol and decreased HDL cholesterol levels in the serum which increases the chances of myocardial infarction.

Uses

Against microbes: *Momordica cymbalaria* has chloroform, petroleum ether, aqueous and ethanol extracts which inhibits the effect of *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumonia*, *Aspergillus niger* and *Pseudomonas aeruginosa* in comparison to standard antibiotics. It indicates that it is effective to prevent these organisms.

Against cancer: The methanol extract of aerial parts of *M. cymbalaria* (200 mg kg⁻¹ of body weight) has been showed significant anticancer activity as compared to standard cyclophosphamide.

Against diarrhea: The extract had a similar activity as that of anti-diarrhoeal drug diphenoxylate. The methanol extract of *M. cymbalaria* (MEMC) significantly inhibited the prostaglandin E2 (PGE2) induced intestinal fluid accumulation (enter pooling). It has been shown that E type of prostaglandin cause diarrhoea in experimental animals as

well as human beings. Their mechanism has been associated with dual effects on gastrointestinal motility as well as on water and electrolyte transport.

Hepatoprotective property: Ethanolic extract of tubers of *Momordica cymbalaria* reported the antioxidant and hepatoprotective properties. The radical forms covalent bonds with sulfhydryl group of several membrane molecules like reduced glutathione leading to this depletion and causes lipid peroxidation. The lipid peroxidation initiates a cascade of reactions leading to tissue necrosis. The antioxidant property of ethanolic extract of tubers of *Momordica cymbalaria* prevented the formation of trichloromethyl peroxy radical there by reducing tissue damage.

Against Ulcer: The aqueous extract of *Momordica tuberosa* is proved to have anti-ulcer property. The reduction in non-protein sulfhydryls concentration, gastric content, haemorrhage and ulceration suggested that the anti-ulcer activity of the aqueous extract of *Momordica cymbalaria* is due to the presence of polyphenolic constituents.

Nephroprotective activity: Tubers of *Momordica cymbalaria* possesses marked nephroprotective activity and could have promising role in the treatment of acute renal injury induced by nephrotoxins. This activity may be attributed to its antioxidant property.

Against diabetes: Alcoholic extract of *M. cymbalaria* has significantly decreased the serum glucose level in both normal and streptozotocin (STZ) / nicotinamide induced type II diabetics. Oral

administration of alcoholic extract of *M. cymbalaria* showed significant regression of the diabetic state and restored the deranged serum glucose, cholesterol, triglycerides, serum insulin and HDL parameters in STZ induced type II diabetes.

Soil and Climate: Sandy loam soils rich in organic matter with good drainage and pH range of 6.5-7.5 is suited for bitter melon cultivation. The plant is a perennial climber available only during the *Kharif* and *Rabi* season. This crop requires a moderate warm temperature. These fruits are produced only in rainy season. This is also the plant that does not rot in heavy rains. Generally June month is considered ideal for planting.

Propagation: They were propagated by round oval seeds with hypogeal germination. Tubers also used for multiplication of plants. The tubers sprout after the onset of monsoon and undergoes dormancy during summer dry periods. Seeds are black in color, shiny and are hard, so generally seeds are not used for propagation, because the rate of germination is very less. This can be overcome by in vitro approach through plant regeneration by organogenesis and somatic embryogenesis. To achieve this, tissue culture system for plant regeneration was established. Tissue culture techniques can be useful for mass propagation by using different explants. Protocols were developed for in vitro cultures of *Momordica cymbalaria* from seeds, root tubers, leaf, internode, and fruit explants. Tissue culture techniques can be useful for mass propagation by using different explants.

Fertilizers: Apply 10 kg of FYM per pit (20 t ha^{-1}) 100 g of NPK 6:12:12 pit^{-1} as basal and 10 g of N pit^{-1} 30 days after sowing. Apply Azospirillum and Phosphobacteria 2 kg ha^{-1} and Pseudomonas @ 2.5 kg ha^{-1} along with FYM 50 kg and neem cake @ 100 kg before last ploughing.

Pests: Hadda beetle, cotton aphid and cucurbit fruit fly are the major pests seen and yellow mosaic virus is found to be the important disease transmitted to subsequent seasons through infected tubers.

Harvest: The plant produces tuberous roots and ribbed fruits as the economical parts. Maximum fruit yield of 500 kg ha^{-1} were obtained.

Conclusion

Exploitation of genetic resource and their diversification by surveying and collection ecotypes, genetic improvement and breeding for sustainable and commercial cultivation of the minor vegetable is essential to exploit the vegetable for future.

Management of Bhendi Shoot and Fruit Borer, *Earias vitella* F., (Noctuidae: Lepidoptera)

P. Yasodha, V. Jegadeeswari and K. R. Vijayalatha

Bhendi, *Abelmoschus esculentus* L., is widely grown in Asia. India ranks first in its production. A total of 130 species of shoot and fruit borer were so far identified worldwide and found to attack many crops especially Malvaceae family. Shoot and fruit borer, *Earias vitella* Fab., Noctuidae: Lepidoptera is the most noxious and destructive pest. Initially caterpillar gain entry into growing shoot tip then bud, flower and developing fruits. Consequently, there is dropping and drying of growing tips. The infested shoot die, the buds, flowers, fruits drop prematurely and affected fruits becomes unfit for human consumption and fetch low market value. This pest causes 40-50% damage of fruit in some areas of south-east Asian countries. In India, the damage due to this pest is up to 35% of the total harvested yield. Chemical control measures for controlling insect pests in the field is the most common approach. However, their massive overuse and frequent misuse has led to problems like developing of insecticidal resistance, resurgence of secondary pests, elimination of natural enemies of pest, residual toxicity hazards to human beings, plants, domestic animals and wild life, contamination of soil, water and food chain and wholesome pollution of environment. Hence, an effective, environmentally safe, ecofriendly and bio-intensive

control measures which may keep the crop pest below ETL is the need of the hour. Need based chemical insecticide may be recommended for management.

Symptoms of damage

- ✓ Terminal shoots wither and droop
- ✓ Shedding of buds and flowers
- ✓ Bore hole in fruits and fee
- ✓ Deformed fruits

Identification of pest

There are two species which commonly attacks, bhendi. The more common one is *E. vitelli* and *E. insulana*.

Earias vitella

Egg: Sculptured egg and sky blue in colour.

Larva: Brownish with white streaks dorsally and pale yellow ventrally.

Adult: Forewing are pale with a wedge shaped green band in the middle.



E. vitella larva and adult Eggs of *E. vitella* on fruit

Adult: Forewing are pale with a wedge shaped green band in the middle.

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E. vitella larva feeding on fruit

Insecticide	Quantity (ml or g lit ⁻¹)
Azadirachtin 0.03% WSP (300 ppm)	5.0 g lit ⁻¹
Azadirachtin 5% Neem Extract Concentrate	5.0 ml per 10 lit
Buprofezin 70 DF	5.5 ml per 10 lit
Emamectin benzoate 5 % SG	3.0 g per 10 lit
Malathion 50EC	3.3 ml per 10 l.
Pyridalyl 10 % EC	1.0 ml lit ⁻¹
Quinalphos 20 AF/td>	1.5 ml lit ⁻¹
Quinalphos 25 % EC	8.0 ml per 10 lit



Adult

Symptoms of damage

E. insulana

Larva: Brown with dorsum showing a white median longitudinal streak

Pupa: Brown and boat shaped

Adult: Forewing are uniformly silvery green

Integrated Management Practices

- ✓ Set up pheromone trap @ 12 ha⁻¹.
- ✓ Collection and destruction of affected fruits.
- ✓ Release of egg parasite *Trichogramma chilonis* @ 1.0 lakh ha⁻¹.
- ✓ Release of 1st instar larvae of green lacewing predator, *Chrysoperla zastrowi* @ 10,000 ha⁻¹.
- ✓ Dust carbaryl 10 % DP @ 25 kg ha⁻¹ or spray *Bacillus thuringiensis* @ 2 g lit⁻¹ or spray any one of the following insecticide.

Celery: A Medicinal Plant of The Nilgiris District

Jegadeeswari, V., K. R. Vijayalatha and P. Yasodha

Introduction

The green leaves and stalk are extremely rich in mineral, vitamins and nutrients that make celery an important medicinal plant. It also contains a good concentration of plant hormones and essential oils that give celery its strong and



characteristic smell. These oils have a specific effect on the regulation of the nervous system with their tranquilizing properties. The seeds of celery relieve flatulence, increase the secretion and discharge of urine and act as an aphrodisiac. They are also used as a tonic, laxative and stimulant. Celery is useful in the treatment of arthritis, rheumatism and gout, nervous afflictions, blood disorders, respiratory disorders, indigestion, kidney and gall stones and insomnia. In the international market, there is a high demand for the celery seed oil in the pharmaceutical industry.

Preferred soil: The plant prefers a deep, fertile, well drained soil with high organic matter and a pH of 5.2 to 6.5. In acid soils where the pH is less than 4, application of dolomite 2.5 t ha^{-1} should be done two months before planting.

Climate: The ecological conditions prevailing in the Nilgiris are well suited for Celery cultivation. Celery is a cool weather crop and prefers moist climate for its growth and establishment. It thrives well when

cultivated at a temperature range of 10°C to 30°C .

It can be grown from 900-2500 m above MSL. Hilly regions are best suited for its cultivation.

Season: It can be cultivated throughout the year in all the three seasons namely main (April-June), autumn (August-October) and irrigated (February-April) in the Nilgiris.

Propagation: It can be propagated by seeds. The seeds are sown in rows in raised nursery bed. The seedlings are ready for transplanting 75 days after sowing.

Seed rate: The seed rate is 1.25 kg ha^{-1} and 100 m^{-2} nursery area is essential for one ha area. The seeds are sown in rows in nursery after treating with 3% panchagavya solution. Nursery beds of 1m width, 15 cm height and convenient length is preferred. 20 kg of FYM, 10 kg of Biodynamic compost, 5 kg of Vermicopost, 200 g VAM, 200 g Azospirillum and 200 g Phosphobacteria should be applied per square metre area. The seeds are broadcasted evenly in the nursery bed after mixing with 10 parts of sand. The seeds germinate three weeks after sowing and the crop duration in the nursery is 75 days.



Land preparation: The field should be prepared to a fine tilth and organic manures viz., Farm yard manure 30 t ha^{-1} , Biodynamic compost 5 t ha^{-1} , Ver-

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micompost 5 t ha⁻¹, Azospirillum 10 kg ha⁻¹, Phosphobacteria 10 kg ha⁻¹, VAM 10 kg ha⁻¹, Neem cake 1.25 t ha⁻¹, *Trichoderma viride* 2.5 kg ha⁻¹, *Pseudomonas fluorescens* 2.5 kg ha⁻¹ and *Metarrhizium anisopliae* 10 kg ha⁻¹ should be incorporated in the soil before planting. The soil should be sprinkled with horn manure 75 g ha⁻¹ and 1.5 kg of cow pat pit by dissolving in 40 litres of water.

Planting: Planting should be done during the rainy season. The seedlings are transplanted at a spacing of 45 x 15 cm.



Irrigation: Celery requires regular and frequent irrigation. The root system is shallow and it cannot tolerate dry weather. Hence frequent irrigation at weekly intervals is essential for the good establishment of the crop.

After cultivation: It is necessary to keep the field free from weeds. About 4-5 weeding is essential to encourage good growth of the crop.

Growth promoters

- ✓ Foliar spraying of panchagavya @ 3 per cent four times at 15 days interval after planting
- ✓ Spraying 10% vermiwash four times at fortnight intervals before harvesting.
- ✓ Foliar spraying of dasagavya @ 3 per cent four times at fortnight intervals before harvest.
- ✓ Foliar spraying of 5% Manchurian tea extract 3 times at fortnight intervals.

Pests and diseases: Aphids, armyworm, cutworms

are the common pests seen. Leaf spot and root rot are the common diseases.

Harvest: The crop will be ready for harvest at 115 days after transplanting. The outside stalks may be used for the preparation of soup and the inner stalks are more tender and tasty.



Yield: The average yield is 30.5 t ha⁻¹.

Precision Agriculture: The Smart Farming Revolution

P. Sangameshwari

Abstract

Precision agriculture (PA) involves the use of advanced technology to help farmers manage their fields with greater accuracy and efficiency. Its primary goal is to enhance profitability, promote sustainability, and protect the environment. Often referred to as satellite agriculture, as-needed farming, or site-specific crop management (SSCM), PA relies on specialized equipment, software, and IT services to achieve these objectives. This innovative approach ensures that crops and soil receive precisely what they need to maintain optimal health and productivity. By automating and streamlining the collection and analysis of data, precision agriculture enables farmers to make informed management decisions that can be swiftly implemented, even in small sections of larger fields. With advancements in agricultural technology, precision farming holds the potential to significantly boost productivity. It is estimated that a single farmer can eventually feed up to 265 people using the same acreage. The approach allows for more efficient use of essential inputs like fertilizers, pesticides, tillage, and irrigation water. This not only improves crop yields and quality but also reduces environmental pollution. In today's context of rising input costs, declining commodity prices, and growing environmental concerns, both farmers and policymakers are seeking ways to improve efficiency, reduce costs, and adopt sustainable agricultural practices. Despite some challenges associated with precision farming, there is great optimism that this technology will offer substantial benefits to farmers who embrace it, ensuring a more sustainable and productive future for agriculture.

Introduction

Precision agriculture is a modern farming system that uses technology to boost long-term productivity, efficiency, and profitability while protecting the environment and wildlife. It focuses on doing the right thing at the right place, in the right way, and at the right time. By combining advanced tools like GPS and GIS, precision agriculture enables farmers to manage their fields more effectively and sustainably. This approach relies on scientific methods and knowledge to optimize agricultural

resources, reduce pollution, and promote sustainable farming. Here are some of the key technologies and methods used in precision agriculture:

- ✓ Predicting and monitoring crop yields using advanced technology.
- ✓ Sensors to measure field conditions like soil health, moisture, and nutrients.
- ✓ Remote sensing with satellite imagery to identify and solve field issues.
- ✓ Decision-support software for better farm management.

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- ✓ Robotics for precise application of fertilizers, pesticides, and seeds.

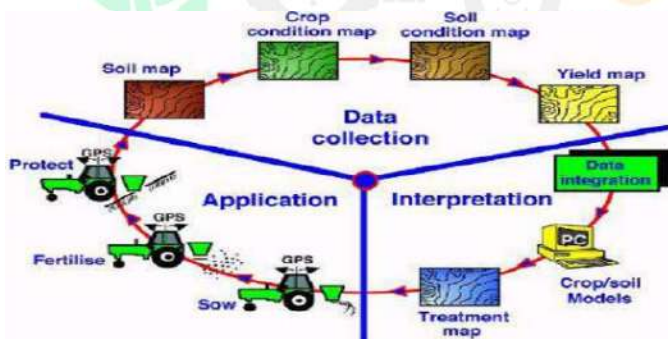
Understanding Field Variability and Site-Specific Nutrient Management

Field conditions often vary significantly, even within a single farm:

Variability within fields: Crop growth tends to be better near waterways and flat areas of the field. In contrast, sloped areas where erosion has depleted the topsoil often suffer from moisture stress and reduced plant growth.

Yield differences: It's important to note that achieving the same yield across all areas of a field is not always realistic.

Traditional knowledge: Historically, farmers relied on years of trial and error to develop a mental map of how to manage different areas of their fields.



Precision Agriculture's Contribution

Precision agriculture revolutionizes this process by automating and simplifying data collection and analysis. This technology enables farmers to make informed, site-specific management decisions that can be quickly applied to targeted areas of a field, maximizing efficiency and productivity.

Site-Specific Nutrient Management (SSNM)

SSNM is a plant-focused approach designed to ensure crops receive the right nutrients at the right time and in the right amounts. Key aspects of SSNM include:



Universal principles: The approach provides guidelines that can be applied to various farming contexts.

Optimal nutrient application: Farmers are guided on how to manage nitrogen (N), phosphorus (P), and potassium (K) effectively to meet crop needs.

Timely nutrient delivery: Essential nutrients are supplied as needed throughout the growing season, ensuring crops are adequately nourished.

Seasonal and location-based strategies: SSNM provides tools to help farmers determine when and how much fertilizer to apply, tailored to the specific conditions of their rice fields and the growing season. By combining SSNM with precision agriculture, farmers can improve crop yields, reduce resource waste, and adopt sustainable farming practices.

Right product: Match the fertilizer product or nutrient source to crop needs and soil type to ensure balanced supply of nutrients.

Right rate: Match the quantity of fertilizer applied to crop needs, taking into account the current supply

of nutrients in the soil. Too much fertilizer leads to environmental losses, including runoff, leaching and gaseous emissions, as well as wasting money. Too little fertilizer exhausts soils, leading to soil degradation.

Right time: Ensure nutrients are available when crops need them by assessing crop nutrient dynamics. This may mean using split applications of mineral fertilizers or combining organic and mineral nutrient sources to provide slow-releasing sources of nutrients.

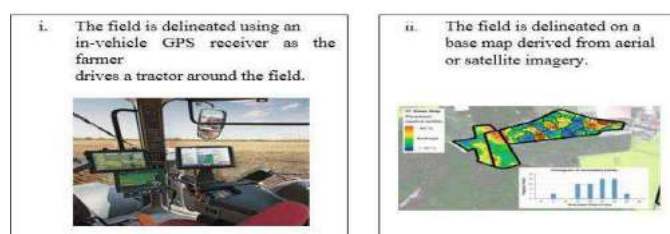
Right place: Placing and keeping nutrients at the optimal distance from the crop and soil depth so that crops can use them is key to minimizing nutrient losses. Generally, incorporating nutrients into the soil is recommended over applying them to the surface. The ideal method depends on characteristics of the soil, crop, tillage regime and type of fertilizer.

Tools Precision agriculture is usually done as a four-stage process to observe spatial variability: 1. Data collection 2. Variables 3. Strategies 4. Implementing practices

Data Collection

Geolocating a field allows farmers to overlay and analyze soil data effectively. This is achieved using two primary methods:

Geolocation: Mapping field positions to align soil analysis results with precise field areas.



Variables

Intra- and inter-field variability arises from several factors, including:

- ✓ Climatic conditions
- ✓ Soil characteristics
- ✓ Cropping practices
- ✓ Weeds and diseases

Two types of indicators help manage these variables:

Permanent indicators: Primarily soil-based, providing information about key environmental constants.

Point indicators: Used to monitor crop status, such as detecting diseases, water stress, nitrogen deficiency, or lodging.

Strategies for Field Input Management

Farmers can use soil maps to adjust inputs through two main approaches:

Predictive Approach: Based on the analysis of static indicators like soil composition, resistivity, and field history before and during the crop cycle.

Control Approach: Updates information from static indicators throughout the crop cycle using tools like:

- ✓ Sampling techniques
- ✓ Remote sensing technologies
- ✓ Proxy-detection methods
- ✓ Aerial or satellite imagery

Implementing Precision Agriculture Practices

Advancements in new information and communication technologies (NICT) make crop management more efficient and accessible. Key technologies include:

Positioning Systems: GPS receivers for precise field

geolocation using satellite signals.

Geographic Information Systems (GIS): Software to process and interpret field data.

Variable-Rate Equipment: Tools like seeders and spreaders to customize input applications according to field variability.

By combining these strategies and technologies, precision agriculture enables farmers to optimize productivity, reduce waste, and promote sustainable farming practices.

Mobile Apps in Precision Agriculture

With the widespread use of electronic devices like smartphones and tablets and the availability of reliable internet connectivity, sharing and accessing information from anywhere has become easier than ever. Android apps, in particular, offer quick and efficient functionalities that align with modern technological advancements. In precision agriculture (PA), these apps provide significant benefits to farmers, especially in monitoring agricultural activities and exchanging information.

Features of Agricultural Apps

- ✓ Access to weather updates, market rates and availability of resources.
- ✓ Predictive weather analysis for better planning.
- ✓ Information on seed varieties, fertilizers, pesticides and herbicides.

Benefits of Mobile Apps in Precision Agriculture

- ✓ Real-time data compilation and analysis.
- ✓ Reduction in water waste and improved crop management.

- ✓ Optimal utilization of labor and resources.
- ✓ Increased food production to meet global demand.
- ✓ Monitoring of soil and plant parameters for better health.
- ✓ Automation of field management tasks.
- ✓ Better insights for informed decision-making.
- ✓ Reduced environmental pollution.

Challenges in Precision Agriculture

- ✓ Precision farming is not universally applicable to every crop type.
- ✓ Farmers must meet several technological, technical and economic prerequisites before adopting this approach.

Conclusion

Precision agriculture empowers farmers to use essential inputs like fertilizers, pesticides, tillage, and irrigation water more effectively. This efficient use leads to higher crop yields and better quality while minimizing environmental impact. In the current context of rising input costs, declining commodity prices, and growing environmental concerns, precision agriculture offers a sustainable solution. Governments and farmers are actively seeking ways to boost efficiency and reduce costs. Despite some challenges, this technology holds immense potential to enhance productivity and sustainability for farmers who embrace it.

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Management of Rice Stem Borer: *Scirpophaga incertulas* (Walker) (Pyraustidae: Lepidoptera)

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Rice, a staple food for more than half of the global population, is grown in more than 100 countries with 90 per cent of the total global production from Asia. There are more than 1,10,000 cultivated varieties of rice can be categorized as either white or brown. In addition to calories, rice is a good source of magnesium, phosphorus, manganese, selenium, iron, folic acid, thiamin and niacin; but it is low in fiber and fat. Although brown rice is promoted as being “healthier” because of bioactive compounds, including minerals and vitamins. Though rice is affected but more than 100 pests, the predominant pest irrespective of countries is stemborer.

Nature of damage: Larva feeds inside the stem causing drying of the central shoot called ‘dead heart’ in young plant or drying of the panicle called ‘white ear’ in older plants. October to December has been found conducive for the multiplication of the insect.

Life history: The female lays 15-18 eggs in a mass near the tip on the upper surface of tender leaf blade and covers them with buff coloured hairs and scales. A female lays about 2-3 egg masses and the

incubation period ranges from 5-8 days. The newly hatched pale white larva enters the leaf sheath and feeds for 2-3 days and bores into the stem near the nodal region. Usually only one larva is found inside a stem but occasionally 2-4 larvae may also be noticed. The larva becomes full grown in 33 - 41 days and measures about 20 mm long. It is white or yellowish white with a well developed prothoracic shield. Before pupation it covers the exit hole with thin webbing and then forms a white silken cocoon in which it pupates. The pupa is dark brown and measures 12 mm long. The pupal period varies from 6-10 days and may get prolonged depending on the weather conditions. The entire life-cycle is completed in 50-70 days.

ETL

- ✓ 2 Egg masses m⁻².
- ✓ 10% Dead: Vegetable stages; hearts.
- ✓ 2% White: Flowering stage ear.

Management Strategies

- ✓ Grow resistant varieties like TKM 6, IR 20 and IR 26.
- ✓ Removal and destruction of rice stubbles from field and also collection and destruction of egg

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masses.

- ✓ Clipping the tip of the seedlings prior to transplantation to eliminate egg masses.
- ✓ Collection and destruction of moths using light traps.
- ✓ An ETL of 10% dead heart in vegetative stage and presence of 1 moth or 1 egg mass m^{-2} . If crossed, spray any one of the following insecticides. Acephate 75 % SP 267-400 g $acre^{-1}$, Carbofuran 3% CG 10 kg $acre^{-1}$, Carbosulfan 6% G 6.7 kg $acre^{-1}$, Carbosulfan 25% EC 320-400 ml $acre^{-1}$, CartapHydrochloride 50 % SP 400 g $acre^{-1}$, Chlorantraniliprole 18.5 % SC 60 ml $acre^{-1}$, Chlorantraniliprole 0.4 % G 4 kg $acre^{-1}$, Chlorpyrifos 20% EC 500 ml $acre^{-1}$, Fipronil 5% SC 400-600 g $acre^{-1}$, Fipronil 80%WG 20-25 g $acre^{-1}$, Flubendiamide 20% WG 50 g $acre^{-1}$, Flubendiamide 39.35% M/M SC 20 g $acre^{-1}$, Thiacloprid 21.7% SC 200 g $acre^{-1}$, Thiamethoxam 25% WG 40 g $acre^{-1}$.
- ✓ Release the egg parasitoid, *Trichogramma japonicum* on 30 and 37 DAT twice @ 5 ml ha^{-1} release $^{-1}$.
- ✓ Apply *Bacillus thuringiensis* var. *kurstaki* and neem seed kernel extract in the combination of 2.5 kg ml^{-1} and 1% to reduce the oviposition by the stemborer.

Management of Brinjal Shoot and Fruit Borer: *Leucinodes orbonalis* (Pyrastidae: Lepidoptera)

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Brinjal (*Solanum melongena* L.) is one of the most popular vegetables of India belonging to Solanaceae family. It is also called as poormans vegetable. Brinjal is cultivated in India over an area of 7,36,000 ha with a production of 12826 MT. In India, West Bengal is the highest producer of brinjal. Brinjal is rich in minerals like phosphorous, iron, calcium, vitamin C and B and they are low in calories and fats which also present fiber and protein. It is found to be affected by several pests which make low productivity of brinjal. Most of the insects are hard to control and generally chemical control is not the best option which is being used for the management. Among the insect pests of brinjal, shoot and fruit borer is the most dominant insect and causes 80-90% loss.

Nature of damage: Larva borer into tender shoots and causes withering of terminal shoots / dead hearts - also bores into petioles of leaves, flower buds and developing buds, cause withering of leaves, shedding of buds and make fruits unfit for consumption. Attacked fruits are with boreholes plugged with excreta. Loss due to this pest can be up to 70%.

Biology

Egg: 3-4 days - 150-350 creamy white eggs laid singly on leaves tender shoots, flowers and developing fruits.

Larva: 15 days - 5 instars: stout, pink coloured. Pupa: 6-8 days. Pupate on plant itself, boat shaped cocoon.

Adult: Medium sized with white wings with triangular brown and red markings on forewing.

Total Life cycle: 17-50 days.



Management

- ✓ Remove the affected terminal shoot showing boreholes.
- ✓ Remove the affected fruits and destroy.
- ✓ Avoid continuous cropping of brinjal crop
- ✓ Grow the varieties with long and narrow fruits in endemic areas
- ✓ Install pheromone trap @ 12 ha⁻¹
- ✓ Encourage the activity of larval parasitoids: *Pristomerus testaceus*, *Cremastus flavoorbitalis*

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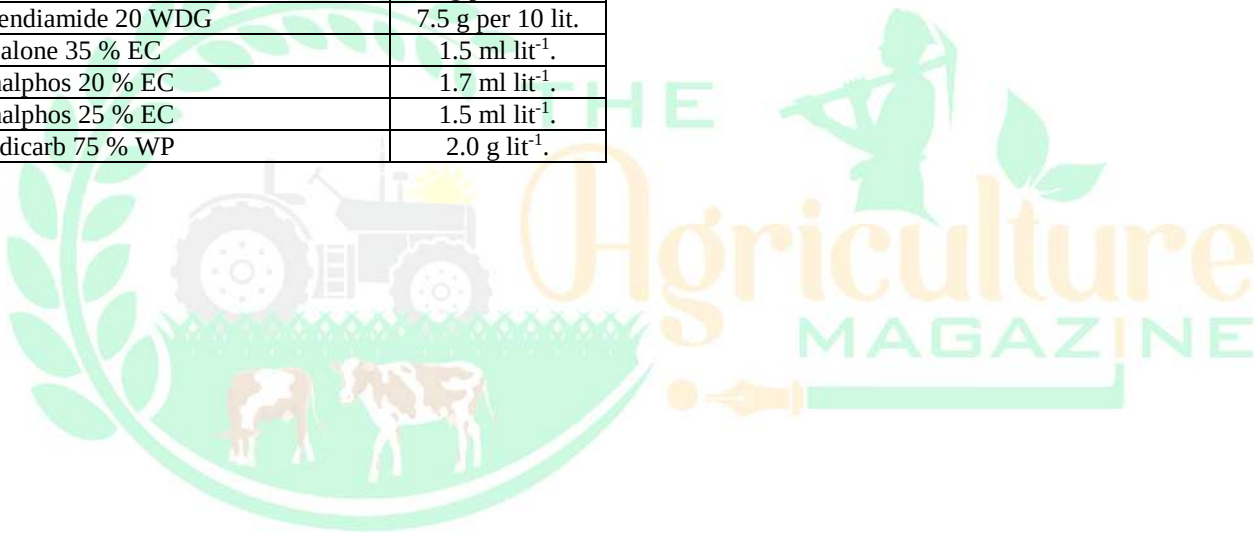
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- ✓ Avoid use of synthetic pyrethroids
- ✓ Avoid using insecticides at the time of fruit maturation and harvest
- ✓ Neem seed kernel extract (NSKE) 5 % or spray neem seed kernel extract 5% or any one of the spray Neem Seed Kernel Extract 5 % or any one of the following chemicals starting from one month after planting at 15 days interval.

Insecticide	Quantity (ml or g lit ⁻¹)
Azadirachtin 1.0% EC (10000 ppm)	3.0 ml lit ⁻¹ .
Azadirachtin 0.03 % WSP (300 ppm)	5.0 g lit ⁻¹ .
Dimethoate 30 % EC	7.0 ml per 10 lit.
Emamectin benzoate 5 % SG	4 g per 10 lit.
Flubendiamide 20 WDG	7.5 g per 10 lit.
Phosalone 35 % EC	1.5 ml lit ⁻¹ .
Quinalphos 20 % EC	1.7 ml lit ⁻¹ .
Quinalphos 25 % EC	1.5 ml lit ⁻¹ .
Thiodicarb 75 % WP	2.0 g lit ⁻¹ .



Zeolite: A Soil Amendment

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Introduction

The increasing population pressure leads to increased food demand, and at least 50% more food production is required to meet people's demand by 2050, with no possibility of horizontal land diversification. In order to ensure food and nutritional security, intensive agricultural practises necessitate the use of irrational chemical inputs, water, and heavy machinery. The consequences of intensive practises include soil and water quality degradation, such as depletion of soil organic carbon and inherent soil nutrient status, heavy metal contamination, and residual fertiliser, among other things. Zeolites are natural aluminosilicates found in rocks all over the world. The use of zeolite has grown in popularity in recent years due to the numerous benefits it provides. Clinoptilolite zeolites because of their high porosity, cation exchange capacity, and selectivity for ammonium and potassium cations, zeolites are useful in agriculture. Natural zeolites have been reported to be widely used as sandy soil amendments. In arid and semiarid environments, zeolitic amendment is an effective way to improve soil condition. They are thought to be good soil ameliorating substances because they have high water and nutrient holding capacity (WHC); they improve infiltration rate, saturated hydraulic conduc-

tivity, cation exchange capacity, and prevent water losses from deep percolation. Furthermore, zeolites have the potential to be used as a fertiliser and chelating agent. Zeolites reduce the rate of nutrient release from both organic and inorganic fertilisers, resulting in improved nutrient availability throughout the crop growth stages. Recognizing all of the following advantages, the use of zeolites in agricultural research has grown in popularity over the last two decades. Zeolites are rapidly becoming the focus of serious research in dozens of agricultural laboratories both at home and abroad. Farming with natural zeolites has assumed great significance in this context. Structure and Properties of Zeolite Structurally, zeolite is comprised of aluminosilicate (AlO_4 and SiO_4) tetrahedrons, joined into three-dimensional frameworks and seems like a honeycomb structure. The cages in the porous structure of zeolite are approximately 12 Å in diameter, interlinked through the channels of 8 Å diameter, includes 12 tetrahedrons rings. The pores are interconnected and form long wide channels of varying sizes depending on the mineral.

These channels allow the easy movement of the resident ions and molecules into and out of the structure. The negative charge of aluminium ions in the zeolite structure is balanced by positively charged

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ed cations. The general empirical formula that refers to a zeolite structure is $M_2nO \cdot Al_2O_3 \cdot xSiO_2 \cdot yH_2O$. M refers to any alkali or alkaline earth cation; the valence of the cation is indicated by n, x ranges between 2 and 10, and y ranges between 2 and 7, with structural cations comprising Si^{2+} , Al^{3+} and Fe^{3+} and exchangeable cations K^+ , Na^+ and Ca^{2+} (Hemingway *et al.*, 1984). Zeolites are useful as industrial water softeners, in the removal of radioactive Cs^+ and Sr^{2+} cations from liquid nuclear waste and in the removal of toxic heavy metal cations from groundwater and run-off water. Surfactant-modified zeolites (SMZ) find particular application in the co-removal of both toxic anions and organic pollutants. Toxic anions such as arsenite, arsenate, chromate, cyanide and radioactive iodide can also be removed by adsorption into zeolites that have been previously loaded with co-precipitating metal cations such as Ag^+ and Pb^{2+} which form practically insoluble complexes that are contained within the zeolite matrix.

Effect of zeolites on physical properties of soil

Evidence has revealed that, a significant difference in apparent density of zeolite treated soils. Several researches have reported gradual decrease in bulk density due to the increase in the applied dose of porous zeolite which have a positive impact on the physical properties of soil particularly on total porosity resulting in reduced virtual density values is consistent. Other investigations reported the increase in soil moisture content, porosity, reduced bulk density and the horizontal spread of water to sandy soil with the application of zeolite.

Effect of zeolites on chemical properties of soil

Soil chemical properties are observed to be improved with the application of combination natural zeolite (Louhar *et al.*, 2020). It was reported that the agrozol type of natural zeolite, when combined with organic fertilizer (manure) can be successfully utilized as amendments for problematic soils having unfavourable chemical properties as well as for enhancing the practice of cultivation of certain fruit crops on such soils (Glisic *et al.*, 2009). Zeolites are being investigated for NH_3 volatilization, soil exchangeable NH_4 and available NO_3 contents with surface-applied urea without additives (Baerlocher *et al.*, 2007). Treatments with zeolite significantly reduced NH_3 loss over the urea treatment without additives. There is a potential for compound fertilizer when applied in combination with zeolite to improve nitrogen use efficiency by lowering ammonia volatilization and increasing

Zeolite as a soil conditioner

- ✓ Improving soil physical properties and chemical properties
- ✓ As a Soil Amendments
- ✓ Nitrogen management
- ✓ Phosphorus management
- ✓ Organic manure handling and management
- ✓ Slow release of herbicides
- ✓ Slow release of nutrient
- ✓ Soil Microbial population
- ✓ Plant growth

Conclusion

There is a growing interest in the use of non-

porous zeolites in agriculture as a result of public concern regarding the negative effects of chemical fertilisers on the agroecosystem. Zeolite amendment is an efficient method for enhancing soil's physical properties, such as bulk density, porosity, mean weight diameter, hydraulic conductivity, infiltration, and moisture content. Zeolites are capable of minimising ammonia volatilization losses and enhancing soil ammonium ion retention. When combined with macronutrients or micronutrients, zeolites function as a slow-release fertiliser. Zeolite may have some effect on the microbial dynamics of soil. Zeolites are effective as soil ameliorants and for the remediation of soils contaminated with heavy metals. In conclusion, zeolites have the potential to be used as a source of soil conditioner that improves soil physico-chemical and biological properties, thereby enhancing crop production.

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Insect Pest Management Practices in Organic Agriculture

Megha Chaturvedi and Amit Kumar Bana

Organic Agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved.

- ✓ Wyss *et al.* (2005) proposed a conceptual model of pest management practices in organic production.
- ✓ In this model, indirect, preventative measures are of highest priority followed by direct and curative measures only when needed.

First phase practices

First-phase practices are implemented in the initial stages of farm plan to reduce the likelihood of pest infestation and damage. Cultural practices are the oldest techniques used for pest suppression, and they have their roots in traditional agriculture (Morales, 2002).

As limited range of suppressive pest control tactics are available to organic growers, knowledge intensive cultural practices form the basis of organic pest management programs.

- ✓ Crop isolation or rotation strategies are most

effective against pests that do not disperse over great distances or that overwinter near host crop fields.

Example include the carrot rust fly, *Psila rosae*, Colorado potato beetle, *Leptinotarsa decemlineata* and onion maggot, *Delia antiqua*.

Tillage Practices: Tillage can significantly affect insect pests and natural enemy abundance and diversity. Conservation tillage conditions favour a rich soil biota that can improve nutrient recycling and plant health. Mechanical weed control may reduce numbers of generalist arthropod predators, particularly spiders and staphylinid beetles.

Host Plant Resistance: HPR is considered the foundation of IPM but for economic reasons it has had limited application. The efficacy of synthetic insecticides combined with limited tolerance for pest damage made insecticide applications more cost-effective than the planting of a pest resistant/tolerant variety having less than optimal production or marketing qualities.

Second phase strategies

Includes ecological engineering approaches like: conservation biological control and intercropping.

Conservation Biological Control: Conservation biological control is appropriate and effective in

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organic agriculture because there is minimal use of broad-spectrum pesticides that constrain natural enemies.

Intercropping: Nother approach for managing pests involves intercropping with weeds or secondary crops to interfere directly with pests concentrated areas of host plants are easier for herbivores to find and colonize. The presence of plants distantly related to the crop plant can visually or chemically interfere with specialist herbivores, making the habitat less favourable.

Third phase strategies

Biological control approaches like inoculation and inundation are best implemented after setting in place the types of structural and conservation biocontrol strategies covered in first and second phase strategies. In greenhouse crops, spider mites have been successfully controlled by releasing predatory mites and similarly, whiteflies have been controlled by releasing parasitoid wasps (Weintraub *et al.*, 2002).

In field-grown crops, parasitoid releases have been effective in the management of lepidopteran pests of vegetables aphids in wheat, and leafhoppers in vineyards. In addition, releases of mite, coccinellid and lacewing predators significantly reduced spider mites, aphids, and leafhoppers in perennial crops.

Fourth phase strategies

Regulation of Insecticides, Pheromones, and Repellents: Fourth-phase strategies include the application of insecticides of biological and mineral origin, pheromones for mating disruption and repell-

ent agents as physical barriers. In organic agriculture these are used as a last option for the control of pests when all methods used in preceding phases have failed. A broad array of pest-repellent products, including homemade herbal teas, plant extracts, and fermentation products, and industrial clay and rock powder products (e.g., kaolin) are authorized for use in organic agriculture.

Current Status

- ✓ Insecticides are rarely used in organic field corn production but they play an important role in organic vegetable and fruit production where they are needed for the management of sucking and chewing insects.
- ✓ Botanical insecticides such as pyrethrum, rotenone, neem, and plant oils are commonly used in organic farming, others such as ryania, nicotine and sabadilla are used less frequently. Organic farmers also produce certain plant (e.g., garlic, black pepper, and stinging nettle) and compost extracts to yield teas and washes to control aphids and other insects. In tree fruit production, mineral oils are applied during winter dormancy to kill the overwintering developmental stages of pests.

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Adaptation: An Overview

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Adaptation in Crop Plants

Adaptation in Crop Plants refers to the process by which crop plants evolve and change in response to their environment and external factors such as climate, soil conditions, and pest pressures. This process involves genetic changes and physiological responses that allow crop plants to thrive in specific conditions, ultimately leading to improved yields and resilience. Understanding and harnessing the mechanisms of adaptation in crop plants is crucial for developing agricultural practices that can sustainably meet the world's food demands in the face of changing environmental conditions.

Role of adaptation in crop plants

The role of adaptation in crop plants is crucial for their survival and productivity. Adaptation allows crop plants to thrive in a wide range of environmental conditions, such as varying temperatures, soil types, and water availability. Through adaptation, crop plants can develop traits that make them more resilient to stress, pests and diseases, ultimately leading to better yields and quality of produce. Additionally, adaptation enables crop plants to evolve and become better suited to their specific growing regions, contributing to the overall sustainability and success of agricultural systems.

How Crop Plants have evolved to Survive in Extreme Environments: Explores the fascinating

adaptation processes that crop plants have undergone to thrive in harsh and extreme conditions. It delves into the mechanisms and genetic changes behind their ability to withstand environmental stressors such as extreme temperatures, limited water availability, and poor soil quality. The article also discusses the implications of this evolution for agriculture and food security, highlighting the importance of identifying and harnessing these adaptive traits to develop more resilient crop varieties.

Unlocking the Secret Language of Crop Plants:

Exploring how they communicate and adapt to their environment for better agricultural practices and food security.

Adaptation is crucial for ensuring sustainable agriculture:

In the face of changing climates. Implementing practices and technologies that allow for adaptation to changing environmental conditions is essential for the long-term success of agricultural systems. By adopting adaptive strategies, farmers can better cope with the challenges posed by climate change, ensuring the continued productivity and resilience of agricultural operations.

The Unexpected Ways Crop Adaptation Can Lead to Global Food Security:

Discusses the various unanticipated methods by which the adaptation of crops can contribute to ensuring global

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food security. It delves into the nuanced ways in which crop adaptation initiatives can address food production challenges, increase resilience to environmental stressors and enhance overall agricultural sustainability on a global scale.

The role of adaptation in hybrid development: In crops is integral to the enhancement of plant resilience and productivity. This process involves a meticulous selection and breeding of parent plants with favorable traits, such as disease resistance, high yield potential, and environmental adaptability. Through this deliberate adaptation, breeders can produce hybrid crops capable of thriving in diverse environmental conditions. Consequently, this process contributes significantly to global food security and the long-term sustainability of agriculture.

The role of adaptation in genetic study: It is to understand how organisms have evolved and adapted to their environments through genetic changes. This involves studying how genetic variations within populations may confer advantages or disadvantages in specific environments, and how these variations may be inherited over generations. By studying adaptation, geneticists can gain insight into the mechanisms of evolution and the factors that drive genetic diversity within and between different species.

The role of adaptation in managing abiotic stress: It is crucial for the survival and success of organisms in challenging environments. Adaptation allows organisms to adjust to and thrive in the face of various environmental stresses such as extreme

temperatures, salinity, drought, and other non-living factors. Through adaptation, organisms can develop physiological, morphological, and behavioral traits that help them cope with abiotic stressors. This can include changes in metabolic processes, alterations in growth patterns and the development of specialized structures or mechanisms to mitigate the impact of abiotic stress. Understanding the role of adaptation in abiotic stress management is essential for conservation efforts, agricultural practices, and the development of resilient crop varieties in the face of changing environmental conditions.

The role of adaptation in managing biotic stress: It is a critical aspect of maintaining ecosystem balance and promoting sustainable agricultural practices. Adaptation involves the ability of an organism or ecosystem to adjust to changes in its environment to minimize the impact of biotic stressors such as pests, diseases, and invasive species. By understanding the mechanisms of adaptation, we can develop strategies to enhance the resilience of ecosystems and agricultural systems, ultimately improving food security and environmental sustainability.

The role of adaptation in managing climate change: It is crucial for addressing the impacts of changing weather patterns, rising sea levels, and extreme weather events. Adaptation involves implementing strategies to help communities and ecosystems adjust to these changes, such as developing resilient infrastructure, promoting sustainable agricultural practices, and enhancing early warning

systems. Effective adaptation measures can reduce vulnerability and increase the ability of societies to cope with the challenges posed by climate change.

Adaptation plays a crucial role in managing the effects of global warming: It involves making adjustments and changes to social, economic, and environmental systems in response to the changing climate. This may include developing early warning systems for extreme weather events, implementing infrastructure to withstand sea level rise, and creating more resilient agricultural practices. Additionally, adaptation efforts can encompass policies and strategies to address the impacts of climate change on vulnerable communities, ecosystems, and natural resources.

The role of adaptation in yield improvement: It can be understood as the process of making adjustments or changes in various factors such as crop varieties, management practices and environmental conditions to enhance the productivity and efficiency of agricultural yields. Adaptation plays a crucial role in addressing challenges such as climate change, soil degradation and evolving pest and disease pressures, ultimately contributing to sustainable food production and food security.

Edible Coatings to Enhance Shelf Life of Custard Apple

Kaustubh Yashvant Deshmukh and Priya Suresh Gawande

The custard apple (*Annona squamosa* L.), belonging to the Annonaceae family, originated from tropical America. It is recognized by various local names across India, such as Sugar apple, Sweet sop, Sitaphal and Sharifa. This fruit grows best in tropical and warmer sub-tropical areas, particularly in states like Maharashtra, Andhra Pradesh, Madhya Pradesh, Bihar, Assam and Odisha. Custard apple is a perishable crop commonly found in forested regions, with Rajasthan ranking among the top ten states for its cultivation, where commercial farming is also expanding.



Custard apple is enjoyed fresh for its sweet, slightly tangy, and aromatic pulp. The pulp is also used in various products like drinks, ice creams, and milk-based items. Nutritionally, custard apple pulp contains around 73.3% moisture, 1.6% protein, 0.3% fat, 0.7% minerals, and 23.9% carbohydrates, with a calorific value between 822 to 1050 kcal per kg.

Being climacteric, custard apples have a short shelf life, lasting about 3-4 days at room temperature, with changes in colour due to oxidation. Storage and post-harvest treatments, including hormone treatments, fungicides, cold storage, pulp processing, and edible coatings, are essential to prolong shelf life

(Gohlani and Bisen, 2012). Novel approach to enhance the fruit's shelf life involves fruit coatings, which improve the fruit's outer appearance and help modify the internal atmosphere (Saftner, 1999). This technique has emerged as a novel, effective post-harvest treatment, replacing older methods to prolong freshness by minimizing moisture loss and retaining firmness. These coatings, acting as barriers to oxygen and lipids, prevent moisture loss at low to medium humidity levels due to the hydrogen bonding capabilities of their polymers. Research conducted by Yaman and Bayoindiri (2002) on cherries revealed that edible coatings reduce weight loss, enhance firmness, retain ascorbic acid, titratable acidity and skin colour, ultimately extending the fruit's shelf life. These eco-friendly, biodegradable coatings, made from polysaccharides, fats and proteins, have gained inter-national popularity. Waxes and starch-based materials are highly effective for minimizing transpiration loss. Since custard apple is a perishable fruit, coatings that add glossiness and retards process of ripening is found advantageous. Edible coating is environment friendly technology widely applied to control moisture, gas exchange and oxidation processes. By modifying the internal gas composition, they serve as an effective alternative to modified atmosphere stor-

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age. Edible films and coatings can incorporate active ingredients, enhancing food safety, nutritional value and sensory appeal.

Types of Edible Coatings

Sago Coating: Commonly used in the food industry as a thickener, stabilizer and gelling agent, sago starch is an abundant, cost-effective polysaccharide. Due to its high amylose content (27%), it forms strong, film-like barriers that slow down micro-organism growth and moisture loss, making it suitable for extending fruit shelf life. Studies have shown sago starch to be effective in maintaining fruit quality, reducing moisture loss and preserving firmness (Wong *et al.*, 2014).

Chitosan: Chitosan, a natural biopolymer derived from chitin (commonly found in shellfish exoskeletons), with antimicrobial and film-forming properties, is effective in extending the shelf life of custard apples. When applied as a coating, chitosan reduces moisture loss, controls gas exchange, and slows the respiration rate, thereby delaying ripening and maintaining freshness. It also inhibits microbial growth, reducing spoilage and preserving the fruit's appearance, texture, and nutritional quality. Being biodegradable and safe for consumption, chitosan provides an eco-friendly, consumer-friendly alternative for post-harvest preservation of custard apples.

Carnauba Wax: Derived from the Brazilian palm tree (*Copernicia cerifera*), carnauba wax has a high melting point and enhances the toughness and lustre of fruits, reducing water loss and extending shelf life. It also helps maintain fruit firmness and appearance.

Carnauba wax-coated fruits experience reduced transpiration, contributing to better preservation. Carnauba wax has proven effective for improving fruit storage. Recognized as a GRAS (Generally Recognized as Safe) substance by the FDA (2014), it has been applied as an emulsion for coating fresh produce since 1950's. The concentration of carnauba wax used in food coatings varies based on the specific organoleptic and physical characteristics of the food. Widely used in food applications, numerous studies support its use in different products (Goncalves *et al.*, 2010). When applied to fruits, carnauba wax alters their respiration rate, reducing weight loss, maintaining firmness, and slowing ripening-related changes. Additionally, it helps prevent bruising and maintains visual appeal. Combining carnauba with polyethylene wax has shown superior preservation compared to other supplementary components (Lam *et al.*, 2009).

Leaf extract: Custard apple leaf extract is used as a coating to enhance antimicrobial properties, helping to preserve fruit quality, extend shelf life and reduce shrivelling, rich in secondary metabolites, these extracts strengthen the fruit's defense against microbes during storage. Leaf extracts from plants like guava, papaya, aloe vera and custard apple are increasingly used in commercial coatings to enhance their efficacy. Studies by Bautista-Banos *et al.* (2000) demonstrated formulated extracts from custard apple (*Annona reticulata* L.) and papaya (*Carica papaya* L.) inhibited spore formation and germination in pathogens like *Rhizopus stolonifer*

and *Colletotrichum gloeosporioides*. Additionally, they prevent growth of fungi such as *Fusarium oxysporum*, *Penicillium digitatum*, and *Rhizopus stolonifer*, which are significant causes of post-harvest diseases in stored fruits and vegetables (Snowdon, 1990). Custard apple leaf extract, therefore, plays a key role in inhibiting fungal growth during storage.

Advantages of Waxing Custard Apple

Extended shelf life: The wax layer helps preserve freshness by reducing moisture loss and slowing ripening, extending the fruit's shelf life.

Protection: Wax acts as a barrier against external factors, such as bacteria, fungi and physical damage, protecting the fruit during transit and storage.

Quality: Waxing helps maintain the texture, flavour and nutritional content by minimizing dehydration and reducing bruising or spoilage.

Enhanced external appearance: Waxing gives custard apples a glossy, attractive look, appealing to consumers.

Improved marketability: Waxing enhances custard apple's market appeal, attracting more customers and potentially boosting sales.

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Climate Resilient Agriculture to Enhance Food Security

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Abstract

Climate change is the greatest threat to the agriculture and it can elude the food security of the country. Government of India have target to become net zero carbon emission country by 2070. To meet the energy demands India is moving towards renewable source of energy and substituting fossil fuels. Agriculture is vulnerable to climate change it significant to move towards resilience to ensures the production sustainability and food security. This paper provides the important glimpse of different climate resilient agricultural practices in order combat climate change.

Introduction

It is well known fact that India is one of the top agricultural produces exporting countries and self-sufficient in food production as of now. Sudden flash floods, drought, heat waves, cold waves and intensification of cyclones are harbinger for upcoming peril. Indian agriculture currently facing stagnating net available area, plateauing of yield levels, deterioration in soil fertility, and decreases in the per capita availability of land (Currently 0.12 ha per capita availability of agriculture land against 0.63 ha in 1950-51). To address, resilience in agriculture is the key. Resilience in agriculture is an ability of the farming system to resist the ill effects of Climate change and a capacity to recover quickly after damage. The Agri food system is huge, untapped source of low-cost climate change action. The UN second SDG emphasises the food security of the country. India ranks 105th out of 127 countries (2024

GHI report) in the global hunger index it stresses the importance of food security.

Challenges in present day agriculture

The UN Food and Agriculture Organization (FAO) estimates that there is a need to produce about 50% more food by 2050 in order to feed the increasing world population. Projected climate change scenario for Indian subcontinent and the results indicated an increase in annual mean maximum and minimum surface air temperatures by 0.7°C and 1.0°C respectively over land in the 2040s as compared to the 1980s level. Nevertheless, increase in CO₂ concentration in the atmosphere is beneficial to C₃ plants like rice and wheat, on the contrary the crop duration is shrinking due to temperature raise which attributes yields loss. Likewise, research indicates that increased CO₂ levels in livestock feed led to higher lignin content, which in turn negatively impacts the digestibility for

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ruminants, affecting their nutritional security. Currently farmers are facing declining in the production potential due to vagaries in the rainfall distribution pattern, terminal heat stress, frost damage, increase in the diseases and pest infestation, water shortage during the critical growth period for moisture stress, high rainfall during harvest season is catastrophic for farmers socio economic condition.



Strategies for climate resilient agriculture

Crop management: Adoption of improved climate resistant varieties (tolerant to terminal heat stress, flood, heat waves, NUE, submergence tolerance etc.) should be incorporated in the existing cropping system. Millets being naturally Climate Resilient crops, adopting millet-based cropping system can thrive to both nutritional as well as food security of the country with less cost of cultivation compared to wheat and rice. Maintenance of seed bank preserves the plant genetic species and overcomes seed shortage. Alteration of existing crop calendar (date of sowing,) is significant to increase the yields in a prevailing change in climatic condition.

By practicing Crop rotation and discouraging monoculture helps to maintain soil health, as well as higher productivity can be accomplished. Cultivation of direct seeded rice and SRI method helps reduce nitrous oxide emission from the rice field. Management of pests and disease with amalgamation of traditional, biological and chemical method effectively saves the cost incurred for cost of cultivation as well as sustains the ecosystem. Growing of horticulture crops like tomato chilli cabbage and cucurbits in a greenhouse condition increases the yield as well as crops are protected from biotic and abiotic stress in turn farmer get high B:C ratio

Soil and water conservation: To cater the needs of crops and to maintain soil quality diversified source of nutrient (organic manure, green manuring biofertilizers etc.) is beneficial. Site specific nutrient management and precision nutrient management helps to apply fertilizers judiciously as and when crop required. And helps to reduce nitrogen losses through denitrification, volatilization, leaching in turn reduces the nitrous oxide emission to the atmosphere. Conservation agriculture (zero tillage, permanent soil cover, crop diversification) is a startling paradigm to tackle the greenhouse gas emission and sequestering carbon in the soil without jeopardise the crop productivity. Alternate land use system like agroforestry increases the tree cover in turns sequesters the carbon in biomass and soil. *In-situ* water conservation practices (broad bed and furrow, mulching) *ex-situ* moisture conservation

practices (farm pond) are reported to increase in the yield and income during deficit rainfall. Application of biochar is reported to be increase the soil enzymes as well as SMBC and a solution for residue management. Adoption of overhead irrigation system and micro irrigation system ensures the higher water productivity. Bore well recharges directly feeds the aquifer and increases water table level. Lasser land levelling is reported to increase irrigation efficiency and reduces the water loss, duration of irrigation less compared to conventional methods and saves the electricity incurred for application

Livestock management: Growing of pasture crops or fodder crops helps sustain livestock component in lean period. Processing of fodder into silage and hay ensures nutritious feeds through the year. Alternate land use system like agri-silvi-pastoral or horti-silvi-pastoral systems are promising strategies to manage the livestock component economically and it yields higher dividends to farmer. Breeding for climate resilient sheep and goat (heat stress) improves adaptability for existing condition. Proper housing structure helps maintains the health of livestock component. Disease surveillance (Vaccination programmes) is another significant step for betterment of livestock. Maintenance of gene bank ensures supply of strains for further breeding programme.



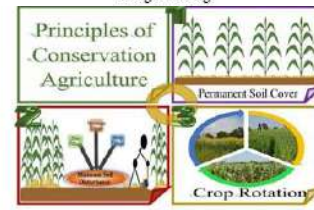
Good ventilated housing structure



Silage making



Green house cultivation



conservation agriculture



Agroforestry system



Broad bed and furrow



Farm pond



Drip irrigation

Policy and institutional support (Risk management): National Innovation on Climate Resilient Agriculture is a network project of ICAR which aims at enhance resilience of Indian agriculture to climate change. It consists 4 components Strategic Research, Technology Demonstration, Capacity Building and Competitive Grants. National mission on Sustainable Agriculture was formed by GOI under NAPCC during 2014-15 with objectives of conserve natural resources, soil health management, optimize the utilization of water resource etc.

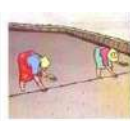
Some of the important govt schemes which supports CRA are Pradhan Mantri Krishi Sinchayee Yojana (2015) Paramparagat Krishi Vikas Yojana (2015) Bhartiya Prakritik Krishi Padhati Programme



Young seedling



Single seedling/hill



Square planting



Weeding by Cono weeder



Alternate wetting and drying

(2020-21) with aim of more crop per drop, to promote organic and natural farming and to promote traditional indigenous practice respectively. Some of the other schemes which aims at Risk management are Pradhan Mantri Kisan Samman Nidhi (2019) and Pradhan Mantri Fasal Bheema Yojana (2016) to provide farmer with a financial aid of 6000 Rs per year (three instalments) and Insurance for crop failure during unavoidable crop losses with 2% premium rate for *Kharif* and 1.5% for *Rabi* season crops respectively.

NITI Aayog, MoA & FW, GOI and FAO jointly launched the Investment Forum for Advancing Climate Resilient Agri-food Systems in India on Jan 18-19 2024 with aim to develop an investment and partnership strategy to advance climate resilient agri-food systems among the govt, private sector, and farmer's organizations and financial institution in India.

Constrains in adoption: Reluctancy of farmers towards adoption of new technologies due to their socio-economic condition. Even though lot of research works done in crop improvement, regional specific varieties are need to release. Poor maintenance of custom hiring centre and lack availability implements during peak sowing time. Formulation of specific policy or scheme related to CRA is not up to the mark. Lack of effective weather forecasting at regional level.

Conclusion

By successful adopting the above technologies in the agriculture, India can always be a self-

sufficient in food production and farmer will sustain, full stop for suicide. Better management of livestock and components and crop components leads prosperity in farming system with improvement in the environment. Even though lot of work as done in CRA technology practices adoption rate and field level implementation are still crawling. Extension workers should play crucial role to bring these technologies to farmer's field. Credit support from the government for research in CRA should be continuous. Government should legislate climate related law for Resilience

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Nutrition Garden: Key to Improved Nutritional Well-being

Meghna Sarma, Moloy S. Baruah and Mokidul Islam

Introduction

India is the world's second-largest food producer, yet it also has the second-largest population of undernourished individuals. Alarmingly, over half of Indian women experience anemia, contributing to the high incidence of low birth weight in infants. An inadequate diet and food scarcity are closely linked to elevated rates of stunting, obesity, and mortality in children under five. To address these challenges, the Government of India has launched initiatives aimed at ensuring food security and providing access to quality nutrition. However, it's essential to adopt a multifaceted approach to tackle food security effectively. Community and nutrition gardens can significantly enhance national food security and improve dietary diversity, helping to combat malnutrition.

Nutrition encompasses all aspects of food and how the body uses it. Most people eat primarily because they are hungry, but hunger alone does not indicate what to eat. When properly designed, nutrition gardens can generate a surplus of fruits and vegetables, which can be sold to meet local demand, especially as neighbours recognize their organic quality. To achieve the goal of providing a diverse diet, it is essential for nutrition gardens to include poultry, trees, a composting unit and other management practices that support this holistic approach.

Plants require various types and quantities of nutrients to stay alive and healthy throughout their lives. Similarly, from conception through old life, individuals need an adequate diversity of nutrients. Small children, pregnant or nursing moms, pregnant or lactating mothers, in particular requires enough nutrition to support optimal growth, mental development and health. Therefore, we need to eat a variety of plant foods every day to stay healthy and fit. One of the numerous issues faced by the socioeconomically disadvantaged portions of our society is ensuring year-round dietary diversity for the family, particularly women of reproductive age and children. The Ministry of Rural Development has issued a guideline for the MGNREGS - individual benefits plan to promote 'nutrition gardens,' with the purpose of increasing nutritional diversity at the household level while also supporting income and employment for the family.

Objectives of Nutrition Garden

- ✓ By recycling home trash, greywater, and other resources, the front yard, backyard, and space around the living space can be used to grow nutrient-dense vegetables and fruits.
- ✓ The goal is for all family members, particularly women and children, to consume at least 150-200 gm of green vegetables and fresh fruits per person per day throughout the year.

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- ✓ Integrate backyard poultry and goat farming for improved soil nutrient availability and increased income.

Benefits of Nutrition Garden

- ✓ Reduce the hunger periods
- ✓ Small farms focusing on cash crops can reduce market dependence by production for own consumption
- ✓ Multiple and mixed cropping - increases dietary diversity and soil nutrition
- ✓ Organic farming- safe food, low cost, less time involvement (more resilient crops) and improved organic waste management
- ✓ Clean environment- Less disease- Better nutrition
- ✓ Recycling of the waste water
- ✓ Use of degradable lands i.e. useful for the production of food, fodder and fuel
- ✓ Preservation of natural resources like forests and water bodies
- ✓ Increase the biodiversity i.e. improves sources of food for both animals and human
- ✓ Reduced the cost of production - supports consumption of nutritious food on regular basis, more profits from sale, scope to buy food that is essential but cannot be grown on own farm
- ✓ Good source of uncultivated foods- allows growth of wild foods - weeds, small insects, local fishes, wild fruits.

The owner of a garden can choose any of the activities that are appropriate for her garden and submit plans accordingly. It is possible to keep track

of the daily output. The notebook can assist in keeping track of consumption and surplus production money. This paperwork is intended primarily for demonstration villages and lead farmers, rather than for all homes. A village seed bank should be kept in order to preserve and share seeds.



Care to set up Nutrition Garden

Fertilizer: Cow dung manure and compost are the best supplements for the optimal growth of vegetables. Nourish the soil with fertilizer before transplanting or sowing. You can also use fish emulsion or manure tea every 2-3 weeks in the growing period.

Mulching: Mulching is done to help the soil retain moisture and stay weed-free. You can mulch both the container and garden soil with leaf molds, bark, compost, or straw.

Pest and Diseases: Vegetable plants are susceptible to aphids, powdery mildew, and Downy mildew. So, take preventive measures like choose pest-resistant varieties, and avoid keeping the plant in soggy soil. Apart from that, you should snip off the infected parts from the plant and apply the neem oil solution near the soil.

Support: Many vine vegetable plants like cucumber, tomatoes, beans, and gourds need support as they grow. So provide them the support of trellis, fences, or stakes.

Harvest: Harvest the vegetables when they are fully ripe, especially tomatoes and gourds. But some

plants like Pumpkin, chili, colocasia tubes, and onions are an exception and should be harvested before they attain full ripening. Harvest the root vegetables, when they are tender; otherwise, they become stiff, hard, and lose their best taste.

Performance of Agri-Nutri Gardens

Presently there are 10.01 million Agri Nutri gardens against 8 million SHGs and 85 million SHG households (11.7%) were available across country (Farm Livelihoods Monthly Report 2022), indicating a large gap in geographical saturation. Other challenges too plague the nutri-garden initiative, such as, inadequate means and methods to ensure quality of the garden (variety of the produce and sufficiency for family size) and 365-day sustainability of the garden. Besides, there are operational hurdles, such as poor capacities of human resource involved in implementation, inadequate use of technology and weak convergence with line departments. There is a need to look at multiple strategies to combat these challenges, such as better alignment between key ministries/departments- Agriculture, Horticulture, Animal Husbandry, Rural Development, Women and Child Development, Health, MGNREGS and others.

Conclusion

The Government of India launched the National Nutrition Mission, or POSHAN Abhiyaan, aimed at achieving a malnutrition-free India through a multi-ministerial convergence approach. This initiative seeks to create synergy by linking the programs of various key departments to reach a

common objective. As part of this effort, the National Rural Livelihood Mission promotes kitchen gardens as a strategy to combat malnutrition by encouraging healthy eating and enhancing agro-ecological practices. Households are encouraged to cultivate vegetable gardens, resulting in increased vegetable consumption, improved dietary diversity, and additional income. Additionally, the Ministry of Human Resource Development has established guidelines for 79 school nutrition (kitchen) gardens in government and aided schools as part of the midday meal scheme. Successful initiatives across states provide valuable lessons that can be shared and replicated to enhance outcomes.

- ✓ For promotion of community gardens following recommendations are necessary Scale up the practice of kitchen gardens to promote increased consumption of diverse and nutrient-rich foods through convergence under the National Nutrition Mission or POSHAN Abhiyaan.
- ✓ Capacity-building on kitchen gardens can be incorporated as part of training curriculum of community health workers/anganwadi workers under ICDS. This will enhance their knowledge on benefits of nutrition gardens and raise awareness in the community.
- ✓ The Village Health and Nutrition Day, a Government of India initiative to improve access to health and nutrition services, can be utilised to raise awareness on nutrition gardens, and also demonstrate how the food grown can be introduced in the daily diet.

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Medicinal and Therapeutic Uses of Periwinkle (*Catharanthus roseus* L.)

Guddu Rai and Sujata Upadhyay

Abstract

There are over 3,50,000 plant species on Earth and each one has its own therapeutic significance. Many phytochemicals found in medicinal plants have been shown to be safe and effective substitutes for synthetic medications in the treatment of chronic and infectious diseases. Periwinkle is one of the important medicinal plants which belongs to the family Apocynaceae and is also known by several other names such as sadafuli and barmasi. It contains a variety of phytochemicals with various biological functions, such as anti-inflammatory, anti-cancer, anti-bacterial, anti-fungal, and antidiabetic properties that has increased interest in this plant around the world. It was from this plant that the first clinically effective anticancer medications were developed, specifically vinblastine and vincristine.

Introduction

Periwinkle (*Catharanthus roseus*) popularly known as the anticancerous drug yielding plant belonging to the family Apocynaceae is an important medicinal plant widely grown in tropical and sub-tropical regions which has originated in central Madagascar island. It was introduced to the other parts of the world during the 18th century and is presently cultivated in Europe, India, China and America. Almost all the parts of this plant including leaf, shoot and roots are known to contain more than 200 alkaloids which have therapeutic usage against various diseases. Vinblastine and vincristine are the main alkaloids present in the aerial parts (leaves) of this plant is used in the treatment of cancer and proved to be a milestone in cancer chemotherapy. Another alkaloid ‘rubacine’ derived from its roots is used as anti-arrhythmic and hypotensive agent.

Besides this, the plant also shows anti-ulcer, anti-diabetic, anti-oxidant, anti-diarrhoeal and anti-bacterial properties. There are about two common cultivars of this plant which are named on the basis of their flower colour that is the white flowered “Alba” and the pink flowered “Rosea”. The phytochemicals found in *Catharanthus roseus* can be divided into two categories: primary metabolites and secondary metabolites. Primary metabolites are produced during the growth phase, while secondary metabolites are derived from primary metabolites but do not directly participate in the plant's life processes. The primary metabolites identified in *Catharanthus roseus* include purines, pyrimidines, amino acids and carbohydrates. Secondary metabolites comprise alkaloids, flavonoids, saponins, steroids, phenols, glycosides etc.

Traditional uses: Periwinkle has been used in diff-

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erent countries as a traditional medicine. It has been used as a diuretic, anti-dysenteric, anti-haemorrhagic, and wound-healing agent since BC50. Traditionally, this plant was used as a tea to treat toothaches and diabetes in Brazil and Jamaica (Raju *et al.*, 2022). The people of Kancheepuram, Tamil Nadu, India, make a powder from the entire plant, mix it with cow's milk, and take it orally to treat diabetes (Holdsworth, 1990). The *Catharanthus roseus* dried roots have been found to be helpful in prevention of urogenital infections in South Africa (Muthu *et al.*, 2006).

Medicinal and Therapeutic uses of Periwinkle

Anticancer property: The plant *Catharanthus roseus* produces the anticancer alkaloids Vinblastine and Vincristine from its stem and leaves. These alkaloids are effective in inhibiting the growth of certain human tumours. Vinblastine is used experimentally to treat neoplasms and is recommended for Hodgkin's disease and chorio carcinoma. Vincristine is another alkaloid which is utilized for treating leukaemia in children. Vinblastine is marketed as Velban, while Vincristine is known as Oncovin.

Wound healing property: Vinca helps manage wound healing when wound contraction is combined with hydroxyproline and increased tensile strength (Nayak *et al.*, 2007).

Anti-microbial property: Vinca leaf extract demonstrated noticeably greater efficacy when tested for antimicrobial properties compared to extracts from other parts of the plant. The vinca leaf extract's antibacterial qualities were examined using agonist

microorganisms, and it was discovered that the extracts could be used as a preventative measure to cure various illnesses (Patil and Ghosh, 2010).

Anti-ulcer property: Vincamine and vindoline alkaloids have proved anti-ulcer properties. Vincamine found in vinca plant leaves, has neuroprotective and cerebro-vaso dilatary property.

Hypotension property: The extract from vinca leaves has a major role on hypotension. About 150 beneficial alkaloids and other pharmacologically active compounds have been found in vinca leaves.

Hypolipidemic property: Vinca leaf juice has significant antiatherosclerosis activity, as evidenced by a decrease in serum levels of total cholesterol, triglycerides, LDLc, VLDLc, and aortic, liver, and kidney histology (Mishra and Verma, 2017).

Anti diabetic property: The ethanolic extracts of *Catharanthus roseus* leaves and flowers demonstrated a dose-dependent reduction in blood sugar that was on par with that of prescription medication. Blood sugar reduction is comparable to that of the common medication glibenclamide (Raju *et al.*, 2022).

Conclusion

For most people worldwide, medicinal plants are the only source of life-saving medications. They remain a vital therapeutic tool for curing human ailments. Early man explored these immediate natural surroundings in search of defence mechanisms, longevity, and ways to eliminate pain and discomfort. It resulted in the creation of numerous medicinal agents as well as the use of minerals, plant

and animal products, among others. Nowadays, there is a resurgence of interest in traditional medicine and a growing need for more plant-based medications since green medicine is more reliable and safer than pricey synthetic drugs, many of which have negative side effects. Since ancient times, *Catharanthus roseus* has been studied for its phytochemical components and potential medicinal uses. The plant has a vast number of phytochemical components with a range of therapeutic uses. Additionally, the plant has a number of attributes, including antimicrobial, anti-diarrhoeal, anti-helminthic, anti-cancer, and anti-diabetic properties. Therefore, there is need for further research on vinca and its production technology needs to be strengthened so as to meet the demands of the modern pharmaceutical industry.

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Lemongrass: A Potential Aromatic Crop with Diverse Uses

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Abstract

The aroma industry has a high demand for an essential oil made from lemongrass, which is primarily grown for its economic value. This crop offers farmers significant advantages in terms of increased revenue, wasteland utilization and crop protection from grazing and wild animals. It offers many advantages in the areas of ecology, medicine, agriculture, nutrition and the economy. Through targeted agricultural interventions, it could result in revolutionary changes in the fragrance industry.

Introduction

Lemongrass is a member of the genus *Cymbopogon* and family Gramineae (Poaceae) which yields aromatic oil. Essential or aromatic oils are concentrated secondary metabolites that serve a variety of purposes in plant systems. They are made up of hundreds of organic compounds that function at various levels, such as terpenoids, benzenoids and organic sulphur and nitrogenous compounds (Gawali and Meshram, 2019). The word “*Cymbopogon*,” which refers to the flower spike arrangement, is derived from the Greek words “*Kymbe*” (boat) and “*pogon*” (beard). Lemongrass is an aromatic, multicut perennial grass and commonly referred to as “East Indian Lemongrass”. Citral, a cyclic monoterpene, is primarily responsible for the prefix “lemon” owing to its typical lemon like odour. It is a perennial tropical plant originated in Australia and Asia. Since 90% of lemongrass oil is shipped from the port of Cochin, it is also commonly referred to as

Cochin oil in international trade. It is one of the aromatic crops included in the Aroma Mission, which was started by the Council of Scientific & Industrial Research (CSIR) of the Union Ministry of Science & Technology, Government of India. An area of 16,000 hectares yields about 1000 tons of lemongrass annually worldwide. In India, it is grown on 4000 hectares of land, yielding about 250 tons year⁻¹ (Dhayal *et al.*, 2023).

Different species of Lemongrass

***Cymbopogon flexuosus* (2n= 20, 40):** It is referred to as Malabar, Cochin, or East Indian grass. It is a sturdy, tufted perennial grass that grows to a height of roughly two meters. The leaves have lanceolate and linear shapes. Large and heavily branched, the inflorescence has a terminal drooping panicle with paired spikes on the tertiary branches. The spikes produce spikelets in pairs, with one pedicellate and the other sessile. Awned bisexual florets make up the sessile spikelet, while awnless staminate florets

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make up the pedicellate (Ganjewala *et al.*, 2013). Two varieties or types are identified based on the colour of stem under this species.

***Cymbopogon flexuosus* var. *flexuosus*:** The grass is red and the colour of the stem and leaf sheath is either purple or reddish. It is acknowledged as the true lemongrass. The essential oil has a high citral content (more than 75-80%), is well soluble in alcohol, and is therefore of superior quality.

***Cymbopogon flexuosus* var. *albescens*:** The white stem of this grass is what distinguishes it from other types. The plant typically grows in the wild. The essential oil is regarded as being of lower quality since it has less than 65-70% citral and is poorly soluble in alcohol.

***Cymbopogon citratus* (2n = 40, 60):** It is referred to as American lemongrass or West Indian. It is a perennial grass without stems that forms big tussocks with many stiff tillers growing from a short rhizomatous rootstock. Under cultivation, it hardly ever flowers. The leaf blade is glaucous, narrow, linear, drooping, and has a scabrous margin. The ligule is truncate, the inflorescence is infrequent, and there is a large, loose panicle. The spathe bracts are long, narrow, sessile spikelets that are lanceolate, linear, and awnless. With a citral content of 74-76%, the essential oil has poor solubility.

***Cymbopogon pendulus*:** This is Jammu lemongrass, which is dwarf in nature and has white stems. The plant thrives in North India's Sub-Himalayan regions and is resistant to frost. With a citral content of 75-80%, the essential oil has a medium solubility in

alcohol.

Yield and oil content

Lemon grass leaves contain 0.8% aromatic oil, which varies significantly depending on the land's fertility, the climate in the cultivated area, the type of lemon grass being grown, the harvest season, and cultivation techniques. While leaves are shorter during the hot season but the blades are wider, lemon oil recovery and content is highest during the dry months and lowest during the rainy season.

Uses of lemon oil

The perfume industry makes extensive use of lemon oil, both directly and indirectly. It is widely used in tea blending, soaps, detergents, household cleaner, mosquito cream, and agarbatti, among other products. Additionally, oil is a starting material for some significant isolates, like citronellol and geraniol, which can be transformed into some of the most commonly used aromatics. Oil contains α -ionone, an antimicrobial and antifatulent compound that is a precursor to vitamin B₁₂. Cough syrup contains citronella oil, which relieves muscle fatigue and also used for wound healing. The oil has excellent medicinal and therapeutic qualities as well as a pleasant scent (Ranade, 2004). Traditional sources of citral included lemongrass oil. This oil served as a raw material for the production of methyl and ionones. Lemongrass oil possesses bactericidal qualities. Citral, the main constituent of lemongrass essential oil, is frequently found in soaps, candles, detergents, perfumes and cosmetics. Citral is used in the majority of fresh lime-scented soaps and after

shaves. Essential oils are a common component of aromatherapy.

Multi benefits of Lemongrass

Cymbopogon species offer a wide range of economic, nutritional, agricultural, medicinal, and ecological advantages. Its well-ramified root system aids in conserving water and soil. Lemongrass plantations help disperse the flooded fields by drawing moisture upward and evaporating it from the leaves, thereby eliminating the main source of illnesses in low-lying tropical areas where recurring flooding brings water-borne diseases. Its essential oil is utilized in medicine, insect repellent, bactericide, fragrances, cosmetics and flavours. Essential oil effectively combats inflammatory and infectious symptoms due to its potent antiviral, antifungal and antibiotic qualities. Cows are fed the spent grass to produce more nutritious milk, which boosts human immunity. Its leaves are utilized in the production of cardboard and paper. Grass improves soil fertility when it is used as mulch in gardens and orchards. It regulates obesity and treats digestive issues. It helps lower fever, maintains cholesterol levels, strengthens the immune and neurological systems, removes toxic waste, treats a variety of cancers, and has antiseptic qualities.

Conclusion

Lemon grass is grown for commercial purposes in order to extract aromatic oil from the leaves. The soil selection, climate, planting technique, species of lemon grass, fertilizer and manure application, harvesting, etc. must be taken

care of in lemongrass cultivation. Good yield and improved oil recovery from the leaves are the results of good cultivation techniques and precautionary measures used while growing lemon grass. The presence of citral in the oil gives the aromatic oil a lemon-like smell. The oil finds application in detergents, perfumery, and medicine. Therefore, growing lemon grass is very profitable for farmers in regions that receive adequate irrigation and rainfall.

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Agrivoltaics a Way to Reconcile Renewable Energy and Agricultural Production

Gaurav Mahajan

In the developing world where we are struggling to seek alternatives to fossil fuels, a promising solution has been put forth by scientists in the form of integration of solar panels with farming practices referred to be as Agrivoltaics. Agrivoltaic system is an innovative approach that combines agricultural production with solar energy generation on the same land. This dual-use system, also known as agro-photovoltaics, allows crops to grow under solar panels, balancing energy and food production on a single plot. The theoretical concept is described as a complex system within agriculture where it is required to elevate the tilt-mounted panels on a stable support structure to optimize both the crop (primary use) and electricity yield (secondary use). Dupraz *et al.*, 2011, defined, for the first time, this hybrid combination as an agrivoltaic system (AV). This configuration enhances the land equivalent ratio as a key role to improve the productivity on the same land unit, even more so than agroforestry systems. In Italy, by 2021, about 1 million new photovoltaic systems (agricultural, residential, industrial, and tertiary) were installed in different regions (mainly southern), and the area taken up by ground-mounted systems was 152.1 square kilometers, accounting for just 0.05% of the national total area (2023). In India, agrivoltaic farms are mainly devoted to experimental

purposes with different crops, as is the case in Germany, which has vegetable crops, such as winter wheat, potato, and cabbage, but no fruit crops beneath the panels (Pulipaka *et al.*, 2023).

Agrivoltaic systems involve installing solar panels above farmland. The panels are typically mounted at a height that allows farm machinery to pass underneath and spaced in a way that lets sunlight reach the crops. This configuration creates a partially shaded environment, which can benefit certain crops while also generating electricity. The key benefits of Agrivoltaic Systems include:

Enhanced Land-Use Efficiency: By producing both crops and solar energy on the same land, agrivoltaic systems maximize land-use efficiency. This is especially useful in areas with limited arable land, as it reduces competition between agriculture and solar projects. Further, this is particularly advantageous in regions with limited arable land or where there is a need to diversify income sources for farmers increase land-use efficiency by producing both food and energy on the same plot.

Water Conservation: The shading provided by solar panels reduces soil temperature and decreases evaporation rates, which helps conserve water. In water-scarce regions, this can be a significant advantage, as crops may require less irrigation.

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Microclimate Modification: Solar panels create a cooler microclimate under their shade, which can protect crops from extreme heat and drought, improving resilience to climate variability. This is beneficial for heat-sensitive crops, as well as for soil health. Solar panels provide partial shading for crops, which can be beneficial under certain conditions. The shading reduces crop exposure to direct sunlight, which helps decrease water evaporation from soil and can reduce crop heat stress, especially during hot seasons. Partial shading also creates a microclimate under the panels that can help conserve moisture in the soil, making it potentially easier to manage irrigation needs in dry regions.

Increased Solar Panel Efficiency: The evapotranspiration from plants can cool the air around the solar panels, which can enhance panel efficiency. Solar panels tend to produce electricity more efficiently at lower temperatures, so this cooling effect can improve their output.

Additional Revenue Streams for Farmers: Farmers can generate income from both agricultural yields and solar energy production. The revenue from energy generation can provide financial stability, helping farmers buffer against market fluctuations in crop prices or poor growing seasons.

Environmental Benefits: Agrivoltaics promotes renewable energy production and reduces the need to clear additional land for solar farms. It also supports soil conservation and biodiversity when diverse crops or cover crops are grown under the panels. Combining energy and crop production reduces the

need to clear additional land, which conserves biodiversity and reduces habitat loss. Agrivoltaic systems can also contribute to a reduction in greenhouse gas emissions by promoting renewable energy sources alongside traditional farming.

Likewise two sides of the coin, Agrivoltaic systems also poses certain challenges to be deal with:

Challenges and Considerations

Installation and Maintenance Costs: Initial costs for setting up Setting up agrivoltaic systems can be costly due to the need for elevated or adjustable solar panel structures that are compatible with agriculture. Maintenance may also be more complex, as both crops and solar panels require coordination.

Shading Effects on Crop Yields: The shading from solar panels may affect crop growth. While some crops benefit from partial shading, others may experience reduced photosynthesis, potentially leading to lower yields. It is important to select crops suited to the microclimate created by the panels.

Agricultural Equipment Access: Solar panels must be installed at a height that allows farm machinery to pass below, which requires careful planning and design. Elevated structures and precise layout help ensure that standard farming equipment can be used without interference. Agrivoltaic systems require adjustments to traditional farming practices, including the use of machinery for harvesting and irrigation, due to the presence of solar infrastructure.

Management Complexity: Combining agriculture with solar energy production adds complexity to farm management, as farmers need to consider both

the needs of the crops and the optimization of solar panel output. Use of transparent or semi-transparent solar panels to allow some light penetration. Implementing agrivoltaic systems holds promising, but optimizing the system to local conditions and crop requirements is crucial for maximizing both energy and crop production. This may require specialized training and support.

The global interest in the agrivoltaic sector is growing, with significant and accelerated progress in emerging agrivoltaic technologies and engineering design configurations. However, these advancements are deflected by limited investigations into agricultural performance. Agrivoltaic systems can be tailored to different agricultural practices, climates, and energy needs. Agrivoltaic systems offer diverse solutions for integrating renewable energy with agriculture, allowing farmers to select a setup that best meets their land-use goals, crop needs, and energy production targets. Agrivoltaic systems hold potential as a sustainable solution for meeting food and energy demands simultaneously. Research is ongoing to optimize system designs, understand crop responses to shading, and reduce costs. As interest grows, agrivoltaic systems could play a significant role in helping meet renewable energy goals, support agricultural resilience, and promote sustainable land use.

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CRISPR-Cas Technology: Unlocking Gene Editing Potential and Addressing Key Challenges

Kamsali Pruthvi Raju, Gundrathi Navya Sri, Kongari Soniya, Aman Tigga and K. Suresh

Abstract

CRISPR-Cas, often called “CRISPR,” stands for “Clustered Regularly Interspaced Short Palindromic Repeats” are the bacterial genome sequences that are providing protection against viruses when combined with a series of “CRISPR-associated (CAS) proteins.” CRISPR technology was first discovered in bacteria in the 1980s. It is a revolutionary gene-editing technology originally discovered as a bacterial immune defense system. CRISPR allows scientists to precisely modify DNA sequences, enabling targeted gene editing. This tool has transformed genetic research and holds potential in medicine, agriculture, and biotechnology.

Introduction

In early 1990s CRISPR (clustered regularly interspaced short palindromic repeats) technology was first identified in bacteria (*Escherichia coli*) where the bacterial genome consists of unique palindromic sequences and spacer sequences. These spacer sequences were matched with the viral genome sequence which is used by the bacteria as defense mechanism against viral infections. In 2012, Jennifer Doudna and Emmanuelle Charpentier adapted this system for precise gene editing, leading to a powerful tool for modifying genes in various organisms. They were awarded the Nobel Prize in Chemistry in 2020 for their groundbreaking work.

CRISPR CAS: CRISPR CAS consists of guide RNA for target sequence recognition and CAS, a

CRISPR associated protein acts as endonucleases that causes double strand break to achieve specific targets. CAS 9 is an associated protein functions as endonucleases by cutting the both strands of DNA. To eliminate the nucleotide sequence responsible for particular function we have to provide complementary sequence so that these two sequences form a complex and destroyed (knock out) by the action of endonuclease. Thus, the undesirable effects are eliminated by using CRISPR CAS technology. We can also precisely add nucleotide sequence (knock in) responsible for improving yield and drought resistance.

Applications: CRISPR CAS technology can be used for wide variety of applications by altering the DNA sequence associated with it.

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Gene therapy: By correcting specific mutations in patient cells, it aims to cure these diseases at the genetic level. Genetic disorders like Sickle cell anemia, cystic fibrosis and muscular dystrophy, is the result of faulty genes present in the human cell. By using CRISPR CAS Technology, we can edit those genes by altering the nucleotide sequence or by removing the particular sequence responsible for the disease.

Agriculture improvements: By using the CRISPR CAS technology the genes responsible for the biotic stress, and abiotic stress, toxins, allergies and yield can be altered such that those genes won't express result in improved yield and reduced toxins in the plant.

Functional genomics: CRISPR enables researchers to "knock out" specific genes, allowing them to study the gene's function and gain insights into its role in health and disease. This understanding is essential for advancing drug discovery and genetic research.

Cancer treatment: Researchers are using CRISPR to enhance immune cells' ability to identify and attack cancer cells and to target cancer-causing genes, offering potential new therapy.

Animal Breeding: CRISPR enables selective gene editing in livestock to enhance desired traits, like lean meat, disease resistance, and faster growth, providing an alternative to traditional breeding methods.

Infectious Disease Control: CRISPR is being researched to develop diagnostics for infections like COVID-19 and HIV, as well as possible treatments

by targeting viral genomes directly.

Precise gene editing: This technology allows us to precisely edit the particular trait nucleotide sequence of an organism without affecting the other functions.

Permanent Gene knock out: These technologies allow us to completely eliminates the sequence of gene permanently so that no need to remove the sequence again.

Synthetic Biology: CRISPR designs organisms with new capabilities, such as waste degradation or biofuel production.

Constraints of CRISPR CAS

Off target effects: CRISPR can sometimes bind to and edit DNA sequences that are similar but not identical to the intended target, leading to unintended genetic modifications. This results in side effects, disruption of essential genes and unknown genetic modifications.

Variable efficiencies of sg RNA: The efficiency of sg RNA is varied due to the Sequence Composition of sgRNA, secondary Structures in sgRNA and Position of Target Site Relative to PAM that affects the efficiency of the CRISPR CAS.

Low homology directed repair efficiency: It is mainly due to Cell Cycle stage Dependence, Template Degradation and competence of non-homologous end joining (NHEJ).

Low PAM size limitation: PAM sequences are short DNA motifs (e.g., NGG for Cas9) that must be adjacent to the target DNA sequence for CRISPR to bind and make a cut. This requirement limits the regions in the genome that CRISPR can edit, as not

all sequences have a nearby PAM site. Consequently, some target sites cannot be accessed by certain Cas proteins, which restricts editing flexibility. Different Cas proteins recognize different PAM sequences.

Ethical Concerns: The ability to edit genes, especially in human embryos or germline cells, raises profound ethical questions about consent, equity, and the potential for “designer babies”.

Immune Reaction: The human body may express an immune response to CRISPR proteins, making it challenging for therapeutic applications and risks of inflammation or other immune-related side effects.

Conclusion

The future of CRISPR-Cas technology is incredibly promising, with potential applications across health, agriculture, and environmental sectors that could address some of the world’s most pressing challenges. However, realizing this potential will require ongoing research to address technical and ethical challenges, ensuring that CRISPR is both safe and accessible for all.

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Introduction to *Phytophthora* Diseases in Arecanut and their Management

Kruthika R., Rani Jayadurga Nayak and Th. Sunita Devi

Abstract

The arecanut palm (*Areca catechu*), a monocot widely cultivated in India and other Asian countries, produces a masticatory nut known as arecanut, betelnut, or supari. Despite its cultural and economic significance, arecanut cultivation faces serious challenges due to various diseases, especially those caused by *Phytophthora* species. These diseases, notably fruit, bud, and crown rots, result in significant crop losses. *Phytophthora meadii* is the primary pathogen in India, with outbreaks occurring mostly in regions with heavy monsoon rains, such as Karnataka, Kerala, and Assam. Over the years, multiple strategies have been developed to manage *Phytophthora* diseases, including mechanical methods (such as covering fruit bunches), biological control using *Trichoderma* and other bioagents, and chemical fungicides like Bordeaux mixture, fosetyl-Al, and metalaxyl. Despite these efforts, substantial yield losses continue, and all currently cultivated arecanut varieties remain susceptible to *Phytophthora* diseases. Research is ongoing to develop resistant varieties through interspecific hybrids and to identify effective integrated disease management practices that combine mechanical, biological, and chemical control methods.

Introduction

The arecanut palm produces a popular masticatory nut called arecanut, betelnut, or supari. While supari is a processed and perfumed nut powder for mastication that is popular in northern India and Pakistan, the word betelnut refers to how arecanut and betel leaf (a twiner) are chewed together. Since ancient times, the behavior of “chewing” has been a symbol of friendship and overall well-being. Even during festivals in Hindu temples, betelnut and arecanut are offered to deities as worship materials.

No Hindu auspicious occasion, such as a marriage or betrothal ceremony, is complete without the guests receiving arecanut and betel leaves. Arecanut palm is a popular crop in India in the states of Kerala, Karnataka, and Tamil Nadu in southern India and in Assam, Meghalaya, and West Bengal in northeastern India. The areca palm is a monocot that belongs to the family Palmae. The commonly cultivated species is *Areca catechu* in most of the countries where it is used for chewing. In Sri Lanka, the fruits of *Areca concinna* are occasionally chewed. In the world, the

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majority of production is in India, followed by China. India leads in arecanut production by area (43.01%), followed by Bangladesh (33.00%), Indonesia (11.27 %), and Myanmar (5.71%). Similarly, India ranked first in output (50.37%), followed by Bangladesh (18.27%). Myanmar (11.31%) and Indonesia (7.37 %). Furthermore, arecanut is grown in limited quantities in several countries such as Nepal, China, Sri Lanka, and Malaysia. The average productivity of arecanut at the global level stood at 14.60 q/ha. Sri Lanka stood out from other arecanut-growing countries at first with a production of 35.14 q ha⁻¹ followed by Nepal (33.10 q ha⁻¹) and Myanmar (29.00 q ha⁻¹). Although India ranks first in global manufacturing, its productivity is poor with its global ranked seventh in terms of productivity, with a productivity level of 17.15 q ha⁻¹ which is practically on line with global production (Jamanal and Murthy, 2022).

Phytophthora diseases in arecanut

Arecanut, a long-lived perennial crop, faces challenges from various pests, diseases, and physiological disorders at different stages of its growth. One of the most destructive diseases impacting arecanut is caused by *Phytophthora* spp., which can lead to significant crop losses, with some palms losing either part or all of their yield, and in severe cases, even the death of the palm itself. The fungal infection primarily targets the immature nuts, the developing bud, and the crown of the palm, resulting in fruit rot, bud rot, and crown rot, respectively, which severely impact the plant's vital-

ity and productivity (Saraswathy, 2004). Initial studies on *Phytophthora* infections in arecanut were conducted over a century ago by Butler, an imperial mycologist, who paved the way for extensive research that has since been undertaken to understand and manage these diseases effectively. This accumulated knowledge has become instrumental in addressing *Phytophthora* diseases in arecanut through improved management strategies.

Occurrence and distribution of *Phytophthora*

The disease known as fruit rot in arecanut was initially documented in 1906 by Butler in the region of Mysore. Over time, it spread into the Dakshina Kannada and Uttara Kannada districts of Karnataka and extended into various parts of Malabar and Cochin in Kerala. By 1910, Coleman observed that the incidence of the disease had steadily increased each year, likely due to a growing accumulation of inoculum in these endemic regions of South India. This led to substantial economic losses for the region. In areas where this disease is prevalent, symptoms typically begin appearing with the onset of monsoon rains and persist until mid-August, as the humid and rainy conditions favor disease development. Crown rot, another significant disease, results from prolonged pathogen infection and may continue affecting the palm up until October, sustained by these favorable weather conditions. Reports indicate that both fruit rot and crown rot diseases are widespread throughout arecanut-growing regions receiving ample rainfall during the Southwest monsoon (Sarma *et al.*, 2002).



Koleroga disease of arecanut



Bud rot disease of arecanut

Etiology

Research on *Phytophthora* isolates from various arecanut-growing regions has confirmed that *P. meadii* is the primary pathogen responsible for fruit rot disease in arecanut across India, with no indications of *P. arecae* presence. Alongside *P. meadii*, *P. hevea* has also been identified as a contributing species (Chowdappa *et al.*, 2003; Prathibha *et al.*, 2020). The oomycete responsible for these infections produces a coenocytic mycelium that later forms septa and undergoes asexual reproduction through sporangia and chlamydospores. When male and female gametes (antheridia and oogonia) merge, sexual reproduction occurs, resulting in the formation of oospores. Most strains of *P. meadii* infecting arecanut are heterothallic, exhibiting both A1 and A2 mating types. However, *P. arecae* and *P. meadii* have also demonstrated the

ability to develop sexual organs within single cultures and naturally infected nuts, suggesting a homothallic reproductive mode (Ramakrishnan and Seethalakshmi, 1956).

Integrated disease management

Diseases caused by *Phytophthora meadii* have long posed a severe threat to arecanut production, representing one of the most destructive challenges for farmers over the past several decades. Despite the development of various disease management practices, fruit rot continues to lead to significant yield losses in many regions. Over the years, researchers nationwide have dedicated considerable efforts to identifying effective treatments, including chemical controls, biological agents, and integrated management strategies. This ongoing research aims to minimize the impact of *P. meadii* on arecanut and ensure more reliable production yields.

Host plant resistance

Host-plant resistance offers an eco-friendly, cost-effective, and sustainable method for managing *Phytophthora* diseases. Identifying stable sources of resistance to fruit rot disease is essential for developing resistant varieties. However, in the current situation, all cultivated varieties and germplasms of arecanut (*Areca catechu*) are vulnerable to this disease. Efforts to find resistance sources in closely related *Areca* species have suggested that *Areca triandra* and *A. concinna* could serve as potential candidates for breeding interspecific hybrids with disease resistance. Additionally, *Areca*

normabyu, *A. concinna*, and *Actinorytis calapparia* have shown resistance to fruit rot, remaining unaffected under disease-endemic field conditions for extended periods. These wild species may serve as valuable sources of resistance to *Phytophthora meadii*. (Muralikrishna *et al.*, 2018).

Mechanical methods: In the early 1950s, arecanut farmers commonly protected their crops from fruit rot disease by covering the bunches before the monsoon season. They traditionally used materials such as areca leaf sheaths, known as “Kotte,” or dry grass, called “Karada,” as a barrier against the onset of disease. Over time, polythene coverings (ranging from 125-200-gauge and sized 24×30 inches) were introduced, proving to be even more effective at preventing fruit rot. Research in this area demonstrated that when bunches were covered before the start of monsoon rains, complete protection against fruit rot could be achieved (Chowdappa *et al.*, 2002; Sastry and Hedge, 1985).

Biological method: In response to the negative impacts of fungicides, researchers have explored bio-agents and plant extracts that could effectively combat *Phytophthora meadii*. Laboratory findings revealed that several bio-agents, including *Trichoderma viride*, *T. harzianu*, *Aspergillus terreus*, and *Pseudomonas fluorescens*, showed promise against *P. meadii*. Similarly, research conducted at CPCRI in Kasaragod demonstrated that certain bacterial isolates, antagonistic to *P. meadii*, were compatible with the fungicides potassium phosphonate and Ovis 20. Further screening of three native *Trichoderma*

species against a highly aggressive strain of *P. meadii* showed that *T. virens* had the highest level of mycelial growth inhibition in both simultaneous inoculation and when inoculated 48 hours after *P. meadii*. Based on these findings, it has been recommended that these effective fungicides, along with *T. virens*, be further evaluated in field trials to support the development of integrated management practices against *Phytophthora* diseases. (Shalini and Rajashekhar, 2006).

Chemical management: Numerous experts have tried to identify an efficient chemical to control the diseases because it poses a continual threat to arecanut crops in southern India. Venkatarayan (1943) suggested spraying of 1 per cent Bordeaux mixture using a spreader prior to the start of monsoon and 30 to 45 days after the initial spray. During 1985-1990, more research on the management of fruit rot was conducted using novel systemic and contact fungicides. Despite the contact fungicides, such as copper oxychloride (Blitox), Mancozeb (Dithane M45), and Captafol (Difolatan) pathogen in the research conducted in the lab (Saraswathy, 1999), However, it was shown that these fungicides were ineffective in controlling fruit rot in the field as a result of inadequate retention capacity particularly when it's rain season. One of the systemic fungicides tested: fosetyl-Al (Aliette) or metalaxyl at 0.5 per cent gave good control over fruit rot at 0.15 per cent (Sastry and Hedge, 1985).

Conclusion

In conclusion, the arecanut palm, an import-

ant crop in India and other parts of Asia, is highly valued for its socio-cultural and economic significance. However, the cultivation of arecanut faces substantial challenges due to various diseases, particularly those caused by *Phytophthora* species. *Phytophthora meadii* is identified as the primary pathogen responsible for fruit, bud, and crown rot, leading to significant yield losses. The disease is especially prevalent in regions with heavy monsoon rains, which provide favorable conditions for its spread. Over the years, multiple disease management strategies have been developed, including mechanical, biological, and chemical methods. Although some fungicides and biological agents like *Trichoderma* species have shown promise, the persistence of *Phytophthora* diseases in endemic areas remains a major constraint. Additionally, while efforts to develop resistant varieties of arecanut have yet to yield success, research into inter-specific hybrids involving wild species offers a potential avenue for long-term disease resistance. An integrated approach combining host resistance, biological control agents, mechanical protection, and chemical fungicides may offer the most effective means of managing *Phytophthora* diseases in arecanut cultivation. Further research and field studies will be essential to develop sustainable and effective management practices for the future.

Advances in Understanding Photosynthesis Efficiency

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Abstract

Photosynthesis is the cornerstone of life on Earth, driving the conversion of solar energy into chemical energy and supporting global food and energy needs. Despite its critical importance, the efficiency of photosynthesis in most crops remains suboptimal, with only a small fraction of sunlight converted into biomass. Advances in understanding photosynthesis efficiency have opened new avenues to enhance crop productivity and address food security challenges. Recent breakthroughs include elucidating the mechanisms of light harvesting, optimizing Rubisco activity, and engineering more efficient photorespiration pathways. The application of synthetic biology, CRISPR-based genome editing, and high-throughput phenotyping has accelerated the development of crops with improved photosynthetic performance. Additionally, understanding the integration of photosynthesis with other metabolic and physiological processes offers further opportunities to boost efficiency. This article reviews recent progress in photosynthesis research, exploring how these advancements can revolutionize sustainable agriculture and meet the demands of a growing global population.

Introduction

Photosynthesis, the process through which plants convert light energy into chemical energy, is vital for life on Earth. However, natural photosynthetic efficiency is inherently low, with most crops converting only about 1-2% of sunlight into biomass (Zhu *et al.*, 2010). Enhancing photosynthesis efficiency has become a focal point in agricultural research to meet the growing demands for food, fuel, and fibre in a changing climate.

This article explores recent advances in understanding and improving photosynthesis efficiency, emphasizing their implications for sustainable agriculture.

The Fundamentals of Photosynthesis Efficiency

Photosynthesis efficiency can be broadly divided into:

Light Capture Efficiency: The ability of plants to capture and utilize sunlight.

Energy Conversion Efficiency: The effectiveness

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of converting captured light into chemical energy.

Biochemical Efficiency: The capacity to fix carbon through the Calvin-Benson cycle and related processes.

Each stage has limitations that contribute to the suboptimal performance of photosynthesis. Efforts to enhance efficiency focus on overcoming these constraints.

Advances in Light Harvesting Efficiency

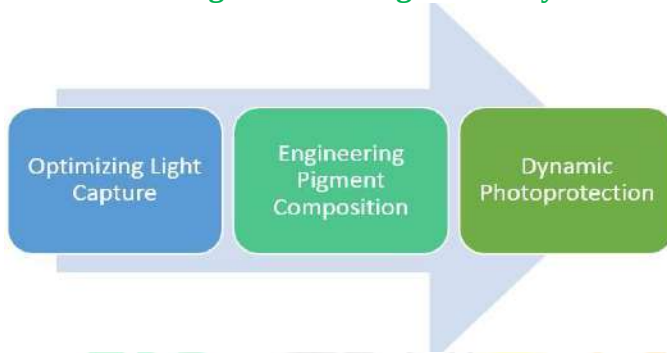


Fig. 1: Advances in light harvesting efficiency

Optimizing Light Capture

- ✓ Modern crops often capture more sunlight than they can utilize, leading to photoinhibition.
- ✓ Research on chlorophyll optimization seeks to balance light capture and energy conversion to minimize energy wastage (Ort *et al.*, 2011).

Engineering Pigment Composition

- ✓ Altering the composition of light-harvesting complexes can enhance photosynthetic efficiency under varying light conditions.
- ✓ For example, reducing chlorophyll levels in upper canopy leaves while increasing levels in lower canopy leaves improves whole-canopy efficiency in rice and wheat (Slattery *et al.*, 2017).

Dynamic Photoprotection

- ✓ Mechanisms such as non-photochemical quenching (NPQ) protect plants from excess light damage.
- ✓ Accelerating NPQ recovery time allows plants to utilize fluctuating light more effectively (Kromdijk *et al.*, 2016).

Enhancing Rubisco Efficiency

Rubisco: A Bottleneck in Photosynthesis

- ✓ Rubisco, the key enzyme in carbon fixation, has low catalytic efficiency and often fixes oxygen instead of carbon dioxide, leading to energy loss through photorespiration (Parry *et al.*, 2013).

Rubisco Engineering

- ✓ Advances in protein engineering have produced Rubisco variants with improved specificity for carbon dioxide and higher catalytic rates.
- ✓ Introducing Rubisco from cyanobacteria into crops has shown potential for enhanced photosynthetic efficiency (Lin *et al.*, 2014).

CO₂ Concentrating Mechanisms (CCMs)

- ✓ Incorporating CCMs, such as those found in C₄ plants and algae, into C₃ crops can increase carbon fixation efficiency.
- ✓ Engineering bicarbonate transporters and carboxysomes has shown promise in preliminary studies (Price *et al.*, 2013).

Improving Photorespiration Pathways

Photorespiration consumes energy and reduces photosynthesis efficiency in C₃ plants. Several strategies have been explored to mitigate these losses:

Synthetic Bypass Pathways

- ✓ Introducing synthetic pathways, such as the glycolate oxidase-bypass, reduces energy losses by redirecting photorespiratory intermediates (South *et al.*, 2019).

Engineering C₄ Traits into C₃ Crops

- ✓ Incorporating C₄ photosynthesis traits into C₃ crops like rice enhances carbon assimilation and reduces photorespiratory losses.
- ✓ Despite technical challenges, progress in this area holds significant promise (von Caemmerer *et al.*, 2012).

Integrating Photosynthesis with Whole-Plant Physiology

Optimizing Stomatal Conductance

- ✓ Modulating stomatal opening improves water-use efficiency and ensures adequate CO₂ supply for photosynthesis.
- ✓ Genetic modifications targeting stomatal density and behaviour have enhanced photosynthesis in drought-prone environments (Lawson and Matthews, 2020).

Linking Photosynthesis to Sink Strength

- ✓ Improving the transport and storage of photosynthates enhances carbon utilization efficiency.
- ✓ Increasing sink strength, such as grain or fruit development, has shown potential to boost overall productivity.

Technological Innovations Driving Photosynthesis Research

High-Throughput Phenotyping: Advances in imaging and remote sensing technologies allow for

large-scale screening of photosynthetic traits under field conditions.

Synthetic Biology and Genome Editing: Tools like CRISPR-Cas9 enable precise editing of photosynthesis-related genes, accelerating trait improvement (Chen *et al.*, 2019).

Systems Biology Approaches: Integrative models combining transcriptomics, proteomics and metabolomics provide insights into complex photosynthetic pathways and their regulation.

Challenges and Future Directions

Trade-Offs and Constraints: Enhancing one aspect of photosynthesis may inadvertently affect others, such as nitrogen use efficiency or plant architecture.

Field Testing: Laboratory success must be translated to field conditions, where environmental variability poses significant challenges.

Policy and Adoption: Integrating advanced photosynthesis traits into breeding programs requires supportive policies and farmer acceptance.

Conclusion

Advances in understanding and improving photosynthesis efficiency hold transformative potential for addressing global food security challenges. By leveraging insights from light harvesting, Rubisco engineering, photorespiration, and whole-plant integration, researchers are paving the way for more productive and sustainable agricultural systems. Continued interdisciplinary efforts, supported by technological innovations, will be critical for translating these advancements into tangible benefits for farmers and ecosystems world-

wide.

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Integrated Pest Management: A Sustainable Approach

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Abstract

Integrated Pest Management (IPM) represents a holistic and sustainable approach to pest control, emphasizing environmental stewardship and economic viability. By combining biological, cultural, mechanical, and chemical methods, IPM minimizes reliance on chemical pesticides while maximizing crop protection. This article explores the principles, components, and advantages of IPM, as well as challenges and future directions. Highlighting its role in reducing environmental impact and ensuring long-term agricultural productivity, the discussion underscores IPM as a cornerstone of sustainable agriculture.

Introduction

Agriculture has always been at the mercy of pests that threaten crop yields and food security. Traditionally, chemical pesticides have been the primary tool to combat these challenges. However, the environmental and health risks associated with pesticide overuse, coupled with the emergence of pesticide-resistant pests have necessitated alternative approaches. Integrated Pest Management (IPM) has emerged as a comprehensive and sustainable solution, balancing effective pest control with minimal environmental disruption.

IPM is not a single pest control method but rather a combination of strategies tailored to specific crop and pest conditions. By integrating multiple approaches, IPM seeks to reduce pest populations to economically and ecologically acceptable levels. This article delves into the principles, methods, and benefits of IPM, showcasing its potential to transfo-

rm pest management in agriculture.

Principles of Integrated Pest Management

IPM operates on several core principles that distinguish it from conventional pest control methods:

Prevention: Emphasizing proactive measures to avoid pest infestations through cultural and agronomic practices.

Monitoring: Regular observation and identification of pest populations to assess their levels and dynamics.

Thresholds: Defining action thresholds the pest density at which control measures become necessary.

Combination of Strategies: Utilizing multiple control methods biological, mechanical, cultural, and chemical to manage pests sustainably.

Evaluation: Continuously assessing the effectiveness of implemented strategies and adjusting as needed.

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Components of IPM

Cultural Control

Cultural practices are preventive measures aimed at reducing the habitat and resources available to pests. These include:

Crop Rotation: Alternating crops to disrupt pest life cycles.

Intercropping: Growing different crops together to deter pests.

Sanitation: Removing crop residues and weeds that serve as pest breeding grounds.

Optimal Planting Times: Timing sowing and harvesting to avoid peak pest activity.

Biological Control

Biological control involves using natural enemies of pests to reduce their populations. Examples include:

Predators: Lady beetles and lacewings feed on aphids and other pests.

Parasitoids: Wasps lay eggs inside pests, killing them as the larvae develop.

Pathogens: Fungi, bacteria, and viruses target specific pests.

Biological control is environmentally friendly and supports biodiversity, making it a cornerstone of IPM.

Mechanical and Physical Control

These methods physically remove or block pests. Examples include:

Traps: Sticky traps, pheromone traps, and light traps attract and capture pests.

Barriers: Netting or row covers prevent pest access

to crops.

Manual Removal: Hand-picking pests or pruning infested plant parts.

Chemical Control

Chemical pesticides are used in IPM as a last resort when other methods fail to keep pest populations below the threshold. Emphasis is placed on:

Selective Pesticides: Targeting specific pests with minimal impact on non-target organisms.

Minimal Application: Applying the lowest effective dose to reduce environmental contamination.

Resistance Management: Rotating chemical classes to prevent resistance development.

Monitoring and Decision-Making

Monitoring involves regularly scouting fields to identify pests, assess their density, and detect natural enemy populations. Tools like pheromone traps, sticky cards, and remote sensing technologies aid in accurate pest identification. Decision-making is guided by economic thresholds, ensuring interventions are cost-effective and necessary.

Advantages of IPM

Environmental Benefits

Reduced Chemical Use: Minimizes pesticide application, reducing soil, water and air contamination.

Biodiversity Conservation: Protects beneficial organisms like pollinators and natural predators.

Soil Health Preservation: Prevents chemical buildup and supports soil microbiota.

Economic Advantages

Cost Savings: Reduces expenditure on chemical pesticides and mitigates crop losses.

Sustainable Yield: Enhances long-term productivity through improved ecosystem health.

Social and Health Benefits

Reduced Health Risks: Limits exposure to harmful pesticide residues for farmers and consumers.

Community Engagement: Encourages collaboration among farmers, researchers, and policymakers.

Challenges in Implementing IPM

Despite its benefits, IPM faces several challenges:

Knowledge and Awareness: Many farmers lack understanding of IPM principles and techniques.

Cost and Resources: Initial investments in monitoring tools and biocontrol agents can be prohibitive.

Resistance from Stakeholders: Pesticide manufacturers and distributors may resist the shift away from chemical reliance.

Climate Variability: Changing weather patterns can influence pest dynamics and complicate IPM planning.

Policy and Regulation: Insufficient support for IPM adoption through subsidies, training, and research funding.

Future Directions

To overcome challenges and scale IPM adoption, future efforts should focus on:

Education and Training: Expanding farmer education programs and providing access to IPM resources.

Technological Advancements: Leveraging AI, machine learning, and big data for predictive pest modeling and real-time decision-making.

Policy Support: Implementing government policies that incentivize IPM through subsidies and research funding.

Global Collaboration: Facilitating knowledge exchange and collaborative research to address transboundary pest challenges.

Sustainable Inputs: Developing eco-friendly biopesticides and enhancing the availability of biological control agents.

Conclusion

Integrated Pest Management offers a sustainable alternative to traditional pest control methods, balancing effective pest suppression with environmental conservation. By combining biological, cultural, mechanical and chemical approaches, IPM reduces reliance on chemical pesticides and promotes long-term agricultural resilience. Although challenges remain, the growing recognition of IPM's benefits provides a strong foundation for its broader adoption. As agriculture faces mounting pressures from population growth and climate change, IPM stands out as a vital tool in ensuring food security and environmental sustainability.

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Innovations in Pest Management: Reducing Chemical Use

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Abstract

Pest management is a critical component of modern agriculture, ensuring food security and minimizing crop losses. However, the excessive reliance on chemical pesticides has raised significant concerns, including environmental degradation, human health risks, and the emergence of resistant pest species. This article explores innovative approaches in pest management aimed at reducing chemical use. Emphasizing sustainable and environmentally friendly strategies, it delves into integrated pest management (IPM), biological control, genetic engineering, precision agriculture, and advancements in digital technologies. These methods not only mitigate the adverse effects of chemical pesticides but also promote long-term agricultural productivity. The article concludes by advocating for a holistic and collaborative approach to pest management, integrating traditional knowledge with modern science to achieve sustainable agricultural practices.

Introduction

Pest infestations have long been a bane to agricultural productivity, jeopardizing food security and economic stability. Historically, chemical pesticides have been the go-to solution to counter these challenges. Despite their effectiveness, the overuse of these chemicals has led to serious repercussions, such as soil degradation, contamination of water bodies, loss of biodiversity, and health risks to humans and animals. Furthermore, pests have evolved resistance to many chemical solutions, rendering them less effective over time. This growing awareness has prompted a shift toward innovative pest management strategies that reduce chemical use while maintaining or enhancing agricultural productivity. This article examines these innovations, highlighting their potential to transform

modern agriculture into a more sustainable and resilient system.

The Problem with Chemical Pesticides

Chemical pesticides have revolutionized agriculture since their widespread adoption in the mid-20th century. Yet, their indiscriminate use has led to multiple challenges:

Environmental Impact: Pesticides can contaminate soil, water, and air, causing harm to non-target organisms such as pollinators, aquatic life, and beneficial insects.

Human Health Concerns: Pesticide residues in food and water have been linked to various health issues, including cancer, neurological disorders, and hormonal imbalances.

Resistance Development: Continuous exposure to chemicals has resulted in pests developing resistance

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necessitating higher doses or newer, often more toxic pesticides.

Economic Costs: Dependence on chemical solutions increases input costs for farmers, many of whom already face financial instability.

These issues underline the urgent need for alternative pest management strategies that are both effective and environmentally sustainable.

Innovative Approaches in Pest Management

Integrated Pest Management (IPM)

IPM is a holistic approach that combines multiple strategies to manage pest populations at acceptable levels while minimizing environmental impact. Key components of IPM include:

Cultural Practices: Crop rotation, intercropping, and maintaining field hygiene to disrupt pest life cycles.

Mechanical Control: Using traps, barriers, or manual removal to reduce pest populations.

Biological Control: Introducing natural predators or parasitoids to suppress pest populations.

Selective Chemical Use: Employing pesticides as a last resort and in minimal quantities.

The success of IPM lies in its adaptability, allowing farmers to tailor strategies based on specific crop and pest dynamics.

Biological Control

Biological control leverages natural predators, parasitoids, or pathogens to manage pest populations. For instance:

Predatory Insects: Lady beetles and lacewings feed on aphids and other pests.

Parasitoids: Wasps that lay eggs inside pest hosts, eventually killing them.

Microbial Control: Using bacteria (e.g., *Bacillus thuringiensis*), fungi, or viruses to target specific pests.

This method significantly reduces chemical dependence and promotes ecological balance.

Genetic Innovations

Advances in biotechnology have opened new avenues for pest management, such as:

Genetically Modified Crops (GMCs): Crops like *Bt* cotton and *Bt* corn produce toxins that target specific pests, reducing the need for external pesticide applications.

RNA Interference (RNAi): A cutting-edge technology that silences specific genes in pests, inhibiting their growth or reproduction.

While promising, these technologies require careful regulatory oversight to address concerns about biosafety and potential ecological disruptions.

Precision Agriculture

Precision agriculture involves using technology to optimize farm inputs and practices. Key tools include:

Remote Sensing and Drones: Identifying pest infestations early through aerial imagery.

IoT Sensors: Monitoring soil, moisture, and pest activity in real time.

Data Analytics: Predicting pest outbreaks based on weather patterns and historical data.

These tools enable targeted interventions, minimizing the indiscriminate use of chemicals.

Digital and AI Technologies

Artificial intelligence (AI) and machine learning are revolutionizing pest management by:

- ✓ Analyzing vast datasets to identify pest trends.
- ✓ Offering decision support systems for timely interventions.
- ✓ Developing mobile apps that provide farmers with real-time pest diagnostics and management recommendations.

Such innovations enhance accuracy and efficiency, empowering farmers to adopt sustainable practices.

Challenges and Limitations

Despite their promise, innovative pest management strategies face several challenges:

Cost: Initial investments in technology and training can be prohibitive for small-scale farmers.

Knowledge Gaps: Many farmers lack awareness or access to these advanced techniques.

Resistance from Stakeholders: Pesticide manufacturers and distributors may resist changes that threaten their business models.

Regulatory Hurdles: Developing and approving new biocontrol agents or genetic technologies is a time-consuming and complex process.

Addressing these challenges requires concerted efforts from governments, researchers, and industry stakeholders to promote adoption and scale these innovations.

Future Directions

The future of pest management lies in integrating traditional knowledge with modern science.

Potential developments include:

Enhanced Biopesticides: Developing microbial-based solutions with higher efficacy and broader pest coverage.

Advanced AI Models: Creating more sophisticated algorithms for pest prediction and control.

Global Collaboration: Sharing knowledge and resources to tackle transboundary pest challenges, such as locust swarms.

Policymakers must also play a pivotal role in incentivizing sustainable practices through subsidies, training programs, and research funding.

Conclusion

Innovations in pest management are reshaping agriculture, offering sustainable alternatives to chemical pesticides. By embracing strategies like IPM, biological control, genetic technologies, and precision farming, we can reduce the ecological footprint of pest control while enhancing food security. However, realizing the full potential of these innovations requires a collective effort to overcome financial, educational, and regulatory barriers. As we move forward, a balanced approach that combines modern technology with ecological principles will be key to achieving sustainable agricultural practices.

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Major Pests of Citrus and their Management

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Abstract

Citrus is one of the most important fruits and one of the largest fruit industries in the world, grown in more than 52 countries around the world. In India, 250 species of insects and mites have been reported infesting different species of citrus. These pests significantly contribute towards the citrus decline in the region. For management of these pests, diagnosis of the causes of decline, the rejuvenation schedule may be formulated with multi-disciplinary approach. More information is needed on some of the key elements required for environmentally friendly management Biological control through augmentation and conservation of parasitoids integrated with other non-pesticide measures need to be tested with holistic approach in citrus. More attention should be given to the knowledge of the biology and ecology of parasitoid species. Bio-pesticides, including botanicals, can offer a safe and effective alternative to conventional insecticides for controlling the pest within an integrated pest management programme.

Sap feeders

Citrus aphids

Black aphid: *Toxoptera aurantii*,

Brown aphid: *Toxoptera citricida*

Symptoms of damage

- ✓ Feed on tender foliage and flowers.
- ✓ Transmit tristeza virus disease.
- ✓ Nymphs and adults suck the sap of leaves
- ✓ Wilting and flower dropping
- ✓ Infested leaves - cup shaped and crinkled
- ✓ Growth of the plants is hindered.

Identification of pest



Crinkling of leaves

Adult wingless forms (apterae)

Adult winged forms (alatae)

Management

- ✓ Use yellow sticky trap
- ✓ Spray with methyl demeton (Metasystox) or dimethoate (Rogar) 2 ml lit⁻¹.
- ✓ Use some concinellid beetles and syrphid flies

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Citrus Black fly, *Aleurocanthus woglumi*

Symptoms of damage

- ✓ The cell sap is sucked from the leaves - piercing stylet
- ✓ Leaf curling.
- ✓ Leaves fall off immaturely.
- ✓ Honey dew secretion development of sooty mould fungus.
- ✓ Leaf turns to black in colour and affects photosynthetic activity of the leaves.
- ✓ Affected trees produce - few blossoms which develop into inspid fruits.



Identification of pest

- ✓ Nymphs are flattened, oval in shape and scale like in appearance.
- ✓ Adult - minute insect, shiny black with grey dusting on the body.
- ✓ Wings are extending beyond the tip of the abdomen.

Management

- ✓ Collect and destroy the damaged plant parts along with nymphs, pupa and adults.
- ✓ Spray with 2 ml of chloropyriphos litre⁻¹ of water
- ✓ Female lays eggs on lower surface of leaves in a form of three (15-22 eggs/whorl) whorls.
- ✓ The entire plant canopy should be drenched with

the solution.

- ✓ Encourage activity of parasitoids, *Encarsia sp.*, *Eretomocerus serius* and *chlysoperla sp.*

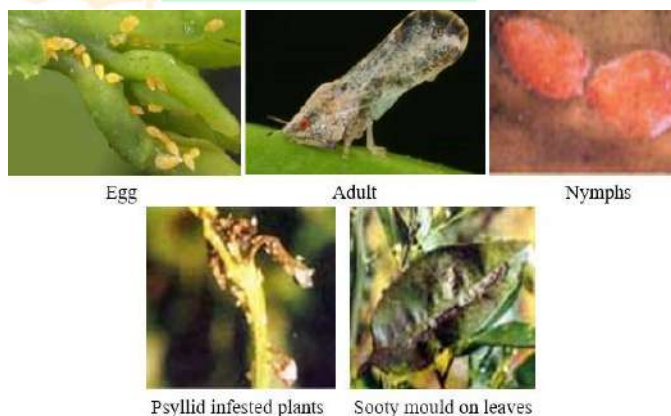
Citrus psyllid, *Diaphorina citri*

Symptoms of damage

- ✓ Both nymphs and adults suck sap from the plants and injection of toxic saliva.
- ✓ Nymphs - are more destructive, crowd on the terminal shoots, buds and tender leaves.
- ✓ Excrete honeydew - growth of sooty moulds.
- ✓ Affected plant parts dry and die away.
- ✓ It is transmits the “Greening” virus.

Identification of pest

- ✓ Nymphs - are flattened, oval in shape and scale like in appearance.
- ✓ Adult - minute insect, shiny black with grey dusting on the body.
- ✓ Wings are extending beyond the tip of the abdomen.



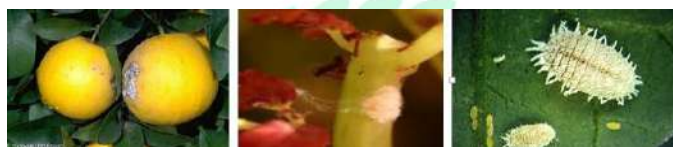
Management

- ✓ Collect and destroy the damaged plant parts.
- ✓ Spraying with systemic insecticides at flush growth periods.
- ✓ Encourage the activities natural enemies such as Syrphids and Chrysopids.

Mealy bug, *Planoccus citri*

Symptoms of damage

- ✓ Both nymphs and adults suck the sap from the cells of tender branches and fruits.
- ✓ Turn pale colour.
- ✓ Affected plant parts - wilt and dry up.
- ✓ Large amounts of honey dew excrete - sooty mould fungus.
- ✓ Fungus covers the foliage and fruits.
- ✓ In severe infestation the flowers do not form fruits.



Mealy bug on fruits

Egg mass

Adult female and crawlers

Identification of pest

- ✓ Eggs are laid in clusters, protective cottony mass
- ✓ Nymphs are amber coloured with white waxy coating with filaments.
- ✓ Adult - Male is winged, long antenna and without mouth parts.
- ✓ Female is wingless, flat body and short, waxy filaments along the margins

Management

- ✓ Collect and destroy the damaged leaves, twigs and stems.
- ✓ Debark branches and apply methyl parathion paste.
- ✓ Use sticky trap (5 cm length) on fruit bearing shoots.
- ✓ Spray dichlorvas 0.2% in combination with fish oil rosin soap 25 g lit⁻¹.

- ✓ Single soil application of aldicarb 10G at 50 g tree⁻¹ at the time of pruning
- ✓ Soil treatment with chlorophyriphos apply on the near the tree trunk.
- ✓ Spraying of trees with acephate, methomyl, or chlorpyriphos.
- ✓ Field release of Australian lady bird beetle *Cryptoleamus montrouzeri* 10 per tree.

Fruit sucking moth, *Otheris materna*, *O. ancilla*, *O. fullonica*

Symptoms of damage

- ✓ Adult pierce the fruit and suck the juice
- ✓ Rotting at the feeding site
- ✓ Fruit dropping

Identification of pest

- ✓ Larva - orange blue and yellow spots on velvety dark speckled on the body.
- ✓ Adult - stout moth and orange coloured wing.
- ✓ *Otheris materna* - three black spots on the fore wing.



Management

- ✓ Destroy the weed host *Tinospora cardifolia* and *cocculus pendules*
- ✓ Bag the fruit with polythene bag (500 gauge)
- ✓ Apply smoke to prevent adult moth
- ✓ Trap crop - growing tomato crop in orchards to attract the adult moth.
- ✓ Poison bait dilute suspension of fermented molasses and malathion 0.05% (50 EC at 1 ml/lit)

- ✓ Use light trap or food lure to attract moths

Citrus thrips, *Thrips nilgiriensis*

Symptoms of damage

- ✓ Nymphs and adults lacerate the leaf tissue and suck the sap from fruits.
- ✓ Leaf curling.
- ✓ Ring like appearance on the fruit.
- ✓ Irregular mottled patches on rind.

Identification of pest

Adult - yellowish, fringed wing



Scarring on Fruit Shoot damage Leaf damage

Management

- ✓ Collect and destroy the damaged plant parts.
- ✓ Spraying with systemic insecticides at flush growth periods.
- ✓ Encourage the activities natural enemies such as Syrphids and Chrysopid.

Cottony cushion scale, *Icerya purchase*

Symptoms of damage

- ✓ Nymphs and adults suck the sap from leaves
- ✓ Honey dew excretion
- ✓ Development of sooty mould fungus



Identification of pest

- ✓ White, ribbed masses that hold up to 800 red eggs.
- ✓ Nymphs are red with black legs and antennae.
- ✓ Adults are covered in white hair.

Management

- ✓ Spray dormant oil in late winter before spring.
- ✓ Spray horticultural oil, if needed, year round.
- ✓ Apply mixture of manure compost tea, molasses, citrus oil.
- ✓ Garlic-pepper tea also helps.
- ✓ Natural predators usually keep this insect in check.
- ✓ Control ants and dust which can give the scale a competitive advantage.
- ✓ Field release of vedalia and Australian ladybugs.

Leaf feeder

Citrus leaf miner, *Phyllocnistis citrella*

Symptoms of damage

- ✓ Caterpillars are attacked tender leaves and feed on the epidermis.
- ✓ Making silvery appearance presence on the lower surface of leaves.
- ✓ Leaves - distorted and crinkled
- ✓ Severe attack caused defoliation
- ✓ Encourage the incidence of citrus canker



Serpentine larva

Crinkled leaves

Identification of pest

- ✓ Eggs are minute, flattened presence on the lower

side of the midrib.

- ✓ Larvae -minute, yellowish or reddish and apodous.
- ✓ Settled down on the edge of the folded leaves.
- ✓ Adult - minute moth, black spot at the tip of the fore wing.

Management

- ✓ Mixed in a litre of water at weekly intervals at the time of emergence of new flush.
- ✓ Spray application of NSKE 5%

Citrus butterfly, *Papilio demolious*, *P. Polytes*, *P.helenus*

Symptoms of damage

- ✓ Caterpillars prefers on light green tender leaves.
- ✓ Feeding voraciously and leaving only the mid-ribs.
- ✓ Severe infestation the entire tree gets defoliated.

Identification of pest

- ✓ Early stage larva resembles bird dropping.
- ✓ Grown up larva - cylindrical, stout, green and brown lateral bond.
- ✓ Adult Dark brown swallowtail butterfly with numerous yellow marking.



Management

- ✓ Hand pick the larvae and destroy
- ✓ Field release of parasitoids *Trichogramma evanescens* and *Telenomus sp* on eggs.
- ✓ *Brachymeria sp* on larvae and *Pterolus sp.* on pupae.

Microbial Composting: Unlocking the Power of Microbe

Ayushi Shrivastava and Diptimayee Dash

Introduction

Composting is a natural process that relies on the decomposition of organic matter by microorganisms, and when talking about *microbial composting*, we are specifically focusing on the role of microbes mainly bacteria, fungi. They help in accelerating and optimizing the breakdown of organic materials. It is also called as biotransformation, which is biological modification that alters the chemical structure of compost. This type of composting offers a faster composting process than traditional. Microbial composting process involve microorganisms, primarily bacteria and fungi, to break down organic materials into simpler forms. These microbes are the true workhorses of composting they feed on carbon-rich (brown) and nitrogen-rich (green) materials, transforming them into humus, which is the dark, nutrient-rich material that makes compost so valuable for plants.

The substrate for composting

The materials that undergo degradation (biotransformation) are referred to as substrates. This includes:

Lignin: It is a major structural component of plants, and is the one that is degraded the slowest. Its degradation is primarily accomplished by fungi, particularly white rot fungi.

Cellulose: It is the most abundant component of

plants. Many fungi, bacteria, and also myxomycetes are involved in the degradation of cellulose, among them Fungi are most important.

Hemicellulose: Xylan, among the hemicelluloses, is the most important and is found in straw, bagasse (up to 30%), and wood (2% to 25%). The main degrading enzymes are xylanases, produced by many bacteria and fungi. Other hemicellulose are pectin and starch.

Phases of Microbial composting

Mesophilic Phase: It is the first stage of composting, the temperature at this stage is relatively low (25-45°C) which supports the survival of mesophilic bacteria (those that thrive in moderate temperatures) and hence are the primary decomposers. They break down easily degradable materials (sugars, proteins). At this stage compost worms, millipedes, etc. act as catalysts. The mesophilic microbes in spite of being in higher number than thermophiles, leads to rise in temperature seen towards the end of this phase.

Thermophilic Phase: As the compost heats up (around 45-71°C), thermophilic microorganism, which thrive in higher temperatures, take over. Previously flourishing mesophilic organisms die off and are eventually degraded by the succeeding thermophilic organisms, along with the remaining, easily degradable substrate. These bacteria are capable of breaking down tougher materials like cellulose, lignin, and proteins, effectively reducing

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the volume of organic waste. The high temperatures also help kill weed seeds, pathogens, and harmful microbes. The decomposition continues to be fast, and accelerates until a temperature of about 62°C is reached. The thermophilic stage usually is inhabited by thermophilic bacteria, actinomycetes rather than thermophilic fungi.

Cooling phase (Second Mesophilic Phase): When the activity of the thermophilic organisms ceases due to exhaustion of substrates, the temperature starts to decrease which leads to third stage of composting i.e. the cooling phase. The second mesophilic phase is characterized by an increasing number of organisms that degrade starch or cellulose. Among them are both bacteria and fungi.

Maturation Phase: During the maturation phase, the quality of the substrate declines, and in several successive steps the composition of the microbial community is entirely altered. Usually, the proportion of fungi increases, while bacterial numbers decline. Compounds that are not further degradable, such as lignin-humus complexes, are formed and become predominant.

How Does Microbial Composting Work?

Microbial composting is essentially an accelerated version of the natural decomposition process (Composting).

Here's how it works:

Microbial Colonization: Once you add organic material to the compost pile, microbes quickly colonize the material. The process begins when microbes begin to break down simple organic comp-

ounds, such as sugars and proteins from substrates.

Production of Heat: As microbes consume the organic material, they produce heat as a byproduct. This heat accelerates the breakdown of complex organic compounds like cellulose and lignin.

Aerobic Respiration: Most of the microbes involved in composting require oxygen (aerobic decomposition) to break down organic matter efficiently. This is why turning the compost regularly is important.

Nutrient Cycling: As the microbes break down organic matter, they release essential nutrients like nitrogen, phosphorus, and potassium, which become available for plants when the compost is added to the soil. This is why compost is often called "black gold" it's a natural fertilizer that helps improve soil structure, water retention, and fertility.

End Product: After several weeks to months, the compost reaches a state where most of the organic matter has been broken down into humus which is compost.

Benefits of Microbial Composting

Faster Decomposition: Microbial composting speeds up the natural breakdown of organic materials. By optimizing the conditions for microbial activity such as maintaining the right balance of carbon and nitrogen, moisture, and oxygen you can create high-quality compost in a shorter time than traditional methods.

Enhanced Soil Fertility: The end product of microbial composting humus contains a wealth of nutrients that can replenish depleted soil, improve its

texture, and enhance its ability to retain moisture.

Reduced Waste: Microbial composting helps divert large amounts of organic waste (such as food scraps, yard waste, and agricultural byproducts) into compost. This reduces methane emissions.

Disease and Pest Suppression: The high temperatures generated by microbial composting during the thermophilic phase can kill weed seeds, pathogens, and harmful microorganisms, resulting in healthier compost and soil.

Sustainability: By relying on the natural processes of decomposition, microbial composting offers a sustainable solution for waste management and soil enrichment. It's a process that requires few resources, minimizes environmental harm, and supports biodiversity.

How to Optimize Microbial Composting at Home

To get the most out of microbial composting, it's important to create the right conditions for your microbial. Here are some tips to help you optimize the composting process:

Maintain a Proper Carbon-to-Nitrogen Ratio:

The ideal compost mix contains a balance of carbon-rich (browns) and nitrogen-rich (greens) materials. A good rule of thumb is a 25:1 to 30:1 ratio of carbon to nitrogen.

- ✓ **Browns (carbon sources):** Dry leaves, straw, sawdust, cardboard, and paper.
- ✓ **Greens (nitrogen sources):** Fruit and vegetable scraps, grass clippings, coffee grounds, and fresh plant material.

Ensure Proper Moisture: Microbes need moisture

to function, but too much moisture can lead to anaerobic conditions. Aim is to keep your compost pile as moist.

Aerate the Pile: Microbes require oxygen to break down organic matter efficiently. Regularly turning your compost pile is advised (every few weeks) to ensure good aeration.

Add Compost Starters or Activators: In some cases, you may want to jumpstart composting, adding compost starter can be a good idea. These products contain beneficial microbes or enzymes that help speed up the decomposition process. You can also add a handful of finished compost to introduce microbes from an already active pile.

Monitor Temperature: Microbial composting works best when the compost reaches and maintains a temperature of around 35-65°C) during the thermophilic phase. Use a compost thermometer to monitor the temperature. If it gets too high, turn the pile to release some heat. If it gets too low, add more greens to boost microbial activity.

Challenges and Considerations

While microbial composting is relatively straightforward, there are a few common challenges to be aware of:

Odors: If your compost pile smells unpleasant (like rotten eggs), it may be too wet or lacking oxygen. Ensure that you turn the pile regularly and add more dry materials if necessary.

Slow Decomposition: If decomposition is slow, the carbon-to-nitrogen ratio may be off. Try adjusting the balance by adding more greens (nitrogen) or

more browns (carbon).

Pests: Composting food scraps, especially in warm climates, can attract rodents and flies. To prevent this, cover your compost pile with a layer of browns or bury food scraps deeper in the pile.

Conclusion

Microbial composting is a powerful and efficient way to recycle organic waste, enrich the soil, and promote a healthy garden or farm. By understanding the role of microorganisms in the composting process and creating optimal conditions for their activity, you can speed up decomposition, produce high-quality compost, and contribute to sustainability.

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Renewable Energy in Agriculture: Solar, Wind and Biomass

Jack Ningthoujam and Pukhrambam Sunilkumar Singh

Introduction

Agriculture, a vital sector for food security and economic development, is heavily dependent on energy. Traditionally, fossil fuels have been the primary energy source for agricultural operations, but these have led to significant environmental issues such as greenhouse gas emissions, soil degradation, and rising energy costs. As the global population grows and the impact of climate change becomes more apparent, there is an increasing need for sustainable energy solutions in agriculture. Renewable energy sources solar, wind, and biomass offer promising alternatives to conventional energy, helping farmers reduce their carbon footprint, increase energy independence, and lower operational costs. Renewable energy is not only a way to combat environmental issues but also an economic opportunity for farmers. By adopting these green technologies, farmers can not only reduce their reliance on external energy sources but also potentially generate extra income by selling surplus energy back to the grid. In this article, we explore the roles of solar, wind, and biomass energy in modern agriculture, focusing on their applications, benefits, and the challenges they present.

Solar Energy in Agriculture

Solar energy is one of the most widely used renewable energy sources in agriculture. Its versatility makes it applicable to a variety of agricultural activities, from irrigation to greenhouse operations and even crop drying. Solar power systems harness sunlight using photovoltaic (PV) panels or solar thermal collectors and convert it into electricity or heat.

Applications of Solar Energy in Agriculture

Solar-Powered Irrigation Systems: Irrigation is a critical agricultural practice that consumes a significant amount of energy, especially in water-scarce regions. Traditional irrigation methods, such as those powered by diesel or electric pumps, are costly and environmentally harmful. Solar-powered irrigation systems, however, use photovoltaic panels to power water pumps, providing a sustainable solution for farmers. These systems are particularly beneficial in remote or off-grid areas where access to conventional electricity is limited.

Benefits of solar-powered irrigation systems include:

- ✓ **Reduction in energy costs:** Solar power eliminates the need for expensive fuel or electricity.

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✓ **Sustainability:** Solar energy is clean and reduces the carbon footprint of agricultural activities.

✓ **Reliability:** With no fuel dependency, solar-powered systems are highly reliable in areas with consistent sunlight.

Solar Greenhouses: Solar energy can also be used to power heating systems in greenhouses, allowing for the cultivation of crops in colder climates or during off-seasons.

Solar-Powered Crop Drying: Solar dryers reduce the need for fossil fuels and help preserve the quality of crops by avoiding the over-drying that can occur with conventional methods.

Solar-Powered Equipment: In remote areas, solar power can provide electricity for agricultural operations, reducing the need for fuel and lowering operational costs.

Benefits of Solar Energy in Agriculture

Cost Savings: After the initial installation, solar systems have low maintenance and operational costs, leading to long-term savings for farmers.

Environmentally Friendly: Solar energy is a renewable and clean source of power that reduces greenhouse gas emissions.

Energy Independence: Farmers can generate their own electricity, reducing dependence on external energy sources.

Increased Productivity: Solar energy allows for year-round operations in greenhouses, irrigation systems, and drying facilities.

Challenges and Considerations

While solar energy has immense potential in

agriculture, several challenges remain:

High Initial Costs: The installation of solar panels and related infrastructure can be expensive, particularly for small-scale farmers.

Energy Storage: Solar power generation is intermittent, dependent on sunlight. Storage solutions such as batteries are needed to ensure a consistent energy supply, adding to the cost.

Geographic Limitations: Solar energy is most effective in areas with high sunlight exposure. Cloudy regions or those with limited sunlight may not fully benefit from solar energy.

Wind Energy in Agriculture

Wind energy is another renewable energy source that can be harnessed for agricultural purposes. Wind turbines convert the kinetic energy of wind into electricity, which can be used to power farm operations or sold back to the grid. While wind energy is not as widely utilized as solar energy in agriculture, it holds great potential, particularly in regions with high wind speeds.

Applications of Wind Energy in Agriculture

Wind-Powered Water Pumps: In areas where access to electricity is limited or expensive, wind-powered water pumps provide an effective solution for irrigation and livestock watering. These systems work by using wind energy to power pumps that draw water from wells or surface water bodies, reducing reliance on costly electricity or fuel-powered pumps.

Wind-Powered Grain Drying: Wind turbines can also be used to power grain drying systems. Grain

drying is essential for preserving the quality and shelf life of crops, and using wind energy to power this process makes it more sustainable. Wind-powered drying systems can significantly reduce the carbon footprint of post-harvest operations.

On-Farm Power Generation: Wind turbines can generate electricity for on-farm use, powering equipment, lighting, and other energy needs. Farmers in windy regions can install turbines to offset their energy consumption and lower operational costs. Surplus electricity can often be sold to the grid, providing an additional income stream.

Benefits of Wind Energy in Agriculture

Sustainability: Wind energy is renewable and produces no greenhouse gas emissions during operation.

Energy Independence: Wind energy allows farmers to generate their own electricity, reducing dependence on external power sources.

Cost Efficiency: Once installed, wind turbines have low operating costs and can provide a reliable source of energy for agricultural operations.

Challenges and Considerations

Location Dependency: Wind energy is most effective in regions with consistent and strong winds. Areas with low wind speeds may not be suitable for wind power generation.

High Initial Investment: The installation of wind turbines can be costly, and the economics may not be feasible for smaller farms.

Maintenance: Wind turbines require regular maintenance to ensure efficient operation, and repairs can

be costly, especially in remote areas.

Biomass Energy in Agriculture

Biomass energy refers to the use of organic materials such as crop residues, animal waste, and forestry byproducts to generate energy. Biomass can be used to produce heat, electricity, or biofuels, providing farmers with a way to recycle waste materials and reduce their dependence on fossil fuels.

Applications of Biomass Energy in Agriculture

Biomass for Heating: Biomass can be used as a fuel source for heating systems, especially in greenhouses and livestock barns. Wood pellets, crop residues, or animal manure can be burned to produce heat for maintaining optimal temperatures for plant growth or animal welfare.

Biogas Production: Biogas is produced through the anaerobic digestion of organic materials such as manure, food waste, and crop residues. The process produces methane, which can be used for electricity generation, heating, or even as a transportation fuel.

Biofuels for Machinery: Biomass can also be converted into biofuels like biodiesel or bioethanol, which can be used to fuel farm machinery, such as tractors and trucks.

Benefits of Biomass Energy in Agriculture

Waste Utilization: Biomass energy allows farmers to utilize agricultural and animal waste for energy, reducing disposal costs and environmental impact.

Carbon Neutral: Biomass is considered carbon-neutral because the carbon dioxide released during combustion is offset by the carbon absorbed by plants during their growth.

Energy Independence: Biomass provides farmers with an alternative to fossil fuels, reducing their dependence on external energy sources.

Local Economic Development: Biomass energy can create local jobs in energy production, waste management, and equipment maintenance.

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Floral Therapy: The Mental and Emotional Benefits of Floral Gardening

Uppuleti Sai Prakash, Rani Jayadurga Nayak, Madhavi Yampalla, C. Sreenivasa Reddy and Srinivasulu G. B.

Abstract

Flower gardening, often seen as a leisurely activity, holds profound mental and emotional benefits. Known as floral therapy, this practice fosters mindfulness, reduces stress, alleviates anxiety, and enhances overall well-being. The sensory engagement of gardening and the joy of nurturing life contribute to mental clarity and emotional stability. Beyond individual benefits, it fosters social connections and a sense of purpose. This article explores the therapeutic potential of flower gardening, the psychological mechanisms behind its impact, and how it can be integrated into daily life as a tool for holistic mental health.

Introduction

In an era of rapid technological advancement and escalating urbanization, mental health challenges such as stress, anxiety, and depression are on the rise. While medical interventions and therapy offer critical support, alternative and complementary practices are gaining traction for their holistic approach to well-being. Among these, floral therapy the mental and emotional benefits derived from flower gardening stands out as an effective and accessible method to enhance mental health. By engaging with nature through the cultivation and care

of flowers, individuals can find solace, joy, and a renewed sense of purpose.

The Therapeutic Potential of Flower Gardening

Stress Reduction and Relaxation: Flower gardening provides a natural escape from the pressures of daily life. The act of digging soil, planting seeds, and nurturing growth fosters a sense of calm and relaxation. Research indicates that spending time in green spaces lowers cortisol levels, the hormone associated with stress, and promotes the release of endorphins, which elevate mood. The vibrant colors, pleasant fragrances, and tactile sensations of flowers

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create a multi-sensory experience that soothes the mind and body.

Enhancing Mindfulness and Focus: Gardening inherently requires focus and attention to detail, qualities that align closely with mindfulness practices. As individuals immerse themselves in planting, watering, and weeding, they become more attuned to the present moment. This engagement helps to quiet the noise of racing thoughts and cultivates a meditative state. Flower gardening is thus a practical way to integrate mindfulness into daily life, promoting mental clarity and emotional balance.

Boosting Mood and Emotional Well-Being: The simple act of tending to flowers has been shown to elevate mood and enhance emotional well-being. Witnessing the growth and bloom of plants nurtures a sense of accomplishment and joy. The vibrant colors and natural beauty of flowers have been linked to positive emotions and can serve as a natural remedy for feelings of sadness or fatigue. In fact, horticultural therapy programs often include flower gardening to aid individuals struggling with depression and anxiety.

Strengthening Social Connections: Flower gardening is not only an individual pursuit but also a community activity. Community gardens, horticulture clubs, and shared gardening spaces bring people together, fostering social interactions and building relationships. For individuals experiencing loneliness or social isolation, participating in gardening activities provides an opportunity to connect with

others and develop a sense of belonging.

Encouraging a Sense of Purpose: Engaging in gardening offers a sense of purpose and responsibility. The cycle of planting, nurturing, and harvesting creates a tangible connection to life's rhythms, instilling a sense of achievement and fulfillment. For individuals recovering from trauma or facing life transitions, gardening can serve as a metaphor for growth and resilience, offering hope and motivation.

The Psychological Mechanisms behind Floral Therapy

Biophilia Hypothesis: The biophilia hypothesis posits that humans have an innate affinity for nature. Engaging with flowers satisfies this intrinsic need, reducing stress and enhancing well-being.

Sensory Stimulation: The colors, textures, and scents of flowers stimulate the senses, activating the brain's reward pathways. This sensory engagement fosters relaxation and joy.

Mind-Body Connection: Physical activity involved in gardening, such as digging, planting, and watering, releases endorphins and reduces muscle tension. This connection between physical exertion and mental relaxation enhances overall well-being.

Creative Expression: Designing flower arrangements and garden layouts allows individuals to express creativity, which has been linked to improved mental health and emotional resilience.

Restorative Environments: Gardens are restorative spaces that provide a break from urban environments. Being surrounded by flowers and greenery

facilitates cognitive recovery and reduces mental fatigue.

Integrating Flower Gardening into Daily Life

Creating Personal Garden Spaces: Even small spaces, such as balconies or windowsills, can be transformed into flourishing gardens. Container gardening with colorful flowers like marigolds, petunias, or geraniums can brighten any living space.

Participating in Community Gardens: Joining a local community garden allows individuals to enjoy the benefits of gardening while fostering social connections and sharing knowledge.

Engaging in Seasonal Gardening: Adapting gardening practices to the seasons ensures year-round engagement. For instance, spring and summer can be dedicated to vibrant blooms, while fall and winter focus on hardy plants or indoor gardening.

Incorporating Floral Therapy in Healthcare: Hospitals, rehabilitation centers, and mental health facilities can incorporate flower gardening programs to aid recovery and provide therapeutic benefits to patients.

Educational Initiatives: Schools and community organizations can introduce gardening programs for children and adults to promote environmental awareness, mental health, and community bonding.

Challenges and Overcoming Barriers

Space Constraints: Limited space in urban areas can hinder access to gardening. Solutions include vertical gardens, container gardening, and rooftop gardens.

Time and Effort: Gardening requires time and

physical effort, which may deter some individuals. Simplified techniques, such as low-maintenance plants and automated watering systems, can make gardening more accessible.

Lack of Knowledge: Beginners may feel overwhelmed by the technical aspects of gardening. Community workshops, online tutorials, and gardening apps can provide valuable guidance.

Environmental Concerns: The use of chemical fertilizers and pesticides in gardening can harm the environment. Opting for organic methods and sustainable practices can mitigate these issues.

Future Directions for Floral Therapy

Integration with Digital Tools: Apps and platforms that provide gardening tips, track plant growth, and connect gardeners can enhance the experience and accessibility of floral therapy.

Research and Development: Continued research on the psychological and physiological impacts of gardening can provide deeper insights and validate its therapeutic potential.

Policy Support: Governments and organizations can promote floral therapy through funding for community gardens, educational initiatives, and healthcare integration.

Corporate Wellness Programs: Businesses can include gardening activities in their wellness programs to support employees' mental health and productivity.

Conclusion

Floral therapy harnesses the mental and emotional benefits of flower gardening to promote

holistic well-being. By reducing stress, enhancing mindfulness, and fostering social connections, it offers a simple yet profound way to improve mental health. With its accessibility and wide-ranging benefits, flower gardening can be embraced by individuals, communities, and institutions as a powerful tool for emotional resilience and mental clarity. As awareness grows, integrating floral therapy into daily life holds the promise of a brighter, healthier future for all.

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Tech-Driven Agriculture: Precision Farming's Impact on Efficiency and Sustainability

Nimisha Jain Tiwari, R. C. Jain, Nity Sharma, Rajkumar Dasharath Shinde and E. Yaiphaleima

Abstract

Tech-driven agriculture, particularly through precision farming, is revolutionizing modern agricultural practices by enhancing both efficiency and sustainability. This paper explores how precision farming, through the use of advanced technologies such as GPS, IoT sensors, satellite imagery, and data analytics, optimizes resource use and crop management. By allowing for real-time monitoring and tailored interventions, farmers can significantly reduce inputs like water, fertilizers, and pesticides while maximizing yield. Furthermore, this approach supports environmental sustainability by reducing greenhouse gas emissions, improving soil health, and minimizing the ecological footprint of farming practices. The paper also delves into the economic benefits, challenges, and future directions of precision farming, highlighting its pivotal role in addressing global food security and climate resilience.

Introduction

In an era marked by rapid population growth, climate change and resource scarcity, the agricultural sector faces unprecedented challenges. The global demand for food is projected to increase by 70% by 2050, requiring innovative solutions to boost productivity while minimizing environmental impact (FAO, 2017). Traditional farming methods, which often rely on a one-size-fits-all approach, are becoming increasingly inadequate in addressing the-

se complex challenges. In response, the agricultural industry is witnessing a paradigm shift towards tech-driven agriculture, particularly through the adoption of precision farming. This approach leverages advanced technologies such as the Internet of Things (IoT), satellite imagery, drones, Global Positioning Systems (GPS), and data analytics to enhance agricultural efficiency and sustainability. This article aims to explore the multifaceted impacts of precision farming, including its efficiency gains, sustainability

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benefits, challenges, and future directions.

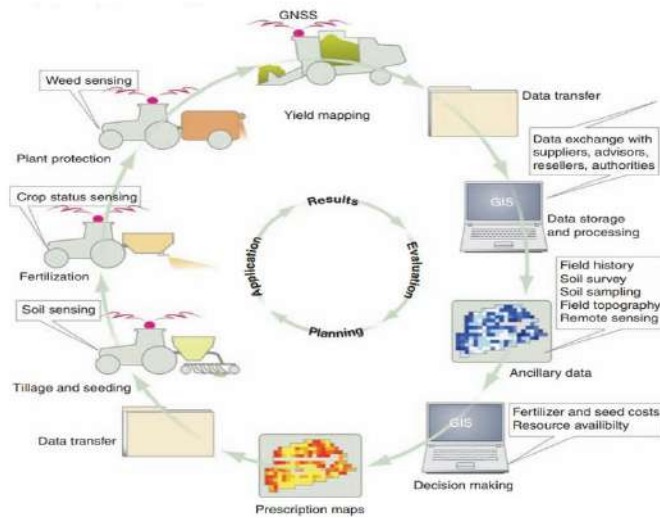


Fig 1: Precision agriculture information flow in crop production (Gebbers and Adamchuk, 2010)

What is Precision Farming?

Precision farming, often referred to as precision agriculture or site-specific crop management (SSCM), is a farming methodology that utilizes technology to observe, measure, and respond to variability in crops and soil conditions (Gebbers and Adamchuk, 2010). By integrating data-driven decision-making into farming practices, precision farming allows for a tailored approach that optimizes resource use and improves crop yield.

Key Technologies in Precision Farming

Global Positioning Systems (GPS): GPS technology is crucial for mapping fields and guiding machinery with high precision. This technology enables farmers to create field maps that identify variations in soil types, moisture levels, and nutrient needs, allowing for site-specific interventions.

Internet of Things (IoT) and Sensors: IoT devices and sensors monitor environmental factors such as soil moisture, temperature and humidity in real-time.

These devices provide farmers with actionable insights, enabling them to make informed decisions regarding irrigation, fertilization and pest management.

Drones and Satellite Imagery: Aerial imagery captured by drones and satellites allows for comprehensive monitoring of crop health and growth patterns. Farmers can detect issues such as pest infestations or water stress early, allowing for timely interventions.

Big Data Analytics and Artificial Intelligence (AI): The integration of big data analytics and AI into precision farming provides powerful tools for interpreting vast amounts of data. Predictive analytics can help farmers determine optimal planting and harvesting times, improving efficiency and productivity.

Efficiency Gains from Precision Farming

The adoption of precision farming technologies has led to significant efficiency gains across various aspects of agricultural production.

Optimal Resource Use: One of the primary benefits of precision farming is its ability to optimize resource use, particularly concerning water and inputs like fertilizers and pesticides. Traditional farming practices often apply these resources uniformly across entire fields, leading to wastage and environmental degradation. Precision farming technologies, such as soil moisture sensors and smart irrigation systems, enable farmers to apply water only when and where it is needed, significantly reducing water usage and conserving this vital resource. Research

indicates that smart irrigation systems can reduce water consumption by up to 30% while maintaining or even increasing crop yields (Zhang and Kovacs, 2012).

Yield Maximization: Precision farming techniques allow for real-time monitoring of crop health, leading to improved yields. Satellite imagery and drone technology provide farmers with detailed insights into their fields, enabling them to identify areas needing attention. For instance, a farmer can use drone imagery to spot nutrient deficiencies or pest infestations early on, allowing for targeted interventions rather than broad-spectrum applications. This tailored approach can result in yield increases of 10-30% (Shirsath *et al.*, 2017).

Reduced Labor Costs: Automation is another critical component of precision farming that contributes to efficiency. GPS-guided machinery and autonomous drones can perform tasks such as planting, spraying, and harvesting with minimal human intervention. This reduces labor costs and increases the speed at which these tasks can be completed. For example, automated tractors can work around the clock, maximizing operational efficiency and productivity (Schrijver, 2016).

Sustainability Impacts

Beyond efficiency, precision farming plays a significant role in promoting sustainability within the agricultural sector.

Soil Health Preservation: Precision farming practices help preserve soil health by minimizing the over-application of fertilizers and pesticides. By app-

lying inputs only where they are needed, farmers can prevent nutrient runoff into water bodies, protecting aquatic ecosystems. This targeted approach also supports soil microbial health, which is essential for nutrient cycling and overall soil fertility (Bongiovanni and Lowenberg-DeBoer, 2004).

Reduction in Greenhouse Gas Emissions: The efficient use of inputs in precision farming contributes to a decrease in greenhouse gas emissions. For instance, optimizing nitrogen application not only improves crop yield but also reduces the release of nitrous oxide, a potent greenhouse gas that contributes to climate change. Additionally, GPS-guided tractors that operate more efficiently consume less fuel, further lowering the carbon footprint of farming operations (Shirsath *et al.*, 2017).

Biodiversity and Ecological Balance: Precision farming enhances biodiversity and ecological balance by minimizing the use of harmful chemicals. By reducing pesticide and herbicide applications, farmers can protect beneficial insects, such as pollinators and natural pest predators, which are critical for maintaining healthy ecosystems. This shift towards sustainable practices helps preserve the ecological integrity of agricultural landscapes (Zhang and Kovacs, 2012).

Challenges in Precision Farming

While precision farming offers numerous benefits, several challenges hinder its widespread adoption.

High Initial Costs: One of the most significant barriers to adopting precision farming is the high

upfront cost of acquiring advanced technologies and equipment. The investment required for sensors, drones, and data management systems can be prohibitive, especially for small and medium-sized farms (Schrijver, 2016). While the long-term savings are evident, the initial financial burden may deter many farmers from making the switch.

Data Management and Integration: The vast amounts of data generated by precision farming tools can be overwhelming for farmers. Interpreting and utilizing this data effectively requires specialized knowledge, which may necessitate external consulting or training. Additionally, integrating data from various sources such as drones, IoT devices, and GPS systems can be complicated due to compatibility issues (Gebbers and Adamchuk, 2010).

Connectivity Issues: Limited internet access in rural areas presents a significant challenge to fully realizing the potential of precision farming. Reliable connectivity is essential for real-time data transmission from IoT sensors and for utilizing cloud-based analytics platforms. Without robust internet infrastructure, farmers may struggle to leverage the benefits of precision farming technologies (Shirsath *et al.*, 2017).

Future Directions and Innovations

The future of precision farming is promising, with several innovations poised to enhance its efficiency and sustainability further.

Artificial Intelligence and Machine Learning: The integration of AI and machine learning into precision farming is expected to revolutionize predictive capa-

bilities. AI algorithms can analyse historical and real-time data to provide farmers with even more precise recommendations for crop management, optimizing planting schedules, irrigation practices, and pest control measures (Shirsath *et al.*, 2017).

Blockchain for Transparency: Blockchain technology is emerging as a tool for ensuring traceability and transparency in the agricultural supply chain. By integrating precision farming data with blockchain, farmers can provide consumers with detailed information about how and where their food is produced. This transparency can foster consumer trust and promote more sustainable consumption practices (Schrijver, 2016).

Remote Sensing and Autonomous Machinery: Advancements in remote sensing technology, combined with the development of fully autonomous farming machinery, promise to make precision farming even more efficient. Autonomous machines will be able to perform tasks such as planting, spraying, and harvesting while communicating with one another and adapting to changing field conditions in real-time (Zhang and Kovacs, 2012).

Conclusion

Precision farming represents a transformative shift in agriculture, addressing the critical challenges of efficiency and sustainability. By optimizing resource use, improving yields, and reducing environmental harm, precision farming offers a pathway to meet the growing global food demand while safeguarding natural resources. However, overcoming barriers such as high costs, data manage-

ment challenges, and connectivity issues will be essential for its widespread adoption. As technology continues to evolve, precision farming will play an increasingly vital role in creating a more sustainable, efficient and resilient agricultural system, contributing to food security and environmental conservation.

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Cover Crops: An Effective Technique to Reduce Soil Erosion

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Abstract

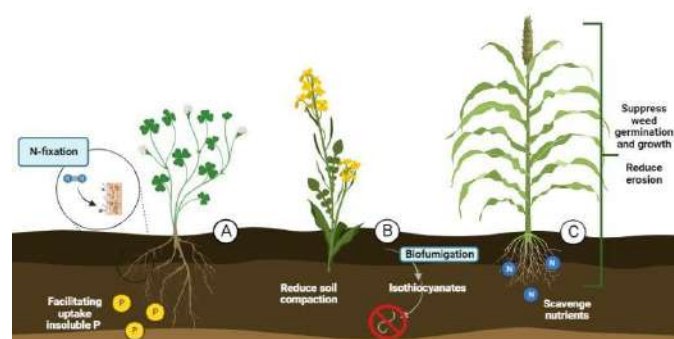
Soil erosion poses a significant threat to agricultural productivity, water quality, and environmental stability globally. Cover crops have emerged as a promising solution to combat soil erosion through mechanisms such as surface protection, enhanced soil structure, and increased water infiltration. This review evaluates the effectiveness of cover crops in reducing soil erosion across diverse contexts, highlights quantitative evidence from research studies, and examines the challenges and opportunities in their adoption. The findings underscore that while cover crops can reduce erosion by up to 90% under certain conditions, their broader implementation requires addressing economic, management, and awareness barriers. The review concludes with recommendations for enhancing cover crop adoption to safeguard soil health and agricultural sustainability.

Introduction

Soil erosion remains a critical environmental challenge that impacts agricultural productivity, water quality, and ecosystem stability worldwide. The loss of topsoil not only reduces the land's fertility but also contributes to sedimentation in water bodies, affecting aquatic ecosystems and water management systems. Traditional soil conservation methods, such as terracing and contour farming, have proven effective but often require significant labor and resources. Among the sustainable strategies to combat soil erosion, the use of cover crops has garnered significant attention due to their multifaceted benefits.

Cover crops, grown primarily to protect and enhance soil rather than for harvest, serve as a natural shield against erosive forces. Their ability to stabilize

soil, improve organic matter, and enhance water retention makes them a valuable tool in modern agricultural systems. This review explores the mechanisms by which cover crops reduce soil erosion, assesses their effectiveness in different environmental and management contexts and identifies the challenges and opportunities associated with their adoption. The aim is to provide insights that can guide policy, research, and agricultural practices toward more sustainable soil conservation strategies.



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Mechanisms of Erosion Control by Cover Crops

Numerous studies have demonstrated the effectiveness of cover crops in reducing soil erosion. A meta-analysis of 22 studies found that cover crops reduced soil erosion by an average of 43% compared to bare soil. Another study conducted in the United States found that cover crops reduced sediment loss by up to 90% in no-till corn-soybean rotations.

Cover crops employ a multifaceted approach to mitigate soil erosion, leveraging physical, chemical, and biological mechanisms to protect the soil. These mechanisms work in concert to provide comprehensive erosion control. Physically, cover crops shield the soil surface from the erosive forces of rainfall, reducing soil particle detachment and displacement. Additionally, the roots of cover crops enhance soil structure by promoting aggregation and increasing soil porosity. This, in turn, enables greater water infiltration, reducing surface runoff and the associated erosion risks. Biologically, cover crops stimulate soil microorganisms, which produce binding agents that hold soil particles together, further reinforcing soil structure. Following termination, the residual biomass of cover crops provides an additional layer of protection, acting as a mulch to safeguard the soil against wind and water erosion. By harnessing these mechanisms, cover crops offer a powerful tool for mitigating soil erosion, promoting soil health, and supporting sustainable agricultural practices.

Effectiveness of Cover Crops in Reducing Soil Erosion

The erosion-mitigating potential of cover crops is influenced by several factors, including species selection, planting density, and management practices. For example, grasses like rye and oats are more effective at reducing soil erosion than legumes like clover and vetch. Similarly, higher planting densities and optimal management practices can enhance the erosion-mitigating effects of cover crops. Research studies from diverse regions and agricultural systems consistently affirm the efficacy of cover crops in mitigating soil erosion. The following factors influence their effectiveness:

Type of Cover Crop: Effective cover crop species for erosion control include grasses like rye (*Secale cereale*) and oats (*Avena sativa*), which boast dense root systems and robust biomass production. Legumes, such as clover and vetch, enhance soil fertility but may not offer the same level of erosion protection as grasses. However, combining grasses and legumes in a mixture often maximizes erosion control and other ecological benefits, making it a popular strategy for sustainable agriculture.

Soil Type and Topography: Cover crops are particularly beneficial for soils that are vulnerable to erosion. Coarse-textured soils, for instance, are more susceptible to erosion, but they can greatly benefit from the stabilizing effects of cover crops. Similarly, on sloped terrains, cover crops play a crucial role in reducing soil loss by slowing down surface runoff and trapping sediments, thereby mitigating the risk of erosion.

Climatic Conditions: Cover crops have been shown

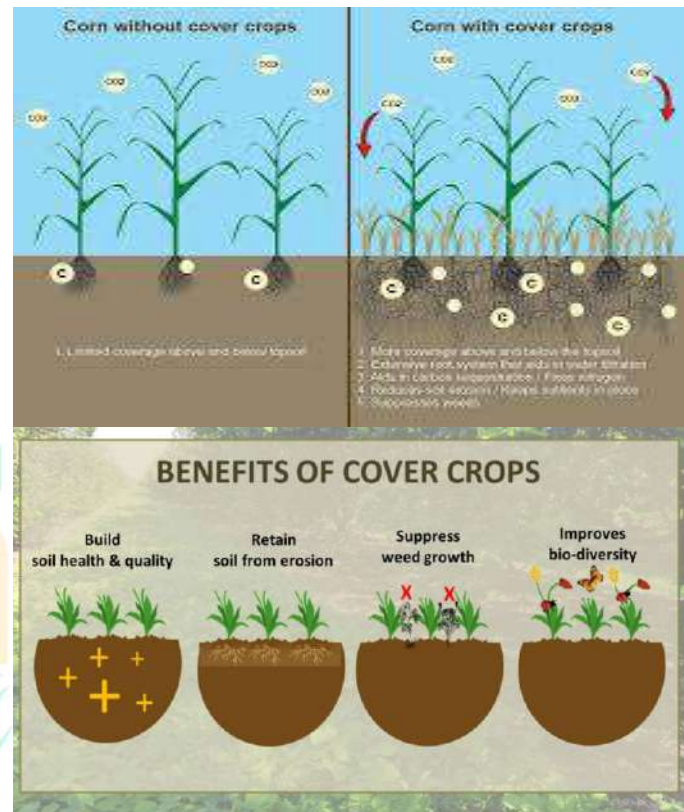
to be highly effective in mitigating erosion in various environmental conditions. In regions prone to heavy rainfall, cover crops play a crucial role in minimizing water-induced erosion by stabilizing the soil and reducing runoff. Conversely, in arid and semi-arid regions, cover crops help combat wind erosion by anchoring the soil and preventing sediment transport.

Management Practices: Effective implementation of cover crops requires careful consideration of timing and complementary conservation practices. The optimal timing of planting and termination is crucial, as cover crops should establish a robust canopy before the onset of the erosion-prone season. Furthermore, conservation tillage practices can significantly amplify the benefits of cover crops by preserving soil structure and residue cover, thereby enhancing soil health and erosion resistance.

Quantitative Evidence

Numerous studies have quantitatively demonstrated the efficacy of cover crops in reducing soil erosion. Research has consistently shown that cover crops can significantly mitigate soil loss, with varying degrees of effectiveness depending on the specific cropping system and regional context. For instance, a comprehensive meta-analysis conducted by Zhang *et al.* (2019) revealed that cover crops reduced soil erosion by an average of 58% across diverse cropping systems. Similarly, a study in the U.S. Midwest found that cereal rye cover crops decreased sediment loss by up to 90% in no-till corn-soybean rotations (Kaspar *et al.*, 2011). In tropical regions, legume cover crops have been shown to

decrease soil loss by 30-50%, as reported by Lal *et al.* (2007). These findings collectively underscore the significant potential of cover crops to mitigate soil erosion and promote sustainable agricultural practices.



Challenges in Adoption: Despite the well-documented benefits of cover crops, their widespread adoption is hindered by several significant barriers. One of the primary challenges is the perceived economic cost of implementing cover crops. Farmers may view cover crops as an additional expense without immediate financial returns, which can be a deterrent.

Another obstacle is the complexity of managing cover crops. Integrating cover crops into existing cropping systems requires careful planning, specialized knowledge, and a deep understanding of

species selection, planting schedules and termination methods. This can be overwhelming for farmers who are already managing multiple aspects of their operations.

Regional variability is another factor that can limit the effectiveness of cover crops. The success of cover crops depends on site-specific factors, such as soil type, climate, and topography, making it difficult to provide generalized recommendations. This variability requires farmers to have a deep understanding of their local conditions and to be able to adapt their cover crop strategies accordingly. Finally, limited awareness of the long-term benefits of cover crops is a significant barrier to their adoption. Many farmers are unaware of the positive impact that cover crops can have on soil health, productivity, and overall ecosystem function. Educating farmers about the benefits of cover crops and providing them with the necessary knowledge and resources is essential for promoting their widespread adoption.

Opportunities and Future Directions

To enhance the adoption and effectiveness of cover crops in reducing soil erosion, several strategies can be pursued:

To promote the widespread adoption of cover crops, research and development efforts should focus on breeding varieties that offer high biomass production, rapid establishment, and adaptability to diverse climates. This will enable farmers to maximize the benefits of cover crops while minimizing potential drawbacks. Policy support is also crucial for encouraging the use of cover crops.

Governments and agricultural organizations can provide financial incentives, technical support, and educational programs to help farmers overcome the initial costs and challenges associated with implementing cover crops.

Technological innovations, such as precision agriculture tools, can also play a vital role in optimizing cover crop management. By tailoring species selection and planting strategies to local conditions, farmers can maximize the effectiveness of their cover crops and minimize potential environmental impacts. Finally, integrating cover crops with other conservation practices, such as contour farming and terracing, can amplify erosion control benefits. By adopting a holistic approach to soil conservation, farmers can create more resilient and sustainable agricultural systems that benefit both the environment and their bottom line.

Conclusion

Cover crops are a vital component of sustainable agriculture, offering a multifaceted solution to soil erosion, soil health, water quality, and biodiversity. To facilitate their widespread adoption, it is essential to address the economic, management, and awareness barriers through collaborative research, policy initiatives and educational programs. As climate change exacerbates erosion risks, cover crops will play an increasingly crucial role in protecting soil resources and ensuring agricultural resilience. By harnessing the benefits of cover crops, farmers can enhance soil fertility, control weeds, and promote sustainable agricultural

practices, ultimately contributing to a more resilient and environmentally conscious food system. Cover crops are a valuable tool for mitigating soil erosion. The evidence suggests that cover crops can significantly reduce soil erosion by promoting soil cover, improving soil health, and enhancing hydrological processes. To maximize the erosion-mitigating potential of cover crops, farmers and land managers should consider factors like species selection, planting density and management practices. By integrating cover crops into sustainable agricultural systems, we can combat soil erosion, promote ecosystem resilience, and ensure long-term agricultural productivity.



Role of Carbon Dioxide and Oxygen on Growth and Development under Protected Cultivation of Vegetable Crops

Marimuthu J., K. R. Vijayalatha, V. Jegadeeswari and S. Nithila

The productivity of a crop is influenced not only by its heredity but also by the microclimate around it. The components of crop microclimate are light, temperature, air compositions and the nature of the root medium. In open fields, only manipulation of nature of the root medium by tillage, irrigation and fertilizer application is possible. The closed boundaries in greenhouse permit control of any one or more of the components of the microclimate.

Carbon dioxide

Carbon dioxide (CO₂) is an essential component of photosynthesis (also called carbon assimilation). Photosynthesis is a chemical process that uses light energy to convert CO₂ and water into sugars in green plants. These sugars are then used for growth within the plant, through respiration. The difference between the rate of photosynthesis and the rate of respiration is the basis for dry-matter accumulation (growth) in the plant. In greenhouse production the aim of all growers is to increase dry-matter content and economically optimize crop yield. CO₂ increases productivity through improved plant growth and vigour. Some ways in which productivi-

ty is increased by CO₂ include early flowering, higher fruit yields, reduced bud abortion in roses, improved stem strength and flower size. Growers should regard CO₂ as a nutrient.

For the majority of greenhouse crops, net photosynthesis increases as CO₂ levels increase from 340-1,000 ppm (parts per million). Most crops show that for any given level of photosynthetically active radiation (PAR), increasing the CO₂ level to 1,000 ppm will increase the photosynthesis by about 50% over ambient CO₂ levels. For some crops the economics may not warrant supplementing to 1,000 ppm CO₂ at low light levels. For others such as tulips, and Easter lilies, no response has been observed. Carbon dioxide enters into the plant through the stomatal openings by the process of diffusion. Stomata are specialized cells located mainly on the underside of the leaves in the epidermal layer. The cells open and close allowing gas exchange to occur. The concentration of CO₂ outside the leaf strongly influences the rate of CO₂ uptake by the plant. The higher the CO₂ concentration outside the leaf, the greater the uptake

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of CO₂ by the plant. Light levels, leaf and ambient air temperatures, relative humidity, water stress and the CO₂ and oxygen (O₂) concentration in the air and the leaf, are many of the key factors that determine the opening and closing of the stomata.

Ambient CO₂ level in outside air is about 340 ppm by volume (0.035 %). All plants grow well at this level but as CO₂ levels are raised by 1,000 ppm photosynthesis increases proportionately resulting in more sugars and carbohydrates available for plant growth. Any actively growing crop in a tightly clad greenhouse with little or no ventilation can readily reduce the CO₂ level during the day to as low as 200 ppm. The decrease in photosynthesis when CO₂ level drops from 340 ppm to 200 ppm is similar to the increase when the CO₂ levels are raised from 340 to about 1,300 ppm. As a rule of thumb, a drop in carbon dioxide levels below ambient has a stronger effect than supplementation above ambient.

In temperate regions, during winter times of the year in new greenhouses, and especially in double-glazed structures that have reduced air exchange rates, the carbon dioxide levels can easily drop below 340 ppm which has a significant negative effect on the crop. Ventilation during the day can raise the CO₂ levels closer to ambient but never back to ambient levels of 340 ppm. Supplementation of CO₂ is seen as the only method to overcome this deficiency and increasing the level above 340 ppm is beneficial for most crops. The level to which the CO₂ concentration should be raised depends on the crop, light intensity, temperature, ventilation, stage of the

crop growth and the economics of the crop. For most crops the saturation point will be reached at about 1,000-1,300 ppm under ideal circumstances. A lower level (800-1,000 ppm) is recommended for raising seedlings (tomatoes, cucumbers and peppers) as well as for lettuce production. Even lower levels (500-800 ppm) are recommended for African violets and some Gerbera varieties. Increased CO₂ levels will shorten the growing period (5-10%), improve crop quality and yield, as well as, increase leaf size and leaf thickness. The increase in yield of tomato, cucumber and pepper crops is a result of increased numbers and faster flowering per plant.

Supplementing Carbon Dioxide in Greenhouses:

Carbon dioxide can be obtained by burning carbon-based fuels such as natural gas, propane, and kerosene, or directly from tanks of pure CO₂. Each source has potential advantages and disadvantages. When natural gas, propane or kerosene is burned, not only CO₂ is produced, but also heat is generated that can supplement the normal heating system. However, incomplete combustion or contaminated fuels may cause plant damage. Most sources of natural gas and propane have sufficiently low levels of impurities, but notify your supplier of your intention to use the fuel for CO₂ supplementation. Sulphur levels in the fuel should not exceed 0.02% by weight. Combustion of fuels also generates moisture. For natural gas it is estimated that about 1.4 kg of water vapour is generated for each m³ of gas burned. For propane the amount of moisture generated per kg of CO₂ is slightly less than it is for

natural gas. Natural gas, propane and liquid fuels are burned in specialized CO₂ generators located throughout the greenhouse. The size of the unit and the degree of horizontal airflow in the greenhouse determine the number and the location of these units. The most important feature of a burner should be that it burns the fuel completely. Some manufacturers make burners in which either natural gas or propane can be used, as well as units with adjustable outputs. A potential disadvantage of this system is that the heat generated by these units may have a localized effect on temperature and disease incidence (i.e. Powdery mildew and Botrytis), particularly in tall growing crops. Alternatively, a portion of the flue gas (exhaust gas) from natural gas boilers connected to hot water heating systems can be directed into the greenhouse as a means of supplementing CO₂ to the crop. The boiler must be equipped with a flue gas condenser specifically designed for this purpose. This allows for safe flue gas introduction into the greenhouse. The flue gases are extracted where the boiler connects to the stack. These units are designed to reduce the temperature and moisture impact on the greenhouse environment, and have monitoring systems that safe guard against flue gas introduction when the carbon monoxide (CO) level is higher than a set level (usually 6-10 ppm). Liquid carbon dioxide has become popular among many growers even though it is usually more expensive. The main advantages of using liquid CO₂ include purity of product, no concerns about crop damage, nor heat or moisture production, better control of

CO₂ levels and the flexibility to introduce the CO₂ within the plant canopy at any time. Pure CO₂ is delivered in bulk by truck to the greenhouse. Special storage tanks rented from the supplier are required at every site. The compressed CO₂ is in a liquid state and must be vaporised through vaporiser units. The distribution system for liquid CO₂ in the greenhouse is simple to design and install.

Precision control of CO₂: Today, most growers monitor and control the greenhouse environment with sensors linked to a central computer to allow integration of the different environmental factors. A carbon dioxide controller, usually an infrared gas analyser (IRGA) is used to monitor and maintain the minimum and maximum CO₂ level in the greenhouse. Usually a single IRGA is used per operation. Multiple readings within individual compartments or from different zones can be obtained by using a scanner or a multiplexer. The IRGA unit can be stand-alone or, as in most cases, connected to the environment control computer. In the latter case the environment control computer is used to control the CO₂ level, through integration with light levels, stage of ventilation, and wind speed. Infra-red gas analysers require routine calibration to insure accurate measurement of the CO₂ levels.

Distribution of Carbon Dioxide in the Greenhouse: It is important to have an adequate distribution system. The distribution of CO₂ depends mainly on air movement within the greenhouse(s), as CO₂ does not travel very far through diffusion. For instance, when a single source of CO₂ is used for a

large surface area or several connecting greenhouses, a distribution system must be installed. This system must be designed to evenly distribute the CO₂ in the greenhouse especially when flue gas CO₂ or liquid CO₂ is used. Air circulation using horizontal airflow fans or fan-jet system provides uniform distribution by moving large volumes of air within the greenhouse when top vents are closed or exhaust fans are not operational. Today, growers supplementing with liquid CO₂ or flue gas CO₂ have a central header with small individual tubes (with evenly spaced holes) placed low in the crop canopy or in the case of bench crops, under the bench. The potential for low CO₂ levels inside a dense crop canopy (chrysanthemums) makes it beneficial to supplement within the canopy. Air movement around the plants will also improve the CO₂ uptake because the boundary layer around the individual leaf is lessened bringing the CO₂ molecules closer to the leaf.

Plant Damage as a Result of CO₂ Supplementation: Do not allow excessive CO₂ levels in greenhouses. Levels of 5,000 ppm can cause dizziness or lack of co-ordination to humans. Higher than recommended levels can cause necrosis of old tomato and cucumber leaves. African violet leaves become very hard and brittle, show a very dark greenish-grey colour and often malformed flower petals, which do not fully expand. A similar symptom with freesia flowers has been observed where the CO₂ burner was used to provide the majority of the heat requirements of the greenhouse, and thereby generating excessive amounts of CO₂.

Except in emergencies, do not use CO₂ burners as the prime heating system.

Since sulphur dioxide can cause acute necrosis (0.2 ppm in the air), the sulphur content of the fuels should be less than 0.02%. Ethylene at 0.05 ppm and propylene at higher levels can cause premature senescence on tomato and cucumber plants, induce sleepiness in carnations, create flower shatter of geraniums, promote excessive side shoot development, prevent normal flower initiation, and flower bud abortion in chrysanthemums and poinsettia. Ethylene is often produced as a result of incomplete combustion, while propylene is usually associated with the use of propane. Leaky propane supply lines have created serious financial damage to growers in the past. Carbon monoxide (CO), which usually does not create any problems by itself, is often used as the indicator for incomplete combustion. Levels exceeding 50 ppm CO in the flue gases are an indication of the presence of ethylene at levels capable of causing crop damage. Burners with a high flame temperature can cause the formation of nitrous oxides (NO_x and NO₂). Excessive amounts of nitrous oxide can cause diminished growth or even necrosis. Boilers equipped with low NO_x burners must be used for flue gas utilisation as a CO₂ source. A low level of both SO₂ and NO_x in combination can cause greater phytotoxicity damage or be more detrimental to the plants than a high level of either. Excessive and prolonged use of CO₂ (especially in tomatoes) results in the plants not responding well to the suppl-

emental CO₂. Interruption of the CO₂ application for a few days results in an improved response.

Advantages

- ✓ Increase in photosynthesis results in increased growth rates and biomass production.
- ✓ Plants have earlier maturity and more crops can be harvested annually. The decrease in time to maturity can help in saving heat and fertilization costs.
- ✓ In flower production, supplemental CO₂ increases the number and size of flowers, which increase the sales value because of higher product quality.
- ✓ Supplemental CO₂ provides additional heat (depending upon the method of supplementation) through burners, which will reduce heating cost in winter.
- ✓ It helps to reduce transpiration and increases water use efficiency, resulting in reduced water use during crop production.

Disadvantages

- ✓ Higher production cost with a CO₂ generation system.
- ✓ Plants may not show a positive response to supplemental CO₂ because of other limiting factors such as nutrients, water and light. All factors need to be at optimum levels.
- ✓ Supplementation is more beneficial in younger plants.
- ✓ Incomplete combustion generates harmful gases like sulphur dioxide, ethylene, carbon monoxide and nitrous oxides. These gases are responsible

for necrosis, flower malformation and senescence if left unchecked, resulting in a lower quality product.

- ✓ Additional costs required for greenhouse modification. Greenhouses need to be properly sealed to maintain a desirable level of CO₂.
- ✓ Excess CO₂ level can be toxic to plants as well as humans.
- ✓ On warmer days, it is difficult to maintain desirable higher CO₂ levels because of venting to cool the greenhouses.

Oxygen

- ✓ Plants need oxygen for their growth.
- ✓ The oxygen is absorbed by the roots in its dissolved form.
- ✓ Oxygen is important for the active uptake of essential nutrients like nitrogen, phosphate and potassium, but also for the build-up of proteins and dry matter production.
- ✓ A lack of oxygen in irrigation water causes serious growth problems, as André knows.
- ✓ Dissolved oxygen is also important for substrate quality.
- ✓ High dissolved oxygen concentrations cause a competitive increase in soil life, to the disadvantage of pathogens.
- ✓ The amount of dissolved oxygen also regulates the production of substances that suppress diseases and pests.

Oxygen-enriched nutrient solution on greenhouse

Plant organs, including roots, require oxygen for aerobic respiration. Roots can utilize oxygen

dissolved in water or directly in gaseous form, although it must be dissolved into water to be used within the cell. Hypoxia (low oxygen) in the root zone can inhibit root respiration, mineral uptake, and water movement into the roots. As a result, shoots can exhibit reduced stomata conductance and wilting. As well, low root zone oxygen is believed to increase the susceptibility to infection by some diseases such as *Pythium*. Major changes in cell metabolism and genetic expression are also induced by low oxygen. Anoxia (total absence of oxygen) also has severe effects on the plant but is unlikely to occur in the porous substrates used in greenhouse vegetable production. Plants grown solely in water must have oxygen supplied to the solution. Morard and Silvestre (1996) reported that without oxygen replenishment, cucumber will reduce nutrient solution oxygen from saturation (8 mg L^{-1}) to 0 mg L^{-1} in 60 min (root fresh weight of 25 g L^{-1} of nutrient solution at 20°C media temperature). However, the majority of plants are raised in an air, water and solid matrix that has complex physical properties and interactions which are still not fully understood (Raviv *et al.*, 2004). The literature on plant response to substrate properties and oxygen levels is unclear. Greenhouse growers have expressed concern that the oxygen content of nutrient solutions may be sub-optimal for plant growth. This is especially important in the summer when greenhouse temperatures are high and the oxygen-holding capacity of water is reduced. Higher temperatures also increase the biological demand for oxygen through increased

rates of root and micro-organism respiration (Jackson, 1980), which may further reduce oxygen concentrations of solution in the root zone. Recently technology has become available from a number of companies that enable oxygen to be diffused into solution in a cost-effective manner. The technology produces very small bubbles of pure oxygen that can boost the oxygen content of water to very high levels (up to 40 mg L^{-1}). Using this technology, the objectives of this study were to determine the effect of high solution oxygen content on cucumber and pepper yield and fruit shelf-life. This was part of a larger study, conducted at three research sites, to examine oxygen enrichment in hydroponic cucumber, pepper, and tomato and organic tomato.

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Climate Control and Automation in Greenhouse

Marimuthu J., K. R. Vijayalatha, V. Jegadeeswari and S. Nithila

Abstract

The discovery that many plants could be shielded from various biotic and abiotic stressors through the use of greenhouse crops was a pivotal moment in agricultural history. It developed as a mechanism to shield crops from harsh and unfavorable circumstances that hinder plant growth. Controlling the greenhouse gets challenging since it is a nonlinear system. The following factors influence plant growth: temperature, relative humidity, carbon dioxide, nutrients, water availability, and growing media. The control of these factors has a significant impact on the crop plants' quality and output. The majority of growers place the most priority on temperature and humidity out of all the factors as they control the rates at which different metabolic processes involved in plant development react. Furthermore, controlling the temperature directly affects the greenhouse system's carbon dioxide and relative humidity levels. This study examines and discusses problems related to the automation control system design process in greenhouses.

Introduction

Computers are becoming more and more common for greenhouse management in nations with unsuitable climatic conditions for plant growth. Computers are utilized in the Netherlands for a variety of purposes, including irrigation management, boiler control, and climate control (which includes temperature, humidity, CO₂ level, and artificial lighting). Southeast Spain is presently seeing a large installation of automatic greenhouse temperature control systems. Climate control is a basic necessity that helps prevent extreme conditions

(high temperatures, high humidity, etc.) that can harm crops and achieve suitable temperature integrals that can speed up crop development and quality while lowering pollution and energy use. Fast and slow dynamics, the former linked to the greenhouse environment and the latter to crop development, are characteristics of the agricultural production system.

The physical climate can be treated as instantly realizable through the control in seasonal optimization as a first approximation. The primary enhancements to computer-based climate control are

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to data logging, monitoring, alarm features, and climatic set-point determination. Because of the high production needs as well as the requirements for diversity, quality, and market presentation, the agro-alimentary industry is implementing new technologies these days. Physical processes including mass balance (CO_2 concentration and water vapour fluxes) and energy transfer (heat and radiation) combine to produce the microclimate's dynamic behavior. The greenhouse's structure, the crop's kind and condition, the outlet environmental conditions, and the control actuators' impact all affect these processes. The primary methods of regulating the greenhouse climate include CO_2 injection to affect photosynthesis, fogging/misting for humidity, shading and artificial light to alter internal radiation, and ventilation and heating to adjust interior temperature and humidity levels. The amount of sunlight and ventilation in a greenhouse have an impact on its temperature. The purpose of greenhouses is to retain solar heat. Protected cultivation is a process of growing crops in a controlled environment. This means that the temperature, humidity, light and such other factors can be regulated as per requirement of the crop. This assists in a healthier and a larger produce. There are various types of protected cultivation practices. Some of the commonly used practices are forced ventilated greenhouse, naturally ventilated polyhouse, insect proof net house, shade net house, plastic tunnel and mulching, raised beds, trellising and drip irrigation. These practices can be used independently or in combination, to provide

favourable environment to save plants from harsh climate and extend the duration of cultivation or off-season crop production. Adoption of drip irrigation under raised beds (you will read about it in Unit 4) covered with mulch films not only eradicates weeds but also maintains moisture in the soil for a prolonged period by minimising evaporation losses.

Climate Control: Air temperature as well as solar radiation and air relative humidity is one of the most important variables of the greenhouse climate that can be controlled. It conditions not only crop development and production but also energy requirements, which can account for up to 40 percent of the total production costs. The majority of plants grown in greenhouses are warm-season species, adapted to average temperatures in the range 17-27 °C, with approximate lower and upper limits of 10 and 35 °C.

Ventilation cooling and shading

Removal of heat load is the major concern for greenhouse climate management in arid and semi-arid climate conditions. This can be achieved by:

- ✓ Reducing incoming solar radiation;
- ✓ Removing extra heat through air exchange; and
- ✓ Increasing the fraction of energy partitioned into latent heat.

Shade screens and whitewash are the principal measures taken to reduce incoming solar radiation; greenhouse ventilation is an effective way to remove extra heat through air exchange between the inside and outside (when the outside air temperature is lower) and evaporative cooling is the common

technique for reducing sensible heat load by increasing the latent heat fraction of dissipated energy. Other technological cooling solutions are available (heat pump, heat exchangers), but are not widely used.

Ventilation: A simple and effective way of reducing the difference between inside and outside air temperatures is to improve ventilation. Natural or passive ventilation requires very little external energy. It is based on the pressure difference between the greenhouse and the outside environment, resulting from the outside wind or the greenhouse temperature. The external cool air enters the greenhouse through the lower side openings while the hot internal air exits through the roof openings due to the density difference between air masses of different temperature; the result is a lowering of the greenhouse temperature. The necessary ventilation rate can be obtained by natural or forced ventilation; ventilators should, if possible, be located at the ridge, on the sidewalls and the gable. A total ventilator area equivalent to 15-30 percent of the floor area was recommended by White and Aldrich (1975); over 30 percent, the effect of additional ventilation area on the temperature difference was very small.

Forced ventilation: The principle of forced ventilation is to create airflow through the house. Fans suck air out on one side, and openings on the other side let air in. Forced ventilation by fans is the most effective way to ventilate a greenhouse, but it consumes electricity. It is estimated that the electrical energy requirements for ventilation of a greenhouse

located in the Mediterranean are about 70 000 kWh per greenhouse ha.

Shading: The entry of direct solar radiation through the covers into the greenhouse enclosure is the primary source of heat gain. The entry of unwanted radiation (or light) can be controlled by shading or reflection. Shading can be achieved in several ways: paints, external shade cloths, nets (of various colours), partially reflective shade screens (Plate 6), water film over the roof and liquid foams between the greenhouse walls. Shading is the last resort for cooling greenhouses, because it affects productivity; however, shading can in some cases result in improved quality. Baille *et al.* (2001) reported that whitening on glass material enhanced slightly the PAR (photosynthetically active radiation) proportion of the incoming solar irradiance, thus reducing the solar infrared fraction entering the greenhouse a potential advantage compared with other shading devices, another advantage of whitening is that it does not affect ventilation, while internal shading nets negatively affect the performance of roof ventilation. Whitening also significantly increases the fraction of diffuse irradiance, which is known to enhance radiation-use efficiency.

Evaporative cooling: One of the most efficient solutions for alleviating climatic conditions is to use evaporative cooling systems, based on the conversion of sensible heat into latent heat through evaporation of water supplied directly into the greenhouse atmosphere (mist or fog system, sprinklers) or via evaporative pads (wet pads). Evaporative

cooling allows simultaneous lowering of temperature and vapour pressure deficit, and its efficiency is higher in dry environments. The advantage of mist and fog systems over wet pad systems is the uniformity of conditions throughout the greenhouse, eliminating the need for forced ventilation and airtight enclosure

Fog system: Water is sprayed as small droplets (in the fog range, 2-60 nm in diameter) with high pressure into the air above the plants in order to increase the water surface in contact with the air.

- ✓ Fog systems can be high (40 bars) or low (5 bars) pressure systems; high pressure systems are more effective than low pressure.
- ✓ The nozzles of the fog system should be located at the highest possible position inside the greenhouse to allow water evaporation before the water drops to the crop or the ground.
- ✓ During operation of the fog system, a vent opening of 20 percent of the maximum aperture should be maintained.
- ✓ Nozzles with fans provided 1.5 times better evaporation ratio and three times wider cooling area than nozzles without fans. Nozzles with fans produce a lower and more uniform air temperature.

Fan and pad cooling: The fan-and-pad cooling system is most commonly used in horticulture. Air from outside is blown through pads with as large a surface as possible and which are kept permanently wet by sprinkling. The water from the pads evaporates and cools the air; outside air humidity

must therefore be low. There are basically two systems of fan-and-pad cooling: the negative-pressure system and the positive-pressure system.

Negative-pressure system: The negative-pressure system consists of a pad on one side of the greenhouse and a fan on the other. The fans suck the air through the pad and through the greenhouse. The pressure inside the greenhouse is lower than the pressure outside; hot air and dust can therefore get into the greenhouse. There is a temperature gradient from pad to fan.

Positive-pressure system: The positive-pressure system consists of fans and pads on one side of the greenhouse and vents on the other. The fans blow the air through the pads into the greenhouse. The pressure inside the greenhouse is higher than outside; dust cannot get into the greenhouse.

Cooling efficiency should provide inside air humidity of about 85 percent at the outlet; higher air humidity slows down the transpiration rate of the plants. Plant temperature can then increase above air temperature. It is important that the pad material have a high surface, good wetting properties and high cooling efficiency. It should cause little pressure loss, and should be durable.

The average thickness of the pad is 100-200 mm. It is essential that the pad be free of leaks through which air could pass without making contact with the pad. Different pad materials are available, such as wood, wool, swelling clay minerals, and specially impregnated cellulose paper. The pad area depends on the airflow rate necessary for the cooling

system and the permissible surface velocity over the pad. Average face velocities are 0.75-1.5 m s⁻¹. Excessive velocities may cause problems with drops entering the greenhouse. The pad area should be about 1 m² per 20-30 m² greenhouse area.

The maximum fan-to-pad distance should be 30-40 m. Belt-driven or direct-driven propeller fans are used. Direct-driven fans are easier to maintain. Fans should be placed on the lee side of the greenhouse. If they are on the windward side, an increase of 10 percent in the ventilation rate will be needed.

The distance between fans should not exceed 7.5-10 m, and fans should not discharge towards the pads of an adjacent greenhouse less than 15 m away. All exhaust fans should be equipped with automatic shutters to prevent air exchange when fans are not operating, and also to prevent back-draught when some are not being used.

Heating

Greenhouse heating is essential even in countries with a temperate climate, like the Mediterranean region, in order to maximize crop production in terms of quantity and quality and thus to increase overall efficiency.

There are various ways to calculate greenhouse heating needs (Hg) (W). The simplest is proposed by ASAE (2000):

$$H_g = U A (T_i - T_o)$$

Where:

U = heat loss coefficient (W m⁻² K⁻¹)

A = exposed greenhouse surface area (m²)

T_i = inside air temperature (K)

T_o = outside air temperature (K)

Heating systems: The heating system must provide heat to the greenhouse at the same rate at which it is lost. There are several popular types of heating systems for greenhouses. The most common and least expensive is the unit heater system.

Unit heaters: Warm air is blown from unit heaters with self-contained fireboxes. Heaters are located throughout the greenhouse, each heating a floor area of 180-500 m². The typical cost, including installation is Rs 344-688 m⁻² of greenhouse floor.

Central heating: Steam or hot water is produced, plus a radiating mechanism in the greenhouse to dissipate the heat. The typical cost of a central boiler system for 1 ha, including heat distribution and installation, is Rs 2500-7000 m⁻² of greenhouse floor space, depending on the number of heat zones and the exact heat requirement.

Placement of heating pipes is very important as it is directly related to heat loss

- ✓ Wall pipe coils
- ✓ Overhead pipe coils
- ✓ In-bed pipe coils
- ✓ Floor pipe coil

Pipe/rail heating systems: These systems maintain uniform temperatures with a positive effect on the microclimate. Air movement caused by the warmer pipe/rail reduces humidity around the plant. Such systems are suitable for vegetable production.

Radiant heater systems: These heaters emit infrared radiation, which travels in a straight path at

the speed of light. The air through which the radiation travels is not heated. After objects such as plants, walks and benches have been heated, they will warm the air surrounding them. Air temperatures in infrared-radiant-heated greenhouses can be 3-6 °C cooler than in conventionally heated greenhouses with equivalent plant growth. Grower reports on fuel savings suggest a 30-50 percent fuel reduction with the use of low energy infrared-radiant heaters, as compared with the unit heater system.

Thermostats and controls: Various thermostat and environmental controllers are available for commercial greenhouse production. Sensing devices should be placed at plant level in the greenhouse: thermostats at eye level are easy to read but do not provide the necessary input for optimum environmental control. An appropriate number of sensors are needed throughout the production area. Environmental conditions can vary significantly within a small distance. Thermostats should not be placed in the direct rays of the sun as this would result in poor readings; they should be mounted facing north or in a protected location. It may be necessary to use a small fan to pull air over the thermostat to get appropriate values.

Dehumidification

- ✓ Condensation refers to the formation of drops of water from water vapor.
- ✓ Condensation occurs when warm, moist air in a greenhouse comes into contact with a cold surface such as glass, fiberglass, plastic or structural members.

- ✓ The air in contact with the cold surface is cooled to the surface temperature.
- ✓ Condensation is a symptom of high humidity and can cause significant problems (e.g. germination of fungal pathogen spores, including *Botrytis* and powdery mildew).

Dehumidify the greenhouse

- ✓ Combined use of heating and ventilation
- ✓ Absorption using hygroscopic material
- ✓ Forced ventilation usually with combined use of a heat exchanger
- ✓ Anti-drop covering materials

Carbon Dioxide Enrichment: Methods In the early 1960s, CO₂ applicators with liquid CO₂ tanks were installed at a greenhouse range and were serviced by CO₂ distributors. CO₂ gas formed above the liquid in these tanks and was carried by metal tubing to the greenhouses. A set of pressure regulating valves reduced the pressure to a low level. Once in the greenhouse, the gas was distributed along the length of the greenhouse in a plastic tube 3 to 6 mm in diameter with needle holes at every 30 cm along the length. Burners were developed as a substitute for the more expensive liquid and solid CO₂ applicators. Some early equipment was large and had to be located outside the greenhouse. The exhaust, essentially pure CO₂, was brought into the greenhouse through a duct and distributed along the length of the greenhouse. Smaller generators were developed that were installed overhead in the greenhouse. These systems are less expensive and they produce CO₂ in openflame burners using kerosene,

propane, or natural gas. Partly because of the recent shifts in fuel costs, larger greenhouse firms find the cost of CO₂ from direct sources of CO₂ comparable to that of CO₂ generated from the combustion of fuel. Unlike CO₂ generation in burners, the use of liquid CO₂ is of purity and releases no heat, which can be a disadvantage during the winter and advantage at the beginning and end of the hotter CO₂ injection season. The simpler forms of CO₂ injection control use either a time clock or a light sensor to turn the CO₂ generator ON in the morning and OFF in the evening. During the day, the CO₂ generator is automatically turned OFF when the ventilating fans are ON. In the event of roof ventilation, mechanical switches are installed on the ventilators to allow the CO₂ generator to operate only when the vents are open less than 5 cm. Simple CO₂ testers consist of a small hand pump that is stroked a given number of times to pass air through a tube.

The tube contains a CO₂ sensitive chemical that changes colour as CO₂ is absorbed. The length of the tube that changes colour is measured on a scale that directly indicates the level of CO₂ in the air passed through the tube. The present, more sophisticated CO₂ generator control systems are based on CO₂ sensors. These sensors continually monitor the CO₂ level in the greenhouse and a single sensor can be connected to several greenhouses by sampling tubes and air samples drawn by a pump. The signal from the sensor is used to control the CO₂ generator so that a constant CO₂ level can be maintained. Information from the single sensor with

multiple sampling tubes is received by a computer, which in turn controls CO₂ generators in each greenhouse.

Computerized Control Systems

Microprocessors: Dedicated microprocessors can be considered as simple computers. A typical microprocessor will have a keypad and a two- or three-line liquid crystal display of, sometimes, 80-character length for programming. They generally do not have a floppy disk drive. They have more output connections and can control up to 20 devices. With this number of devices, it is cheaper to use a microprocessor. They can receive signals of several types, such as, temperature, light intensity, rain and wind speed. They permit integration of a diverse range of devices, which is not possible with thermostats. The accuracy of a microprocessor for temperature control is quite good. Unlike a thermostat, which is limited to a bimetallic strip or metallic tube for temperature sensing and its mechanical displacement for activation, the microprocessor often uses a thermistor. The bimetallic strip sensor has less reproducibility and a greater range between the ON and OFF steps. Microprocessors can be made to operate various devices, for instance, a microprocessor can operate the ventilators based on the information from the sensor for the wind direction and speed. Similarly, a rain sensor can also activate the ventilators to prevent the moisture sensitive crop from getting wet. A microprocessor can be set to activate the CO₂ generator when the light intensity exceeds a given set

point, a minimum level for photosynthesis.

Computers

Now-a-days, computer control systems are common in greenhouse installation throughout Europe, Japan and the United States. Computer systems can provide fully integrated control of temperature, humidity, irrigation and fertilization, CO₂, light and shade levels for virtually any size growing facility. Precise control over a growing operation enables growers to realize savings of 15 to 50% in energy, water, chemical and pesticide applications. Computer controls normally help to achieve greater plant consistency, on-schedule production, higher overall plant quality and environmental purity. A computer can control hundreds of devices (vents, heaters, fans, hot water mixing valves, irrigation valves, curtains and lights) within a greenhouse by utilizing dozens of input parameters, such as outside and inside temperatures, humidity, outside wind direction and velocity, CO₂ levels and even the time of day or night.

Advantages of Computerized Control System

- ✓ The computer always knows what all systems are doing and, if programmed properly, can coordinate these systems without overlap to provide the optimum environment.
- ✓ The computer can record the environmental data, which can be displayed to show current conditions or stored and processed ones to provide a history of the cropping period, and if desired it may also be displayed in table or graph form.

- ✓ High speed computer with networking facility can control several remotely located greenhouses, by placing the computer in a central area and the results can be monitored frequently by the management.
- ✓ With proper programming and sensing systems, the computer can anticipate weather changes and make adjustments in heating and ventilation systems, thus saving energy
- ✓ The computer can be programmed to sound an alarm if conditions become unacceptable to and to detect sensor and equipment failure.

Conclusion

The synthesis of a climate controller using conventional control methods becomes challenging because of the physical dynamics present in a greenhouse. While the humidity was indirectly managed by the ventilation rate regulation (which influences both temperature and humidity), the temperature was controlled by controlling the water temperature inside a suitable network of pipes evenly dispersed across the greenhouse. Therefore, employing these technologies was a very costly and ineffective method of control. In order to provide the most favorable environment for crop development based on the growth patterns of greenhouse crops and market demands, automatic greenhouse control became the standard approach. Some even eliminate the limitations of the natural environment. It works well for production on a big scale as well.

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Value Addition in Rose

T. Uma Maheswari, I. Geetalakshmi and P. Yasotha

Roses are having foremost commercial importance because of its place among the flower crops and are one of the oldest fragrant flowers to be cultivated by human being. Its different types having beautiful flowers of exquisite shape, sizes, be witching colours and most delightful fragrance has made it an important flower for its varied uses. Rose petal is one of the best ingredients for giving a natural boost to your health and beauty. It is high in Vitamin C, Pectin and Citric Acid. Rose has astringent and anti-inflammatory properties. Some of the value added products are listed below;

Rose water: Rose water is an important value added product from rose petals. It is a flavoured water made by steeping rose petals in water. Additionally, it is the hydrosol portion of the distillate of rose petals, a by-product of the production of rose oil for use in perfume. It is used as a perfume, in medicines and confectionary. It has the property of cooling the body and is often used in eye lotions and eye drops for its soothing qualities. It is also used in drinking water and sprinkled on the guests at weddings, feasts and other religious and social functions

Rose oil: Rose oil is important commercial product obtained from rose petals. Rose oil is the essential oil

extracted from the petals of various types of rose. Apart from sweet fragrance, it has medicinal property and is often used in Ayurveda.

Rose Attar: Rose attars are extracted through steam distillation, while rose absolutes are obtained through solvent extraction, the absolute being used more commonly in perfumery. Bulgarian rose otto is largely used in perfuming soaps and cosmetics.

Rose Petals Powder: It is made by grinding Dried Rose Petals to a fine mesh. Rose petal powder is like an elixir. It can be used in various wonderful ways, giving innumerable benefits to the skin and hair due to its soothing fragrance.

Gul-roghan: It is rose hair oil prepared from rose petals by enfleurage with wet sesamum seeds.

Pankhuri: Dried rose petals are known as pankhuri which is occasionally used for preparing sweetened cold drinks.

Gulkand: Rose petals are also preserved for direct consumption, by making gulkand which is prepared by pounding equal proportions of petals and white sugar. It is considered both as tonic and laxative.

Rose extract/ Rose Essence: It is a much more concentrated form than rose water, and is made by infusing rose petals in vodka over a long period of

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time to extract the entire flavor.

Rose syrup: It is a beverage made from rose water, with addition of sugar.

Candied rose petal: Candied rose petal is prepared by painting both sides of each rose petal with the egg wash, simple syrup, or prepared meringue powder. Then sugar is sprinkled on both sides of the prepared petals. Then the petals are set on a piece of parchment paper or wax paper and kept dried overnight.

Rose petal jam: Rose petal jam is prepared with boiling rose petals, lemon juice or citric acid and sugar in water along with pectin.

Rose petal jelly: Rose water extract after boiling with rose petals is boiled with sugar, pectin and lemon juice or citric acid to get rose petal jelly.

Rose conserve: It is prepared as like rose jam. It is prepared with boiling rose petals, citric acid and sugar in water along with pectin.

Rose vinegar: Rose vinegar is made by infusing rose petals in warm vinegar over a long period of time to extract all the flavor.

Rose wine: Rose wine is prepared by boiling the rose petals in water along with some cardamom capsules. Then the extract is fermented by adding yeast and strained.

Rose petal ice cream: Rose petal ice cream is prepared by blending rose water/ rose puree with Cream, milk, sugar, salt, in a bowl. Then it is poured in an ice maker and is frozen.

Rose falooda: It is made by assembling basil seeds, cooked noodles, rose syrup, milk and vanilla ice

cream in layers to a tall glass.

Rose cake: Rose petals, rose water, cake flour, sugar, baking powder, salt, milk, egg whites, rose butter cream are required to bake rose cake.

Fruit of roses are known as hips. Rose hips are very good sources of ascorbic acid, every 100 g of rose hip syrup contains 150 mg of ascorbic acid compared with only 50 mg present in fresh orange juice, 20 mg in tomatoes and 5 mg in apples.

Rose hip syrup: It is made from rose hips, which are the fruits of roses. Rose hip syrup is made by blending the juice extract after boiling the chopped rose hip in water with sugar syrup.

Rose hip candy: Rose hip candy is prepared by boiling the rose hips in sugar syrup till they attain softness followed by drying.

Rosehip oil: It is also known as rosehip seed oil. Unlike rose oil, which is extracted from rose petals, rosehip oil is pressed from the fruit and seeds of the rose plant. It is Prized since ancient times for its valuable healing benefits, rosehip oil is loaded with skin-nourishing vitamins and essential fatty acids. It also contains phenols that have been shown to have antiviral, antibacterial, and antifungal properties. Rosehip oil is often used as a carrier oil for essential oils which are too intense to put on skin directly.

Rose hip serum and rose hip face cream: Rose hips are utilized in the manufacturing of cosmetics like rose hip serum and rose hip face cream.

Rosehip powder: It is ground from dried rose hip. The powder can be added to smoothies, jams, honey, herbal syrups, and body care products.

Rose hip tea: It is prepared by steeping crushed rose hips in boiling water for 10-15 min, then straining the liquid before ingesting.

Pot pourri: Dried rose petals are kept in a large bowl along with orange peel and dried lavender. Then it is sprinkled with lavender oil and transferred to one or more glass jars. Then it is sealed to allow the aromas to blend for a day or two.

Veni: Veni is a hair adornment prepared with flowers used for hair decorations. Rose petal veni is used for special functions like dance programs, festivals, and marriages. These are very aromatic and beautiful and mesmerizing which can be used as a hair ornament.

Garlands: Garlands prepared with scented rose flowers are used to worship God and for marriage functions.

Bouquets: A flower bouquet is a collection of flowers in a creative arrangement. Flower bouquets can be arranged for the decor of homes or public buildings, or may be handheld. Handheld bouquets are classified by several different popular shapes and styles, including nosegay, crescent, and cascading bouquets. Cut roses have the highest demand throughout the world and year round. The cut flowers are used for making bouquets, vases and table decoration

Rose boutonniere& wrist corsage: Bridal accessories made with rose flowers for wedding function are rose boutonniere and wrist corsages. A corsage is a small bouquet of flowers worn on clothing or around the wrist for formal occasions, commonly by females in the United States.

Stage decoration with roses: Cut roses are used for decorating stages in functions and marriages for providing aesthetic value.

Conclusion

Thus, value addition in rose is a very good source of income for self-employment to the rural youth. Rose flowers provide an opportunity to convert them into remunerative value-added products.

Soil Conditioner

Chauhan Aditi and Sonal Tripathi

Abstract

Soil conditioning is essential for several reasons, with key objectives including preventing soil degradation, enhancing soil air and water dynamics, improving drainage and aggregation, and reducing issues like soil crusting and compaction. It also helps address water repellence and other challenges. Soil conditioners can include organic materials, gypsum, lime, natural deposits, and water-soluble polymers, cross-linked polymers that retain moisture, living plants, microbes, and various industrial by-products. These conditioners are valuable because they improve soil's functionality as an ecosystem and its effectiveness in supporting crop growth.

Introduction

Conventional agriculture, which relies heavily on the use of fertilizers and pesticides, has significantly contributed to global food production, but it has come at the cost of soil degradation, reduced fertility, lower crop yields, and damage to ecosystem health. The decline in soil productivity can be attributed to physical limitations such as surface crusting, hardening, subsurface compactness, low or excessive permeability, and issues like soil erosion caused by wind and water. Soil conditioning refers to any process that enhances a soil's ability to support higher crop yields or improves its overall functionality. A soil conditioner is any product that, although it may contain limited nutrients, is primarily used for its positive impact on the biological, physical, or chemical properties of the soil. These conditioners can also serve as growth

media for plants. Soil conditioning helps form and stabilize aggregates that promote seed germination and seedling emergence. An effective soil stabilizer will help protect aggregates from rain-induced breakdown and maintain good water infiltration. Soil conditioners include a variety of materials such as organic matter, gypsum, lime, and natural deposits, water-soluble and cross-linked polymers that retain moisture, living plants, microbes and some industrial by-products.

Importance and function

Soil conditioners play a crucial role in enhancing the physical, chemical, and biological properties of the soil. They help maintain the pH of problematic soils, such as acidic or alkaline ones. In dry and sandy soils, soil conditioners improve water retention, infiltration, percolation, and permeability. They also create a favourable environment that attra-

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cts beneficial microorganisms and earthworms. By improving the soil's physical characteristics, soil conditioners enhance aeration, water retention, root development, and overall soil ecosystems. These conditioners are especially useful for improving poor soils or rehabilitating soils damaged by improper management. Additionally, they enrich the soil with nutrients, supporting healthier, stronger plants with higher yields. Over time, soil can become compacted, reducing air space; soil conditioners help alleviate this compaction and hard pan issues. They also boost soil fertility and help maintain soil in optimal condition.

Soil conditioners can be classified based on two criteria: (A) The origin of the materials, and (B) The composition of the materials.

Origin of the Materials

Composts: Compost is created through the decomposition of organic waste by microorganisms in the presence of oxygen. It offers several benefits as a soil conditioner, such as increasing organic carbon content, boosting microbial activity, and providing plant nutrients like nitrogen, phosphorus, potassium, and magnesium. Compost also strengthens roots and can suppress soil-borne pathogens like *Pythium*, *Phytophthora*, and *Fusarium*. Overall, compost helps maintain and enhance soil stability and fertility.

Farmyard Manure (FYM): Farmyard manure is a bulky organic manure made from the decomposition of a mixture of animal dung, urine, and bedding material. It is a rich source of nutrients and improves

the physical, chemical, and biological properties of soil by adding organic matter. FYM can be used in various types of problematic soils and crops.

Green Manures: Green manure crops are specifically grown to add nutrients and organic matter to the soil. These crops are rotated with other plants, ploughed under, and incorporated into the soil to provide similar benefits as traditional manures. Green manures help maintain soil structure, promote aeration, drainage, aggregation and enhance microbial activity, which in turn improves soil fertility.

Sewage Sludge: Sewage sludge, or biosolids, are organic solids treated to stabilize organic matter, reducing odour and preventing pest attraction or disease spread. Rich in nutrients and organic matter, biosolids can be applied to agricultural soils under regulatory control to ensure safety, limiting heavy metals, weeds, and pathogens.

Crop Residues: Crop residues are the leftover plant materials after harvesting, including stalks, stems, leaves, and seed pods. These residues are valuable organic matter that can be returned to the soil for nutrient recycling, improving the physical, chemical, and biological properties of the soil. Incorporating crop residues enhances nutrient cycling, soil and water conservation, and increases subsequent crop yields.

Peat Moss: Peat moss is formed from partially decayed plant material in peatlands, bogs, and moors under acidic and anaerobic conditions. It helps improve soil structure by increasing water retention

capacity.

Humates: Humates are products derived from oxidized lignite, an ancient organic soil substance found in lignite outcrops. Unlike peat, humates are fully decayed, making their nutrients available to plants. They contain up to 35% humic acids, which help dissolve and make other nutrients accessible to plants.

Biochar: Biochar is a fine, granular, black charcoal material produced by slow pyrolysis of biomass, typically from agricultural or forestry industries. Its high surface area, negative surface charge, and high charge density make it effective at adsorbing cations and retaining nutrients, which can be exchanged with the soil, microorganisms, and plant roots. Biochar stabilizes biomass and native soil organic matter, improving soil aeration, microbial activity, and reducing greenhouse gas emissions such as methane (CH₄), carbon dioxide (CO₂), and nitrous oxide (N₂O).

Inorganic Soil Conditioners

Inorganic soil conditioners are either mined, by-products of manufacturing, or a combination of both, and can be naturally occurring or synthetically produced. These include mineral conditioners like gypsum, lime, pyrites, crushed rocks, fly ash, sulphur, zeolites, and phosphogypsum, as well as synthetic conditioners such as water-soluble polymers, hydrogel polymers, and synthetic binding agents like anionic and catalytic polymers. Inorganic conditioners mainly improve soil physical properties, enabling better utilization of soil and water

resources. These conditioners interact with soil constituents, especially clay, through physico-chemical reactions. Their use leads to improved soil aggregation, porosity, hydraulic conductivity, reduced bulk density, and better water infiltration and permeability.

Mineral Conditioners: These are used to treat problematic soils, such as gypsum, lime, sulphur, and crushed rocks.

✓ **Gypsum:** A moderately soluble source of calcium and sulphur, gypsum helps improve plant growth and displaces exchangeable sodium in high-sodium soils. It can reclaim sodic soils, soften alkali hard pans, and improve infiltration in puddled soils. Additionally, gypsum reduces erosion and nutrient runoff, particularly phosphorus.

✓ **Lime:** Composed mainly of calcium-based minerals, lime is used to correct soil acidity. It raises soil pH, particularly in soils with pH below 6.0, where nutrient absorption is hindered. Lime is a source of calcium and helps restore pH balance in acidic soils.

✓ **Fly Ash:** A by-product of thermal power plants, fly ash improves soil fertility and crop productivity by mobilizing both macro and micronutrients. It is also used to create a novel soil conditioner called “Biosil.”

Other Mineral Conditioners: These include limestone, dolomite, crushed rock, and elemental sulphur. These products, rich in calcium and magnesium, are applied in large quantities to improve the

physical condition of problematic soils.

Synthetic Binding Agents: These are high-molecular-weight, long-chain organic compounds applied in small amounts to bind soil particles and form stable aggregates. Polymers like polysaccharides (PSD) and polyacrylamides (PAM) are used to stabilize soil aggregates, maintain fertility, and prevent surface crusting, especially in sodic soils with an exchangeable sodium percentage (ESP) greater than 20. These compounds are typically sprayed onto the soil surface or added to irrigation water.

Cationic Polymers: Cationic polymers, such as polyvinyl chloride (PVC) and polyphenol hydrochloride (PPH), are absorbed by clay particles through cation exchange, with calcium acting as a bridge. These polymers have high flocculating power and help stabilize clay aggregates.

Anionic Polymers: Anionic polymers like hydrolysed polyacrylonitrile (HPAN) and Vinyl Acetate-Maleic Acid (VAMA) copolymers are used to prevent crusting in sodic soils. They stabilize flocculated clays by binding particles together through hydrogen bonds without having flocculating power themselves.

Non-Ionic Soil Conditioners: Non-ionic polymers, such as polyvinyl alcohol (PVA), help stabilize soil aggregates by forming complexes with expanding clay lattices, reducing swelling, and enhancing the stability of aggregates.

Polyacrylamide: Used since the 1950s, polyacrylamide is a synthetic polymer that improves soil

physical properties by reducing surface sealing, increasing seedling emergence, and reducing runoff and erosion. It is particularly effective in coarse-textured soils that have high macrospore percentages.

Other Soil Conditioners

This category includes industrial wastes, enzymes, microorganisms, and activators.

Conclusion

To meet the growing global demand for food, the widespread use of soil conditioners, alongside conservation farming methods, is essential. Soil conditioners improve the functionality of soil as an ecosystem and its efficiency in supporting crop growth. Before using inorganic or organic conditioners, it is important to assess the specific needs of the land to ensure their appropriate application.

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Role of Biofertilizers in Agriculture

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Abstract

Biofertilizers are vital for promoting healthy crop growth and the production of nutritious food. With the world's population steadily increasing, modern soil management primarily relies on inorganic, chemical-based fertilizers, which pose significant risks to human health and the environment. As a sustainable alternative, biofertilizers have emerged as a promising solution for enhancing soil fertility and boosting crop yields. They play a crucial role in integrated nutrient management systems. Commonly utilized microorganisms in biofertilizers include nitrogen-fixing bacteria, potassium and phosphate solubilizers, plant growth-promoting rhizobacteria (PGPR), endo- and ectomycorrhizal fungi, cyanobacteria, and other beneficial microscopic organisms. These biological fertilizers contribute significantly to soil productivity and sustainability while offering eco-friendly and cost-effective solutions for farmers, thus helping to protect the environment.

Introduction

In India, the rapidly growing population poses a significant challenge to food security. To meet the rising demand for food, it is crucial to substantially enhance agricultural productivity in the coming decades. However, in pursuit of higher yields, farmers have become increasingly reliant on chemical fertilizers. This excessive and uncontrolled use of chemical fertilizers has severe consequences for both environmental ecosystems and human health. The use of microbial biofertilizers is being recognized as a viable alternative to chemical fertilizers in agriculture due to their ability to enhance crop productivity and ensure food safety. Biofertilizers are substances containing living microorganisms that, when applied to seeds, plant

surfaces, or soil, rapidly colonize the plant's rhizosphere or interior. These microorganisms promote plant growth by improving the supply and availability of essential nutrients to the host plant. Biofertilizers contribute to nutrient enrichment through natural processes such as nitrogen fixation, phosphorus solubilization, and the production of growth-promoting substances. The advantages of biofertilizers include being a cost-effective nutrient source, providing essential micro and macro-nutrients, supplying organic matter, secreting plant growth hormones, and mitigating the harmful effects of chemical fertilizers (Gaur, 2010). Various microbes, as integral components of the soil, play a vital role in maintaining soil health by supporting biotic processes essential for nutrient mobilization

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and sustainable crop production (Ahemad and Kibret, 2014).

Classification of Biofertilizers

Nitrogen-Fixing Biofertilizers

Free-Living: Examples include *Azotobacter*, *Clostridium* and *Anabaena nostoc*.

Symbiotic: Includes microorganisms like *Rhizobium* and *Anabaena azollae*.

Associative Symbiotic: *Azospirillum* is a prominent example.

Phosphorus-Solubilizing Biofertilizers

Bacteria: Species such as *Bacillus subtilis* and *Pseudomonas striata*.

Fungi: Includes *Penicillium spp.* and *Aspergillus awamori*.

Phosphorus-Mobilizing Biofertilizers

Arbuscular Mycorrhiza: *Glomus spp.* and *Scutellospora spp.*

Ectomycorrhiza: Includes *Laccaria spp.*, *Pisolithus spp.*, and *Boletus spp.*

Potassium-Solubilizing Biofertilizers

✓ Microorganisms such as *Bacillus spp.* and *Aspergillus spp.*

Potassium-Mobilizing Biofertilizers

✓ *Bacillus spp.*

Plant Growth-Promoting Rhizobacteria (PGPR)

✓ *Pseudomonas fluorescens*.

Rhizobium: *Rhizobium* is a soil-dwelling bacterium that colonizes legume roots and fixes atmospheric nitrogen symbiotically. Its morphology and physiology differ between free-living conditions and bacteroid forms in nodules. *Rhizobium* consists of

seven genera and exhibits high specificity for forming nodules in legumes, classified as cross-inoculation groups. Examples of its genera include *R. leguminosarum*, *R. phaseoli*, *R. trifolii*, *R. meliloti*, *R. lupini*, and *R. japonicum*. It can fix approximately 50-100 kg of nitrogen per hectare.

Azotobacter: *Azotobacter* is a free-living bacterium predominantly found in neutral to alkaline soils. It fixes atmospheric nitrogen by converting it into ammonia. Additionally, it produces abundant slime, which aids in soil aggregation.

Azospirillum: *Azospirillum* thrives under both aerobic and anaerobic conditions. It provides additional benefits such as producing plant growth regulators like indole-3-acetic acid (IAA), enhancing disease resistance, and improving drought tolerance. It can fix 20-40 kg of nitrogen per hectare.

Azolla: *Azolla* is a free-floating aquatic fern used as a biofertilizer in wetland paddy fields. It fixes atmospheric nitrogen through its association with nitrogen-fixing blue-green algae (*Anabaena azollae*). It contributes around 40-50 kg of nitrogen per hectare.

Phosphate solubilizing Biofertilizers: This group of biofertilizers hydrolyzes organic and inorganic phosphorus from insoluble compounds, making it available to plants. *Bacillus* and *Pseudomonas* are among the most efficient bacteria in this category.

Phosphate Mobilizing Biofertilizers (Mycorrhiza): Mycorrhiza refers to a symbiotic, usually mutualistic association between fungi and the roots of vascular plants. The fungus colonizes the plant

roots, either within the root cells (intracellularly) or externally. The fungi gain access to carbohydrates from the host plant, while the plants benefit from the mycelium's enhanced capacity to absorb water and minerals. This is particularly useful for plants unable to absorb phosphate ions in basic soils. The mycorrhizal mycelium makes these ions available to the plants they colonize.

Potassium Solubilizing Biofertilizers (KSB):

Potassium in the soil is primarily found as silicate minerals, which are largely inaccessible to plants. These minerals can only become available through slow weathering or solubilization. Potassium-solubilizing microorganisms produce organic acids that decompose silicates, releasing metal ions and making potassium available to plants.

Potassium Mobilizing Bacteria: These biofertilizers mobilize the inaccessible forms of potassium present in the soil, making it available to plants. Certain phosphate-solubilizing biofertilizers, such as *Bacillus spp.* and *Aspergillus spp.*, have also been found to mobilize potassium in addition to solubilizing phosphorus.

Silicate and Zinc Solubilizing bacteria: Microorganisms capable of breaking down silicates and aluminum silicates play a crucial role in soil nutrient availability. *Bacillus spp.* can be utilized as biofertilizers to solubilize silicates and zinc, making zinc accessible to plants.

Plant Growth Promoting Rhizobacteria: Species of *Pseudomonas* and *Bacillus* act as plant growth promoters by producing phytohormones such as

indole-3-acetic acid (IAA), cytokinins, and gibberellins. They also inhibit ethylene production, further supporting plant growth.

Methods of Application of Biofertilizers

Seed Treatment: Approximately 200 grams of biofertilizer is dissolved in 300-400 ml of water and gently mixed with 10 kg of seeds using adhesives like gum or jaggery solution. The treated seeds are spread on a clean cloth under shade to dry and should be sown immediately.

Seedling root dip: This method is suitable for transplanted crops. For paddy, a bed is prepared in the field and filled with water. The recommended biofertilizers are mixed into the water, and the seedling roots are dipped for 8-10 hours before being transplanted.

Soil Treatment: Four kilograms of the recommended biofertilizers are combined with 200 kg of compost and left overnight. The mixture is then applied to the field during sowing or planting.

Advantages of Biofertilizers

- ✓ They are environmentally friendly and cost-effective.
- ✓ They enrich the soil and improve its quality over time.
- ✓ While they may not provide immediate results, their long-term impact is remarkable.
- ✓ They help reduce the overall cost of cultivation.
- ✓ They can increase crop yields by 10-15%.
- ✓ They decrease the dependency on conventional fertilizers.
- ✓ They contribute to the production of plant horm-

ones.

- ✓ They enhance the availability of nutrients to plants.

Precautions for Using Biofertilizers

- ✓ Avoid applying biofertilizers alongside fungicides.
- ✓ Do not expose biofertilizers directly to sunlight.
- ✓ Store biofertilizers at room temperature, ensuring the temperature remains between 0°C and 35°C.
- ✓ Do not store or use leftover biofertilizer solutions overnight.

Conclusion

Biofertilizers play a significant role in enhancing crop production while promoting soil health. They supply plants with growth-promoting hormones and phytochromes, offering an eco-friendly alternative to chemical fertilizers. Unlike chemical fertilizers, biofertilizers do not leave harmful residues in the environment, making them an ideal choice for sustainable agricultural practices.

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Macro and Micro Nutrient Dynamics in Relation to Soil-Plant System

Chauhan Aditi and Sonal Tripathi

Abstract

Nutrient dynamics refers to the processes by which nutrients are absorbed, stored, transferred, and cycled over time and space within an ecosystem (Hauer and Lamberti, 2006; Allan and Castillo, 2007). Nutrients are broadly defined as all chemical elements essential for biological functions, including survival and reproduction (DeAngelis *et al.*, 1989). Organisms require large quantities of macronutrients such as carbon (C), hydrogen (H), nitrogen (N), phosphorus (P), potassium (K), sulphur (S), and calcium (Ca). Other elements, like silicon (Si), are crucial for certain cellular processes. Micronutrients, such as copper (Cu) and zinc (Zn), are needed in smaller amounts (Smith and Smith, 1998). In nature, the availability of certain elements can limit the primary productivity of an ecosystem at specific times and locations. In many aquatic ecosystems, the concentrations, molecular forms, and balance of macronutrients, particularly nitrogen (N) and phosphorus (P), regulate productivity (Officer and Ryther, 1980).

Introduction

Plant growth and development are largely influenced by the types and amounts of mineral nutrients available in the soil. However, plants often face challenges in securing sufficient nutrients due to their limited mobility. There are thirteen essential nutrients that plants absorb from the soil. Of these, six are considered macronutrients, which plants require in larger quantities: Nitrogen, Phosphorus, Potassium (N-P-K), Calcium, Magnesium, and Sulphur. The remaining nutrients, which are needed in smaller amounts, are called micronutrients. These include Iron, Manganese, Boron, Zinc, Copper, Molybdenum, and Chlorine. While the nutrients themselves are the same whether sourced from orga-

nic or synthetic materials, the source can influence how quickly they become available to plants. Nutrient dynamics is defined as the process through which nutrients are absorbed, stored, transferred, and cycled over time and space within an ecosystem (Hauer and Lamberti, 2006).

Nitrogen: Nitrogen in soil exists in three main forms: (a) organic nitrogen, which is linked to soil humus, (b) ammonium nitrogen fixed by specific clay minerals, and (c) soluble inorganic ammonium and nitrate compounds. Most nitrogen in surface soils is bound in organic matter, which is protected from rapid microbial breakdown, with only about 2-3% being mineralized annually under normal conditions. Approximately half of the organic nitro-

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gen is in the form of amino compounds, while the rest remains uncertain. The process of capturing nitrogen in organic forms is known as immobilization, and its gradual release (the conversion from organic to inorganic forms) is called mineralization. Factors such as climate, natural vegetation, soil texture, drainage, and cropping practices significantly influence organic matter and nitrogen content. The soil's inherent ability to support crops is directly related to its organic matter and nitrogen levels, making the management of organic matter a priority in soil management. Some nitrogen released during mineralization is converted into nitrate (NO_3^-). Factors like the supply of ammonium (NH_4^+), population of nitrifying organisms, soil pH, aeration, moisture, and temperature influence nitrification. Certain clay minerals, such as vermiculite and smectites, can fix ammonium nitrogen within their crystal structure. The amount of ammonium fixation depends on the type and quantity of clay present, with up to 8% of the total nitrogen in surface soils and 40% in subsoils being in the fixed form (Brady and Weil, 2007). Soil moisture and temperature affect ammonium fixation, with freezing and drying increasing fixation. Cycles of wetting-drying and freezing-thawing contribute to the stability of fixed ammonium. Potassium ions (K^+) may limit ammonium fixation, as they can occupy fixation sites. Fixed ammonium is believed to be in equilibrium with exchangeable ammonium. Soluble ammonium and nitrate compounds typically make up only 1-2% of total nitrogen in the soil, except where

significant inorganic nitrogen fertilizers have been applied. This is beneficial because inorganic nitrogen can be lost through leaching and volatilization. The major nitrogen losses from soil occur through crop removal and leaching, while under certain conditions, inorganic nitrogen can be converted into gases and lost to the atmosphere, primarily through denitrification and ammonia (NH_3) volatilization.

Phosphorus: The availability of inorganic phosphorus (P) in soil is influenced by several factors: a) soil pH, b) soluble iron (Fe), aluminium (Al), and manganese (Mn), c) the presence of minerals containing Fe, Al, and Mn, d) available calcium (Ca) and calcium-containing minerals, and e) the amount and decomposition of organic matter, along with microbial activity. The first four factors are interconnected, as soil pH significantly affects the reaction of phosphorus with various ions and minerals. The ionic form of phosphorus, which determines its availability to plants, is largely influenced by the pH of the soil solution. In highly acidic conditions, only H_2PO_4^- ions are present. As the pH increases, HPO_4^{2-} ions begin to dominate, and at even higher pH levels, PO_4^{3-} ions become the predominant form. At intermediate pH values, both H_2PO_4^- and HPO_4^{2-} ions may be present. The H_2PO_4^- ion is more readily available to plants than HPO_4^{2-} . Beyond pH and related factors, organic matter and microorganisms also play a crucial role in determining the availability of inorganic phosphorus (Prasad, 2007). Manure has been shown to effectively release phosphorus once it is fixed as Fe,

Al, and Ca phosphates. While organic forms of phosphorus, such as phytin and nucleic acids, can be utilized by plants, inorganic sources of phosphorus are essential for normal plant growth. Even when organic phosphorus is present in substantial amounts, plants often experience phosphorus deficiency due to the limited availability of these forms. In acidic soils, phytin becomes insoluble and unavailable due to reactions with Fe and Al, while in alkaline soils, calcium phytate precipitates, making its phosphorus content inaccessible. The fixation of nucleic acids occurs through a different mechanism, but the end result is the same- low phosphorus availability. Nucleic acids are particularly prone to strong adsorption by clays, such as montmorillonite.

Potassium: Potassium in soils exists in three general forms based on its availability: a) unavailable (such as feldspars and micas), b) readily available (exchangeable and in soil solution) and c) slowly available (non-exchangeable or fixed). The potassium taken up by crops is primarily supplied by the non-exchangeable forms. Several soil conditions influence the fixation of potassium, including (a) the nature of soil colloids, (b) wetting and drying cycles, (c) freezing and thawing, and (d) the presence of excess lime. The ability of different soil colloids to fix potassium varies significantly. For instance, soils dominated by 1:1 type clays, such as kaolinite, fix very little potassium, while 2:1 type clays like vermiculite, smectite, and fine-grained mica (Illite) fix potassium readily and in large amounts. The mechanism of potassium fixation is likely similar to

that of ammonium fixation. Both potassium and ammonium ions have lower affinities for water of hydration compared to other cations like sodium (Na^+) and calcium (Ca^{2+}), making them more easily dehydrated. Due to their small size, they can fit tightly between the silica sheets in the layers of 2:1 type clay minerals. Once fixed in place, these ions become trapped within the crystal structure, preventing the expansion of the clay's crystal lattice and reducing its cation exchange capacity (CEC). Larger hydrated cations like Na^+ , Ca^{2+} , and magnesium (Mg^{2+}) cannot fit between these layers, thus they are not fixed in the same manner.

Calcium: In acid, humid region soils, calcium (Ca) mainly exists in exchangeable forms and as primary minerals. Several soil factors influence the availability of Ca^{2+} to plants: 1) total calcium supply, 2) soil pH, 3) cation exchange capacity (CEC), 4) percentage of Ca^{2+} saturation on CEC, 5) type of soil colloid, and 6) the ratio of Ca^{2+} to other cations in the soil solution. In very sandy, acidic soils with low CEC, the total calcium content may be insufficient to meet the crop's needs. High hydrogen ion (H^+) activity can hinder calcium uptake by plants. In acidic soils, calcium is not readily available at low saturation levels. The percentage of Ca^{2+} saturation decreases as CEC increases, resulting in reduced calcium absorption by plants. High Ca^{2+} saturation generally indicates a favourable pH for plant growth and microbial activity. Moreover, when calcium dominates, the concentration of undesirable cations, like aluminium (Al^{3+}) in acidic soils and sodium

(Na⁺) in sodic soils, is often low. The type of clay in the soil also affects calcium availability; 2:1 clays require a higher Ca²⁺ saturation than 1:1 clays. For example, Montmorillonite clays need over 70% Ca²⁺ saturation for adequate calcium availability, while kaolinitic clays can supply sufficient calcium at 40 to 50% Ca²⁺ saturation. Additionally, the ratios of Ca²⁺ to other cations in the soil solution influence calcium uptake by plants. A Ca/total cation ratio of 0.10 to 0.15 is ideal for providing adequate calcium to most crops. Calcium uptake is inhibited by ammonium (NH₄⁺), potassium (K⁺), magnesium (Mg²⁺), manganese (Mn²⁺), and aluminium (Al³⁺), but is enhanced when plants receive nitrate (NO₃⁻) nitrogen. A high level of nitrate nutrition promotes the synthesis of organic anions, leading to increased cation accumulation, particularly calcium.

Magnesium: Magnesium (Mg) primarily exists as exchangeable Mg²⁺ and in soil solution. The absorption of Mg by plants is influenced by the amount of solution Mg²⁺, soil pH, the percentage of Mg saturation on the cation exchange capacity (CEC), the presence of other exchangeable ions, and the type of clay. In acidic soils, the formation of less available magnesium forms is promoted by soluble magnesium compounds and 2:1 clay minerals. Magnesium ions (Mg²⁺) may become trapped in the interlayer spaces of expanding and contracting minerals. Coarse-textured soils in humid regions are particularly prone to magnesium deficiency, as they typically have low levels of total and exchangeable Mg²⁺. Soils are likely deficient when exchangeable

Mg²⁺ is below 25 to 50 ppm. Exchangeable magnesium usually makes up 4 to 20% of the CEC in soils, and the critical Mg saturation level for optimal plant growth falls within this range, though magnesium saturation should not be lower than 10%. In strongly acidic soils, reduced magnesium uptake can occur due to high levels of exchangeable aluminium (Al³⁺). In acid organic soils, where Al³⁺ is not a primary cause of acidity, magnesium availability may still be negatively affected by high H⁺ ion activity. Magnesium deficiencies can also arise in soils with high calcium-to-magnesium ratios (Ca/Mg), which should not exceed a ratio of 10/1 to 15/1. The continued use of high-calcium liming materials on coarse-textured soils in humid regions can increase the Ca/Mg ratio and lead to magnesium deficiency in certain crops. High levels of exchangeable potassium (K) can also interfere with magnesium uptake by plants. This interaction is likely due to the release of H⁺ ions when ammonium (NH₄⁺) is absorbed by plant roots, as well as the direct effects of NH₄⁺.

Sulphur: Sulphur (S) in soil exists in both organic and inorganic forms, with approximately 90% of the total sulphur in most non-calcareous surface soils being in organic forms. The inorganic forms include sulphate (SO₄²⁻), adsorbed sulphate, insoluble sulphate, and reduced inorganic sulphur compounds. The readily available fraction of sulphur for plants consists of dissolved and adsorbed sulphate. Similar to nitrogen (N), sulphur cycles in soils include gaseous components, and its presence in the soil is

linked to organic matter (OM). Plants absorb dissolved sulphate (SO_4^{2-}) through their roots by diffusion and mass flow. Adsorbed sulphate in highly weathered soils can significantly contribute to the sulphur needs of plants, though it is available at a slower rate than dissolved sulphate. Sulphate adsorption in soil is reversible and influenced by various soil factors, such as clay content, type of clay mineral, presence of hydrous oxides, soil depth, pH, sulphate concentration, time, presence of other anions and cations, and organic matter. The proportion of sulphur in organic forms varies depending on the soil type and its depth within the profile. There is a strong relationship between organic carbon (C), total nitrogen (N), and total sulphur (S) in soils, with the C/N/S ratio in most well-drained, non-calcareous soils being approximately 120/10/1.4. Generally, the C/S ratio in soils varies more than the N/S ratio, which typically falls within the range of 6 to 8:1. The properties of the organic sulphur fraction in soils play a crucial role in determining the release of plant-available sulphur.

Conclusion

Plant growth is influenced by the availability and uptake of external nutrients, which depend on the amounts of nutrients stored in the soil and how well they are recycled within the plant. Although plants cannot move and often face nutrient shortages, they employ various mechanisms to acquire the necessary macro- and micronutrients for proper growth, development, and reproduction. The efficiency of these mechanisms significantly impacts crop yields,

plant community structures, soil ecology, ecosystem health, and biodiversity. Thus, understanding the demand, supply, and availability of nutrients is crucial for optimizing crop growth.

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Microbial Fertilizers: A Way to Lessen Chemical Use

Satyendra Kumar Jha and Swati Thakur

Abstract

Microbial fertilizers are popularly referred to as biofertilizers. They are environmentally favorable substitutes for chemical fertilizers. These products improve plant development using naturally existing microorganisms and by improving availability of nutrients, fixing atmospheric nitrogen, and decomposing organic matter. With the increasing issues emanating from the use of synthetic fertilizers, microbial fertilizers allow for reduced chemical input, thus, maintaining or improving crop yields. This article will discuss the different kinds of microbial fertilizers and the mechanisms they operate in, alongside recent research regarding the benefits of these biofertilizers. It also discusses the obstacles to wider adoption and potential solutions.

Introduction

The modern use of synthetic chemical fertilizers in agriculture, however, has had drastic environmental effects in terms of soil degradation, water pollution, and loss of biodiversity. These types of fertilizers will eventually decrease soil fertility after some long time use, leading to dependence on external sources for inputs. The agricultural sector is now looking more at sustainable practices like microbial fertilizer application as a way of reducing use of chemicals without sacrificing productivity.

Microbial fertilizer is a kind of microbial inoculant, which improves the natural plant growth by atmospheric nitrogen fixation, organic matter decomposition, improving nutrient absorption, and better soil structure. One most simple working mechanism involves the contribution of these alive

organisms to the natural soil nutrient cycles, presenting a more environmentally friendly alternative to chemical fertilizers. This review deals with the present status of microbial fertilizers, the different kinds, how they reduce chemical input, as well as the challenges and opportunities towards adoption.

Types of Microbial Fertilizers

Nitrogen-Fixing Bacteria: Most plants cannot tap directly into the atmosphere and absorb nitrogen, which is a vital nutrient for plant growth. Nitrogen-fixing bacteria such as *Rhizobium*, *Azotobacter*, and *Azospirillum* are responsible for changing atmospheric nitrogen into forms that can be easily absorbed by plants. It forms symbiotic association with leguminous plants to provide natural nitrogen fertilization, thereby reducing the use of synthetic nitrogenous fertilizers.

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According to recent study of Alori *et al.* (2022) nitrogen-fixing bacteria were demonstrated to improve soil nitrogen availability, which increased crop yield potential by up to 20%. This potential demonstrates that these little organisms could serve as substitutes for chemical nitrogen fertilizers but still be at par with productivity.

Phosphate-Solubilizing Microorganisms

Phosphorus is one of the most essential among all nutrients, but it is in forms in soil where plants cannot utilize a lot of phosphorus insolubility. Phosphate-solubilizing microorganisms such as *Bacillus*, *Pseudomonas*, and some filamentous microorganisms like *Aspergillus* can mobilize that insolubility and make them bioavailable. These microorganisms excrete organic acids that solubilize phosphorus compounds, making them available for plant absorption.

Zhang *et al.* (2023) report application of phosphate-solubilizing bacteria increased available phosphorus in soil by 40%, decreasing chemical phosphorus fertilizer application. It also refers to increased nutrient availability benefiting crop growth and yield.

Mycorrhizal Fungi: Mycorrhizal fungi tend to develop a haemorrhagic fungus, a symbiotic association with the root systems of plants, and thereby extend and increase root surface areas to modify the nutrient acquisition ability of the plant, particularly in its uptake of phosphorus and micronutrients.

Arbuscular mycorrhizal fungi (AMF) are the

most widely distributed; they increase the nutrient uptake of crops, improve the structure of soils, and enhance plant resistance to drought. Verbruggen *et al.* (2021) showed that AMF increased phosphorus uptake by 30% and improved plant growth under nutrient-limited conditions. Increased application of mycorrhizal fungi would replenish the soil so that it will no longer depend on chemical fertilizers and restoration of its health through the formation of constructive, sustainable microbial ecosystems.

Plant Growth-Promoting Rhizobacteria (PGPR):

Plant growth-promoting rhizobacteria (PGPR) refers to general bacteria that inhabit plant roots and induce plant growth through the production of phytohormones and increased nutrient availability while offering protection against pathogens. PGPR such as *Bacillus subtilis* and *Pseudomonas fluorescens* serve to enhance root growth, increase nutrient uptake, and induce plant defense responses.

According to a recent study conducted by Ali *et al.* (2022), PGPR-treated crops increased yields by 15-25% compared to untreated crops. PGPR increases the nutrient efficiency of plants, resulting in decreased need for synthetic input thereby increasing sustainability in agriculture.

Mechanisms of Microbial Fertilizers in Reducing Chemical Use

Nutrient Cycling and Availability: Microbial fertilizers help for the cycling of major nutrients such as nitrogen, phosphorus, and potassium forms, accessible to plants. Nitrogen-fixing bacteria convert atmospheric nitrogen into ammonia.

Phosphate-solubilizing microorganisms liberate Phosphate bound into soil compounds, whereas other microorganisms enhance availability of micro-nutrients. Hassan *et al.*, hence, have studied the microbial fertilizers to increase nutrient availability by 25%, reducing the use of chemical fertilizers. These microorganisms form a part of natural soil processes and provide plants with a greater nutrient supply without applying external chemical inputs, thereby increasing plant growth.

Soil Structure and Organic Matter: The use of microbial fertilizers can enhance soil structure and organic matter content. Mycorrhizal fungi and exopolysaccharides produced by bacteria help in soil particle aggregation increasing overall soil porosity and retention of water. All improved soil structures enhanced root growth resulting in the utilization of nutrients without the use of chemical soil conditioners. According to Xia *et al.* (2022), microbial fertilizers improve organic matter by 20%, thereby improving soil fertility restoration of degraded agricultural soils. This improves the soil health where chemical dependence in the input is reduced and the long-term sustainability of agriculture is promoted.

Enhanced Plant Stress Resistance: Microbial fertilizers also assist plants by enabling them to withstand environmental stresses like drought, salinity, and disease. Some PGPRs and mycorrhizal fungi induce plant defense mechanisms, thus enhancing the tolerance of plants to abiotic and biotic stresses and improving water and nutrient uptake.

As reported by Patel *et al.* (2023), crops treated with microbial fertilizers are reportedly 30% drought-tolerant than the untreated crops. This increased drought tolerance reduces reliance on pesticide and herbicide application, thereby minimizing chemical input in agriculture.

Benefits of Microbial Fertilizers

Environmental Sustainability: It's also reduced the environmental pollution that chemical fertilizers cause by using microbial fertilizers. Chemical fertilizer overuse causes water pollution, eutrophication, and greenhouse gas emissions. Microbial fertilizers contribute to nature without the associated environmental hazards. According to Johnson *et al.* (2022), it was observed that fields treated with microbial fertilizers had a runoff nitrogen quantity reduced by 50% and greenhouse gas emissions reduced by 30% when compared to conventional synthetic-field counterparts. This clearly shows how microbial fertilizers can be potent agents in alleviating conventional environmental degradation caused by agriculture.

Long-term Soil Fertility: Soil health can be deteriorated by chemical fertilizers over time by disturbing soil microbial communities, causing nutrient imbalances. However, microbial fertilizers increase soil fertility by promoting microbial diversity, more organic matter, and nutrient cycling. Such improvements represent better soil productivity over the years without enormous chemical inputs. Continuous application of microbial fertilizer has been reported by Delgado *et al.* (2023) to increase

levels of soil organic carbon and microbial biomass, which help restore degraded soil.

Economic Benefits for Farmers: Even though the microbial fertilizers seem to be costlier initially, they eventually result in saving for future use because of their long-term use in place of chemical fertilizers and pesticides. Increased productivity of crops along with the health of the soil will lead to more consistent harvests that are less expensive to produce and more profitable to the farmers. Kumar *et al.* (2023) studied the cost-benefit analysis done on farmers using microbial fertilisers, indicating 15-20% decrease in fertilizer cost and an increase of 10-15% in crop produce over 5 years due to microbial fertilizer, implying economic viability of the products.

Challenges in Adoption

Inconsistent Results: The major challenges while using microbial fertilizers fall under the effective variability of the product as per soil types, climate, crop species, etc. In some instances, these microbial fertilizers do not yield as much instant result as chemical fertilizers do and may lead to uneven results among farmers. A study by Jones *et al.* (2021): states that although microbial fertilizers proved to be effective when applied in controlled experiments, there was extremely variable performance among different field conditions. Thus further studies have been suggested with regard to optimizing the use of these products concerning different agricultural surroundings.

Lack of Awareness and Education: Most farmers do not really understand the usefulness of microbial

fertilizers, in addition to a poor training on effectiveness of application of these fertilizers. Takes greater education and outreach to ensure farmers understand how to incorporate any microbial fertilizers into their farming practices and to appreciate the long-term benefits it brings.

Conclusion

Natural microbial fertilizers are the best source which helps in reducing chemical fertilizers as they make nutrient availability, help the soil, and improve crop resilience under stress. These factors facilitate more sustainable farming practices that protect the environment and ensure long-term productivity. There are challenges of variable performance and the need for awareness, but research and education would break these barriers. They are a very important component of the transition to sustainable agriculture: reduced inputs of increasingly smaller synthetic chemicals give rise to healthier ecosystems.

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Endophytes Mediated Heavy Metal Stress Alleviation in Plants

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Introduction

Rapid urbanization, industrialization and intensive agriculture are main causes of heavy metals pollution on a global scale. Heavy metals are non-degradable and without intervention they persist in soil for centuries. The persistence of heavy metals may adversely affect the ecosystem, not only agricultural product and water quality, but also soil microorganisms and human health (Rho *et al.*, 2018). However, innate defense strategies of prokaryotes allow the uptake of heavy metal ions and their utilization as nutrients by absorptive and accumulative capacity. Likewise, a eukaryotic microbial system such as fungus has been reported to have enough strategies to survive with metal stress. The development of metal resistance in microorganisms has evolved due to their continual exposure to toxic metals since life started at least 3.5 billion years ago. In this context, recent studies have found that inoculation of plants with selected and acclimatized endophytic microbes have the capacity to alleviate metal induced phytotoxicity and enhance biomass production of plants when grown in metal contaminated soils (Rho *et al.*, 2018).

Endophytic bacteria

Particularly, in order to circumvent the metal stress, endophytic bacteria have evolved several types of mechanisms, through which they alleviate

the toxicity of metal ions. These mechanisms include the efflux of metal ions exterior to the cell, transformation of metal ions to less toxic forms, sequestration of metals on the cell surface or in intracellular polymers, precipitation and adsorption/desorption. Jan *et al.* (2019) found that cadmium resistant endophytic bacterium *Serratia* sp. LRE07 absorbed over 65% of Cd and 35% of Zn in bacterial cells from single metal solution, thereby significantly reduced the phytotoxic effects of the metals by sharing the metal load due to its ability of biosorption and bioaccumulation. Molina *et al.* (2014) recently found that endophytic bacteria could modulate the activity of plant antioxidant enzyme (such as POD, CAT, SOD, glutathione peroxidase, ascorbate peroxidase) as well as lipid peroxidation (malondialdehyde formation), which confronted plant defense mechanisms, especially resisted the heavy metal-induced oxidative stress in plants. Also, the alteration of the levels of 1-aminocyclopropane-1-carboxylate (ACC) by various bacteria can affect heavy metal tolerance directly through the manipulation of ethylene levels in plants. In addition, certain endophytic bacteria can also use methylation as a metal resistance or detoxification mechanism. For instance, some mercury resistant endophytic bacteria express MerB gene encoding organo-mercurial lyase cleaves organomercurials into mercuric ion (Hg^{2+})

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and MerA gene encoding mercuric reductase converts highly toxic ionic Hg^{2+} into less toxic volatile Hg^0 , thus alleviate metal toxicity and improve the efficiency of phyto-volatilization. Further, the extracellular polymeric substances (EPS) secreted by endophytic bacteria, consist mainly polysaccharides, proteins, nucleic acids and lipids, also play a significant role in metal complexation thereby reducing their bioaccessibility and bioavailability in plants. To understand whether bacterial endophytes are an ideal candidate for HM tolerance, Franco *et al.* (2021) performed a meta-analysis of the literature on bacterial endophyte and HM tolerance from the last 10 years and estimated the effective microbial size. The study concluded an overall positive effect on plant growth and metal tolerance in different species, suggesting the beneficial prospects of endophytes as biological agents in HM tolerance and mitigation.

Endophytic fungi: In addition, endophytic fungi also have greater potential for remediation by virtue of their aggressive growth, greater biomass production and extensive hyphal network. Fungal endophytes remarkably exhibits excellent metal-binding capacity and provide more advantages over bacterial bioaugmentation. The tolerance mechanisms employed by endophytic fungi have been basically categorized into biosorption, bioaccumulation, biotransformation and efflux of metal ions. Sharma *et al.* (2022) studied the effect of fungal seed endophyte *Dysphania ambrosioides* on the accumulation and tolerance of Cd and Zn metals in the plant,

defining key prospects in decreasing metal toxicity and promoting metal phytoextraction in important agriculture crops. Abhinandana *et al.* (2024) isolated 83 arsenic tolerant fungal endophytes from the plants grown in arsenic-contaminated areas of Karnataka and among them were found efficiently enduring metal stress up to 2000 ppm with tolerance index >0.5 . Further these isolates were subjected to various in vitro growth promoting traits viz., phytohormones production, phosphate solubilization, siderophore production, HCN production and ACC deaminase activity under normal and arsenic stress (100 ppm) condition. Indole acetic acid produced by fungal endophytes ranged between $120\text{--}610\ \mu\text{g mL}^{-1}$, which was reduced to $50\text{--}340\ \mu\text{g mL}^{-1}$ when they were grown on arsenic induced medium. Acc deaminase activity was observed in all the eight arsenic resistant fungal endophytes in presence of ACC source. This process can affect heavy metal tolerance directly through the manipulation of ethylene levels in plants (Abhinandana *et al.*, 2023). Similarly, Khan *et al.* (2017) observed that greater amount of metal was accumulated by fungal endophytes intracellularly at Cd concentration of $100\ \mu\text{g mL}^{-1}$. Cd bioaccumulation capacity ranged from 2.3 ± 0.1 to $11.9 \pm 0.6\ \text{mg g}^{-1}$ depending on the fungal strain. In another report, Shahabivand *et al.* (2017) indicated that *P. indica* enhanced the tolerance of sunflower (*Helianthus annuus* L.) to cadmium (Cd) toxicity by immobilizing Cd in the roots. This fungus also modulates antioxidant responses of plants to ameliorate Cd stress.

Mohd *et al.* (2017) observed that endophytic fungal cell wall was able to adsorb arsenic in a non-linear fashion, suggesting that increasing the concentration resulted in satiate the as adsorption. Adsorption of arsenic was 28.8 and 20% at 0.1 and 2 mM arsenic respectively and observed that arsenic adsorption saturated at 4 mg per gram cell wall. Recently, Kaewdoun *et al.* (2016) have reported two fungal strains *Fomitopsis meliae* and *Ganoderma steyaertanum* to form metal oxylates (zinc oxylate, cadmium oxylate, lead oxylate) by bioprecipitation. Abazar *et al.* (2021) showed cadmium induced ROS generation in *Aspergillus niger* B77 and tolerance of the strain is supported by the efficiency of its antioxidative defense system. Activities of SOD and GR was found to sharply increase in *Aspergillus niger* strain on arsenate stress up to 100 mg L⁻¹.

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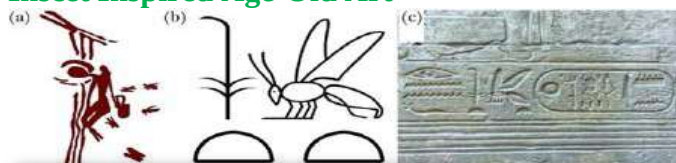
Role of Insects in Art Media and Decoration

Sai Thilak K. and Bindu Panickar

Introduction

Art is a human imagination or skill that can be expressed through various art media platforms like painting, sculptures, mixed media, and other artistic works. Decoration is an art or process in which arranging objects or things in a pattern that enhance their beauty for appearance and increases their aesthetic value. From age old insects are not only helping in mankind for survival but now a days they are also contributing a lot towards the art and decoration. Here insects are explored in various kind of art forms like painting, sculpture designs, jewellery designs, traces from insect nest, insect shaped jewellery from ancient world and in ancient India. Various insects from different orders are used in different arts mostly direct insects of coleopterans and insect products from hymenopterans group of insects. Not only insect but the products from the insects are also contributing greatly towards the insect arts. For e.g.: lac insect dye, honey bee products like (propolis, wax, honey) and insects like silk worms from which silk and cocoons are used in the various forms of art.

Insect Inspired Age-Old Art



(a) Reproduction of rock art depicting a honey collector surrounded by bees painted on a wall in the Spider Cave (near Valencia, Spain).

(b) Logogram for the king of Upper and Lower Egypt including the bee hieroglyph.

(c) Carving of the same logogram (centre) followed by a cartouche (name plate) on a wall of a temple in Karnak (Luxor, Egypt).



(a) Ancient Greek bronze coin depicting a honeybee.

(b) Coin from Tonga depicting 20 honeybees flying around a central hive produced as part of the FAO international coin program (1975-1979) to promote sustainable agriculture.



(a) Sculpture of the bee-representing Mayan god *Ah-Mucen-kaab* located at its temple in Tulum (Mexico) presented in its typical descending form.

(b) Drawing of a ritual censer depicting the descending god holding in his arms honey pots like

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those produced by stingless bees (Žračka *et al*, 2018).

(c) Details of the Trojo-Cortesan Mayan codex depicting rituals related to honey harvesting and protection of *Melipona beecheii* (Xunan-kaab) hives.

Inscet Inspired Modren Day Structures



(a) Skep beehive, a classic design that has inspired humans for over 2,000 years.

(b) The Bee hive building in Wellington (New Zealand) which hosts the executive wing of the New Zealand parliament.

(c) Cover for the album The Hive, an award-winning architectural installation derived from a multi-disciplinary collaboration between various musical and architectural artists. The installation is an abstraction of the honeycomb used by bees.

Bee Avatars

Bee avatars within a generated Minecraft natural environment. Bees were introduced into the game in 2019 as a recognition by developers for their invaluable services to humans. Image by Amelie Dyer.



Insect Products in Art and Decoration

Lac bug-derived shellac decorating a piece of Tibetan horse armour.



Iridescent beetle elytra incorporated in an ear ornament made



by the Awajún people of South America.

Another striking example is the singing shawls made by the Karen people of Myanmar and northern Thailand. The elytra of beetles are arranged within the shawls.



Cochineal insects: Used to create a vibrant red pigment, known as “kirmizi”, for painting and dyeing fabrics (carmine dye).



Shellac: Derived from the secretions of scale insects, used as a varnish and binding agent.



Lac insects: Secreted a resin used as a binding agent, pigment and varnish in painting.



Bee wax: Used as a binding agent and medium in encaustic painting.



Insects Byproducts Contibution in Art and Decoration

Lac Bangles: Lac bangles are a traditional form of jewellery in India, particularly in the states of Rajasthan and Gujarat.



Lac bangles are a beautiful and meaningful part of Indian jewellery, showcasing the country's rich

cultural heritage and craftsmanship.

Honey as Binding Agent in Paints



In both ancient days painting and to the modern day of painting honey is used as a binding agent in the colours used for painting.

Propolis



This piece has been made by an accumulation of thousands of silkworm's cocoons and then varnished with a thin layer of a natural honeybee bio resin.

Silk



Insect art using insect bodily products:

(a-c) Silk: (a) Insects and Grasses (Yamamoto Baiitsu, 1847).

(b) Silkworm Book: The Analects of Confucius (Xu Bing, 1998) “investigates the significance of silk and paper as mediums in practicing calligraphy” with *Bombyx mori* larvae.

(c) Silk No.3 ABC (Kazuo Kadonaga, 2006) offered viewers an opportunity to witness 50,000 silk-spinning *B. mori* larvae create a work independent of

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the artist's “arbitrary” vision.

Bee Wax



Hive Helmet

A glass dress, a shoe and a handbag (Aganetha, 1992-99)

Wax being malleable, easily melted or pigmented and insoluble in water, offers multifarious uses to artists, including as sculpting, casting, and Mold-making material.

Insect Dyes



Ink from female cochineal beetles, a cactus parasite native to South America, which is used to make the common red dye carmine.

Cochineal: pigment made from raw, dried, pulverized cochineal bugs.

Conclusion

With these I conclude that not all the insects are harmful but some insects which are of prime important order like hymenopterans and other insects like beetles, other pollinating agents play important role in the crops production. Not only through insects but lot of arts and decorations are made from there structures and also from their products like as mentioned above. In future we should know more

about insects which are using in art media. Artists can collaborate with each other to know about more use of insect and its body parts as art media. In our country only limited research had taken place in representing the insects in arts. So, there is good scope in exploring more insects in future that contribute towards art.

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Growing with LEDs: Benefits in Floriculture

Sahil, Anjana Sisodia, Anil K. Singh and Vandana Sisodia

Abstract

The production and appearance of certain floriculture crop species that are used for landscaping and ornamentation are greatly influenced by the quality of light. As an additional or primary source of lighting for agricultural production, light-emitting diodes (LEDs) offer enormous potential for use both on and off Earth. LEDs are superior to conventional horticultural lighting systems in a number of ways. LEDs are more suited for plant-based applications than many other light sources because of their small size, robustness, extended lifespan, cool emission temperature, and ability to pick particular wavelengths for a targeted plant response. But as plants grow through different stages, they need different wavelengths of light, and LED lighting can offer the right spectrum for each step. It also has the benefit of producing less heat and infrared radiation than conventional lighting techniques, which lowers the possibility of heat stress in plants exposed to high illumination levels. Crop production is year-round because indoor farming entails growing crops in a confined space with artificial lighting. There are many potential advantages of LED technology for the controlled environment agriculture sector, but more work needs to be done to put floriculture at the forefront of this exciting new field.

Introduction

As the global population grows, the challenge of producing food and ornaments sustainably through conventional agriculture methods is being put to the test. The introduction of vertical farming and greenhouse technology has made it possible to cultivate crops indoors in a controlled environment, helping to meet the demand. However, in indoor growing environments, natural sunlight is either absent or inadequate, necessitating the use of artificial lighting as a replacement or supplement. LED lighting is becoming popular in the agricultural

sector, particularly in areas like greenhouse cultivation and indoor flower cultivation. An LED is a semiconductor device that emits light when an electric current flows through it. LED technology has revolutionized the field by providing efficient and precise control over light spectra, making LED grow lights a promising alternative to natural sunlight.



Source: <https://www.agritechtomorrow.com/main/monitoring-growing>

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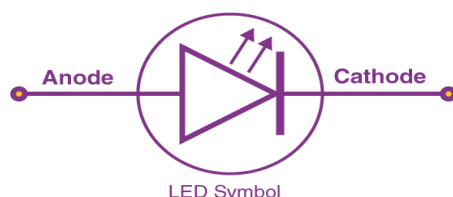
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In floriculture and scientific research, various lighting technologies have been used, such as high-intensity discharge bulbs, fluorescent lights, metal halide lights and traditional incandescent bulbs. Each lighting type has been fine-tuned to suit different plant species, providing control over light exposure, affecting plant growth patterns, and enhancing photosynthesis. Nowadays, LED lighting is gaining attention as a viable choice for plant cultivation in controlled environments due to its capacity to emit specific wavelengths of light that is must requirement of the flowering crops due to their susceptible nature. This feature of LEDs enables highly customized lighting setups, which can greatly improve plant growth and development in floriculture.

What is LED?

An LED, or Light Emitting Diode, is a semiconductor component that produces light when an electric current flows through it. In an LED, the passage of electricity results in the merging of electrons and electron vacancies (holes), which generates light. LEDs are designed to allow current to flow in a single direction and prevent it from flowing backward. While the symbol for an LED looks similar to that of a p-n junction diode, it differs by featuring two arrows that indicate the light-emitting function of the diode.



Source: <https://byjus.com/>

Importance in floriculture

Controlling light plays a key role in turning on almost all the plant genes that promote the growth of plants. In the farming area of greenhouse growing, using electricity is a significant cost, accounting for about 20-30% of all the costs involved in making things. It's important for greenhouses to keep the right light conditions for plants, especially in places where the amount of daylight changes a lot and there's not enough light for the plants to grow well. Following are some important aspects of LEDs:

- ✓ Used in areas like greenhouses, tissue culture labs and post harvest quality management.
- ✓ The spectrum of the LED lighting system can be modified and optimized to more closely meet the needs of plant photoreceptors, thereby improving efficiency and reducing energy waste. That increases the photosynthesis and yield of the crop.
- ✓ In protected cultivation, sunlight frequently fails to provide the ideal conditions for plant growth because of factors like clouds, rainfall, and varying weather conditions. Here LEDs can play a major role as artificial source of light.
- ✓ In greenhouses, the primary lighting is provided by High-Pressure Sodium (HPS) lamps. These lamps function at high temperatures, approximately 200°C, producing significant infrared heat. This heat generation renders HPS lamps unsuitable for use in energy-efficient greenhouse designs in the near future. So LEDs are very good replacement of these lamps.

Functions

Innovative LED technology provides a new approach to lighting control. Furthermore, maximizing LED performance requires a deep understanding of biological, physiological, and technological aspects. For example, when using narrow-spectrum LEDs, accurately adjusting light ratios is essential for eliciting the intended plant responses.

Following are some key points elucidating how LEDs working affect plant growth:

Enhance photosynthesis efficiency and yield: Due to their easy spectral composition control, low radiant heat output, and easy light intensity adaptation to plant photoreceptors LEDs increase the efficiency of photosynthesis and hence yield. Lights with wavelength as red (660 nm) and blue (453 nm) increased the seedling height, early flowering, flower number in Snapdragon and Geranium. In roses, applying B (20%) and R (80%) LED lighting in a growth chamber raised the proportion of dry weight allocated to the leaves. However, this lighting arrangement led to a decrease in leaf area, plant height, and shoot biomass, without affecting the flowering process.

Affecting flowering behavior: Every plant requires light of a specific wavelength for a fix time period for flowering. LEDs can be adjusted at specific a wavelength required by the plant. That helps in getting higher yield and synchronous flowering. For example, in Saffron Red (660 nm), blue (450 nm), and green (500-600 nm) increased the flower induct-

ion and in Carnation white (400-730 nm), blue (460 nm), and red (660 nm) increased the vase life and number of flowers. When chrysanthemum cuttings were exposed to blue, green, red, and white LED lights, it was observed that the addition of blue light led to flower bud development in approximately 20.5 days.

Strengthen the plant defense mechanism:

Modifying the spectrum of light wavelengths offers an intriguing way to activate specific biosynthetic pathways, thereby boosting the levels of essential phytochemicals. This technique can be used to improve both the growth efficiency and overall quality of ornamental plants. LED lights attract and divert the moths away from the desired plants, thus reducing the damage they can cause. In chrysanthemum cultivation, after introducing a biocontrol agent (*Orius laevigatus*) to establish an adequate population, different light frequencies are examined to determine their effect on egg-laying behavior. It was found that using a combination of red, blue, and green light resulted in a higher number of eggs produced by *O. laevigatus*.

Maintaining post harvest quality: In Daffodil, exposure to blue light while storing decreased the activity of the ACS1 and ACO1 genes, involved in the production of ethylene. On the other hand, exposure to red light enhanced their activity, affecting the aging process. Additional LED lights were placed up high around the base, offering a complete range of light wavelengths (300-800 nm). This setup helped to delay the deterioration of the

lower leaves and encouraged the growth of flowers in potted rose plants, in contrast to placing them down, which emphasized the best configuration for taking care of indoor plants.

Effect on secondary metabolites production: In Saffron application of Red (660 nm), blue (450 nm), and green (500-600 nm) increased total flavonoids, flavonols, flavonol glycosides while in Carnation white (400-730 nm), blue (460 nm), and red (660 nm) results in decreasing of carotenoids.

Plant Architecture: Light-emitting diode (LED) technology enables the precise tuning of light to create customized light combinations that shape plant form. The characteristics of plants are typically determined by elements such as the spread of branches, their compactness, root development, and foliage expansion, all of which are significantly impacted by the color and spectrum of LED illumination. A recent investigation demonstrated that solely green light stimulated growth in plants through the hormone brassinosteroids. Nevertheless, mixing a moderate green frequency with other light wavelengths, including red, far-red, and white, led to shorter petunia plants with an increased number of branches.

Flower and leaf colour: Research has demonstrated that adding LED lights with red and blue colors to the mix boosts the production of anthocyanins and carotenoids, resulting in more colorful leaves and an enhanced appeal to the plant's decorative qualities. For geraniums and purple fountain grass, using red and blue LED lights towards the end of the growing

process greatly enhanced the redness of the flowers, as measured by the chroma index, thus improving their visual attractiveness, quality, and desirability in the market. Hibiscus flowers exposure to red light helped in achieving a deep red hue in the petals.

Qualities of LEDs

LED lights are a better choice than conventional lights because they are more energy efficient, durable, and environmentally friendly:

Provide quality light: Sodium lights produce a high-intensity yellow-orange light that benefits plants during the flowering stage but is less suitable for the vegetative stage. On the other hand, Horticulture LEDs offer a fully adjustable spectrum, allowing growers to tailor the lighting to the specific needs of their plants.

More efficient: LED is more efficient source of light as compare to conventional light sources. LED efficiency $2.7 \mu\text{mole J}^{-1}$, sodium lamps efficiency $1.7 \mu\text{mole J}^{-1}$.

Instant light: Conventional light sources used to get time to start-up whereas LED lights illuminated instantly without losing time.

Least heat production: Horticulture LEDs produce far less heat, reducing the risk of heat stress and lowering the need for extensive cooling systems.

Environmentally friendliness: LEDs do not contain hazardous materials like mercury, which is found in some HPS bulbs, making disposal safer and more environmentally responsible. LEDs are also free of toxic chemicals and can reduce your carbon footprint.

More lifespan and ease of maintenance: Sodium lights typically have a lifespan of 10,000 to 24,000 hours, depending on usage and maintenance. In contrast, Horticulture LED can last between 50,000 to 100,000 hours. So LEDs have lower maintenance cost.

Types of LED grow light

There are several kinds of LED grow lights. Choosing the best one is an important thing. These grow lights are classified based on the area of their application. Choosing the right LED grow light for the needs relies on various considerations given following:

- ✓ Location (if used in a greenhouse or not)
- ✓ Crop and growing stage
- ✓ Spectrum
- ✓ Coverage area
- ✓ Wattage
- ✓ Voltage
- ✓ Number of plugs
- ✓ Mounting accessories

Merits

Even though LEDs are the newest innovation in lighting, they have already outperformed other options with their attractive and remarkable features. They come with numerous built-in advantages and are prime contenders for affordable lighting solutions in the future.

- ✓ LEDs generate more light per watt compared to incandescent bulbs, making them advantageous for battery-operated or energy-efficient devices.
- ✓ LEDs can generate light in particular colors with-

out the need for color filters, unlike traditional lighting methods. This capability enhances efficiency and can lower upfront costs.

- ✓ Since they are made of solid materials, LEDs are less prone to getting broken by outside impacts.
- ✓ LEDs illuminate instantly and don't require a starter or ballast to function. As low-voltage electronic components with a simple design, they can be easily controlled with straightforward and affordable techniques.
- ✓ LEDs lack mercury, unlike compact fluorescent bulbs, making them viewed as eco-friendly.
- ✓ These electronic components are built to resist moisture and can operate effectively in humid environments without requiring any adjustments to their settings.

Challenges

- ✓ At present, LEDs are more expensive than traditional lighting technologies when evaluated on a price-per-lumen basis. However, their long lifespan makes the higher initial cost less significant.
- ✓ An LED's operating temperature should not surpass 150°C, as going beyond this threshold can result in device failure. Overheating of the LED package may occur if the LED is driven excessively in high ambient temperatures.
- ✓ Another drawback is that if an LED fails, the whole module needs to be replaced, as replacing just one LED within the module is not feasible.

Conclusion

The type and amount of light covering

aspects like spectral composition and duration affect plant growth and function, and interact with environmental conditions to shape plant responses. While natural sunlight provides a full light spectrum, plants in controlled settings often need longer light periods. LED lights are vital for this purpose, as they supply the necessary light for plant development while minimizing energy use and heat production. They also offer the ability to adjust the light spectrum to suit specific plant requirements. Choosing the right LED light is essential and depends on factors such as plant type, cultivation area, and growth stage. As a relatively new technology in agriculture, LED grow lights are continually advancing, offering farmers growing benefits, especially in boosting crop productivity.

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Ashwagandha: The Herb of Resilience – From Earth to Energy

Sachin Prakash Nagre and Madhana Keerthana S.

Introduction

Imagine an herb that has been silently thriving on the edges of dusty fields in India for thousands of years. Now, picture it becoming a global sensation, hailed as a *super-herb* for stress, sleep, and overall vitality. That's ashwagandha - an ancient warrior in a modern world. From the soil it grows in to the benefits it brings to your life, ashwagandha's story is nothing short of fascinating. This humble root packs a punch of health benefits, but how is it grown? What challenges does it face in the fields, and how does it travel from dusty soil to your wellness routine? Let's uncover the surprising journey of ashwagandha - one of nature's most innovative healing herbs.

Botanical Description

Kingdom: Plantae

Order: Solanales

Family: Solanaceae (nightshade family)

Genus: *Withania*

Species: *Withania somnifera*

In India, two species of *Withania* are found:

- ✓ *Withania somnifera* (Ashwagandha)
- ✓ *Withania coagulans* (Panir)

Chromosome Number: $2n = 48$

Origin: Native to Northwestern and Central India and the Mediterranean region of North Africa.

Common name: Indian ginseng, Aswagandha,

Clustered Winter Cherry, Winter cherry, Indian Ginseng, Strychnos, Peyette, poison gooseberry etc.,

Growth and Distribution: Ashwagandha is a hardy, drought-tolerant shrub that grows up to 1.5 meters tall. It thrives in dry, acidic soils of subtropical and semi-arid regions. Major cultivation areas in India include Rajasthan, Punjab, Haryana, Uttar Pradesh, Gujarat, Maharashtra, and Madhya Pradesh, where over 5,000 hectares are under cultivation.

From Roots to Leaves: The Unique Benefits of Ashwagandha

Ashwagandha isn't just an ordinary plant; it's an *adaptogen*. Ashwagandha is more than just an herb; it's an adaptogen, which means it helps the body adapt to stress. It's packed with powerful compounds, like withanolides, that contribute to its calming effects, making it a favourite for reducing anxiety, improving sleep, and even boosting brain power. Not only does it promote mental well-being, but ashwagandha is also used to enhance physical strength, improve immunity, and support hormonal balance. The list of benefits seems endless, which is why ashwagandha is being hailed as a modern-day miracle herb. So, what makes ashwagandha so special? Its many health benefits come from the powerful compounds found in different parts of the plant. Let's take a closer look at how each part of the ashwagandha plant helps with its amazing healing

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properties:

Roots: Rich in alkaloids (e.g., withanine, somniferine), amino acids, starch, volatile oil, and steroids. The total alkaloid content in Indian roots ranges from 0.13% to 0.31%, with higher yields reported elsewhere. Notable amino acids include aspartic acid, glycine, and tryptophan.

Leaves: Contain withanolides (e.g., Withaferin A), alkaloids, amino acids, chlorogenic acid, tannins, and flavonoids. These bioactive compounds contribute to its health benefits.

Fruits: Green berries are rich in amino acids, tannins, flavonoids, and the proteolytic enzyme chamase, which enhances amino acid content.

Other Parts: Shoots are rich in protein, calcium, and phosphorus and stem and bark contain tannins, flavonoids, and amino acids.



Growing Ashwagandha

Growing ashwagandha isn't just about planting a seed and waiting for it to grow. It's a delicate balance between nature and careful farming techniques.

Climate and Soil Requirements: Sandy loam or light red soil with a pH of 7.5 to 8.0 and good drainage. Grows best in semi-tropical areas with 500-750 mm of rainfall with above mean sea level of 1500m. It can tolerate temperatures between 20°C to 38°C and even as low as 10°C.

Nursery Raising and Planting Techniques:

Ashwagandha is propagated by seeds, which are sown in well-prepared nursery beds. While direct broadcasting in fields is possible, the transplanting method is preferred for better quality, especially for export. Nursery beds are enriched with compost and sand, and about 5 kg of seeds is sufficient for 1 hectare. Seeds are treated with carbendazim to prevent diseases and are sown just before monsoon. Germination occurs within 5-7 days, and 35-day-old seedlings are transplanted into the main field. For field preparation, 2-3 ploughings followed by levelling and applying 10-20 tonnes of farmyard manure ensure proper soil tilth. Seedlings are spaced 60 cm x 30 cm for optimal growth, with about 55,000 plants per hectare. A seed rate of 10-12 kg ha^{-1} is recommended. Line sowing (20-25 cm apart) is preferred over broadcasting for better root development and ease of field operations. Seeds should be sown 1-3 cm deep and treated with thirum or dithane M45 (3 g kg^{-1}) to prevent seed-borne diseases.

Variety: A high-alkaloid, short-stature variety named "Jawahar," released by Jawaharlal Nehru Krishi Vishwavidyalaya, Madhya Pradesh, is highly suitable for high-density planting. It matures in 180 days, and its dry roots contain 0.30% withanolides.

Intercultural Operations: Thinning should be done 25-30 days after sowing to maintain a plant population of 30-60 plants per square meter. Weeding is necessary 20-25 days after sowing and again 20-25 days after the first weeding.

Ashwagandha thrives with organic manure; applying 10 tonnes of farmyard manure or 1 tonne of vermicompost per hectare is ideal. For better yields, add 15 kg of nitrogen and 15 kg of phosphorus ha^{-1} . The crop requires minimal water. Overwatering or heavy rainfall can harm the plants, so it's important to avoid excess moisture. A light shower after transplanting ensures better seedling establishment, and in dry conditions, irrigation every 10 days is sufficient.

Pests and Diseases: Ashwagandha is generally pest-resistant, but if insects attack, spraying Rogor or Nuvan (0.6%) 2-3 times can help. For aphids and mites, a mix of 0.5% Malathion and 0.1%-0.3% Kelthane at 10-15-day intervals are effective. Diseases like seedling rot and blight may occur under high heat and humidity. Using disease-free, treated seeds, applying 2-2.5 kg ha^{-1} of Carbofuran, and adding neem cake can prevent issues like root damage. Crop rotation, timely sowing, and proper drainage also help protect the crop.

Harvesting and Yield: Ashwagandha is ready for harvest when leaves dry and berries turn yellow-red, typically 150-180 days after sowing (January-March). Roots are dug out carefully to avoid damage. After cutting stems 1-2 cm above ground, roots are washed, cut into small pieces (7-10 cm), and dried to 10-12% moisture. Roots are graded based on size and quality, with premium grades fetching better prices. From 1 hectare, yields are 3-5 quintals of dry roots and 50-75 kg of seeds, with potential yields up to 1 tonne in ideal conditions. Roots measuring 6-15 mm

in diameter and 7-10 cm in length are preferred. Alkaloid content in roots ranges between 0.13% and 0.31%.



Medicinal Properties of Ashwagandha

Ashwagandha, known for its health benefits, contains compounds called withanolides that contribute to its therapeutic effects. Here are some key properties:

Stress Relief: Ashwagandha is an adaptogen, helping the body manage stress by lowering cortisol levels, which reduces anxiety and improves mood.

Boosts Immunity: It strengthens the immune system by increasing white blood cell production, helping to fight infections.

Enhances Energy: Ashwagandha boosts energy and stamina, making it helpful for reducing fatigue and improving physical endurance.

Supports Brain Health: It improves memory and cognitive function while protecting brain cells from oxidative stress.

Anti-Inflammatory: The herb reduces inflammation, helping manage conditions like arthritis and other inflammatory diseases.

Hormonal Balance: Ashwagandha supports thyroid health and helps balance hormones, promoting fertility and overall well-being in both men and women.

Antioxidant: It protects the body from cell damage

and premature aging by neutralizing free radicals.

Supports Heart Health: Ashwagandha lowers cholesterol and blood pressure, reducing the risk of heart disease and improving circulation.

Improves Sleep Quality: It promotes relaxation and better sleep, especially for those suffering from insomnia related to stress or anxiety.

Blood Sugar Regulation: Ashwagandha helps regulate blood sugar levels, improving insulin sensitivity and supporting metabolic health.

Challenges Faced by Farmers

Like any crop, growing ashwagandha comes with its own set of challenges. But despite being a tough plant, it's not invincible. Here are some hurdles that farmers face:

Unpredictable Climate: Though ashwagandha is drought-resistant, extreme weather like sudden heavy rainfall or a long drought can affect yields. Unseasonal weather can damage the crop, leading to a poor harvest.

Overharvesting and Sustainability: As the demand for ashwagandha grows, there's a risk of overharvesting from the wild. To protect wild populations, sustainable farming practices are essential.

The Global Boom

As people around the world are looking for more natural ways to manage stress and improve overall health, ashwagandha is quickly becoming a sought-after herb. Its benefits are not just a trend; scientific studies are increasingly supporting its power to help with everything from anxiety to

athletic performance. Moreover, the global market for herbal supplements is expanding rapidly, with ashwagandha leading the charge. This has opened up new economic opportunities for farmers in countries like India, where the herb is grown.

Ashwagandha's Future: A Legacy of Health and Sustainability

With its ancient roots and modern-day relevance, ashwagandha is poised for an exciting future. Farmers, scientists, and wellness enthusiasts alike are working together to ensure that ashwagandha remains accessible and sustainable for generations to come. By combining traditional farming wisdom with modern, innovative practices, ashwagandha is on track to be the next big thing in natural health. With its rich history in traditional medicine and a growing body of scientific evidence supporting its health benefits, ashwagandha is more than just a fad. As interest in natural wellness solutions grows, the demand for ashwagandha is expected to continue soaring. As the industry expands, it's crucial that sustainable farming practices are prioritized, ensuring that ashwagandha remains available for future generations to enjoy its remarkable benefits.

In Conclusion: A Super Herb for Super Health

Ashwagandha is more than just an ancient remedy; it's a modern-day solution to many of the stresses of contemporary life, it's a symbol of resilience and balance. From its humble beginnings in the soil to its transformative impact on your health, this little root carries centuries of wisdom and a

bright future ahead. And as the demand for this incredible herb grows, farmers and scientists alike are working together to ensure that ashwagandha continues to thrive, both for our health and the planet's well-being.



Insect Apocalypse: How the Modern Era is Threatening Tiny Lives

Debashis Mandal, Amit Layek and Debanjan Baul

Abstract

In recent decades, insect populations worldwide have been rapidly declining, threatening ecosystems and human societies. Human activities, such as habitat destruction, agricultural intensification, pesticide use, and climate change, are driving these declines. Insects play essential roles in pollination, nutrient recycling, and food webs, with over 80% of flowering plants relying on them for pollination. The loss of these vital ecosystem services poses serious risks to biodiversity and food security. Studies in Europe and North America document significant reductions in insect biomass, with some regions seeing up to a 70% decline. Insects in tropical and developing regions, including India, face similar threats, but data is sparse. Urgent conservation actions are needed, including habitat restoration, reduced pesticide use, and more research on insect populations. Raising awareness and implementing policies to protect insect biodiversity is crucial for sustaining the health of ecosystems and human livelihoods.

Introduction

The current geological era defined by human activities that have significantly altered the climate and environment. Over the past 10,000 years, the human population has surged from 1 million to 7.8 billion, resulting in the transformation of much of Earth's arable land into agricultural areas, widespread deforestation, and CO₂ levels at their highest in over 3 billion years. One of the most pressing environmental concerns is the rapid decline of insect populations. Reports indicate fewer insects on windshields, diminished firefly displays, and a decline in moths around streetlights. Insects such as bees, butterflies, damselflies, moths, beetles, and dragonflies are among the most affected. To address

this issue, conservation efforts have been launched, such as Germany's "Action Programme for Insect Protection" in 2018. In 2019, a group of British entomologists called for urgent research into the ecological effects of insect population declines. Despite these efforts, understanding the full scope of insect decline remains limited. According to P.T. Cherian, former director of the Zoological Society of India, nearly 89% of insect species remain unnamed. Many scientists believe that countries like India are also experiencing this global trend of insect population loss. Insects play vital roles in ecosystems, including pollination, biological control, food provisioning, and nutrient recycling. More than 80% of flowering plants depend on insects for pollin-

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ation, while others help decompose organic material like wood, leaves, and carrion. Without insects, these ecosystem services would be severely disrupted. The decline in insects is part of a larger pattern of species loss. Over the last century, populations of terrestrial vertebrates, mammals, and birds have shrunk. A 2020 UN report warned that over a million species could face extinction in the coming decades. Insects, particularly those dependent on native plants, are highly vulnerable as habitats are lost due to deforestation and the spread of exotic species. Addressing the causes of insect decline and protecting biodiversity is critical for the health of ecosystems worldwide.

Why Insect Declines Should Concern Us

Insects are frequently viewed as pests, such as caterpillars that harm plants, but they offer numerous benefits. For example, the butterflies and moths that emerge from caterpillars are vital pollinators, crucial for the production of fruits that humans rely on. Insects also have significant economic importance. Approximately 1,500 species of insects are consumed by 3,000 ethnic groups across 113 countries, with common food sources including grasshoppers, cicadas, ants, and beetles. In the eastern part of Arunachal Pradesh, indigenous communities consume 51 different insect species. Additionally, insects serve as a food source for various vertebrates, such as frogs, reptiles, birds, and mammals. The decline in insect numbers has raised alarms among herpetologists and ornithologists, as it threatens the availability of food for these species.

Insects not only aid in pollination but also contribute to biological control, the recycling of organic matter, and the production of honey, silk, lac, and medicinal products.

Insect Population Trends and Decline

In recent years, a decline in insect populations has been observed across a variety of species, including those that are aerial, ground-dwelling, aquatic, and terrestrial, as well as diurnal and nocturnal insects. The most comprehensive documentation of these declines comes from western and northern Europe, where insect populations have been extensively studied for over a century. Global studies on insect decline are mainly based on data from countries such as the UK, Germany, and the Netherlands, while reports from other regions often remain anecdotal or limited. A study conducted in the UK that focused on four insect orders (Coleoptera, Hymenoptera, Lepidoptera, and Odonata) revealed a 30-60% decrease in their occurrence over the past 40 years. A global review of 73 cases of insect population decline found that 40% of insect species are experiencing declines. In areas like Northern Europe and New England, the extent of population losses in moths and butterflies varies, with northern regions generally exhibiting milder declines compared to more urbanized southern areas. Some regions of southeastern Canada and the northeastern United States have seen less dramatic drops. Interestingly, many of these declines are happening even in protected reserves and conservation areas. For example, a study by the Krefeld

Entomological Society in northwestern Germany revealed a 70% decrease in flying insect biomass over the past 30 years. Similarly, insect biomass in various samples from Puerto Rico's Luquillo Forest Reserve has dropped significantly over four decades, although there is still uncertainty about whether these trends reflect long-term changes. A global assessment suggests an annual decline of 2.5% in insect biomass, though this figure may be biased due to the heavy concentration of data from Europe. Butterflies, as one of the most studied insect groups, have seen considerable population losses in the UK, with over 10 million observations spanning back to the 1780s. In the UK, five butterfly species have gone extinct, 70% of the remaining species have experienced a decline in occurrence, and 57% have seen reductions in abundance. Sweden has also documented significant drops in butterfly populations, with 45% of species showing negative trends since 1950. Moths, which are ecologically and taxonomically diverse, have also been affected. In the UK, two-thirds of macro moth species have declined since 1970, with southern regions facing higher rates of loss compared to the north. Bees, which play a crucial role in pollination and global food security, are increasingly threatened by agricultural intensification, with many bumblebee species in Asia, Europe, and North America either extinct or on the brink of extinction.

What's Driving the Decline of Insects?

Insects are influenced by various factors that similarly affect other animals and plant life. These

include:

Habitat Degradation: Human activities, such as agriculture, construction, and mining, destroy habitats like forests and wetlands, threatening biodiversity. Alterations in local and regional geophysical processes, such as dune stabilization and riverbank changes, can disrupt ecosystems. Water demands for human use, especially in arid areas, are increasing challenges for insect populations.

Deforestation: Tropical forests, rich in biodiversity and insect species, are rapidly cleared to make way for agriculture, especially in Central Africa, Southeast Asia, and South America. This loss of forest ecosystems exacerbates the decline of insect habitats, particularly in biodiversity-rich tropical regions.

Agricultural Intensification: Modern farming practices, including large-scale monocultures, pesticide use, and genetically modified crops, are harmful to insect populations. In regions like Western Europe, Northern Europe, and California's Central Valley, these practices are linked to significant declines in insect diversity.

Land Use Changes: Traditional farming with features like hedgerows and field margins provided critical habitats for insects. The loss of semi-natural landscapes, such as grasslands, which support species like bees, butterflies, and beetles, is a major concern for biodiversity.

Pesticide Use: The use of pesticides, particularly neonicotinoids, is contributing to insect declines, especially among pollinators like bees. Evidence

from the UK and California shows that these chemicals, when spread into natural habitats, harm insect populations.

Climate Change: Climate change, coupled with habitat destruction, is a significant threat to insect biodiversity. As insects are cold-blooded, temperature shifts and changes in rainfall patterns pose risks to their survival and behavior, particularly in tropical regions.

Nitrogen Deposition: Excess nitrogen from human activities, such as fossil fuel combustion, disrupts ecosystems by altering soil chemistry and reducing plant diversity. In Northern Europe, nitrogen deposition has been linked to declining butterfly populations.

Invasive Plants: Non-native plants, often spread by human activity, can reduce food and shelter for native insect species, leading to declines in biodiversity. Invasive plants in landscaping and forestry are especially damaging to native ecosystems.

Light Pollution: Artificial lighting disrupts the behavior and survival of moths and other insects. It affects their navigation, reproductive cycles, and increases predation. Light pollution has been shown to reduce pollinator visits, which impacts crop yields, particularly in thistles.

Current Situation in the Indian Context

Cherian from the Zoological Society points out that without knowing how many species exist, it is impossible to understand their decline, a sentiment echoed by ecologist Raghavendra Gadgkar of IISc,

Bengaluru, who believes there is a lack of data from India on insect population decline. Arati Pannure, in her study on bees at GKVK, highlights the limited knowledge about the status of wild bee pollinators, their life cycles, habitat needs, and their interactions with crop biodiversity. A 2009 study by Nicola Gallai and colleagues revealed that more than 40 percent of honeybee populations in India have vanished in the past 25 years. While wild bees, including honey bees, carpenter bees, bumblebees, and species from other families like Andrenidae, Colletidae, and Melittidae, are vital for pollinating many crops, Pannure notes that there is no clear data on the bee species composition in India. Furthermore, there is a gap in data on other important pollinators such as flies, moths, wasps, beetles, and butterflies. The *Fauna of British India*, published in the early 20th century, remains the only comprehensive reference on Indian insects. Peter Smetacek, founder of the Butterfly Research Centre in Bhimtal, has addressed this issue in his 2011 review in the ENVIS Bulletin. Viraktamath adds that climate change is a contributing factor, altering rainfall distribution and affecting vegetation and insect populations. Technology pollution, such as mobile phone radiation, has also been shown to disrupt honey bee behavior, with studies showing hive collapse due to exposure to electric fields. A small but significant effort to track insect trends is being led by Sanjay Sane, a professor at the National Centre for Biological Sciences. Sane, who started documenting hawkmoths by accident in 2012, has

since been systematically recording their numbers and diversity every new moon. After six years of study, Sane believes that it may take up to ten years to identify any significant trends in the hawkmoth population.

Constraints in the Decline of Species

Long-term data indicates that many insect populations are at risk, but eco-evolutionary forces create both winners and losers. Warmer global temperatures are likely to benefit many species, particularly in temperate regions where cold winters have previously limited some organisms. For example, 15 out of 60 butterfly species in the United Kingdom are expanding their range, with many also seeing population increases. Similarly, among 673 moth species, 160 are experiencing growth in either abundance, geographic range, or both. Climate change-driven shifts in ecosystems, such as woodlands transitioning into savannas or grasslands, can favor grass-feeding insects. While many examples of increasing insect abundance and diversity exist, it's important to recognize that most of these involve more generalist species, whereas specialized species are often in decline. In areas with minimal human influence, insect populations may remain largely unaffected. Successful restoration and conservation efforts in Europe and the United States, such as those for the Duke of Burgundy, Pearl-bordered Fritillary, and Dingy Skipper butterflies in the UK, show that we can address these issues, and that not all challenges are insurmountable, such as regionally persistent pesticide residues or high CO₂

levels.

Visionary planning

Conservation initiatives should include well-defined strategies to handle potential emergencies, supported by recognized experts capable of addressing the challenges that arise. Staying current with global research on the decline of species, is vital. In India, there is an urgent need to raise awareness and recognize the significance of insect loss. The government should increase its efforts by launching projects dedicated to assessing and documenting the status of insect populations, thereby facilitating informed conservation actions.

Conclusion

Insect decline is a growing concern, though its full scope remains uncertain due to the lack of comprehensive global data and a single, identifiable cause. Annual loss rates of 1-2%, observed in regions such as Western and Northern Europe and the United States, may seem small individually but represent a significant ecological crisis when considered over decades. These declines are particularly noticeable in areas with high human activity, intensive agriculture, and those experiencing the effects of climate change, such as drying wet forests. Both terrestrial and aquatic insect populations are affected, as well as species active during the day or night, and both aerial and ground-dwelling insects. For example, studies in Krefeld, Germany, indicate a 75% reduction in aerial insect biomass over the last 30 years. While the full extent of the decline is not yet measured, climate change and its associated impacts, including changes

in precipitation patterns, pose a serious threat to insect diversity and the ecosystems they support, from Polar Regions to the equator. Addressing these issues will require rewilding efforts, the establishment of biodiversity corridors, and the promotion of sustainable agricultural and forestry practices. Raising awareness among entomologists, biologists, and policymakers about the urgency of this crisis is essential to protect insect populations and the broader environmental systems they sustain.

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Reviving Millets in Himachal Pradesh: Trends, Challenges and Sustainable Pathways

Kumari Sandeep, Shilpa and Ajit Sharma

Millets, often referred to as ancient grains, are critical components of traditional diets in many regions, especially those facing water scarcity and variable climatic conditions. These hardy crops thrive in diverse agro-ecological environments, demonstrating resilience in poor soils and with minimal water requirements. Nutritionally rich, millets provide essential nutrients such as fiber, protein, vitamins, and minerals, making them valuable for addressing malnutrition and enhancing food security. Recently, there has been a global resurgence of interest in millets, particularly emphasized by the United Nations' declaration of 2023 as the "International Year of Millets". This renewed focus highlights the potential of these crops in promoting sustainable agriculture and improving food security amid climate change. In the Himalayan region, especially Himachal Pradesh; millets remain integral to subsistence agriculture. Farmers in the region depend on these hardy crops for food, traditional beverages, and cultural heritage. Millets' adaptability to mountainous terrains and unpredictable weather makes them crucial for smallholder farmers. The recent focus on millets highlights the need to study current trends in Himachal Pradesh to

enhance food security, improve nutrition and promote sustainable agriculture. By encouraging millet cultivation, Himachal Pradesh can reduce farmer vulnerability, increase resilience to climate change and contribute to sustainable food systems.

Scenario of millets in Himachal Pradesh

The diverse agro-ecological landscape of Himachal Pradesh, from the Shivalik foothills to the high Himalayan ranges, supports the cultivation of various millets, including sorghum (jowar), finger millet (ragi), pearl millet (bajra), proso millet, foxtail millet, barnyard millet, little millet, and Kodo millet (Sood *et al.*, 2023). Despite this diversity, millet cultivation has shown a declining trend in Himachal Pradesh over recent years. Tables 1-3 provides a comprehensive overview of the district-wise area, production and yield of different types of millets cultivated in Himachal Pradesh during 2021-22 (Anonymous, 2023). The data highlights significant regional differences in cultivation patterns and productivity, reflecting the diverse agro-ecological conditions across the state. In the case of Bajra, Kangra district has the highest area, production and productivity as depicted in Table 1. The total area under Bajra cultivation in Himachal Pradesh is 568

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ha, with a production of 291 tonnes and an average yield of 0.51 tonnes ha⁻¹ across the state. For Ragi, Mandi district takes the lead in cultivation and production, followed by Sirmour and Shimla. The total area under Ragi in the state covers 1131 ha, producing 1060 tonnes with an average yield of 0.94 tonnes ha⁻¹. Other significant producing districts for ragi included Kullu, Shimla and Sirmaur. In the case of small millets Shimla district has the largest area (729 ha) under cultivation, producing 407 tonnes with a yield of 0.94 tonnes ha⁻¹. The total area under small millets in Himachal Pradesh is 1637 ha, with a production of 1101 tonnes and an average yield of 0.67 tonnes ha⁻¹.

Table 1: District-wise Area, Production and Yield of Bajra in Himachal Pradesh (2021-22)

S. No.	District	Area (ha)	Production (Tonnes)	Yield (Tonnes ha ⁻¹)
1.	Kangra	318	177	0.56
2.	Mandi	204	89	0.42
3.	Shimla	35	19	0.56
4.	Solan	11	6	0.56
Total		568	291	0.51

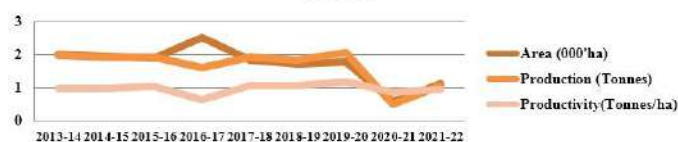
Table 2: District-wise Area, Production and Yield of Ragi in Himachal Pradesh (2021-22)

S. No.	District	Area (ha)	Production (Tonnes)	Yield (Tonnes ha ⁻¹)
1.	Kangra	1	1	0.77
2.	Kullu	89	89	1
3.	Mandi	697	697	1
4.	Shimla	133	120	0.9
5.	Sirmour	202	147	0.73
6.	Solan	9	7	0.73
Total		1131	1060	0.94

Table 3: District-wise Area, Production and Yield of small millets in Himachal Pradesh (2021-22)

S. No.	District	Area (ha)	Production (Tonnes)	Yield (Tonnes ha ⁻¹)
1.	Chamba	583	440	0.75
2.	Kullu	36	20	0.94
3.	Lauhal Spiti	89	117	0.94
4.	Mandi	167	93	0.94
5.	Shimla	729	407	0.94
6.	Sirmour	33	25	0.75
Total		1637	1101	0.67

RAGI



Millets and Bajra

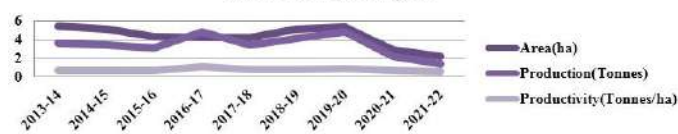


Fig. 1: Trends in Area, Production and Productivity of Millets in Himachal Pradesh

The trend in area and production and productivity of millets in the state has been shown in the Table 4. In 2013-14, the area and production under small millets and Bajra cultivation were 5.41 t ha and 3.60 thousand metric tonnes, respectively, which decreased to 2.22 t ha and 1.41 thousand tonnes in 2021-22. The Compound Annual Growth Rates (CAGR) were obtained as -7.40%, significant at the 5% level of probability for area, while for production, it was -7.1%, which was insignificant. The productivity of millets and bajra has shown a slight positive trend with a CAGR of 0.20%. Increased urbanization and shifting from traditional crops to high-value cash crops in Himachal Pradesh have played a great role in the disappearance of traditional food crops like millets. In this instability indices varied for area, production and productivity as 19.78 per cent, 24.93 per cent, and 17.82 per cent, respectively. In the case of ragi, area and production have shown negative trends with growth rates of -10.20% and -10.00%, both significant at the 1% level of probability. While a slight positive trend in productivity was observed from 0.98 t ha per thousand MT in 2013-14 to 0.94 in 2021-22.

Table 4: Trend in millet area, production and productivity in Himachal Pradesh (2021-22)

Year	Ragi			Small millets and Bajra		
	Area (ha)	Production (Tonnes)	Productivity (t ha ⁻¹)	Area (ha)	Production (Tonnes)	Productivity (t ha ⁻¹)
2013-14	2.01	1.97	0.98	5.41	3.60	0.66
2014-15	1.94	1.91	0.98	5.10	3.39	0.67
2015-16	1.88	1.93	1.03	4.27	3.09	0.73
2016-17	2.52	1.60	0.63	4.20	4.80	1.14
2017-18	1.82	1.92	1.06	4.18	3.36	0.81
2018-19	1.72	1.82	1.06	5.10	4.12	0.81
2019-20	1.76	2.06	1.17	5.32	4.77	0.90
2020-21	0.58	0.49	0.85	2.93	2.15	0.73
2021-22	1.13	1.06	0.94	2.22	1.41	0.63
Total	15.35	14.76	8.70	38.73	30.69	7.07
Mean	1.71	1.64	0.97	4.30	3.41	0.79
Std	0.55	0.53	0.15	1.11	1.12	0.16
CV	32.39	32.03	15.92	25.70	32.81	20.03
CAGR (%)	-10.20**	-10.00**	0.30	-7.40*	-7.10	0.20
	-0.03	-0.04	-0.02	-0.02	-0.04	-0.02
R²	0.50	0.40	0.40	0.50	0.55	0.45
Instability	25.26	27.22	12.25	19.78	24.93	17.82

*, **, *** Denotes significance at 0.05, 0.01, 0.001 levels of probability

Major Initiatives by the Himachal Government to Promote Millets

The Himachal Pradesh government is playing a crucial role in promoting millets through various schemes, export initiatives, and value addition efforts. By leveraging programs like the Rashtriya Krishi Vikas Yojana (RKVY) and the National Food Security Mission (NFSM), the government is enhancing the area and production of millets, providing quality seeds, and offering financial support to farmers. Additionally, initiatives under the Millet Mission and Integrated Scheme for Agricultural Marketing (ISAM) focus on improving marketing infrastructure and promoting value-added millet products. The promotion of organic farming further enhances the sustainability and market value of millets, supported by research and development collaborations with agricultural institutions. The government is investing in infrastructure such as

irrigation, storage and transportation to support efficient supply chains. It is also providing financial assistance to farmers through subsidies, low-interest loans, and crop insurance. Millet-based Farmer Producer Organizations (FPOs) are now being established to enhance market access and export opportunities. These efforts are revitalizing millet cultivation, boosting the agricultural economy, and improving farmers' livelihoods.

Challenges of Millet Cultivation in Himachal Pradesh

Low Awareness and Adoption: Farmers often lack awareness about the benefits and cultivation techniques of millets, leading to lower adoption rates.

Market Access and Pricing: Fluctuations in market prices and limited access to markets can affect farmers' income from millet cultivation.

Soil Degradation: The hilly terrain and soil erosion

contribute to soil fertility loss, impacting millet productivity.

Limited Infrastructure: Inadequate storage facilities and processing infrastructure can lead to post-harvest losses and lower market value in millet cultivation.

Research and Development: Insufficient research on millet varieties suited for Himachal conditions also limit yield improvements and resilience.

Conclusion

It is concluded that the future of millet cultivation in Himachal Pradesh holds great promise, provided the right strategies are implemented. Despite the recent decline, there are significant opportunities to revitalize this sector. Developing climate-resilient millet varieties will help address challenges posed by unpredictable weather patterns. Enhancing infrastructure, including storage and processing facilities, will reduce post-harvest losses and improve market access. Additionally, increasing farmer education and support through training programs will encourage greater adoption and productivity. With continued government backing and focused research on region-specific millet varieties, innovation and growth in the sector can be fostered. Raising awareness of millets' nutritional and environmental benefits will further rejuvenate the millet sector, contributing to food security, sustainable agriculture and improved livelihoods for farmers in Himachal Pradesh.

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Artificial Intelligence in Vegetable Research: Transforming India's Farming Practices for a Greener Future

Prashant Kaushik, Rajesh Kumar and Desh Raj Choudhary

Agricultural AI: A first look

Artificial Intelligence (AI) transforms is dawning a new age in the India's agricultural landscape. AI is the process of teaching computers to mimic human intellect via modelling their thought processes and learning abilities. The use of AI to farming is making this a reality, not just a pipe dream. The weeds are seen and removed by robots, plant health is tracked in real time by drones and the ideal time to harvest is predicted by algorithms. From sowing seeds to gathering the crop, artificial intelligence is improving farming in every way. The need for efficient and sustainable farming techniques is an all time high due to the rising population and the resulting strain on agricultural resources. Increased productions, less resource waste and guaranteed food security are all possible with the help of AI. Because of its prominence in agriculture, India stands to gain a lot from these developments. Artificial intelligence has both obstacles and potential in the field of vegetable science due to the country's varied climate and soil types. How is artificial intelligence changing the face of vegetable growing in India?

Artificial intelligence use cases in plant science agrarian precision

One of the most cutting edge uses of artificial intelligence in farming is precision farming. Using data from sensors, drones and satellites, farmers can control their crops with a level of precision never seen before. This method helps to farmers save water, fertilisers and pesticides by applying them just where they are required at the right time and right amount. Soil moisture sensors integrated into smart irrigation systems, for instance, allow for real-time flow adjustment, guaranteeing that plants get precisely the correct quantity of water. This is especially helpful in India, where there is a serious problem with water shortage. Water efficiency allows farmers to increase agricultural yields while decreasing water expenditures. Also, with precision farming, you may use variable rate technology to apply pesticides, fertilisers and environment to various parts of the field depending on their individual requirements.

Identification of pests and diseases: AI is essential for early pest and disease identification to keep crops healthy and avoid output losses. Images of plants

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may be analysed by machine learning algorithms to detect symptoms of disease and distress. An example of an AI powered tool is the *Plantix* app, which allows farmers to send images of their crops for disease diagnosis. Furthermore, AI has the ability to track insect populations and foretell when outbreaks will occur, allowing for pre-emptive approaches to pest control.

Picking by robots: In the large field for harvesting requires a lot of manual labour and must be done quickly. Artificial intelligence enabled robots can precisely explore fields, detect when veggies are ready and pick them before anybody else. This solves two problems at once: the scarcity of available workers and the need of harvesting fruits and vegetables at their peak for optimum freshness and longevity in the market.

Analysis of soil and climate: Artificial intelligence can sift through mountains of data on weather patterns and soil conditions, yielding useful insights for farmers. In order to maximise production, farmers need to know when to plant certain crops, how to best maintain their fields and what crops to grow based on historical data and current trends. Risks related to weather changes and soil erosion may be reduced with the use of this forecasting capabilities. This can assist farmers in selecting the best crop kinds for the unique climates of various locations in India. Improved agricultural yields and decreased input costs have been achieved in India via the use of drone surveillance to evaluate soil health issues like nutrient deficits, stress, and soil moisture

and direct fertiliser applications.

Modelling crop yields for prediction: Artificial intelligence also does quite well in predictive modelling. Machine learning is able to predict harvest yields with a high degree of accuracy by comparing historical and real-time data. The better marketing choices, resource management and operational planning are all made possible for farmers by this. As an example, ICRISAT has been advising farmers in India on crop production and weather predictions using AI. Because of this, they are better able to adjust to new circumstances and schedule planting and crop harvesting accordingly.

How AI can help farmers' maximised effectiveness and output

Artificial intelligence frees up farmers to concentrate on long term planning by automating mundane but necessary jobs. The higher productivity and greater yields are the results of automated systems that can run continuously. Drones for instance can swiftly scan vast swaths of land and provide to farmers real time data their crops condition. AI can also optimise spacing and planting patterns to provide each plant the best possible environment to develop.

Save money: Farmers may lower input costs by making the better use of available resources. Reduced chemical and water use is a direct result of AI's assistance with targeted fertilisation, irrigation and pest management. Costs may be further reduced by avoiding crop losses via early disease and pest diagnosis. For instance, farmers may significantly

reduce fertiliser expenses without sacrificing crop health by using AI driven soil analysis to apply fertilisers just where they are required. In addition, AI can automate processes to maximise efficiency, minimise fuel use and optimise equipment utilisation.

Enhanced productivity: The improved flavour, nutritional value and storage life are all outcomes of AI-assisted vegetable cultivation. Use of AI is controlled environment agriculture (CEA), which involves manipulating factors like light, humidity and temperature to cultivate certain crops to their optimal potential. Vertical farming and other CEA techniques may be very useful in India's congested metropolitan city. These systems not only make the most efficient use of available space, but they also create a regulated setting where pests and illnesses are less likely to thrive, resulting in healthier and better quality fruit. It may assist with vegetable sorting and grading according to quality criteria.

Enhanced management of resources: In order to manage resources efficiently and sustainably, AI gives the information required, such as when to water and where to apply fertiliser. Efficient management is crucial for the long term survival of agriculture in India due to the scarcity of resources such as water and arable land. AI may assist with water conservation by coordinating irrigation schedules according to soil moisture levels, soil fertility and weather predictions.

Important factors to think about starting expenses for investments: The high cost of high-

tech equipment and software may prevent small-scale farmers, who make up a large part of India's agricultural industry, from affording it. The long-term advantages often surpass the initial expenses and there are an increasing number of choices for renting or sharing technology. The making artificial intelligence technology more affordable for smallholders in India may be achieved via government programs and subsidies. National e-Governance Plan in Agriculture (NeGPA) and Pradhan Mantri Fasal Bima Yojana (PMFBY) are two initiatives that aim to close the digital gap in rural regions.

Examples of real world situations: An agricultural operation in Maharashtra used drones to monitor the condition of their tomato plants. Drones take detailed pictures, which are then processed by AI to identify unhealthy or stressed spots. The farm's water use has been cut by 30% and yields have been raised by 20% after this change was made.

Andhra Pradesh AI-powered disease detection system: The new software from an Andhra Pradesh firm uses plant pictures to help farmers identify agricultural illnesses. The software can detect common ailments and suggest treatments using machine learning. Farmers on a smaller scale, who often lack resources like agricultural extension agents, have benefited greatly from this.

Using robots to harvest in Punjab: A Punjabi vegetable farm used autonomous harvesting robots to combat a scarcity of human workers. With the use of computer vision, these machines can detect when veggies are ready and carefully pick them.

The higher marketable yields have resulted from the implementation resolution of the labour problem, acceleration of harvesting and mitigation of crop damage.

Possible progress

Through improved breeding processes, Scientists may find features that improve nutritional value, drought tolerance and disease resistance by analysing large genomic data sets. This has the potential to produce vegetable types that are more resilient to various climatic conditions of India and need less water and other nutrients to grow.

Conclusion

Vegetable science field is being revolutionised by artificial intelligence, which is providing solutions that improve the agricultural landscape of India in terms of efficiency, sustainability, productivity and production. It is being transformed by AI, including precision farming, disease detection, automated harvesting and predictive modelling. By using AI technology, farmers may enhance their crop quality, save costs, work more efficiently and better manage their resources.

Impact of Climate Change on Agriculture and Livestock

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Abstract

Climate change poses a significant threat to global livestock productivity, with far-reaching consequences for food security, rural livelihoods, and the environment. Rising temperature, changing precipitation patterns, and increased frequency of extreme weather events alter the delicate balance of livestock ecosystem, compromising animal health, welfare, and productivity. This paper reviews the impacts of climate change on livestock productivity, including heat stress, water scarcity, and disease outbreaks. We also discuss the potential adaptation and mitigation strategies, such as climate-smart agriculture, breeding and genetics, and policy and planning measures. The paper highlights the urgent need for a coordinated and multi-faceted approach to address the impacts of climate change on livestock productivity and ensure a sustainable and food-secure future.

Introduction

Agricultural products are an important commodity for global food security because among the agricultural product, livestock is one of the most important part. Livestock provide 17% of global kilocalorie consumption and 33% of global protein consumption. The livestock sector contributes to the livelihoods of one billion of the poorest population in the world and employs close to 1.1 billion people. There is a growing demand for livestock products, and its rapid growth in developing countries has been deemed the “livestock revolution”. Worldwide milk production is expected to increase from 664 million tonnes (in 2006) to 1077 million tonnes (by 2050), and meat production will double from 258 to 455 million tonnes. Livestock production is likely to be adversely affected by climate change, competition

for land and water, and food security at a time when it is most needed. Global climate change is primarily caused by greenhouse gas emissions that result in warming of the atmosphere. The livestock sector contributes 14.5% of global GHG emissions, and thus may increase land degradation, air and water pollution, and declines in biodiversity. At the same time, climate change will affect livestock production through competition for natural resources, quantity and quality of feeds, livestock diseases, heat stress and biodiversity loss while the demand for livestock products is expected to increase by 100% by mid of the 21st century. Climate change poses a formidable threat to global food security, with far-reaching consequences for livestock productivity.



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Rising temperature, altered precipitation patterns, and increased frequency of extreme weather events disrupt the delicate balance of agricultural ecosystems, impacting animal health, welfare, and productivity. As the global demand for animal-derived food products continues to rise, understanding the impacts of climate change on livestock productivity is crucial for ensuring food security, animal welfare, and sustainable agriculture practices. This knowledge informs adaptation and mitigation strategies, enabling farmers, policy-makers, and stakeholders to navigate the challenges posed by climate change.

Direct and indirect impact of climate change: The direct effect of climate change on livestock health includes temperature related to frequent disease incidence and death. The climate change on livestock could cause both direct and indirect effects. The direct effects of climate on animal disease are likely to be most pronounced for diseases that are vector-borne, soil associated, water or flood associated, rodent associated, or air temperature/humidity associated and sensitive to climate. Quantity and quality of feed will be affected mainly due to an increase in atmospheric CO₂ levels and temperature. The effects of climate change on quantity and quality of feeds are dependent on location, livestock system, and species. Quality of feed crops and forage may be affected by increased temperatures and dry conditions due to variations in concentrations of water-soluble carbohydrates and nitrogen. Temperature increases may increase lignin and cell wall

components in plants, which reduce digestibility and degradation rates, leading to a decrease in nutrient availability for livestock. The effects of climate change on livestock diseases depend on the geographical region, land use type, disease characteristics, and animal susceptibility. Animal health can be affected directly or indirectly by climate change, especially rising temperatures. The direct effects are related to the increase of temperature, which increases the potential for morbidity and death. The indirect effects are related to the impacts of climate change on microbial communities (pathogens or parasites), spreading of vector-borne diseases, food-borne diseases, host resistance, and feed and water scarcity. All animals have a thermal comfort zone, which is a range of ambient environmental temperatures that are beneficial to physiological functions. During the day, livestock keep a body temperature within a range of 0.5 °C. When temperature increases more than the upper critical temperature of the range, the animals begin to suffer heat stress. Animals have developed a phenotypic response to a single source of stress such as heat called acclimation. Acclimation results in reduced feed intake, increased water intake, and altered physiological functions such as reproductive and productive efficiency and a change in respiration rate. Heat stress decreases forage intake, milk production, the efficiency of feed conversion, and performance. Warm and humid conditions cause heat stress, which affects behaviour and metabolic variations on livestock or even mortality. Heat stress

impacts on livestock can be categorized into feed nutrient utilization, feed intake, animal production, reproduction, health and mortality. Water availability issues will influence the livestock sector, which uses water for animal drinking, feed crops, and product processes. The livestock sector accounts for about 8% of global human water use and an increase in temperature may increase animal water consumption by a factor of two to three. To address this issue, there is a need to produce crops and raise animals in livestock systems that demand less water or in locations with water abundance. Water salination could affect animal metabolism, fertility, and digestion. Chemical contaminants and heavy metals could impair cardiovascular, excretory, skeletal, nervous and respiratory systems, and impair hygienic quality of production.



Regional Variations and Vulnerabilities: Climate change impacts on livestock productivity vary significantly across regions due to differences in climate patterns, agricultural practices, livestock species, and socio-economic conditions. Regions such as Sub-Saharan Africa, South Asia, and the Middle East are highly vulnerable due to their dependence on traditional, extensive livestock systems and limited adaptive capacity. In contrast, regions like Europe and North America may experie-

nce both challenges and opportunities due to their advanced technological and infrastructural resources. In tropical and subtropical regions, rising temperatures and frequent heatwave significantly reduce livestock productivity by affecting animal health, reproduction and feed efficiency. Cattle, for example, are highly sensitive to heat stress, leading to low milk yield, weight loss, and increased mortality. In temperate regions, livestock may face less direct heat stress but could still experience indirect effects through altered feed availability and disease outbreaks.

Regions already experiencing water Scarcity, such as Sahel, Middle East, and parts of South Asia, is particularly vulnerable to climate-induced droughts. Limited water availability reduces feed crop production, increases competition for water resources, and impacts livestock hydration. Conversely, regions with ample water resources, such as Northern Europe, may experience less acute impact but could still face localized droughts affecting livestock systems. Climate change alters rainfall patterns and temperature regimes, directly impacting pasture growth and forage quality. In arid and semi-arid regions, reduced rainfall decreases grazing capacity, leading to overgrazing and land degradation. In contrast, regions with increased rainfall may benefit from improved pasture growth, through excessive rainfall can also lead to waterlogging and reduced forage quality. Warmer temperatures and changing precipitation patterns expand the range of victors and pathogens increasing

livestock vulnerability to disease such as Rift Valley Fever and tick-borne illnesses. Sub-Saharan Africa and South Asia, with existing disease burdens and limited veterinary infrastructure, are particularly at risk. Cooler regions, such as Northern Europe, may see new disease outbreaks due to vector migration. Regions with low adaptive capacity, such as many developing countries, are more vulnerable to climate-induced livestock productivity losses. Limited access to veterinary care, financial resources and climate resilient livestock breeds exacerbates the challenges. In contrast, high-income countries may leverage technological advancements and policy interventions to mitigate impacts, though disparities may persist at local levels.

Adaptation and Mitigation Strategies: Climate change adaptation strategies are crucial to enhance the resilience of livestock systems. One effective approach is to implement climate-smart agriculture practices, such as agroforestry and conservation agriculture. These practices promote soil health, reduce erosion, and increase water retention, ultimately enhancing the resilience of livestock systems to climate-related stressors. Breeding and genetics also play a vital role in adapting livestock to climate change. Developing and promoting climate-resilient livestock breeds can help farmers and herders to better cope with heat stress, drought, and other climate-related challenges. For instance, some breeds of cattle and sheep are more tolerant to heat stress and can thrive in areas with limited water resources. Feed management is another critical

aspect of adapting livestock to climate change. Implementing efficient feed management practices, such as feed supplementation and rotation, can help reduce the impact of climate-related feed shortages. For example, providing livestock with high-quality feed can help them to better cope with heat stress and other climate-related stressors. Water harvesting and conservation techniques, such as rainwater harvesting and drip irrigation, can help reduce the impact of droughts and water scarcity on livestock productivity. Mitigation strategies are essential to reduce the greenhouse gas emissions from livestock production. One effective approach is to implement manure management practices that reduce methane emissions, such as anaerobic digestion and composting. Additionally, optimizing livestock feed to reduce the carbon footprint of livestock production can help mitigate climate change. Promoting the use of renewable energy sources, such as solar and wind power, can also help reduce the dependence on fossil fuels and mitigate climate change. For instance, using solar-powered pumps for irrigation can help reduce the carbon footprint of livestock production. And policy and institutional support are crucial to promoting climate change adaptation and mitigation in the livestock sector. Establishing policy frameworks that support climate change adaptation and mitigation can help create an enabling environment for farmers and herders to adopt climate-resilient practices. Additionally, providing financial support and extension services can help farmers and herders to implement climate change adaptation and

mitigation measures. Adjusting animal diets can also be used as a mitigation measure, by changing the volume and composition of manure. GHG emissions can be reduced by balancing dietary proteins and feed supplements. If protein intake is reduced, the nitrogen excreted by animals can also be reduced. Supplements such as tannins are also known to have the potential to reduce emissions.

Policy and planning: National policy frameworks are essential for addressing the impacts of climate change on livestock productivity. Governments can establish policies that promote climate-resilient livestock production, such as providing incentives for farmers to adopt climate-smart agriculture practices. Additionally, governments can develop climate change adaptation plans that identify areas of high vulnerability and prioritize adaptation measures. International Corporation is critical for addressing the global impacts of climate change on livestock productivity. Global climate change agreement, such as the Paris Agreement, provide a framework for countries to work together to address the global impacts of climate change. Furthermore international research collaborations can help develop new technologies and practices that enhance the resilience of livestock systems to climate-related stressors.

Regional and local planning are essential for addressing the specific impacts of climate change on livestock productivity in different regions. Regional climate change adaptation plans can identify areas of high vulnerability and prioritize adaptation measu-

res, such as the development of early warning systems for climate-resilient livestock breeds, and provide support for farmers to implement these measures. Funding and investment are critical for supporting the development and implementation of climate-resilient livestock production practices. Governments can provide funding for research and development, extension services, and capacity building to support climate-resilient livestock production. Additionally, international organizations, such as Green Climate Fund, can provide funding for climate-resilient livestock production projects in developing countries.

Capacity building and extension services are essential for promoting the adoption of climate-resilient livestock production practices. Governments and international organizations can provide training and capacity building programs for farmers, extension agents, and other stakeholders to promote climate-resilient livestock production. Additionally, extension services can provide support to farmers in implementing climate-resilient livestock production practices. Research and development are critical for developing new technologies and practices that enhance the resilience of livestock systems to climate-related stressors. Research can focus on developing climate-resilient livestock breeds that can tolerate heat stress, drought, and other climate-related stressors. Additionally, research can focus on developing climate-smart agriculture practices, such as agroforestry and conservation agriculture, that promote soil health, reduce erosion, and increase

water retention. Monitoring and evaluation are essential for assessing the effectiveness of policies and programs aimed at promoting climate-resilient livestock production. Governments and international organizations can establish monitoring and evaluation systems to track progress, identify areas for improvement and make adjustments to policies and programs as needed.



Conclusion

Climate change is now a global concern due to its multidimensional effects and impact on humans, animals, plants, and environment. Research has established that changes in global or regional climate patterns due to climate change are affecting livestock health directly and indirectly. Changes in management, technologies and infrastructure may be necessary to ensure animal production is resilient to climate change effects. The appropriate means of adaption will be dependent on the location, sector and production system. A proactive approach is key to the management of climate risks. Climate change will affect livestock production and consequently food security. Livestock production will be negatively impacted (due to diseases, water availability, etc.), especially in arid and semiarid regions. In addition, climate change will affect the nutritional content of livestock products, which are one of the suppliers of global calories, proteins and essential micronutrients. Conversely, livestock production also influences climate change. However,

there are opportunities to adapt and mitigate the impacts of climate change on livestock productivity. Climate-smart agriculture, breeding and genetics, and policy and planning measure can help reduce the vulnerability of livestock systems to climate-related stressors. To address the impacts of climate change on livestock productivity, a coordinated and multi-faceted approach is necessary. This requires the involvement of governments, international organizations, research institutions, and local communities.

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Influence of Cultural Practices on Pest Management in Mango Orchard

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Abstract

Mango, *Mangifera indica* (L.) is a member of the family Anacardiaceae, one of the most important tropical fruits of the world and the most commercial fruit of India known as the King of fruits. India is the leading mango producer in the world, producing an estimated 24.7 million tons of mangos annually (2018), which amounts almost half of the entire global mango production. Mango production and productivity has been threatened by insect problems. Mango leaf hoppers, fruit flies, stem borer and mealy bug are the most serious insect pests of mango in India. The mango leafhoppers and mealy bugs suck the plant sap from various parts of plants and causes sooty mould. Fruit flies attack fruits causing greater loss at the plog end of each product. Stem borer grub bores in to stem and causes death of mango plant. For the management of these pest's farmers mainly depended on only toxic and costliest chemicals which is not safe as well economical. By practicing eco-friendly cultural practices like pruning, summer ploughing and stem swabbing by farmers in the month of May-June or June-July or within Aug 15th after crop harvest farmers can manage the above-mentioned pests besides many other pests are well as disease with low budget which is economically sustainable and environmentally.

Introduction

Production and quality of mango are mainly hampered by the incidence of about 400 insect pests (Thangamet *et al.*, 2013). Among the Mango pests, mango leafhoppers, fruit flies, stem borer and mealy bug are most serious and widespread pests throughout the country (Ishaq *et al.*, 2004). *Amritodus atkinsoni* (Lethierry), *Idioscopus clypealis* (Lethierry) *I. niveosparsus* (Lethierry) and *I. nitidulus* (Walker), are serious pests of mango at flowering and fruiting stages and could cause yield loss up to 100% (Prabhakara *et al.*, 2011).

The leafhoppers nymphs and adults suck the sap from tender shoots, inflorescence and leaves which cause dropping of flowers and immature fruits. Hoppers also excrete honey dew which develops sooty mould and this black coating interferes with the photosynthetic activity of the plant. Mango stem borer grub after hatching bore into the main stem by feeding causes drying/death of plant. Further after oviposition by fruit flies, maggots upon emergence damages fruits by feeding on pulp content. For the management of these pests farmers extensively/ indiscriminately spraying pesticides for the manage-

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ment of insect pests. This leads to the several problems like resurgence of secondary pests, resistance development and residue problems (Singh *et al.*, 2018). Hence there is a need to manage these pests build up and multiplication/spreading at early stages itself by implementing effective eco-friendly cultural practices.

Pruning: For leaf hoppers *Idioscopus clypealis* Lethierry, *I. nitidulus* Walker and *Amritodus atkinsoni* Lethierry. *Idioscopus niveosparsus* Leth together (Hemiptera: Cicadellidae) management.

Avoid closer planting, as the leafhoppers incidence was very severe in overcrowded orchards because of high relative humidity, which favors leafhoppers multiplication. If already planted, overcrowded and lower branches which are in contact with ground level are pruned immediately after harvesting (May-June is best or June-July or within Aug 15th). After pruning the pruned parts are swabbed with lime to avoid further pest incidence or attraction. After pruning all the branches are directly exposed to the sunlight and free air circulation takes place in the canopy which reduces the relative humidity within the plant canopy and in the orchard. Hence leafhoppers biology and multiplication will be affected. Pruning of overcrowded and overlapping branches also reduces leaf Webber *Orthaga euadrusalis* (Walker) (Lepidoptera: Pyralidae), Shoot webber *Orthaga exvinacea* (Hampson) (Lepidoptera: Pyralidae), Shoot borer *Chlumetia transversa* (Walker) (Lepidoptera: Euteliidae), Red ants *Oecophylla smaradina* Fabricius (Hymenoptera

: Formicidae), Stem borer *Batocera rufomaculata* (De Geer) (Coleoptera: Cerambycidae), Bark eating caterpillar *Indarbela quadrinotata* (Walker) (Lepidoptera: Cossidae) and sucking pests like aphids *Toxoptera odinae* (Van der Goot) (Hemiptera: Aphididae), leaf gall midges, mealy bug and scales infestation. Regular pruning has to be practiced in high density planting which also increases yield. Also as we know that mango is a tropical plant which requires more sunlight for its normal growth and development which helps plant indirectly to get higher yield.

Recommended practices for leafhopper management

- ✓ Smoking of orchards by burning of crop residues /cow dung cake during evening hours.
- ✓ Application of bio-agents, *Lecanicillium lecanii* (Zimmermann), *Metarhizium anisopliae* (Metschnikoff) or *Beauveria bassiana* (Balsamo) @ 5g l⁻¹ during off season and twice at 7 days interval during flowering season.
- ✓ Lime mixed with red soil/red earth (Kannada word = Urimanju) at appropriate time (1st spray at September and October, during fresh leaves emergence time and 2nd spray at December/January/February/March during flowering stage) are sufficient to control the leafhopper population in next upcoming year. This mixture can also be mixed with agave, Opuntia (prickly pear cactus) and Aloe vera plants extracts and sprayed, because these plants have repellent action against insects and also acts as rain fast-

ess.

Digging/Raking/Summer ploughing: For fruit fly *Bactrocera dorsalis*, Hendel *B. correcta* Bezzi and *B. zonata* Saunders (Diptera: Tephritidae) management.

The female punctures outer peel/wall of mature fruits with the help of its pointed ovipositor and insert eggs in small clusters inside mesocarp of mature fruits. Upon hatching, the maggots feed on fruit pulp. Regularly farmers will not collect and remove the fallen and decayed fruits in the mango orchard after harvesting which are infested by fruit fly maggots. After maggot stage they will enter in to the soil for pupation. So that farmers, at least have to follow the summer ploughing of entire orchard or digging/raking of soil under the plant canopy has to be done to avoid further emergence of adults and multiplication. During this process pupae will be exposed to the direct sunlight and killed due to high temperature. Also, expose and kills the pupae of shoot bore *Chlumetia transversa*, Walker, (Lepidoptera: Noctuidae) and eggs of mealy bug *Drosicha mangiferae* Green (Hemiptera: Pseudococcidae). Raking also exposes and kills hibernating stone weevil *Sternonchetus mangiferae* Fabricius (Coleoptera: Curculionidae). Further, exposed eggs and pupae will be eaten by predatory birds.

Stem swabbing/painting: For stem borer *Batocera rufomaculata* DeGeer (Coleoptera: Cerambycidae) management.

One single stem borer is enough to kill the entire plant of mango. Hence to avoid its damage at

the time of oviposition (They are normally placed into an incision in the bark) itself has to be managed by applying low cost/cheap and best easily available red earth, cow dung or lime to the main trunk which acts as a primary physical barrier for oviposition. Further, it also gives protection against hoppers which will shelter in cracks and crevices of the bark, prevent egg laying of mealy bugs which cover with whitish powder and colonize between bark of tree trunk, prevent egg laying of bark eating caterpillar on bark and larvae remain hidden in the tunnel during day time and come out at night, feed on the bark and against mango stone weevils after emergence which remain inactive, hidden in the cracks and crevices on the trunk. Shoot borer after larval stage caterpillars move from the leaves to search for pupation sites in cracks or crevices in the bark was affected.

Recommended practices for stem borer management

- ✓ Swab coal tar + kerosene @ 1:2 (basal portion of the trunk - 3 feet height) after scraping the loose bark to prevent oviposition by adult beetles.
- ✓ If infestations are severe then apply the copper oxychloride paste on the trunk of the tree.
- ✓ One celphos tablet (3 g Aluminum phosphide) per hole.
- ✓ Plug the hole with mud.
- ✓ Swabbing of lime mixed with red soil/red earth can also be applied on main stem up to 8-10 feet, this will also take care of stem borer. If eggs laid on main stem they will not emerge or if emerges early instars will feed on that and they will die.

Recommended practices for mealy bug management

- ✓ Band the trees with 20 cm wide alkalthene of polythene (400 gauge) in the middle of December (50 cm above the ground level and just below the junction of branching).
- ✓ Stem with jute thread and apply a little mud of fruit tree grease on the lower edge of the band.

Conclusion

All the farmers must and should follow these simple, low cost, effective, sustainable and eco-friendly cultural practice like pruning, summer ploughing and stem swabbing in the month of May-June or June-July or within Aug 15th in order to reduce the insect pest damage in mango orchard and to get higher yields.

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Innovative Production System of Vertical Farming for Vegetables

Abirami V., Haripriya Shanmugam and Yogajanma Sahoo

Abstract

Vertical farming is the practice of growing crops or vegetables in vertically stacked layers or hanging the plant parts e.g. vines on vertical structures which supports upright growth. It often incorporates controlled environment which aims to optimize plant growth, and soilless farming techniques such as hydroponics, aquaponics and aeroponics. If we go for fully controlled farming in this type of hydroponics system, there needs to appropriate control of humidity, temperature, light and up to some extent diseases and insect pests. Hydroponics, aquaponics, and aeroponics are common soilless farming techniques used to improve plant growth in a controlled environment. Hydroponic, aeroponic, and aquaponic systems promote efficient crop production with little resource utilization. Vertical farming aims to minimize production costs and sell food at a same price. Price levels as items produced on an open field where the sun, air, soil, and water are nearly free. Controlling every variable comes with a cost. High capital and operational Costs (electricity and labour) push businesses to expand up in order to reach profitability. Concentrate on cultivating high-value crops.

Introduction

Most vertical farms use enclosed structures similar to greenhouses that stack vertically, either directly above each other or staggered for better natural light exposure. If saving space is of utmost importance, hydroponic methods as a growing medium instead of soil, allow for reduced weight and lower water requirements by up to 70%. The use of aeroponics further reduces weight and water requirements. Most vertical farms are either hydroponic or aeroponic and do not have run off, which would make the potted plants heavier. The main advantage of utilizing vertical farming technologies is the increased crop yield that comes

with a smaller unit area of land requirement. The increased ability to cultivate a larger variety of crops at once because crops do not share the same plots of land while growing is another sought-after advantage. Additionally, crops are resistant to weather disruptions because of their placement indoors, meaningless crops lost to extreme or unexpected weather occurrences.

Why Vertical Farming?

Since the arable land is small, with agricultural land covering 38% and arable land covering 11% of the total land area. Further, global projections indicate an increase of only another 2 percent of agricultural land by 2040 (FAOSTAT,

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2012) and by 2050 ground water levels are going to be depleted severely, where scarcity of water for irrigation and even for drinking.

Status of vertical farming in India and around the world:

The global vertical farming market size was valued at USD 2.23 billion in 2018, and is projected to reach USD 12.77 billion by 2026, growing at a CAGR of 24.6% during the forecast period i.e., 2019 to 2026. (Vertical Farming Market Size, Share / Industry Trends and Analysis, 2026). It was introduced in the US and Europe, Spain, Japan and Singapore. In Columbia, Association for Vertical Farming is working on its sustainability. The crops are growing successful in producing vegetables such as lettuce, radishes and onions.

Scope of vertical farming

- ✓ The layers of atmosphere can be used effectively in vertical build ups. Less CO₂ emissions and pollution by decreasing reliance on coal burning power plants and transportation and implementing renewable-sources of energy.
- ✓ Crops will be protected from harsh weather conditions and disturbances like typhoons, hurricanes, floods, droughts, snow and the likes.
- ✓ Food production as well as food transport will not be affected. Crops will be consumed immediately upon harvest since there is no need to transport them to far-off places.

Types of vertical farming

Outdoor vertical farming: Outdoor vertical farming involves the production of vegetables by erecting vertical supporting structures. Buildings

employing locally accessible materials, for example, bamboo structures with G.I. wires supports vegetable climbing.

Indoor vertical farming: Indoor vertical farming includes a variety of fixed or permanent structures that support the plants. Almost all horticulture is done in poly-houses, net houses, shade nets, Bamboo constructions are wrapped in plastic sheets.

Techniques of Vertical farming

Vertical farming techniques include hydroponics, aeroponics, and aquaponics.

Hydroponics is a technique for growing plants without soil. In hydroponic systems, the roots of plants are submerged in liquid solutions. Macro-nutrients with roots sustained by inert (chemically inactive) methods such as Gravel, sand, or sawdust.

Hydroponic structures and their operation

Nutrient solution as well as supporting media can be recycled and re-used in hydroponic systems, allowing for customisation and modification. Here are some of the most frequently used systems: wick, ebb-flow, drip, deep water culture, as well as nutrient film technique.

Wick System: A wick is used to draw nutrients from a feed tank into the growing medium. This is simplest hydroponic system requiring no electricity, pump and aerators (Shrestha and Dunn, 2013).

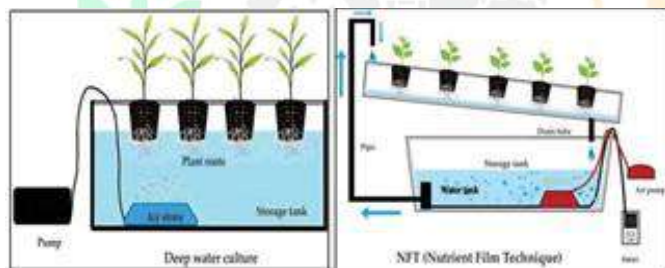
Ebb and Flow (Flood and Drain Culture): These systems work by temporarily flooding the grow tray with nutrient solution and then draining the solution back into the reservoir by a timer operated pump.

Drip Systems: Drip systems are probably the most

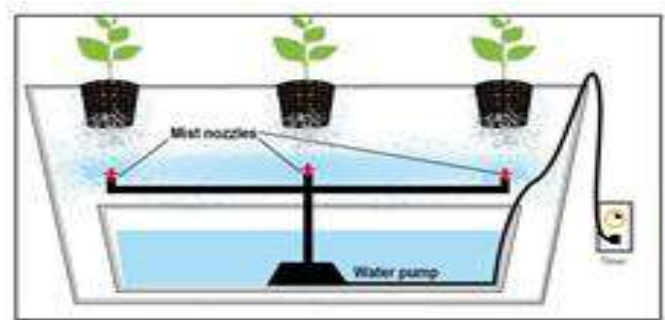
widely used type of eco-farming system in the world. Nutrient solution is dripping onto the base of each plant by a small drip line. The drip hydroponic system is widely used method among both home and commercial growers.

Deep Water Culture: Styrofoam is used to make the platform which holds the plants. It floats on top of the nutrient solution. In deep water culture, roots of plants is suspended in nutrient rich water and air is provided directly to the roots by an air stone.

Nutrient Film Technique (NFT): Tubes or pipes are used to inject the nutrients into to the growing tray. They flow over the plant roots and then drain away. In the 1960s, Dr. Alen Cooper came up with the NFT system to fix the problems with the ebb and flow system (Domingues *et al.*, 2012).



Aeroponics does not need liquid or solid plants to develop in plants, unlike Traditional hydroponics and aquaponics. The air chambers containing the plants. A nutrient-rich liquid solution is misted instead of being suspended.



Aquaponics is the integration of terrestrial plant cultivation and aquatic plant production. Organisms in a closed-loop system that mimics nature itself. Here, a solid removal unit filters. The nutrient-rich effluent from the tanks to a bio-filter, where harmful ammonia gets transformed into nutritious nitrate.

Advantage of vertical farming

Increased crop production: Crops can be cultivated indoors all year round. Depending on the crop, all-season farming enhances the production of the farmed surface by a factor of 4-6. Crops will be sold.

Protection against weather-related issues: Vertical plant farming's output can be substantially independent of weather and protected. It protects against extreme weather events by providing a stable climate.

Environmentally Friendly: Reduces the distance travelled by a significant amount, lowering prices and energy. Consumption and carbon footprint.

Growing High-Quality Produce: Organic produce has higher quality, more nutritional content, and longer shelf life due to the absence of hazardous herbicides and pesticides.

Estimated yield of a Vertical Farm compared to traditional agriculture

Crops	Yield in VF due to tech. (tons/ ha)	Field Yield (tons/ ha)	Factor increase due to Technology
Carrots	58	30	1.9
Radish	23	15	1.5
Potatoes	150	28	5.4
Tomatoes	155	45	3.4
Pepper	133	30	4.4
Peas	9	6	1.5
Cabbage	67	50	1.3
Lettuce	37	25	1.5
Spinach	22	12	1.8
Total (average)	71	28	2.5

Estimated yield of a Vertical Farm compared to traditional agriculture

Crop	Yield in VF due to Tech (tons/ha)	Field Yield (tons/ha)	Increase Factor due to Tech	Factor increase due to Tech and Stacking
Carrots	58	30	1,9	347
Radish	23	15	1,5	829
Potatoes	150	28	5,4	552
Tomatoes	155	45	3,4	548
Pepper	133	30	4,4	704
Strawberry	69	30	2,3	368
Peas	9	6	1,5	83
Cabbage	67	50	1,3	215
Lettuce	37	25	1,5	709
Spinach	22	12	1,8	820

Source: Designed in a CE Study by the author at DLR Bremen.

Disadvantages

High Initial Investment cost, High energy cost as growing plant is entirely with artificial lights, High cost of LED lighting systems. Cost of maintenance: Urban property is much more costly than rural property and the cost to run thousands of LED lights, keeps the temperature perfectly ambient and supply water to plants will outweigh the cost to run a traditional farm unless they can find a way to make the energy renewable and self-sustaining.

Vertical farming v/s traditional farming

Yields are approximately 20 times higher than the normal production volume of field crops. Vertical crop requires only 8% of the normal water consumption used to irrigate field crops. High levels of food safety due to the enclosed growing process. Significant operating and capital cost savings over field agriculture.

The Future of Vertical Farming

Vertical farming helps them in expanding their ability for continuous production in a short growing period with less space and plants can be produced anywhere, i.e., in small spaces with a controlled growth environment. Growers often reply that vertical farming allows them to have higher productivity and yields without any constraints of

climate and weather conditions.

Conclusion

Vertical farming is a new technology reaching towards higher production per unit area of land rather than traditional method of cultivation to meet the demand of increasing population on the same or decreasing land. By using the greenhouses and poly houses in combination with multiple level of growth surfaces can be used with some combinations of vertical farming for lowering the cost of cultivation.

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Scientific Cultivation Technology of Dahlia

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Abstract

Dahlia (*Dahlia* spp.), a popular flowering plant, is renowned for its vibrant colors, diverse forms, and prolonged blooming period. This review paper elaborates on the scientific cultivation practices of Dahlia, encompassing its introduction, botanical characteristics, propagation methods, types, climatic requirements, soil preferences, nutritional needs, intercultural operations, harvesting techniques, post-harvest technology, and pest and disease management. By adopting these advanced cultivation practices, growers can achieve high-quality blooms for ornamental and commercial purposes.

Introduction

Dahlia, belonging to the family Asteraceae, is native to Mexico and Central America. Its captivating flowers make it a favorite among gardeners and florists. The plant's ability to thrive in diverse agro-climatic conditions and its wide range of cultivars have significantly contributed to its popularity worldwide. This paper aims to provide a comprehensive overview of the scientific cultivation practices necessary for maximizing the quality and quantity of Dahlia blooms.

Botany of Dahlia: Dahlia is a herbaceous, tuberous perennial plant characterized by erect stems, pinnate leaves, and inflorescences in the form of composite flowers. Key botanical features include:

Roots: Dahlias possess a unique underground storage system in the form of tubers. These fleshy, tuberous roots are crucial for the plant's survival.

They store nutrients and water, enabling the plant to endure periods of dormancy, particularly during the winter months in temperate regions. This adaptation allows Dahlias to regrow vigorously from the tubers the following spring, making them a perennial despite their above-ground parts dying back.

Stems: Dahlia stems are typically hollow and succulent, contributing to their vibrant appearance. However, this characteristic also renders them somewhat fragile and susceptible to breakage, especially in areas prone to strong winds. Gardeners often provide support to Dahlia plants, such as staking or using cages, to safeguard their stems and prevent them from collapsing.

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Leaves: The leaves of Dahlia plants are arranged oppositely on the stem. They exhibit a pinnately divided structure, meaning they are deeply lobed or divided into leaflets along a central axis. The leaf margins are often serrated, adding to the plant's overall textural appeal. The leaves play a vital role in photosynthesis, capturing sunlight to produce energy for the plant's growth and development.

Flowers: The most striking feature of Dahlia plants is undoubtedly their captivating flowers. These are not single flowers but rather composite inflorescences, meaning they are composed of numerous smaller flowers clustered together.

- ✓ **Ray Florets:** These are the showy, petal-like structures that surround the center of the flower head. They are typically brightly colored and attract pollinators like bees and butterflies.
- ✓ **Disc Florets:** Located in the center of the flower head, these are small, tubular flowers that produce seeds.

The combination of ray and disc florets creates the unique and often dazzling appearance of Dahlia flowers, which come in a breathtaking array of colors, shapes, and sizes.

Fruits: After pollination and fertilization, the disc florets develop into fruits called achenes. Each achene contains a single seed. While Dahlia seeds can be used for propagation, they are often less reliable than vegetative methods like tuber division or cuttings.

Types of Dahlias

Dahlias exhibit immense diversity, categoriz-

ed based on flower size, form, and type:

Single Dahlias: Single row of petals, e.g., Mignon.

Double Dahlias: Fully double flowers, e.g., Decorative, Cactus.

Semi-Double Dahlias: Intermediate forms, e.g., Anemone.

Pompon Dahlias: Small, ball-shaped flowers.

Collarette Dahlias: Inner collar of smaller petals.

Fimbriated Dahlias: Fringed petal edges.

Hybrid Dahlias: Custom hybrids bred for specific traits.



Propagation: Dahlias can be propagated through various methods, each with its unique advantages.



Seed propagation, while suitable for hybridization and developing new cultivars, can lead to variations in plant characteristics. Tuber division, the most common method, ensures genetic fidelity and is relatively simple, requiring the planting of tubers with at least one eye (bud). Cuttings, taken from shoots emerging from tubers, are another effective method for producing uniform plants. Finally, micropropagation utilizes tissue culture techniques to rapidly multiply virus-free plants, particularly valuable for preserving rare or endangered cultivars.

Climatic Requirements: Dahlias thrive in cool, temperate climates with temperatures ranging from 15°C to 25°C. Excessive heat can cause stress and reduce flowering, while frost can damage or kill the plants. They require ample sunlight, ideally 6-8 hours of direct sunlight per day, to ensure vigorous growth and abundant blooms. Consistent moisture is essential, but excessive rainfall or poorly drained soil can lead to waterlogging, which can cause root rot and other problems.

Soil Requirements: Dahlias thrive in well-drained, fertile loam soils with a slightly acidic to neutral pH (6.0-7.0). Ideal soil textures include sandy loam or silty loam, ensuring good aeration for healthy root development. Enriching the soil with compost or well-rotted manure improves its fertility and provides essential nutrients. Excellent drainage is crucial to prevent tuber rot, which can occur in waterlogged conditions.

Nutritional Requirements: Dahlias require balanced nutrition for optimal growth and flowering. Nitrogen promotes vegetative growth, phosphorus supports root development and flowering, and potassium enhances flower quality and disease resistance. A recommended fertilization regime includes a basal dose of farmyard manure (10-15 tons ha⁻¹) and NPK (10:20:10) fertilizer before planting, followed by additional nitrogen applications during the vegetative stage to support vigorous growth.

Intercultural Operations: Efficient cultural practices improve plant health and yield:

✓ **Staking:** Providing support through staking is

crucial for tall marigold varieties to prevent stem breakage due to wind or heavy flowering. This ensures the plants remain upright and promotes better growth.

✓ **Weeding:** Regular weeding is vital to maintain a weed-free environment, which helps prevent competition for nutrients, water, and light. This practice also reduces the risk of disease transmission and pest infestations.

✓ **Pinching:** Pinching involves removing the apical buds to promote lateral branching, resulting in bushier plants with increased flower production. This technique encourages the plant to focus energy on producing more blooms rather than growing taller.

✓ **Mulching:** Applying a layer of organic mulch around the plants helps conserve soil moisture, suppress weeds, and regulate soil temperature. Mulching also adds organic matter to the soil, improving its structure and fertility.

✓ **Irrigation:** Adequate and regular watering is essential, especially during dry spells. Marigolds require consistent moisture to produce healthy growth and abundant blooms. However, over-watering should be avoided to prevent root rot and other problems.

Harvesting: Harvesting marigold flowers requires careful timing and technique to ensure optimal quality. The ideal stage for harvesting is when the flowers are fully developed but not over-mature, as this helps preserve their texture and color. In terms of timing, it's best to harvest marigolds in the early

morning or late evening when the flowers are at their highest turgidity, reducing the risk of wilting. To prevent damage and contamination, use sharp, sterilized tools, such as scissors, pruning shears, or knives, to cut the stems cleanly, just above a leaf node, and handle the flowers gently to avoid bruising.

Post-Harvest Technology

Grading: Post-harvest care begins with grading, which involves sorting marigold flowers based on their size, color, and quality. This step ensures that only the best flowers are selected for market, while inferior ones are removed. Grading helps maintain consistency and quality, ultimately enhancing the marketability of the flowers.

Storage: Proper storage is crucial for extending the vase life of marigold flowers. For tubers, storage temperatures between 2°C to 5°C are ideal. Flowers, on the other hand, require cool, hydrated conditions to prevent moisture loss and maintain freshness. By controlling storage conditions, growers can slow down the aging process and keep flowers fresh for longer.

Packaging: Packaging plays a vital role in protecting marigold flowers during transit. Ventilated boxes are recommended to prevent damage and maintain airflow around the flowers. Proper packaging helps prevent physical damage, reduces moisture loss, and keeps flowers fresh during transportation. This attention to detail ensures that flowers arrive at their destination in optimal condition.

Preservatives: Adding preservatives to vase water

can significantly enhance the shelf life of marigold flowers. A solution containing sucrose and biocides can help extend vase life by providing nutrients, preventing bacterial growth, and maintaining water quality. By using preservatives, growers and florists can keep marigold flowers fresh for longer, reducing waste and improving customer satisfaction.

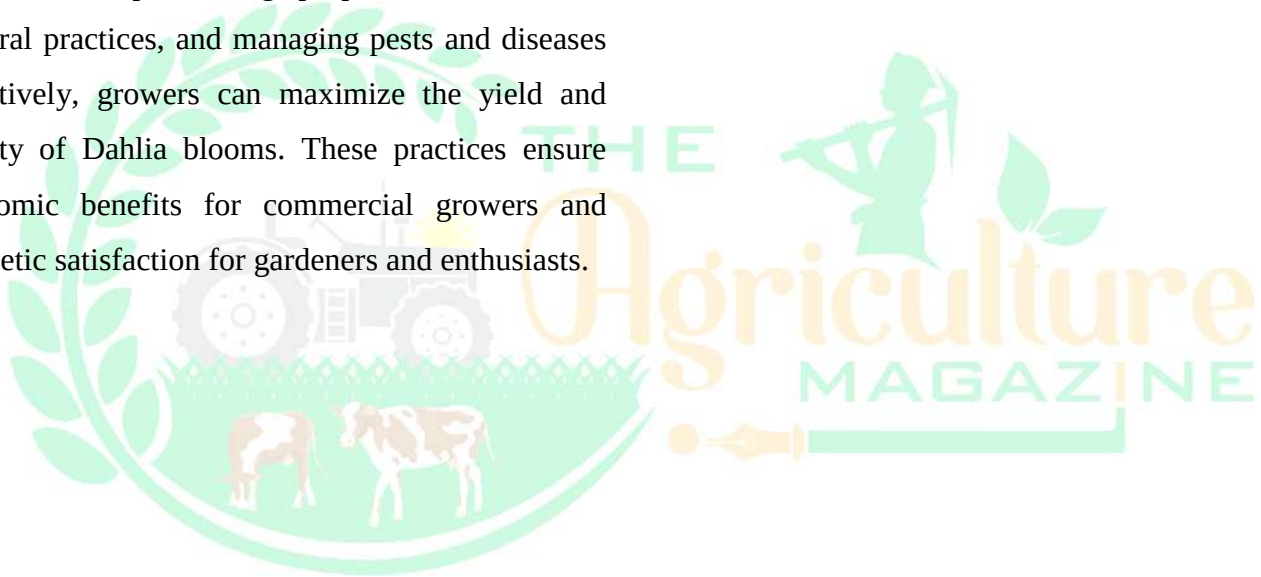
Diseases and Management: Marigolds are susceptible to various diseases that can impact their growth and productivity. Powdery mildew, a common fungal disease, can be controlled using fungicides such as sulfur sprays. Root rot, caused by waterlogging, can be prevented by using well-drained soil and avoiding excessive watering. Viral diseases, such as tomato spotted wilt virus, can be managed by removing infected plants and using virus-free tubers. Additionally, practicing good sanitation, crop rotation, and using resistant varieties can help prevent the spread of diseases. Regular monitoring of the crop for signs of disease and taking prompt action can also help minimize losses.

Insect Pests and Control: Insect pests can also cause significant damage to marigolds. Aphids, small sap-sucking insects, can be controlled using neem oil or systemic insecticides. Thrips, tiny insects that feed on plant sap, can be managed with insecticidal soaps or chemical sprays. Cutworms, caterpillars that can damage stems and flowers, can be controlled using bait or cultural control practices such as removing weeds and debris. Other pests like whiteflies, spider mites, and nematodes can also affect marigolds, and their management requires a

combination of cultural, chemical, and biological control methods. Integrated Pest Management (IPM) strategies that combine these methods can help minimize the use of chemical pesticides and maintain a healthy and productive crop.

Conclusion

The scientific cultivation of Dahlia involves meticulous attention to all aspects of its growth cycle. By adopting advanced propagation techniques, maintaining ideal climatic and soil conditions, implementing proper nutritional and cultural practices, and managing pests and diseases effectively, growers can maximize the yield and quality of Dahlia blooms. These practices ensure economic benefits for commercial growers and aesthetic satisfaction for gardeners and enthusiasts.



Integrated Disease Management in Fruit Crops

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Abstract

Integrated Disease Management (IDM) is a holistic approach to controlling plant diseases that combines cultural, biological, physical and chemical strategies to minimize crop losses and ensure sustainable production. In fruit crops, which are perennial and economically significant, effective IDM strategies are vital for maintaining yield and quality. By reducing reliance on chemical inputs, IDM enhances ecological sustainability, while the adoption of cost-effective measures contributes to economic viability. This article discusses IDM principles, strategies and applications, providing examples from fruit crops like apple, citrus and mango. The integration of disease-resistant varieties, timely cultural practices, biological control agents and judicious chemical use underscores the potential of IDM in promoting sustainable horticulture.

Introduction

Fruit crops are highly susceptible to various diseases caused by fungi, bacteria, viruses and nematodes. These diseases not only reduce yield but also impact the quality and marketability of produce. Traditional disease management practices often rely heavily on chemical pesticides, which can lead to environmental pollution, pesticide resistance and residues on fruits. IDM provides alternatives such as using disease-resistant varieties, biological control agents and improved cultural practices to reduce dependence on chemicals while effectively managing diseases. IDM offers an environmentally friendly and economically viable alternative, emphasizing the integration of multiple disease control methods.

Principles of IDM

Prevention: Emphasizing disease avoidance through proper site selection, resistant varieties and clean planting material.

Monitoring: Regular scouting and identification of diseases to inform decision-making, such as using mobile applications or remote sensing technologies to track disease outbreaks and assess crop health.

Integration: Combining cultural, biological and chemical methods in a compatible and synergistic manner.

Sustainability: Reducing reliance on chemical inputs and focusing on long-term ecological balance.

Strategies in IDM

Cultural Practices

✓ **Crop sanitation:** Removal of diseased plant parts to reduce inoculum sources. For instance, pruning infected branches in apple trees to contr-

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ol fire blight (*Erwinia amylovora*).

- ✓ **Crop rotation:** Reduces soil-borne pathogens, particularly in crops like strawberries.
- ✓ **Proper spacing and pruning:** Improves air circulation and reduces fungal diseases such as powdery mildew in grapes.

Resistant Varieties: Cultivating resistant cultivars is one of the most effective strategies. For example, mango varieties resistant to anthracnose (*Colletotrichum gloeosporioides*) are preferred in disease-prone regions.

Biological Control

- ✓ Use of antagonistic microbes like *Trichoderma* spp. against soil-borne pathogens such as *Fusarium* in banana involves incorporating these beneficial fungi into the soil through seed treatments, root dips, or as part of compost mixtures. These applications help establish a suppressive soil environment, reducing pathogen activity and promoting plant health.
- ✓ Application of *Bacillus subtilis* to suppress bacterial diseases in citrus crops.

Chemical Control

- ✓ Judicious use of fungicides and bactericides when necessary. For example, copper-based fungicides for citrus canker (*Xanthomonas citri*).
- ✓ Adherence to recommended dosages and timings to minimize residue.

Physical Methods

- ✓ Use of heat treatment to sterilize planting materials.
- ✓ Solarisation of soil to control nematodes and

fungal pathogens.

Integrated Use of Inputs: Combining organic amendments, such as compost, with biological control agents enhances soil health and suppresses pathogens.



Advantages and Disadvantages of Integrated Disease Management in Fruit Crops

Advantages

Environmental Sustainability: Reduces chemical pesticide use, minimizing environmental pollution and preserving biodiversity.

Economic Viability: Promotes cost-effective disease management by reducing input costs and increasing yield quality.

Long-term Efficacy: Delays the development of resistance in pests and pathogens by integrating diverse control methods.

Improved Soil Health: Encourages the use of organic amendments and biological controls, enhancing soil fertility.

Enhanced Crop Quality: Reduces pesticide residues, improving the safety and marketability of produce.

Disadvantages

Complexity: Requires knowledge and coordination of multiple management strategies, which can be challenging for farmers.

Time-Consuming: Monitoring, scouting and implementing various measures demand significant time

Table 1: Fruits, Diseases and their Management

Fruit	Disease	Causal Organism	Management Strategies
Apple	Fire Blight	<i>Erwinia amylovora</i>	Pruning infected branches, use of resistant varieties and application of copper sprays.
Citrus	Citrus Canker	<i>Xanthomonas citri</i>	Use of copper-based fungicides, removal of infected parts and planting disease-free stock.
Mango	Anthraxnose	<i>Colletotrichum gloeosporioides</i>	Canopy management, application of fungicides and cultivation of resistant varieties.
Banana	Fusarium Wilt	<i>Fusarium oxysporum</i>	Use of <i>Trichoderma</i> spp., resistant cultivars and crop rotation.
Grape	Powdery Mildew	<i>Uncinula necator</i>	Proper pruning, sulfur applications and improving air circulation in vineyards.
Strawberry	Gray Mold	<i>Botrytis cinerea</i>	Removal of infected fruits, application of fungicides and maintaining low humidity.
Papaya	Papaya Ring Spot	Papaya ring spot virus (PRSV)	Use of virus-free planting material and resistant varieties and controlling aphid vectors.
Pineapple	Heart Rot	<i>Phytophthora cinnamomi</i>	Proper drainage, use of fungicides and resistant varieties.
Guava	Wilt	<i>Fusarium solani</i>	Soil solarization, use of resistant varieties and application of bio-control agents.
Peach	Leaf Curl	<i>Taphrina deformans</i>	Dormant spray of fungicides and removal of infected leaves.

and effort.

Initial Costs: Establishing systems for biological controls or resistant varieties may involve higher upfront investment.

Limited Awareness: Many farmers lack access to training and resources to adopt IDM effectively.

Variable Effectiveness: Success depends on factors like local environmental conditions, availability of resources and proper implementation.

Conclusion

IDM is a cornerstone of sustainable fruit production, offering economic, environmental and social benefits. By integrating diverse management practices, farmers can achieve effective disease control while preserving ecosystem health. Further research should focus on developing region-specific IDM models, identifying novel biological control agents and enhancing disease-resistant crop varieties. Extension activities need to prioritize farmer training programs, dissemination of best practices through workshops and the establishment

of demonstration plots to encourage the adoption of IDM techniques.

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Effective Handling to Prevent Post Harvest Loss of Fruits and Vegetables

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Abstract

Post-harvest losses of fruits and vegetables are a significant concern worldwide, especially in developing countries where inadequate infrastructure, improper handling and limited access to markets can lead to high rates of food waste. Addressing these losses is crucial for improving food security, reducing waste and increasing the availability of fresh produce. The key to minimizing these losses lies in effective post-harvest management practices that preserve the quality, nutritional value and marketability of fruits and vegetables.

Understanding Post-Harvest Losses

Post-harvest loss refers to the reduction in the quantity and quality of produce from the time of harvest to consumption or sale.



Losses can occur due to physical damage, microbial spoilage, physio-logical degradation or poor handling and storage practices. According to the Food and Agriculture Organization (FAO), about 1/3 of all food produced globally is lost or wasted with fruits and vegetables representing a significant portion of this loss.

The factors contributing to post-harvest losses can be grouped into several categories:

Physiological: Respiration and transpiration, leading to wilting, shriveling or rotting.

Mechanical: Physical damage during harvesting, transportation or handling.

Microbial: Spoilage due to bacterial, fungal, or viral infections.

Environmental: Temperature and humidity fluctuations, exposure to sunlight, or poor storage conditions.

Post-Harvest Management Strategies

Effective post-harvest management is essential for reducing losses and ensuring the maximum shelf life of fruits and vegetables. Here are several strategies for managing post-harvest losses:

Pre-Harvest Planning

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Variety Selection: Choose varieties that are more resilient to transport and storage conditions. Some cultivars are more resistant to bruising, spoilage or pests.

Timing of Harvest: Harvesting at the right stage of maturity ensures fruits and vegetables are less prone to rapid deterioration. For example, many fruits and vegetables should be harvested when they are fully ripe but not overripe, as overripe produce is more vulnerable to spoilage.

Handling and Packaging

Gentle Handling: Reduce physical damage by minimizing rough handling and using appropriate tools. Bruising and cuts make produce more susceptible to microbial growth and decay.

Proper Packaging: Use appropriate packaging materials that protect produce during transport and storage. Packaging should allow for ventilation, as many fruits and vegetables release gases such as ethylene, which can accelerate ripening. Packaging that allows air circulation can help prevent premature ripening and mold growth.



Temperature Control

Cold Chain Management: Maintaining the proper temperature from harvest to retail or consumption is one of the most effective ways to reduce post-harvest losses. Cold storage reduces respiration rates and delays spoilage. For many fruits and vegetables, refrigeration or temperature-controlled environments are essential to extend shelf life.

Refrigeration: Many fruits, such as berries, leafy greens, and tomatoes, benefit from cold storage. Some vegetables, like carrots and leafy greens, should be stored in a cool, humid environment to maintain quality.

Cooling Systems: In the absence of refrigeration, cooling systems like evaporative cooling or ice can be used to reduce temperatures temporarily.

Humidity Control

Optimal Humidity: Many fruits and vegetables are prone to dehydration, which leads to wilting and shriveling. Controlling humidity in storage areas is important to maintain the freshness of produce. For instance, leafy greens and herbs benefit from high humidity, while fruits like apples and pears require moderate humidity.

Ethylene Management

Ethylene gas management: Ethylene is a natural ripening hormone emitted by many fruits (e.g., bananas, apples, tomatoes). When these fruits are stored in close proximity to others, they can accelerate the ripening and deterioration of neighboring produce. Using ethylene absorbers or segregating ethylene-producing fruits from sensitive ones can help slow down the ripening process and reduce losses.

Storage and Transportation Techniques

Short-Term Storage

Cool Rooms and Refrigerated Storage: If available, storing fruits and vegetables in cool rooms or refrigerators can significantly slow down degradation. Temperature and humidity should be

carefully controlled, as mentioned earlier.

Modified Atmosphere Packaging (MAP): MAP technology is a technique where the air inside the packaging is modified to slow down respiration and decay. It's commonly used for fresh-cut fruits and vegetables or pre-packaged products.

Long-Term Storage

Canning and Freezing: For longer-term preservation, fruits and vegetables can be frozen or canned. Freezing locks in nutrients, while canning extends the shelf life by using heat to kill bacteria and sealing the product in jars.



Drying: Drying fruits and vegetables is another common method for preservation, particularly for high-moisture crops like tomatoes, apples, and bananas. Drying removes moisture, which helps inhibit bacterial and fungal growth.

Transportation

Proper Transportation Vehicles: Transport vehicles should be clean, dry, and equipped with temperature control systems where possible. Produce should be handled gently to avoid bruising or squashing.



Transportation Time: Minimizing the time between harvest and delivery to market is crucial. Prolonged transportation increases the risk of degradation, especially if proper conditions (such as temperature and humidity) are not maintained.

Minimizing Post-Harvest Losses through education and training

One of the most effective ways to reduce post-harvest losses is to educate farmers, harvesters, and distributors about proper handling and storage techniques. Training programs can provide valuable knowledge on:

Proper Harvesting Methods: Training farmers on the correct tools and techniques for harvesting helps minimize damage.

Storage Solutions: Offering solutions for small-scale storage options, such as coolers or evaporative cooling units, can be especially helpful for smallholder farmers in remote areas.

Market Access: Helping farmers connect with markets through better transportation infrastructure and post-harvest handling practices ensures that produce gets to consumers in good condition.

Technology and innovation in Post-harvest handling

Advancements in technology offer new solutions to reduce post-harvest losses:

Smart Sensors: These devices monitor temperature, humidity, and ethylene gas levels in storage and transport, providing real-time data to optimize conditions and reduce spoilage.



Bio-based Packaging: Researchers are developing sustainable, biodegradable packaging materials that can protect produce from physical damage and reduce environmental impact.

Blockchain and Traceability Systems: Blockchain technology can track produce from farm to market, ensuring that the entire supply chain is transparent

and efficient, reducing losses due to poor handling or storage.

Conclusion

Reducing post-harvest losses of fruits and vegetables is not only a matter of improving food security but also a step toward sustainability. By adopting effective post-harvest handling techniques, such as temperature and humidity control, proper packaging, and gentle handling, we can extend the shelf life of produce, reduce waste, and ensure that fresh fruits and vegetables are available to consumers for longer periods. Collaboration between farmers, supply chain actors, and governments, coupled with advancements in technology and education, will be crucial in achieving these goals and mitigating food loss on a global scale.

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The World Intellectual Property Organization (WIPO)

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Introduction

The World Intellectual Property Organization (WIPO) is one of the 17 specialized agencies of the United Nations. WIPO was created in 1967 “to encourage creative activity to promote the protection of intellectual property throughout the world.” The World Intellectual Property Organization (WIPO) is the United Nations agency dedicated to the use of intellectual property (patents, copyright, trademarks, designs, etc.) as a means of stimulating innovation and creativity. WIPO currently has 185 member states, administers 25 international treaties and is headquartered in Geneva, Switzerland. The current Director-General of WIPO is Francis Gurry, who took office on October 1, 2008. Non-members are the states of South Sudan, Cook Islands, Kiribati, Marshall Islands, Federated States of Micronesia, Nauru, Niue, Palau, Solomon Islands, Timor-Leste, Tuvalu and the states with limited recognition. Palestine has observer status. WIPO has established WIPONet, a global information network. The project seeks to link over 300 intellectual property offices (IP offices) in all WIPO Member States. In addition to providing a means of secure communication among all connected parties, WIPONet is the foundation for WIPO's intellectual property services.

WIPO promote the development and use of

the international IP system through:

Services: It run systems which make it easier to obtain protection internationally for patents, trademarks, designs and appellations of origin; and to resolve IP disputes.

Law: It helps to develop the international legal IP framework in line with society's evolving needs.

Infrastructure: It builds collaborative networks and technical platforms to share knowledge and simplify IP transactions, including free databases and tools for exchanging information.

Development: It builds capacity in the use of IP to support economic development.

WIPO also work with their member states and stakeholders to improve understanding and respect for IP worldwide. It provides economic analysis and statistics. And contribute IP-based solutions to help tackle global challenges.

History

WIPO was formally created by the Convention Establishing the World Intellectual Property Organization, which entered into force on April 26, 1970. Under Article 3 of this Convention, WIPO seeks to “promote the protection of intellectual property throughout the world.” WIPO became a specialized agency of the UN in 1974. The Agreement between the United Nations and the

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World Intellectual Property Organization notes in Article 1 that WIPO is responsible “for promoting creative intellectual activity and for facilitating the transfer of technology related to industrial property to the developing countries in order to accelerate economic, social and cultural development, subject to the competence and responsibilities of the United Nations and its organs, particularly the United Nations Conference on Trade and Development, the United Nations Development Programme and the United Nations Industrial Development Organization, as well as of the United Nations Educational, Scientific and Cultural Organization and of other agencies within the United Nations system.”

WIPO's Strategic Goals

WIPO's nine strategic goals were adopted by the member states in December 2009 in the first phase of comprehensive strategic realignment process within the Organization. They reflect the evolving challenges for WIPO and for intellectual property in today's rapidly changing environment:

- ✓ Balanced Evolution of the International Normative Framework for IP
- ✓ Provision of Premier Global IP Services
- ✓ Facilitating the Use of IP for Development
- ✓ Coordination and Development of Global IP Infrastructure
- ✓ World Reference Source for IP Information and Analysis
- ✓ International Cooperation on Building Respect for IP
- ✓ Addressing IP in Relation to Global Policy Issues

- ✓ A Responsive Communications Interface between WIPO, its Member States and All Stakeholders.
- ✓ An Efficient Administrative and Financial Support Structure to Enable WIPO to Deliver its Programs.

The Strategic Goals provide the framework for WIPO's six year Medium Term Strategic Plan (2010-15).

The objectives of WIPO are

- ✓ To promote the protection of intellectual property throughout the world through cooperation among States and, where appropriate, in collaboration with any other international organization.
- ✓ To ensure administrative cooperation among the Unions.

Functions

In order to attain the objectives, the Organization, through its appropriate organs, and subject to the competence of each of the Unions:

- ✓ Shall promote the development of measures designed to facilitate the efficient protection of intellectual property throughout the world and to harmonize national legislation in this field;
- ✓ Shall perform the administrative tasks of the Paris Union, the Special Unions established in relation with that Union, and the Berne Union;
- ✓ May agree to assume, or participate in, the administration of any other international agreement designed to promote the protection of intellectual property;

- ✓ Shall encourage the conclusion of international agreements designed to promote the protection of intellectual property;
- ✓ Shall offer its cooperation to States requesting legal-technical assistance in the field of intellectual property;
- ✓ Shall assemble and disseminate information concerning the protection of intellectual property, carry out and promote studies in this field, and publish the results of such studies;
- ✓ Shall maintain services facilitating the international protection of intellectual property and, where appropriate, provide for registration in this field and the publication of the data concerning the registrations;
- ✓ Shall take all other appropriate action.

How to become a Member State

WIPO's member states determine the direction, budget and activities of the Organization through the decision-making bodies. To become a member, a state must deposit an instrument of ratification or accession with the Director General. The WIPO Convention provides that membership is open to any state that is:

- ✓ A member of the Paris Union for the Protection of Industrial Property, or member of the Berne Union for the Protection of Literary and Artistic Works; or
- ✓ A member of the United Nations, or of any of the United Nations' Specialized Agencies, or of the International Atomic Energy Agency, or that is a party to the Statute of the International Court

of Justice; or

- ✓ Invited by the WIPO General Assembly to become a member state of the Organization.

WIPO-Administered Treaties

The 24 treaties administered by WIPO are

IP Protection

- ✓ WIPO Convention
- ✓ Beijing Treaty on Audiovisual Performances
- ✓ Berne Convention
- ✓ Brussels Convention
- ✓ Madrid Agreement (Indications of Source)
- ✓ Nairobi Treaty
- ✓ Paris Convention
- ✓ Patent Law Treaty
- ✓ Phonograms Convention
- ✓ Rome Convention
- ✓ Singapore Treaty on the Law of Trademarks
- ✓ Trademark Law Treaty
- ✓ Washington Treaty
- ✓ WCT
- ✓ WPPT

Global Protection System

- ✓ Budapest Treaty
- ✓ Hague Agreement
- ✓ Lisbon Agreement
- ✓ Madrid Agreement (Marks)
- ✓ Madrid Protocol
- ✓ PCT

Classification

- ✓ Locarno Agreement
- ✓ Nice Agreement
- ✓ Strasbourg Agreement

✓ Vienna Agreement

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Sustainable and Diversified Fruit Crop Models for Rajasthan's Dryland Areas

Anita Meena, M. K. Jatav and Manpreet Kaur

Abstract

Rajasthan's dryland areas face challenges due to its arid climate, low and erratic rainfall, and extreme temperature fluctuations. Traditional farming struggles in these conditions, highlighting the need for innovative solutions. Sustainable, diversified fruit-based cropping models offer an effective strategy by combining drought-tolerant fruits like Amla, Ber, Khejri, Bael, Moringa and Karonda with complementary crops. These systems improve resource use, boost farm income, and promote ecological balance. The deep roots of fruit trees conserve moisture, while crop integration enhances soil fertility, provides income stability, and supports long-term agricultural sustainability. This approach helps farmers adapt to climate change and unpredictable weather.

Introduction

The climatic characteristics of dry regions are scientifically significant. This region receives low rainfall, with annual precipitation ranging from 250 to 600 mm, which is unevenly distributed mainly during the monsoon season. High temperatures are a key feature of the climate in dry regions. In summer, temperatures can reach 45-48 °C, while in winter, they can drop to 0 °C. Strong winds are also common in this area, creating dust and sandstorms that impact soil quality. The soil here is often sandy and low in organic matter due to the dry climate and limited water resources, which makes farming challenging. In winter, frost can damage particularly sensitive crops. Due to these climatic characteristics, it is crucial to use appropriate management techniques for agricultural production in Rajasthan's dry region to effectively utilize limited resources and promote

agricultural sustainability. In dry regions, mixed fruit-based cropping models are extremely important, as the unusual climatic conditions here make traditional farming systems challenging. This model involves growing various fruits together, which ensures efficient use of water resources. The deep roots of fruit trees help draw moisture from the soil, allowing them to survive even in dry conditions. Additionally, the mixed cropping system helps maintain soil fertility and provides income stability for farmers through crop diversity. If one crop fails, income from other crops can mitigate financial risks. There is also greater potential for value addition in fruit production, which can increase farmers' income.

Thus, the mixed fruit-based cropping model in Rajasthan's dry region not only boosts agricultural production but also offers a sustainable solution to the effects of climate change, improving the living

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standards of farmers and strengthening the rural economy (Gupta, 2021). The region is also home to drought-resistant horticultural plants, such as Bengal Quince (*Aegle marmelos*), Indian Amla (*Emblica officinalis*), Indian Ber (*Ziziphus mauritiana*), Moringa (*Moringa oleifera*), Indian Khejri (*Prosopis cineraria*), and many other multipurpose species enrich the dry regions (Rani and Agarwal, 2020).

Adopting horticultural plants (Sharma and Kumar, 2020) especially in drought-prone areas, is highly important. Once established, these indigenous plants become a source of sustainable income while maintaining environmental balance. Keeping this need in mind, researchers have developed models for alternative land-use systems that help farmers cope with these challenging conditions. Horticulture not only provides economic benefits to local communities but also helps maintain ecosystem balance.

At the Central Institute for Arid Horticulture (CIAH), Bikaner, various crop models were evaluated after a nine-year cycle. The study focused on crop combinations such as Amla-Ber-Clusterbean-Fennel, Amla-Ber-Clusterbean-Coriander, Amla-Bel-Clusterbean-Coriander, Amla-Khejri-Clusterbean-Ajwain, Amla-Moringa-Clusterbean-Soya, and Amla-Khejri-Grass (*L. indicus*), which are currently in the 16th year of plantation. Amla was chosen as the base crop because it is drought-tolerant and its health benefits are significant. These crop systems include supporting crops like Ber, Bel, Khejri, Moringa, Karonda and Kinnow, which prom-

ote production diversity and ecological balance. The evaluation results clearly showed that these combinations provide economic benefits to farmers and improve agricultural productivity, ensuring the region's stability and the long-term success of agriculture. The results from this evaluation will assist in developing more effective and profitable agricultural systems in the future.

The plant height, canopy, and yield of Amla varied significantly across different crop model systems. The highest Amla yield was found in Amla-Khejri (46.2 kg plant⁻¹), followed by Amla-Ber (44.7 kg plant⁻¹) and the lowest Amla yield was found in Amla-Moringa (40.6 kg plant⁻¹). The Amla-Khejri-Clusterbean-Ajwain crop model recorded the highest organic carbon (0.25%), electrical conductivity (2.00 dS m⁻¹), and pH (8.28), followed by Amla-Ber-Clusterbean.



Figure 1: The Importance of Fennel and Cluster Bean as Ground Storey Crops in a Fruit-Based Cropping System



Figure 2: Crop System for Better Fruit Yield in Bael (*Aegle marmelos*) - Amla (*Emblica officinalis*)

Similarly, the Amla-Khejri-Cluster Bean-Ajwain cropping system showed the highest avail-

ability of nitrogen ($210.3 \text{ kg N ha}^{-1}$), potassium ($401.26 \text{ kg K ha}^{-1}$), micronutrients (Zn 5.11; Cu 0.59; Fe 12.21; Mn 12.91 ppm), and microbial populations (Bacteria $271 \text{ CFU} \times 10^6$; Fungi $221 \text{ CFU} \times 10^3$; Actinomycetes $116 \text{ CFU} \times 10^3$). It was concluded that the Amla-Khejri and Amla-Ber combinations are superior to other cropping systems for the dry regions of Rajasthan. This study can help improve crop selection and management strategies, enabling farmers to gain more profit and enhance agricultural productivity.

Benefits of Fruit-Based Cropping Systems

Fruit-based cropping systems, such as Amla, Amla + Ber, Amla + Bael, Amla + Khejri, Amla + Moringa, and Amla + Karonda, play a crucial role in providing sustainable production and income generation for farmers. The net profits from these systems were recorded as 60251, 81516, 83946, 120183, 58363 and 71744 INR ha^{-1} , respectively. Specifically, the Amla + Khejri combination performed the best with the highest net return of 120183 INR ha^{-1} followed by Amla + Bael and Amla + Ber, with net profits of 83946 and 81516 INR ha^{-1} , respectively. This data shows that fruit-based cropping systems not only help increase income but also support the adoption of sustainable agricultural practices.

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Fungi: The Forbidden Fruit

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A forest is a place where thousands of different organisms meet, creating the most complex network of connections that exist in nature.



Forest ecosystems are also huge factories where solar energy and carbon dioxide from the atmosphere are turned into a huge amount of biomass, which makes up ecosystems, but is also constantly changing. A forest is a system in which each organism plays a role and has an assigned function. It is worth considering the importance of fungi for the functioning of the forest, the most mysterious group of organisms in this forest puzzle.

Fungi, that is representatives of one of the five kingdoms of the world of organisms, play an extremely important, often unnoticeable or underestimated role in the functioning of all ecosystems, including forest ecosystems. It is also one of the richest groups of organisms in terms of species all around the globe. It is estimated, that there may even be over 5 million species of fungi on our planet.

Beneath the towering trees, within the layers of decaying leaves and bark, and among the rich, dark soil of the forest floor, fungi quietly perform essential tasks that sustain life in these ecosystems. Often overlooked by the casual observer, forest fungi are some of the most important organisms in maintaining the health, biodiversity, and functioning

of forests. From decomposers to symbiotic partners, forest fungi are the unsung heroes of the woodland world.

The Role of Forest Fungi

Fungi in forests serve a range of crucial ecological functions that are often invisible to the naked eye. These organisms are involved in nutrient cycling, plant health, and even forest regeneration. Their roles can be broadly categorized into three main groups: decomposers, symbionts and pathogens.

Decomposers: Nature's Recyclers

Fungi are the ultimate recyclers of the forest. As decomposers, they break down dead plant material, such as fallen leaves, twigs, branches, and even the bodies of dead animals. This process is essential for nutrient cycling in forests, as fungi return valuable minerals like nitrogen, phosphorus, and carbon back into the soil. Without fungi, the forest would quickly become clogged with dead organic matter, and the essential nutrients would be locked away, unavailable to new plant growth.

The decay process involves the breakdown of complex organic molecules, such as lignin and cellulose that most other organisms cannot digest. Through this ability, fungi contribute to the creation of humus, the rich, dark layer of soil that supports plant life. The mycelium the vast underground netw-

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ork of fungal threads can spread over vast areas, sometimes covering acres of land, all the while decomposing organic matter and feeding the soil with nutrients.

Symbionts: Partners in Plant Health

Many forest fungi enter into symbiotic relationships with plants, a partnership that benefits both parties. The most common example is the mycorrhizal fungi, which form networks with the roots of plants and trees. These fungi help plants absorb water and essential nutrients, such as phosphorus and nitrogen, from the soil. In return, the plants supply the fungi with sugars produced through photosynthesis.

This mutualistic relationship is especially important in forests, where nutrient availability can be limited. Mycorrhizal fungi can extend the reach of a tree's root system, accessing nutrients in places where roots alone might not reach. Some mycorrhizal species even protect plants from soil pathogens, while others help trees recover from physical damage. In temperate forests, mycorrhizal fungi are key to the growth of many tree species, including oaks, pines, and birches.

In addition to mycorrhizal fungi, there are other types of symbiotic relationships in the forest. Lichens, for example, are mutualistic partnerships between fungi and algae or cyanobacteria. Lichens can often be seen on tree bark or rocks and are sensitive indicators of air quality, as they absorb nutrients directly from the atmosphere.

Pathogens: The Dark Side of Fungi

While fungi are often beneficial to forest ecosystems, some are pathogens that harm plants, trees, and even animals. Fungal diseases can have significant impacts on forest health, sometimes causing widespread damage to entire ecosystems.

One of the most notorious forest pathogens is **Armillaria**, also known as honey fungus, which can infect and kill a wide variety of trees. **Chalara fraxinea**, the causal agent of ash dieback, is another example of a fungal pathogen that has devastated ash populations across Europe. These pathogenic fungi often spread through spores carried by wind, water, or animal activity, and they can be difficult to control once established.

Some fungi are also harmful to animals, including humans. For example, certain species of **Cryptococcus** and **Histoplasma** fungi can cause respiratory infections when their spores are inhaled. Though forest fungi are essential for ecosystem balance, their potential for harm is a reminder of the delicate equilibrium of nature.

The Life Cycle of Forest Fungi

The life cycle of forest fungi is complex and often involves both sexual and asexual reproduction. Most fungi produce microscopic spores that can be carried long distances by wind, water, or animals. When these spores land in a suitable environment, they begin to grow into mycelium, which is the vegetative part of the fungus. The mycelium spreads through the soil or decaying organic matter, absorbing nutrients and preparing for reproduction. Under favorable conditions, the mycelium will form

fruiting bodies what we commonly recognize as mushrooms, toadstools, or puffballs. These fruiting bodies release spores into the environment, where they are dispersed to start the cycle anew. The timing and production of fruiting bodies are often linked to specific environmental conditions, such as moisture, temperature, and the availability of nutrients.

Fungi as Indicators of Forest Health

Forest fungi are also valuable indicators of the health of forest ecosystems. Because they are so sensitive to changes in their environment, fungi can signal shifts in forest conditions caused by climate change, pollution, or land use practices. For example, a decrease in mycorrhizal fungi diversity or the sudden appearance of fungal pathogens can suggest that the ecosystem is under stress.

Additionally, certain species of fungi, such as those that form mycorrhizal partnerships with specific tree species, can provide insight into the overall biodiversity of a forest. When these fungi begin to disappear or struggle to thrive, it may indicate a loss of tree species or a reduction in the forest's ability to support diverse plant life.

Conclusion: Forest Fungi: The Hidden Architects

Though often hidden beneath the forest floor or nestled among the trees, fungi are the unseen architects of forest ecosystems. They drive the decomposition of organic matter, form vital partnerships with plants, and play a role in the health and regeneration of forests. Their quiet but essential work ensures that nutrients are cycled, soil is enriched, and plant life can thrive.

As we continue to understand and appreciate the complexity of forests, it's clear that fungi are indispensable to the web of life. Protecting these mysterious organisms, along with the forests they inhabit, is crucial to maintaining the biodiversity and resilience of our planet's ecosystems. Forest fungi may live in the shadows, but their contributions to the environment are anything but hidden.

Role of Zinc in Plant Nutrition and Crop Yield

Shivam Yadav and Ravina Yadav

Introduction

Zinc is a crucial micronutrient required by plants for various physiological and biochemical processes, contributing significantly to crop yield and quality. Zinc plays a vital role in protein synthesis, enzymatic activation, carbohydrate metabolism, and stress resistance. However, improper fertilization and nutrient imbalances in the soil can lead to deficiencies, impacting plant growth and reducing agricultural productivity. As the global demand for food increases, alongside the rising costs of fertilizers, sustainable practices that minimize environmental impacts are gaining importance.

Zinc and Its Effect on Plant Growth

Zinc plays a key role in essential plant functions, such as fruit development, enzyme activity, and chlorophyll synthesis. It is required in small amounts but is vital for proper functioning. Zinc deficiency in plants can cause physiological stress, leading to reduced enzyme activity, impaired metabolic processes, and disrupted protein synthesis. Plants also struggle to carry out oxidation-reduction reactions and carbohydrate metabolism effectively without sufficient zinc. Excessive use of phosphate fertilizers in soils lacking micronutrients, especially zinc, can exacerbate these deficiencies. This imbalance reduces crop yield and affects plant

health. Additionally, phosphorus levels in the soil interfere with zinc uptake, further diminishing its availability to plants.

Zinc in Soil

The availability of zinc in soil depends on several factors, including soil pH, organic matter, and the presence of other nutrients. The total zinc content in soil ranges from 10 to 300 mg kg⁻¹, with an average of 50 mg kg⁻¹. Zinc is found in the Earth's crust in various forms, such as sulfate, silica, and carbonate minerals, and in soils as water-soluble, exchange-able, organic-bound, or stabilized by clay minerals.

Soil conditions significantly affect zinc uptake by plants. For instance:

- ✓ Highly acidic soils may cause zinc leaching, reducing its availability.
- ✓ Zinc solubility decreases with increasing soil pH, especially in calcareous soils.
- ✓ High phosphorus concentrations in the soil inhibit zinc uptake by plants.
- ✓ Zinc uptake is also influenced by temperature, light intensity, and competition with other metal cations like copper and iron.

Role of Zinc in Enzyme Activity

Zinc is a structural component and activator of numerous enzymes involved in essential plant

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processes:

Alcohol dehydrogenase: Zinc is vital for the conversion of acetaldehyde to ethanol. Zinc deficiency impairs root development.

Carbonic anhydrase: This enzyme contains a zinc atom and catalyzes CO₂ hydration in chloroplasts and cytoplasm, enhancing photosynthesis. Zinc deficiency inhibits its activity.

Superoxide dismutase: Containing both zinc and copper, this enzyme protects plants from oxidative stress. Zinc deficiency increases oxygen free radicals that damage plant tissues.

Other enzymes affected by zinc include alkaline phosphatase, phosphatidic acid lipase, carboxypeptidase, RNA polymerase, and aldolase.

Zinc in Carbohydrate Metabolism: Zinc is crucial for carbohydrate metabolism as it activates enzymes involved in sugar transport and photosynthesis. Enzymes like carbonic anhydrase, fructose-1,6-bisphosphate, and aldolase rely on zinc for optimal function. Zinc deficiency hampers these processes, leading to excessive carbohydrate accumulation in plant leaves.

Zinc in Protein Synthesis: Zinc plays a central role in protein synthesis. It is a key component of ribosomes and activates enzymes involved in protein production. Zinc deficiency can cause amino acid accumulation and reduced protein synthesis, which can severely affect plant growth, particularly during pollen tube formation.

Zinc's Role in Tryptophan Synthesis, Auxin Production and Membrane Protection

Zinc is necessary for synthesizing tryptophan, which is a precursor to the plant hormone auxin (IAA). Zinc deficiency reduces tryptophan and auxin production, hindering leaf growth. Furthermore, zinc plays a vital role in maintaining cell membranes, protecting proteins and lipids from oxidative damage.

Zinc-Phosphorus Interaction and Its Impact on Plant Nutrition

An imbalance between zinc and phosphorus levels in the soil can lead to zinc deficiency. High phosphorus concentrations reduce the transport of zinc from roots to shoots, limiting its availability in plant tissues. Zinc deficiency may also cause increased phosphorus uptake, potentially leading to phosphorus toxicity in plants.

Zinc Interactions with Other Nutrients and Elements

Zinc interacts with several other nutrients in plants:

Nitrogen: Excess nitrogen can accelerate plant growth, diluting available zinc in tissues.

Iron: Zinc deficiency can hinder iron transport to shoots, leading to iron deficiency.

Boron: Zinc deficiency can increase boron concentrations in young leaves and branch tips. Zinc application improves boron uptake in soils with adequate boron.

Cadmium and Copper: Excessive cadmium or copper can compete with zinc for uptake, further aggravating zinc deficiency.

Zinc Deficiency in Plants: Causes, Symptoms and Impact: Zinc deficiency is commonly observed in

eroded, calcareous, and acidic soils. The deficiency is often associated with high phosphorus levels and low organic matter content. Zinc deficiency primarily affects young leaves, causing yellowing between leaf veins. In dicots, internodes shorten, and leaf size reduces. Monocots like corn show banding along the main leaf vein. Zinc deficiency impacts shoot growth more than root growth, leading to reduced yield and impaired pollen fertility.

Zinc Toxicity: Excessive zinc levels can cause toxicity in plants, leading to reduced leaf and root growth, impaired photosynthesis, and disrupted chloroplast activity. Symptoms of zinc toxicity include decreased NADPH production, increased free radicals, and reduced enzyme activity. High zinc concentrations also interfere with the uptake of other essential nutrients, such as phosphorus and iron. Sensitivity to zinc toxicity varies across plant species, with crops like beans, corn, and citrus being highly sensitive, while others like barley, lettuce, and tomatoes show moderate sensitivity.

Zinc Role in Crop Yield and Quality

Zinc influences several plant processes, including nitrogen metabolism, protein quality, photosynthesis, and stress resistance. Zinc fertilization improves crop yield and quality by enhancing nitrogen uptake, reducing phosphorus accumulation, and promoting seedling vigor. Zinc-treated crops also demonstrate better resilience to environmental stress. Studies have shown that zinc application improves the yield of crops like rapeseed, maize, wheat, alfalfa, and potatoes. Zinc-enriched

grains contribute to improved crop productivity, stress tolerance, and biofortification efforts aimed at addressing global zinc deficiency-related health issues.

Conclusion

Zinc is a critical micronutrient for plant health and crop productivity. It supports essential processes such as enzyme activation, carbohydrate metabolism, protein synthesis, and stress resistance. Zinc deficiencies can lead to severe reductions in crop yield and quality, while excessive use can result in toxicity. Sustainable fertilization practices that balance zinc and other nutrients are essential for optimizing crop performance and addressing global micronutrient deficiencies.

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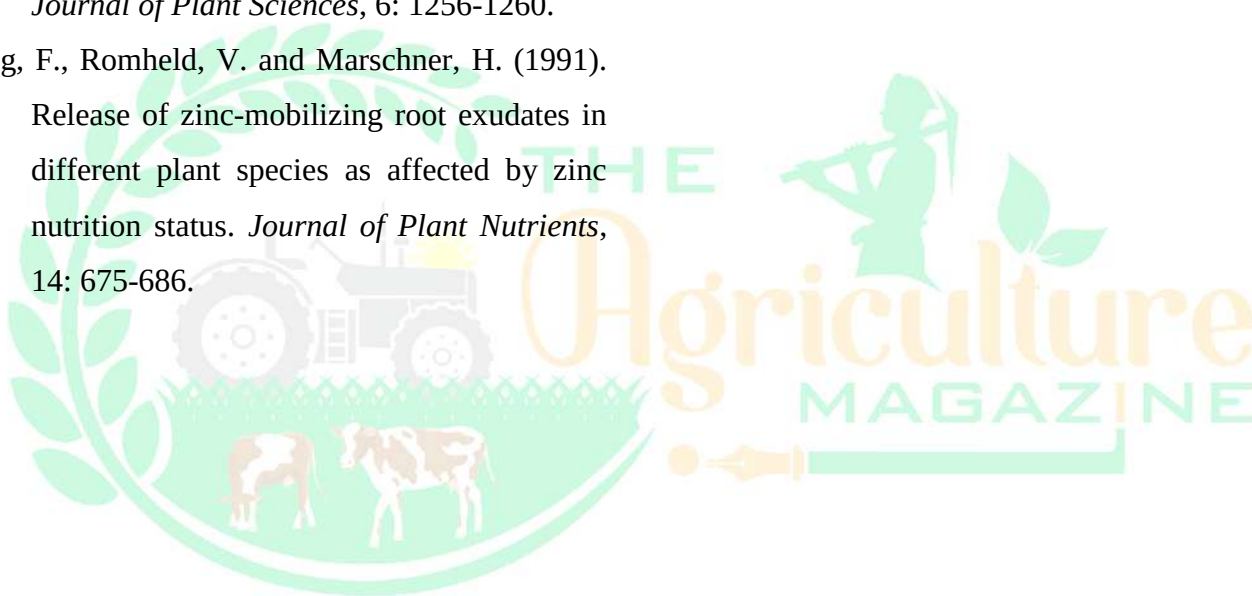
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The Role of Nanotechnology in Advancing Sustainable Agriculture

Shivali Sharma, Thrombo Tayu, Dheeraj Patidar and Gaurav Sharma

Agriculture is considered the backbone of human civilization. Because of its importance, agriculture finds itself under immense pressure while trying to meet the rising demands of a continuously increasing world population. Issues like insufficient arable land, inadequate water resources, soil erosion, and the ecological implications of traditional farming create an acute need for innovation. Amid all these loads of technological revolutions, nanotechnology has come as a transformational tool with the ability to revamp agriculture into becoming a more efficient, sustainable, and productive activity.

Understanding Nanotechnology

Nanotechnology is the manipulation of materials at the molecular or atomic level, usually at a scale of 1 to 100 nanometers. Materials at this scale present unique properties such as an increased surface area, reactivity, and magnetic capabilities. Such properties can open up a host of applications that can help solve many agricultural challenges, from resource efficiency to environmental impact.

Applications of Nanotechnology in Agriculture

Smart Delivery Systems: Traditional methods of applying fertilizers and pesticides lead to wastage and environmental pollution. Nanotechnology provides smart delivery systems that ensure targeted application on plants. Agrochemicals encapsulated in nanomaterials are released in a controlled and slow

manner, which reduces chemical runoff and reduces damage to non-target organisms. Such systems not only enhance resource efficiency but also improve crop productivity.

Water and Soil Remediation: The presence of harmful substances like pesticides and heavy metals in soil and water threatens agricultural productivity and environmental health. Nanomaterials, such as carbon nanotubes, can act as nano-sponges to absorb these contaminants. Purifying water and rejuvenating degraded soils restores essential agricultural resources through nanotechnology.

Advanced Monitoring with Nanosensors: Real-time monitoring of soil health, water quality, and crop conditions is essential in modern precision farming. Nanosensors present a new answer to the call, being highly sensitive and accurate on parameters like nutrient levels, pH, and pest presence. The data provides farmers with the information to make informed decisions, optimizing inputs and maximizing yields.

Green Nanotechnology: Green nanotechnology emphasizes on sustainable nanomaterial synthesis methodologies, which includes the synthesis of materials with the aid of plant extracts, for instance. The application of green nanotechnology, therefore, aligns well with the principles of sustainable agriculture: zero-waste technology and the preventi-

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on of greenhouse gases.

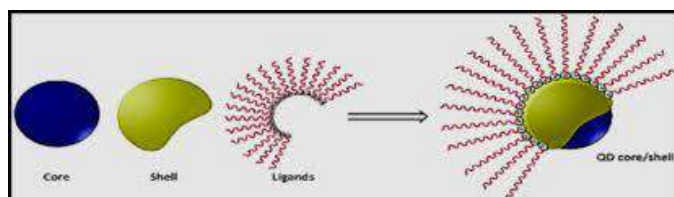
Advanced Food Packaging: Outside of the farm, nanotechnology helps to improve food safety and quality by means of advanced packaging solutions. The nanomaterials used ensure that packaging is durable enough to be extended to shelf life as well as features like contamination detection. These innovations ensure minimal wastage of food and keep agricultural produce fresh for the transportation and storage processes.



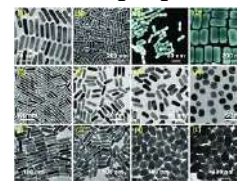
Fig: Various applications of nanotechnology in agriculture (Source: Kaur, 2017)

Specialized Nanotechnologies for Agriculture

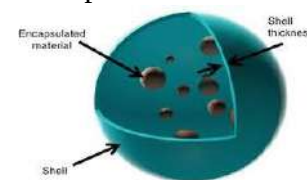
Quantum Dots: QDs, or quantum dots, are semiconductor nanoparticles characterized by having high fluorescence and being more durable. QDs make it possible to perform real-time imaging of plant processes in agriculture, including root growth, which would facilitate research and further crop improvement. Furthermore, QDs can act as photocatalysts for light-powered reactions, and therefore have possibilities in sustainable energy for farms.



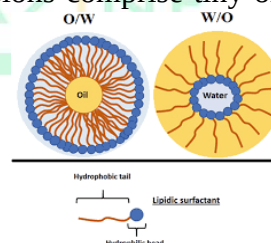
Nanorods: Nanorods, especially gold-based nanorods, have unique optical and electronic properties. These materials can be used in systems that monitor plant health or deliver growth regulators like auxins. Although promising, these materials need to be handled with care to avoid negative effects on plants.



Nanoencapsulation: Nanoencapsulation is a technique, which encloses the substances at nanoscale levels while providing a controlled release. This technique enhances the efficiency of fertilizers and pesticides that are protected from environmental degradations. Precisely delivered chemicals reduce wastage and also minimise the impact on the environment.



Nanoemulsions: Nano-emulsions comprise tiny oil and water droplets which are more stable and efficacious than traditional emulsions.



These find special usage in agricultural sprays because they enhance the uptake of nutrition or pesticide products, thereby minimizing the overall content volume required.

Nanotechnology: Practical Applications

Nanofertilizers for Better Growth: Nanofertilizers, like Nano Max NPK, provide the necessary nutrients, such as zinc and silica, in a more efficient manner than regular fertilizers. Nanofertilizers ensure that nutrients are released in a controlled manner, thereby reducing waste and the environmental impact of

chemical runoff. This is very important in nutrient-deficient soils.

Nanopesticides: Conventional pesticides may be harmful to human health and the environment. Nanopesticides are considered as safer alternatives that incorporate slow-release formulations, enhancing their efficacy in pest control and lowering toxicity. Chitosan-based nanoencapsulation is one such safe pesticide that targets fungal infestation.

Bioremediation: Nanotechnology improves bioremediation, which is a phenomenon where living organisms clean polluted areas. Nanomaterials feed favorable microbes and fungi to break the pollutants, thus restoring soil fertility and making farming sustainable.

Challenges and Ethical Concerns

Despite its promise, nanotechnology in agriculture does raise concerns about potential risks. Nanoparticles may act unpredictably in biological systems, and their unknown impacts on the environment and human health are a concern. Thorough research will be required to understand these interactions, but also robust regulations must be developed to ensure safety.

In addition, the cost of nanotechnology-based solutions will be prohibitively expensive and inaccessible to most developing countries where agricultural innovation is most urgently needed. A collaborative effort between researchers, policy-makers, and industry players is needed to democratize the access of these technologies and promote equal adoption.

Future Outlook

To achieve the potential of nanotechnology in agriculture, several areas are demanding attention:

Advanced Delivery Systems: Develop green mechanisms for the precise delivery of nutrients and agrochemicals.

Wider Application of Nanosensors: Incorporate sensors into precision farming to monitor environmental conditions and crop health.

Life Cycle Analysis: Study the long-term effects of nanomaterials on ecosystems.

Public Outreach: Educate stakeholders about the benefits and risks of nanotechnology to build trust and acceptance.

Conclusion

Nanotechnology is a powerful tool in facing the challenges of modern agriculture. It enhances productivity, reduces environmental impact, and fosters sustainable practices that open up the possibility of attaining food security in an ever-changing world. Yet its adoption must be guided by careful research, ethical considerations and inclusive policies to ensure that its benefits are realized without compromising safety or equity. As we march into the future, nanotechnology can redefine agriculture by linking it with conventional farming and can take humanity a giant stride toward a resilient, sustainable, and prosperous agricultural industry that will be able to meet the requirements of the contemporary and future generations.

Pradhan Mantri Fasal Bima Yojana (PMFBY): A Protective Cover to Agricultural Crops

Pradeep Kumar

PMFBY is an insurance scheme launched by the Indian government on February 18, 2016, aimed at providing financial support to farmers in the event of crop loss due to natural calamities, pests, or diseases. This initiative is a significant step towards enhancing the agricultural sector's resilience and ensuring the financial stability of farmers across India.

Objectives of PMFBY

Financial Support: The primary aim is to provide financial assistance to farmers suffering from crop loss due to unforeseen events, thereby stabilizing their income and encouraging them to continue farming.

Encouragement of Modern Practices: The scheme promotes the adoption of innovative agricultural practices by reducing the risk aversion among farmers.

Credit Flow: It ensures a steady flow of credit to the agricultural sector, contributing to food security and crop diversification.

Key Features

Comprehensive Coverage: PMFBY covers a wide range of crops against various risks, including natural disasters like droughts, floods, and pest attacks. It also includes post-harvest losses during specified periods after harvest.

Affordable Premiums: The scheme aims to reduce the premium burden on farmers, making it easier for them to insure their crops. It operates under a “One Nation, One Scheme” principle, which standardizes coverage across the country. Farmers pay a nominal premium 2% for *Kharif* crops and 1.5% for *Rabi* crops and 5% for commercial and horticulture crops while the government subsidizes the remaining amount. This makes it financially accessible for small and marginal farmers.

Technological Integration: PMFBY employs modern technology such as remote sensing and drones for rapid assessment of crop loss and efficient claim settlements. This tech-driven approach helps streamline processes and improve transparency.

Implementation

The scheme is administered by the Ministry of Agriculture and Farmers Welfare in collaboration with various state governments and insurance companies. It has replaced earlier schemes like the National Agricultural Insurance Scheme (NAIS) and the Modified NAIS, incorporating their best features while addressing previous shortcomings.

Achievements

Since its inception, PMFBY has insured over 56.96 crore applications and disbursed claims amounting to approximately ₹1.54 lakh crore. This

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demonstrates its significant impact on supporting farmers during challenging times.

Eligibility Criteria

- ✓ All farmers growing notified crops in designated areas are eligible.
- ✓ Both loanee (those who take loans) and non-loanee farmers can enroll in the scheme.
- ✓ Farmers must register before the cut-off date set by their respective state governments.

How to Apply PMFBY

- ✓ Visit the nearest Common Service Centre (CSC) or the state agriculture department's official website.
- ✓ Complete the application form with accurate details about crop cultivation, landholding, and other information.
- ✓ Once your application is accepted, pay the subsidised premium and receive the insurance policy document. The premium amount is calculated based on factors like the type of crop, the area sown, and the chosen level of coverage.
- ✓ Upon successful application and premium payment, you will receive a PMFBY policy receipt as proof of your insurance coverage.

What is Fasal Bima Yojana Claim Process

In the unfortunate event of crop loss due to an insured peril, farmers can file a claim under PMFBY. Here's the claim process:

- ✓ Inform the local agriculture department or designated insurance company representative within the stipulated timeframe (around 48 to 72 hours) after the crop loss incident.

- ✓ Officials from the agriculture department and insurance company will visit the affected field to assess the extent of crop damage.
- ✓ The insurance company will determine the claim amount payable to the farmer based on the crop loss assessment report. The amount is calculated based on the sum insured, type of crop loss, and prevailing market prices.

Pradhan Mantri Fasal Bima Yojana is a revolutionary initiative by the Government of India that empowers farmers by providing financial security against crop losses.

Cut-off date: Cut-off date for receipt of Proposals of farmers (loanee and non-loanee) for *Kharif* season is 31st July and for *Rabi* season is 31st December.

Coverage of risks and exclusions

Prevented Sowing/Planting/Germination Risk:

Insured area is prevented from sowing/ planting/ germination due to deficit rainfall or adverse seasonal/weather conditions shall be eligible for indemnity claims upto a maximum of 25% of the sum insured.

Standing Crop (Sowing to Harvesting): Comprehensive risk insurance is provided to cover yield losses due to non-preventable risks, viz. drought, dry spell, flood, inundation, widespread pests and disease attack, landslides, fire due to natural causes, lightning, storm, hailstorm and cyclone.

Post-Harvest Losses: Coverage is available only up to a maximum period of two weeks from harvesting, for those crops which are required to be dried in cut and spread / small bundled condition in the field after

harvesting against specific perils of hailstorm, cyclone, cyclonic rains and unseasonal rains

Localized Calamities: Loss/damage to notified insured crops resulting from occurrence of identified localized risks of hailstorm, landslide, inundation, cloud burst and natural fire due to lightning affecting isolated farms in the notified area.

Add-on coverage for crop loss due to attack by wild animals: States may consider providing add-on coverage for crop loss due to attack by wild animals wherever the risk is perceived to be substantial and is identifiable.

General exclusions: Losses arising out of war and nuclear risks, malicious damage and other preventable risks shall be excluded.

Challenges

Awareness: Despite its benefits, there is a lack of awareness among some farmers about the scheme and how to apply for it.

Delayed Claims: Sometimes, farmers face delays in claim settlements, which can lead to dissatisfaction with the scheme.

Conclusion

Despite challenges such as lack of awareness and delays in claim settlements, PMFBY's implementation has the potential to transform the agricultural landscape by reducing the economic distress caused by crop failures. By integrating technology for efficient monitoring and claim processing, the scheme aims to further improve its effectiveness. Ultimately, PMFBY contributes significantly to the welfare of farmers, fostering a more

resilient agricultural sector and supporting the overall growth of India's rural economy. However, continuous improvements in awareness, implementation, and claim settlement processes are essential for ensuring its success and sustainability.

Regenerative Agriculture

Himani Sharma

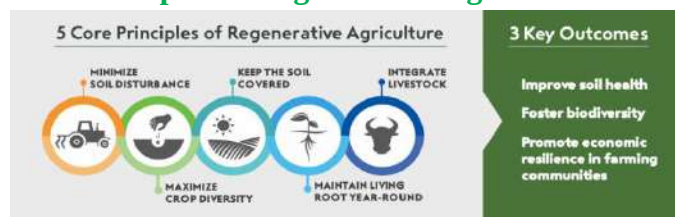
Introduction

A conservation and restoration strategy for food and farming systems is known as regenerative agriculture. It concentrates on restoring topsoil, boosting biodiversity, enhancing the hydrological cycle, strengthening ecosystem services, assisting with biosequestration, enhancing climate change resilience, and preserving the nutritional value of farm soil. By removing carbon dioxide from the environment and sequestering it, regenerative agriculture reduces climate change. With a focus on composting and minimizing soil disturbance, regenerative agriculture is founded on a variety of agricultural and ecological practices.

Principles of Regenerative Agriculture

Regenerative agriculture prioritizes environmental protection and public health. It implies that each farm should make a contribution to environmental protection in addition to producing crops that can be sold. Increased biodiversity, better soil properties, and better environmental circumstances should be the main advantages.

Five Principles of Regenerative Agriculture



A farmer who engages in regenerative agric-

ulture is aware of the following five fundamental concepts as stated by Gabe Brown:

- ✓ There is no longer a need for mechanical, chemical, or physical field remedies. This regenerative agriculture concept echoes the idea of pre-industrial regenerative agriculture. There is no longer a need for mechanical, chemical, or physical field remedies. This regenerative agriculture concept echoes the idea of pre-industrial regenerative agriculture.
- ✓ Utilize cover crops all year long to prevent bare soils from contributing to the runoff. This regenerative farming method also provides grassland and pastureland for chickens and livestock.
- ✓ The expansion of species (e.g., with crop rotation, agroforestry and silvi-pasture techniques).
- ✓ Utilizing animals to assist in agricultural output.
- ✓ The living roots of perennial crops are maintained. All of these concepts aim to preserve a regenerative farming cycle from one year to the next. But nevertheless, they are not all-inclusive, and each farm's particular traits will determine how to combine and use them.

Why is Regenerative Farming worth Implementing?

The lower profit margins of regenerative

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agriculture compared to traditional agriculture are among its most challenging features. However, farmers all over the world are implementing the technique for the benefit of the long term future. The main drivers behind regenerative agriculture are as follows.

Contribute to global food security: People all over the globe are fed by small agricultural businesses. Despite making up 84 percent of all farms, farms smaller than 1 ha to 2 ha hold only 12% of the world's agricultural land. Meanwhile, although they make up just 1% of all farms, large farms hold 65% of cropland.

Reduce greenhouse gas emissions: One of the main factors contributing to global warming is greenhouse gas emissions, of which the commercial food industry is now responsible for about 26%. Regenerative farming is used to solve the issue.

Fight against global warming: Although lowering GHG emissions alone won't be sufficient to stop climate change, it can be combined with soil carbon sequestration gained through regenerative farm management.

Increase yields: Regenerative agriculture strongly encourages organic cultivation. Compared to conventional farming operations, organic farms are more resilient to weather extremes and yield more crops when the going gets tough.

Contribute to the preservation of biodiversity: Versatile species are beneficial to regenerative agriculture as well as the farming business. Environmental sustainability is essential to this type of

farming.

Increase the nutritional value of the product: An improved diet is facilitated by the diversity of crops produced.

Conclusion

Regardless of scale, maintaining soil vitality is the top priority for all agricultural operations, and it appears to be a very challenging task today. It is also one of the main objectives of regenerative agriculture. Recently, farming has been significantly impacted by climate change, and regenerative strategies are battling to bring about a return. Farmers may suffer substantial losses as a result of floods, droughts, extreme heat waves, severe snowfalls, forest fires, tornadoes, storms, and hurricanes. Agriculture and food production are seriously endangered by natural catastrophes, necessitating the creation of adaptable measures. Additionally, severe droughts cause a significant amount of evaporation, which can lead to unusually high rains or even more frequent droughts. When climatic patterns are compared to past meteorological data, they change, and while the amount of rainfall is just slightly below average in some places but exceptionally high in others, causing floods in those areas. Plants cannot withstand droughts and waterlogging, so they die. Organic matter, known for its capacity to retain water and improve soil fertility, is appreciated for its capacity to fight droughts. No-till cultivation facilitates carbon sequestration.

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Rice-Pulse Cropping System: A Sustainable Approach for Agriculture

Chinmaya Kumar Sahoo and Ravi Kiran

Abstract

The rice-pulse cropping system is an integral component of sustainable agriculture, particularly in regions with water limitations or rainfed conditions. This system offers multiple benefits, including improved soil health, enhanced productivity, efficient resource utilization, and increased farmer income. By integrating rice with pulses in a systematic manner, farmers can address challenges such as declining soil fertility, limited irrigation, and climate variability, while ensuring food security and environmental sustainability.

Introduction

Rice is a staple crop for a significant portion of the global population, while pulses are a vital source of protein and nutrients. The integration of these two crops forms a mutually beneficial system, leveraging the unique characteristics of each crop to maximize productivity and maintain soil health. Pulses, being leguminous crops, have the ability to fix atmospheric nitrogen through symbiotic relationships with rhizobia bacteria, enriching the soil for subsequent crops. This characteristic makes pulses an ideal component of a rice-based cropping system, especially in nutrient-depleted soils.

Importance of Rice-Pulse Cropping System:

Soil Fertility Improvement: Pulses contribute significantly to soil health by fixing atmospheric nitrogen, which reduces the dependence on synthetic fertilizers. The root biomass of pulses also adds organic matter to the soil, improving its structure and water-holding capacity.

Efficient Resource Utilization: By alternating rice

and pulses, farmers can utilize residual soil moisture and nutrients effectively, minimizing resource wastage.

Increased System Productivity: Growing pulses after rice provides an additional harvest, thereby enhancing the overall productivity of the land.

Environmental Sustainability: This system reduces greenhouse gas emissions by minimizing the need for chemical fertilizers and enabling better carbon sequestration in the soil.

Economic Benefits: Pulses are high-value crops with significant demand in domestic and international markets, providing farmers with an additional income source.

Suitability of Rice-Pulse Cropping System

The suitability of the rice-pulse cropping system depends on various factors, including water availability, soil type, and climatic conditions:

Rainfed Areas: Pulses like greengram, blackgram, horsegram, and lathyrus are well-suited for rainfed areas due to their low water requirements.

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Irrigated Areas: Soybean is a suitable pulse crop in regions with limited or supplemental irrigation.

Residual Soil Moisture: Crops should be chosen based on the availability of moisture after the rice harvest. For example:

- ✓ If the soil retains sufficient moisture, blackgram can be grown as a paira crop (sown before rice harvest).
- ✓ In drier conditions, lathyrus or horsegram may be more suitable.

Recommended Rice-Pulse Cropping Patterns

Rice-Greengram/Blackgram System

Suitability: Rainfed areas or regions with limited irrigation.

Management: Residual soil moisture should be adequate for successful pulse cultivation. Break the hard pan periodically to enhance water movement.

Rice-Lathyrus System

Suitability: Extremely dry areas where ploughing is not feasible after rice harvesting.

Management: Lathyrus can be sown as a paira crop two weeks before rice harvest.

Rice-Soybean System

Suitability: Irrigated areas with supplemental water availability.

Management: Ensure timely sowing after rice harvest to utilize residual moisture efficiently.

Rice-Horsegram System

Suitability: Medium and upland conditions with early rice harvest and limited soil moisture.

Management: Paira cropping is recommended to optimize water and nutrient use.

Challenges in Rice-Pulse Cropping System

Water Scarcity: Limited irrigation options during the dry season can hinder pulse growth. Efficient water management practices are crucial to address this issue.

Labor Intensity: The transition between rice and pulses often requires additional labor for land preparation and sowing.

Market Fluctuations: Pulse prices can be volatile, impacting farmers' income stability.

Pest and Disease Management: Pulses are vulnerable to pests like pod borers and diseases such as root rot. Integrated pest and disease management strategies are essential.

Conclusion

The rice-pulse cropping system is a promising strategy for sustainable agriculture, particularly in regions with water scarcity or degraded soils. By integrating rice and pulses, farmers can enhance soil fertility, reduce input costs, and achieve higher productivity. The adoption of advanced practices, improved crop varieties, and efficient management strategies can further optimize this system, ensuring environmental sustainability and economic benefits for farmers. For the system to reach its full potential, extension services and government support are crucial in disseminating knowledge and resources to the farming community. Promoting the rice-pulse cropping system can contribute significantly to global food security and the livelihoods of smallholder farmers, demonstrating its relevance in modern agricultural practices.

Man-Animal Conflict in Agriculture: Focus on Elephants and Monkeys

Bhoirab Gogoi, Shourov Dutta and Manoranjan Neog

Introduction

Human-animal conflict is a growing issue in many parts of the world, especially where agricultural expansion intersects with natural habitats. With rising human populations, deforestation, and habitat fragmentation, wildlife is increasingly forced into human-dominated landscapes. Among the many animals involved in such conflicts, elephants and monkeys are particularly problematic in agricultural areas. This article explores the dynamics of man-animal conflict, particularly focusing on the impacts of elephants and monkeys on agriculture, and proposes potential solutions for mitigating these conflicts.

The Concept of Man-Animal Conflict

Man-animal conflict refers to the negative interactions between people and wildlife, often resulting in damage to crops, livestock, property, and even human lives. This conflict typically arises when animals encroach on human settlements or agricultural land, or when humans encroach on animal habitats.

In the context of agriculture, these conflicts manifest when wild animals raid crops, damage infrastructure or compete for water and land resources.

Elephants and monkeys, given their intelligence and adaptability, often find agricultural landscapes attractive due to the easy availability of food and shelter.

Elephants in Agriculture: A Jumbo Problem

Elephant Biology and Behavior

Elephants are the largest land animals and possess enormous appetites. An adult elephant can consume between 150 to 300 kg of plant matter daily, which includes leaves, fruits, bark, and crops. Their size, strength, and intelligence make them formidable raiders of farms and plantations.

Elephants are known for their memory and social structure. Their ability to remember migration routes, water sources, and food locations often leads them back to the same agricultural areas repeatedly. Their social structure, which revolves around matriarch-led herds, also means that if one group learns to exploit an agricultural area, others will follow suit.

Why Elephants Raid Farms

Human expansion into elephant habitats is a primary driver of conflict. As forests are cleared for agriculture, the availability of natural food for elephants declines. Consequently, elephants venture

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into farmland in search of food. Crops such as rice, maize, sugarcane, and bananas, which are cultivated in regions where elephants live, are highly palatable to them.

Elephants often follow traditional migration routes that may now pass through human settlements and farmland, leading to frequent encounters with farmers. Additionally, during periods of drought or seasonal scarcity, agricultural fields offer a more reliable and concentrated food source than the diminishing wild vegetation.

Impact of Elephants on Agriculture

Crop Raiding: Elephants are notorious for raiding fields, particularly at night. They trample crops, pull down trees, and consume large amounts of produce in a short period. This results in significant economic losses for farmers, especially small-scale subsistence farmers who rely on a single growing season to sustain their livelihoods.

Damage to Infrastructure: Beyond crop loss, elephants often damage fences, storage facilities, and water sources. They can easily destroy irrigation systems and water tanks, leading to further agricultural losses. In some cases, they also damage homes and roads, leading to broader community impacts.

Human Casualties and Retaliation: The presence of elephants near human settlements poses a significant threat to human safety. Every year, numerous people are injured or killed by elephants while trying to defend their crops. In retaliation, communities sometimes resort to aggressive measu-

res, including poisoning or shooting elephants, which worsens conservation challenges.

Economic Impact: The economic toll of elephant-related damage is considerable. For smallholder farmers, losing a crop can push families into poverty. The financial burden of rebuilding damaged infrastructure and guarding crops adds to the stress, while national governments often have to allocate significant resources for compensation, mitigation, and elephant conservation efforts.

Monkeys in Agriculture: The Agile Invaders

Monkey Biology and Behavior

Monkeys, particularly species such as macaques and langurs, are highly intelligent, social, and adaptable animals. Their dexterous hands, quick movements, and ability to traverse diverse terrain make them particularly suited to raiding crops. Monkeys are omnivorous, meaning they can feed on a wide range of food sources, from fruits and vegetables to grains and insects.

Monkeys often live close to human settlements, especially where forests are fragmented. They are known for their ability to quickly learn behaviors, including how to exploit human-created food sources. Moreover, their social structure and communication abilities make them effective as crop raiders, as they can coordinate group raids and warn each other of danger.

Why Monkeys Raid Farms

Habitat loss and urbanization are major contributors to monkey invasions in agricultural areas. With shrinking natural habitats, monkeys are

increasingly forced into proximity with human communities. Farms, with their rich variety of fruits, vegetables, and grains, offer an easy source of food.

Monkeys are opportunistic feeders, and the increasing availability of human food sources has conditioned many monkey populations to rely on crops. Furthermore, in some areas, people feed monkeys out of religious or cultural beliefs, reinforcing their reliance on human-provided food.

Impact of Monkeys on Agriculture

Crop Damage: Monkeys are capable of causing extensive damage to crops. They tend to target high-value crops such as fruits (mangoes, bananas, guavas), vegetables (tomatoes, beans), and grains (rice, wheat). Their habit of picking only ripe or nearly ripe produce results in significant economic losses. Moreover, their tendency to spoil or waste large amounts of produce adds to the damage.

Challenges of Control: Unlike larger animals like elephants, monkeys are smaller, more agile, and difficult to deter. Their intelligence allows them to adapt quickly to scare tactics and other deterrents. Traditional methods such as scarecrows or loud noises often prove ineffective after a few attempts, as monkeys quickly learn to ignore them.

Human-Monkey Interaction: Like elephants, monkeys also pose a risk to human safety, albeit of a different nature. Monkeys are known to enter homes, steal food, and even become aggressive if they feel threatened. In some areas, monkey bites are a common concern. Additionally, the long-term presence of monkeys around human settlements can

lead to the transmission of zoonotic diseases.

Economic Impact: For farmers, monkey raids can mean the loss of an entire season's crop. High-value cash crops like fruits are particularly vulnerable, with raids occurring frequently just before harvest. The cumulative losses over time can significantly reduce household incomes and increase food insecurity.

Socio-Economic and Cultural Dimensions of the Conflict

The man-animal conflict, especially in agriculture, has a wide range of socio-economic and cultural implications. In many parts of Asia and Africa, elephants and monkeys hold significant cultural and religious value. For instance, in Hinduism, elephants are associated with the deity Ganesha, while monkeys are linked to Hanuman. This reverence for wildlife can sometimes complicate efforts to manage conflicts, as lethal control methods may be seen as sacrilegious.

Additionally, the economic impact of crop raiding can push already vulnerable rural communities into deeper poverty. Many smallholder farmers rely on agriculture as their primary source of income, and repeated raids by elephants or monkeys can destroy livelihoods. The lack of insurance schemes, limited access to compensation, and inadequate conflict mitigation strategies often leave farmers with few options, leading to frustration and resentment toward wildlife.

Existing Conflict Mitigation Strategies

Various strategies have been employed to mitigate human-wildlife conflicts, particularly invol-

ving elephants and monkeys. These include:

Physical Barriers: Fences, trenches, and other barriers are often used to keep wildlife out of agricultural areas. However, these can be expensive to maintain and are sometimes ineffective against highly determined animals. For elephants, electric fences are a popular option, but they require regular maintenance and can be damaged by storms or other animals. Monkeys, on the other hand, are adept at scaling fences, making them difficult to exclude. Assam Lemon trees are a sustainable bio-fencing solution planted in closer spacing that can help protect farmers' crops and homes from elephants in Assam:

- ✓ **Repel elephants:** The smell of lemons and the thorns of the trees repel elephants.
- ✓ **Additional income:** Farmers can sell the lemons to generate extra income.
- ✓ **Sustainable:** Bio-fences can be sustainable if they are planted in the right place and don't impede elephant movement.
- ✓ **Affordable:** Lemon fences are an inexpensive option.

Guarding and Deterrents: Farmers often employ human or animal guards, especially during harvest time, to protect their crops. In some areas, dogs are used to deter elephants, while in others, farmers rely on firecrackers or other loud noises. Unfortunately, these methods can be labor-intensive and are often only partially effective.

Community-Based Solutions: Some areas have developed community-based conflict management

programs, where local people are involved in monitoring wildlife movements, reporting incidents, and implementing deterrents. In many cases, these programs also involve compensation schemes for farmers who lose crops to wildlife, helping to reduce retaliatory killings.

Habitat Restoration: One of the long-term solutions to human-wildlife conflict is to restore natural habitats and ensure that animals have access to food and water sources within their own territories. This reduces the likelihood of them encroaching on agricultural lands. Reforestation projects, the creation of wildlife corridors, and waterholes in protected areas are examples of such initiatives.

Technology-Based Solutions: Increasingly, technology is being used to mitigate conflicts. For example, early-warning systems using drones or sensor networks can alert farmers to approaching elephants, giving them time to take preventive action. GPS collars on elephants have also been used to track their movements and warn communities in advance. Monkeys are harder to track, but sensor-based deterrents that release ultrasonic sounds have shown some promise.

Future Directions and Recommendations

Addressing man-animal conflict requires an integrated approach that balances the needs of wildlife conservation with the livelihood needs of rural communities. The following strategies could help mitigate future conflicts:

Strengthening Legislation and Enforcement:

Governments must enact and enforce stronger laws to protect wildlife while also compensating farmers for their losses. More robust legal frameworks for land use planning, habitat protection, and human-wildlife conflict resolution are needed.

Expanding Insurance and Compensation

Schemes: Insurance schemes that cover crop damage by wildlife could help reduce the financial burden on farmers. These schemes must be easily accessible, transparent, and provide timely payouts

Conclusion

Man-animal conflict is a complex and multifaceted issue that poses significant challenges to agriculture, wildlife conservation, and rural livelihoods. As human populations continue to grow and agricultural activities expand, the potential for conflict between people and wildlife is likely to increase. However, with the right policies, technologies, and community involvement, it is possible to mitigate these conflicts and promote coexistence between humans and wildlife.

Addressing man-animal conflict requires a holistic approach that integrates conservation efforts with sustainable agricultural practices, modern technology, and local knowledge. By protecting wildlife habitats, improving land-use planning, and supporting rural communities, we can reduce the negative impacts of man-animal conflict and create a future where both people

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The Hidden Gold: Unlocking the Economic Potential of Mushroom Cultivation in India

Neeraj

Introduction

Indian farmers frequently undervalue the potential for economic growth associated with mushroom growing, particularly in rural areas. Because of their low starting cost, rapid payback, and increased demand for healthy nutritious food, mushrooms are not only a delectable culinary ingredient but also a significant cash cow. Straw, sawdust, and agricultural waste are just a few of the substrates that may be used to grow mushrooms, which makes them a sustainable crop. This article delves into the many facets of mushroom cultivation in India, showcasing how it may enhance livelihoods, guarantee food security, and contribute to the economic development of the country. Mushrooms are the fruiting bodies of fungus, of which there are over 10,000 kinds known to exist, only around 100 of which are edible.



The most commonly cultivated mushroom varieties include:

Button Mushroom (*Agaricus bisporus*): The most widely consumed mushroom globally, known for its mild flavour.

Oyster Mushroom (*Pleurotus ostreatus*): Recognized for their delicate flavour and velvety texture and rapid growth. Oyster mushrooms come

in various colours, including white, pink, and blue.

They are often sautéed or used in soups and stir-fries.

Shiitake Mushroom (*Lentinula edodes*): Known for their rich, umami flavour, shiitakes are often used in Asian cuisines. They have a distinctive umbrella-shaped cap and are prized for their health benefits.



Nutritional & Health Benefits of Mushroom

Mushrooms have distinct flavours and textures, making them versatile culinary ingredients. Mushrooms offer a variety of health advantages in addition to their culinary usage. Their variety and nutritional worth make them an important part of diets all across the world. Mushrooms are low in calories but high in nutrients. They include a substantial amount of protein, vitamins, minerals, and antioxidants.

Proteins: High-quality plant protein, essential for vegetarians.

Vitamins: Particularly B-complex vitamins and vitamin D.

Minerals: Such as selenium, potassium and copper.

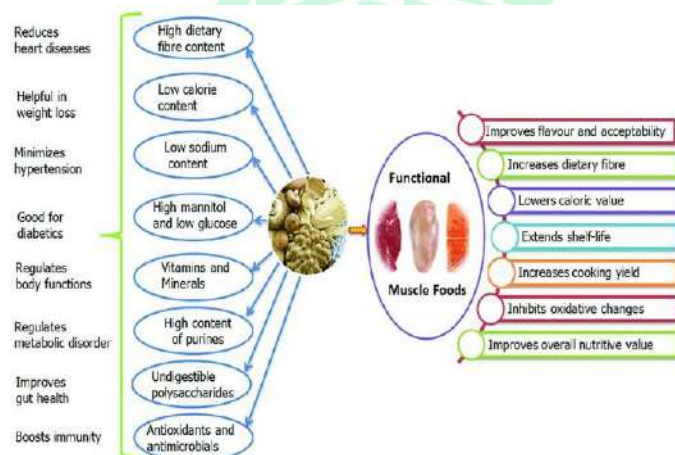
Antioxidants: Compounds that may reduce the risk of chronic diseases.

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Incorporating mushrooms into diets can enhance overall nutrition and health, addressing malnutrition issues prevalent in many parts of India.



The Growing Demand for Mushrooms; Domestic Market Trends & Global Market Potential

The demand for mushrooms in India has surged in recent years due to:

Urbanization: Growing urban populations are driving demand for convenience foods and healthy options.

Changing Dietary Preferences: A shift towards vegetarianism and health consciousness among consumers is increasing the popularity of mushrooms.

The domestic market is anticipated to

increase dramatically, creating several opportunities for farmers. India's export potential in the mushroom industry is significant. The worldwide mushroom market is growing, especially for speciality species such as shiitake and oyster mushrooms. By focussing on quality and sustainability, Indian farmers may get access to lucrative foreign markets.

Economic Viability of Mushroom Farming

Initial Investment and Profitability: Mushroom cultivation demands lower capital investment than the cultivation of traditional crops.

The fundamental needs involved are:

- ✓ **Substrate:** Organic materials such as straw, sawdust, or agricultural waste.
- ✓ **Spawn:** The mushroom seed needed for growing.
- ✓ **Infrastructure:** Low-cost structures for incubation and fruiting.

Income Generation Potential: With possible yields ranging from 200 to 400 kg per cycle, farmers can expect profit within a short cycle typically within 6-8 weeks from planting to harvest. Profits from a well-run mushroom farm may be considerable. For example, depending on the demand and season, button mushrooms can fetch an average market price of ₹80 to ₹200 kg⁻¹. In a year with multiple harvests, a farmer can make a good living.

Mushroom Cultivation Techniques

Selection of Mushroom Varieties: Selecting the appropriate mushroom variety is crucial for successful cultivation. Factors to consider include:

- ✓ **Climate Adaptability:** Varieties that thrive well

under local climatic conditions.

✓ **Market Demand:** Popular varieties that guarantee better sales.

✓ **Growing Conditions:** Mushrooms require specific growing conditions:

✚ **Temperature:** Most varieties thrive at 20-25°C.

✚ **Humidity:** High humidity (60-80%) is essential for healthy growth.

✚ **Ventilation:** Adequate airflow prevents contamination and promotes mycelial growth.

Cultivation Process

The mushroom cultivation process involves various steps including:

Preparation of Substrate: The substrate is sterilized to eliminate contaminants, providing a clean environment for the spawn.

Inoculation: The spawn is mixed into the substrate in a sterile environment.

Incubation: The inoculated substrate is kept under dark and humid conditions to allow the mycelium to colonize.

Fruiting: Light, temperature and humidity are adjusted in order to induce fruiting.

Harvesting: Mushrooms are harvested at peak maturity, usually within 3-4 days after fruiting starts.

Challenges in Mushroom Cultivation

Technical Challenges: Mushroom farming requires specific skills and knowledge. Common challenges include:

✓ **Contamination:** Bacterial or fungal contamin-

ation can ruin a crop.

✓ **Pest Management:** Insects and pests can affect yields if not properly managed.

✓ **Optimal Conditions:** Maintaining the right environmental conditions is crucial for success.

Market Challenges: Farmers often face market-related issues:

✓ **Access to Markets:** Many small farmers struggle to reach larger markets.

✓ **Price Fluctuations:** The prices of mushrooms can vary significantly, affecting profitability.

✓ **Competition:** Imported mushrooms can undercut local prices.

Climate Change: Climate change poses risks to mushroom farming. Unpredictable weather patterns can disrupt production cycles. Farmers must adapt to these changes through resilient practices and diversified cropping systems.

Government Initiatives and Support to Enhance Mushroom Cultivation

Policies and Schemes: The Indian government has implemented various initiatives to promote mushroom farming, including subsidies, training programs and research.

Subsidies: Financial support for infrastructure development, such as cold storage and processing units.

Training Programs: Skill development programs to educate farmers about best practices and new technologies.

Research and Development: Government funding for research on disease-resistant strains and sustain-

able practices.

Future Prospects

Technological Innovations: The future of mushroom farming in India is likely to be shaped by technological advancements. Innovations such as

Controlled-Environment: Utilizing technology to maintain optimal growing conditions, improving yields and quality.

Automation: Implementing automated systems for substrate preparation, monitoring, and harvesting can reduce labour costs and enhance efficiency.

Sustainable Practices: Adopting sustainable practices is essential for the long-term viability of mushroom farming. This includes:

Organic Farming: Growing mushrooms without synthetic chemicals can attract health-conscious consumers.

Waste Utilization: Using agricultural waste as substrate not only reduces costs but also contributes to environmental sustainability.

Export Opportunities: As global demand for mushrooms rises, Indian farmers have a unique opportunity to explore export markets. By focusing on quality, packaging, and certification, they can access lucrative international markets, enhancing their income potential.

Conclusion

Mushroom farming represents a significant opportunity for economic development in India. By unlocking its potential, farmers can improve their livelihoods, contribute to food security, and drive rural development. With the right support, knowled-

ge and investment, mushroom cultivation can emerge as a cornerstone of Indian agriculture, offering a wealth of benefits for farmers and consumers. Mushroom cultivation is indeed the hidden gold for Indian farming with the potential to transform agriculture practices. Through continued efforts to educate farmers, develop sustainable practices, and expand market access, India can harness the full economic potential of mushroom farming for a prosperous future.

Agronomic Practices for Moisture Conservation in Arid Legumes

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Introduction

Legumes are plants belonging to *Leguminosae* family which includes, beans, peas, chickpeas, lentils, lupin, soybean. It comprising about 800 genera and 20,000 species (Stagnari *et al.*, 2017). Legumes are one of the richest sources of proteins, minerals and fibers for animals and human being. They provide not only nutritious food, feed and fodder but also help in conserving the natural resources and maintain ecological balance. Agricultural practices generally associated with field crop production and soil moisture conservation that minimize the amount of water lost from the soils through evaporation and transpiration or evapotranspiration such as, mulching, conservation tillage practices, organic manures, crop rotation, cover cropping, land configuration, weed management, anti-transpirants and intercropping. Due to lack of moisture in arid region, moisture conservation practices are very important for production of arid legumes.

Role of agronomic practices for moisture conservation in arid legumes

Saxena *et al.* (2003) reported that branches plant⁻¹, pods plant⁻¹, seed pod⁻¹ and seed yield of

moth bean obtained significantly higher in weed free check plot. But it was at par with HW at 30 DAS, Fluchloralin 0.75 kg ha⁻¹ or 1.0 kg ha⁻¹.

Gosh *et al.* (2006) observed that conventional tillage + subsoiling alternate year were recorded significantly higher yield of sole soybean, sole pigeon pea and pigeon pea equivalent yield.

Meena *et al.* (2006) revealed that field bunding with application of FYM @ 10 t ha⁻¹ were recorded significantly higher plant height, no. of pod plant⁻¹, 100 seed weight and seed yield of chick pea. But it was at par with field bunding + GM (Dhaincha).

Use of black plastic mulch recorded significantly higher pod plant⁻¹, test weight and pod yield of ground nut in both autumn and spring season was revealed by Ramkrishna *et al.* (2006).

Singh and Rana (2006) revealed that intercropping of Indian mustard and lentil recorded significantly higher equivalent yield of mustard. In case of moisture conservation practices FYM + organic mulch + kaolin also recorded significantly higher yield of Indian mustard, lentil and Indian mustard equivalent yield and which remain at par with Organic mulch + kaolin spray (6%).

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Pramanik *et al.* (2009) reported that raised bed planting techniques gave significantly highest grain yield (2.15 and 2.33 t ha⁻¹) in the year 2005-06 and 2006-07, respectively with maximum WUE (12.06 and 11.33 kg ha⁻¹ mm⁻¹).

Selvi *et al.* (2009) studied that application of 50% RDF + cultural mulch in pigeon pea were obtained significantly higher no. of pods plant⁻¹ and grain yield, which at par with RDF and 50 % RDF + FYM @ 5 t ha⁻¹.

Regar *et al.* (2010) studied on chick pea and recorded significantly highest grain yield with bunding. In case of deep tillage during monsoon was recorded significantly highest plant height, biological yield and grain yield, Whereas, straw mulching 5 t ha⁻¹ produced significantly higher grain yield over straw mulching 2.5 t ha⁻¹.

Aikins and Afuakwa (2012) found that disc ploughing followed by disc harrowing tillage practice recorded significantly higher moisture content in soil after 10 weeks of cowpea planting.

Singh *et al.* (2014) recorded that application of vermicompost @ 2 t ha⁻¹ in field pea resulted in the highest plant height (57.07 cm), nodule plant⁻¹ (36.13), seed pod⁻¹ (5.72) and grain yield (5.72 q ha⁻¹). Kumar *et al.* (2015) observed that pigeon pea + soyabean (1:2) cropping system obtained significantly higher pigeon pea equivalent yield.

Maize - chick pea - green gram cropping pattern obtained significantly higher seed yield and stover yield of green gram. In case of tillage and residues management CT + R produced significantly

higher seed yield and stover yield, reported by Meena *et al.* (2015).

Tomar *et al.* (2016) observed that yield and quality after harvest of urd bean crop were significantly highest under raised bed method of sowing as compared to flat bed method of sowing.

Lyngdoh *et al.* (2017) found that application of Vermicompost + Fish Amino Acid + Panchagavya + Biofertilizers were recorded significantly higher plant height, root nodules plant⁻¹, no. of pod plant⁻¹, no. of seed pod⁻¹, pod yield plant⁻¹ and pod yield (q ha⁻¹) of cow pea.

Sanbagavalli *et al.* (2017) found that application of straw mulch @ 5 t ha⁻¹ in soyabean recorded significantly higher no. of pods plant⁻¹, 100 grain weight and yield. While use of antitranspirants potassium nitrate (1%) produced significantly higher no. of pods plant⁻¹, 100 grain weight and yield. But it was at par with magnesium carbonate (2%) and glycerol (5%).

Shariff *et al.* (2017) reported that application of FYM 1/3 (8.33 t ha⁻¹) + Vermicompost 1/3 (1.66 t ha⁻¹) + *Glyricidia* green manure 1/3 (4.62 t ha⁻¹) in green gram recorded significantly higher no. of pods plant⁻¹, no. of seed pod⁻¹, 100 seed weight, seed yield plant⁻¹ and seed yield ha⁻¹. Whereas, foliar spray of 3 % Panchagavya produced significantly higher no. of pods plant⁻¹, no. of seed pod⁻¹, 100 seed weight, seed yield plant⁻¹ and seed yield ha⁻¹.

Yadav *et al.* (2017) observed that application of vermicompost 2 t ha⁻¹ recorded significantly higher plant height, effective nodules plant⁻¹, no. of

nodules plant⁻¹, DMA plant⁻¹, pod plant⁻¹ and seed yield. Whereas spray of Panchgavya 3% produced significantly higher plant height, effective nodules plant⁻¹, no. of nodules plant⁻¹, DMA plant⁻¹, pods plant⁻¹ and seed yield of chick pea crop. But it was at par with vermiwash 10 %.

Singh *et al.* (2018) reported that plastic mulching, variety HG-563 and fertilizer application 75% RDF with 5 t ha⁻¹ vermicompost recorded significantly higher no. of pods plant⁻¹, no. of seeds pod⁻¹, 100 seed weight, seed yield plant⁻¹ and yield (kg ha⁻¹) of cluster bean.

Rajput *et al.* (2019) reported that application of green leaf manure @ 10 t ha⁻¹ and mulching with maize residues 2.5 t ha⁻¹ were recorded significantly higher plant height, no. of primary branches hill⁻¹, no. of pod plant⁻¹, pod weight and seed yield of pigeon pea.

VAM @12.5 kg ha⁻¹ + crop residue mulching @ 5 t ha⁻¹ + 100% P application recorded significantly higher pods plant⁻¹, test weight and grain yield of pigeon pea, but which remain at par with VAM @ 12.5 5 kg ha⁻¹ + 100% P, reported by Rao *et al.* (2019).

Yadav *et al.* (2019) observed that application of enriched compost (5 t) + *Rhizobium* + PSB gave significantly highest seed yield, straw yield, biological index and harvest index of soybean.

Joshi *et al.* (2020) noticed that seed and stover yield of chickpea was significantly highest under raised bed method of sowing as compared to flat bed method of sowing.

conventional tillage practices recorded significantly higher seed yield and mulching with rice straw @ 2.5 t ha⁻¹ recorded significantly higher plant height (cm), pods plant⁻¹, seed yield (kg ha⁻¹) and high moisture content in soil at 90 DAS of chick pea reported by Deka *et al.* (2021).

Dhale *et al.* (2021) found that subsoiling tillage practices recorded significantly higher no. of pods plant⁻¹, no. of nodule plant⁻¹ and seed yield in soyabean. In case of land configuration broad bed and furrow method produced significantly higher no. of pods plant⁻¹, no. of nodules plant⁻¹ and seed yield.

Conclusion

It can be concluded that by adopting different agronomic practices for moisture conservation viz. mulching, conservation tillage practices, organic manures, crop rotation, cover cropping, land configuration, weed management, use of antitranspirants and intercropping, conserve the moisture and increase the 10-15 per cent yield of arid legumes.

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The Role of Biofuels in Sustainable Agriculture

Pukhrambam Sunilkumar Singh and Jack Ningthoujam

Abstract

Biofuels, derived from renewable biological sources, play a pivotal role in sustainable agriculture by reducing greenhouse gas emissions, diversifying farm incomes, and promoting rural development. They utilize agricultural residues and marginal lands, offering a sustainable alternative to fossil fuels. However, challenges such as land use competition, resource management, and economic viability persist. This article explores the benefits, challenges, and strategies for integrating biofuels into sustainable agriculture, emphasizing advanced biofuel technologies and supportive policies. With innovative approaches and stakeholder collaboration, biofuels can significantly contribute to a resilient and sustainable agricultural future.

Introduction

Sustainable agriculture is an essential pillar for addressing the challenges posed by climate change, population growth, and finite natural resources. Biofuels, derived from biological materials such as plants and organic waste, have emerged as a critical component of the renewable energy portfolio. Their potential to reduce greenhouse gas emissions, decrease dependency on fossil fuels, and promote rural development aligns with the goals of sustainable agriculture. This article explores the role of biofuels in sustainable agriculture, their benefits, challenges, and future potential.

Understanding Biofuels

Biofuels are categorized into different types

based on their sources and production methods:

First-Generation Biofuels: Derived from food crops like corn, sugarcane, and vegetable oils. Examples include ethanol and biodiesel.

Second-Generation Biofuels: Produced from non-food biomass such as agricultural residues, forestry waste, and energy crops like switchgrass.

Third-Generation Biofuels: Developed from algae, which has a high yield potential and can be cultivated in non-arable lands.

Fourth-Generation Biofuels: Emerging technologies that involve capturing carbon dioxide and combining it with biomass to create fuels.

Each generation has unique implications for agriculture, land use and environmental sustainability.

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Benefits of Biofuels in Sustainable Agriculture

Reduction of Greenhouse Gas Emissions: Biofuels contribute to the reduction of carbon dioxide and other greenhouse gases when compared to fossil fuels. For instance, ethanol from sugarcane and biodiesel from soybean can significantly lower lifecycle emissions, thus mitigating the impact of agricultural activities on global warming.

Diversification of Farm Income: Growing biofuel crops provides farmers with an additional revenue stream. Crops such as canola, corn, and switchgrass can be cultivated alongside traditional food crops, enhancing economic resilience in rural communities.

Utilization of Marginal Lands: Non-food energy crops can be grown on marginal lands that are unsuitable for conventional agriculture. This reduces competition with food crops and makes productive use of degraded or low-quality soils.

Waste Management: Agricultural residues and organic waste can be converted into biofuels. This not only reduces waste but also minimizes the environmental burden associated with conventional disposal methods.

Energy Security and Rural Development: Biofuels reduce dependency on imported fossil fuels, enhancing energy security. The establishment of biofuel production facilities creates local jobs and stimulates rural economies.

Soil Health and Crop Rotation: Certain biofuel crops, such as legumes, can improve soil health by fixing nitrogen and enhancing organic matter. Incorporating these crops into rotations can lead to

more sustainable farming systems.

Challenges in Integrating Biofuels with Sustainable Agriculture

Land Use Competition: First-generation biofuels often compete with food crops for arable land, potentially driving up food prices and contributing to food insecurity. The expansion of biofuel crops can also lead to deforestation and habitat loss.

Water Use and Pollution: Biofuel crops like sugarcane and corn are water-intensive, exacerbating water scarcity in certain regions. The use of fertilizers and pesticides can contribute to water pollution and eutrophication.

Energy Balance: The energy required for cultivating, harvesting, and processing biofuel crops can sometimes offset the energy savings they provide. This is particularly true for first-generation biofuels.

Economic Viability: The production and distribution of biofuels often require substantial initial investments. Fluctuating oil prices can make biofuels less competitive, discouraging their adoption.

Technological Barriers: Advanced biofuels, such as those derived from algae or lignocellulosic materials, are still in the developmental stage. Scaling these technologies to commercial levels remains a challenge.

Policy and Regulation: Inconsistent or inadequate policies regarding biofuels can hinder their growth. Subsidies, tariffs, and international trade dynamics often create uncertainties for producers and investors

Strategies for Promoting Sustainable Biofuel Practices

Adopting Second and Third-Generation Biofuels:

Prioritizing non-food biomass and algae-based biofuels can mitigate the food-versus-fuel debate and reduce environmental impacts.

Integrated Farming Systems: Combining biofuel crop production with food crops and livestock can optimize land use and enhance overall farm productivity. Agroforestry systems that integrate biofuel crops with trees and shrubs offer additional environmental benefits.

Efficient Use of Resources: Precision agriculture technologies can optimize inputs such as water, fertilizers and pesticides, reducing the environmental footprint of biofuel crops.

Investing in Research and Development: Continued investment in biofuel technologies can improve efficiency, reduce costs, and enhance scalability. Research should focus on high-yield energy crops, efficient conversion technologies, and waste-to-energy systems.

Supportive Policies and Incentives: Governments should provide incentives for sustainable biofuel production and establish clear regulations to encourage adoption. Carbon pricing, renewable energy mandates, and grants for biofuel research can drive progress.

Public-Private Partnerships: Collaborations between governments, private companies, and research institutions can accelerate the development and deployment of biofuel technologies.

Case Studies and Success Stories

Brazil's Ethanol Program: Brazil has established a successful ethanol industry based on sugarcane. The country's Proálcool program has significantly reduced greenhouse gas emissions and created jobs in rural areas while maintaining food security.

United States Biodiesel Industry: The U.S. has promoted biodiesel production through federal incentives and the Renewable Fuel Standard (RFS). Soybean farmers have benefited from an expanded market, and biodiesel use has reduced emissions in the transportation sector.

India's Jatropha Initiative: India has explored the use of jatropha, a non-food crop, for biodiesel production. This initiative has aimed to utilize degraded lands and provide livelihoods in rural areas, though challenges in scalability remain.

European Union's Renewable Energy Directive: The EU's policies on biofuels emphasize sustainability criteria, promoting second-generation biofuels and reducing the environmental impacts of production.

Future Perspectives

The future of biofuels in sustainable agriculture depends on technological advancements, policy support, and stakeholder collaboration. Innovations in genetic engineering, microbial fermentation, and carbon capture can enhance the efficiency and sustainability of biofuel production. Simultaneously, integrating biofuels into broader climate action strategies such as carbon sequestration and circular economies can maximize their impact.

Conclusion

Biofuels offer significant potential for advancing sustainable agriculture by reducing emissions, diversifying incomes and promoting rural development. However, achieving these benefits requires addressing challenges related to land use, resource management, and technological barriers. By prioritizing advanced biofuels, investing in research, and implementing supportive policies, biofuels can become a cornerstone of a sustainable agricultural future.

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Blossoms in the City: Urban Floriculture Redefining Modern Gardening

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Abstract

Urban floriculture, a subfield of horticulture focused on the cultivation and management of ornamental plants in urban areas, is rapidly gaining momentum as cities worldwide continue to grow. With the increasing challenges posed by urbanization such as pollution, limited green space, and changing climate conditions urban floriculture offers innovative solutions that enhance the aesthetic, ecological, and psychological well-being of urban dwellers. This article delves into the rise of urban floriculture, its impact on modern gardening, and the diverse techniques employed to integrate flowers and plants into city environments. It explores how urban floriculture not only contributes to sustainable living but also fosters a deeper connection between people and nature. Through case studies, trends, and best practices, this piece examines how urban floriculture is transforming cities into vibrant, greener and more livable spaces.

Introduction

In an age of rapid urbanization, cities across the globe are grappling with a paradox: the more urbanized the environment becomes, the more essential nature seems to be for human well-being. As cities continue to expand and densify, urban floriculture has emerged as a key component of reimagining urban landscapes. Floriculture, traditionally associated with commercial flower production

is increasingly being adapted to meet the needs of city environments by transforming empty lots, balconies, rooftops, and even urban walls into lush, colorful, and sustainable green spaces. Urban floriculture not only provides aesthetic value but also offers a wealth of ecological, psychological, and environmental benefits. From reducing the heat island effect to improving air quality, and enhancing mental health, the cultivation of ornamental plants

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and flowers is redefining what it means to “garden” in the modern world. This article explores the role of urban floriculture in reimagining modern gardening, examining its potential to reshape urban living, and discussing practical ways that cities can integrate more floral and plant-based spaces into their infrastructures.

The Rise of Urban Floriculture

Urban floriculture has experienced significant growth in the last few decades. A combination of increasing environmental awareness, population growth in cities, and advances in horticultural techniques has created an ideal environment for the flourishing of flowers and plants within urban spaces. Moreover, there is growing public interest in sustainable living practices, with many urban dwellers recognizing the importance of green spaces to their quality of life. Historically, urban gardening focused mainly on vegetables and herbs, but the contemporary urban floriculture movement has placed emphasis on ornamental plants, flowers, and their ability to enhance public spaces. Whether it's through large-scale flower installations, vertical gardens, or home-based gardening practices, urban floriculture is being incorporated into all aspects of city living.

Changing Perception of Green Spaces in Urban Areas

The concept of “green spaces” in cities is not new, but the increasing awareness of their importance to both the environment and individual wellbeing has led to a rethinking of how these spaces

are designed and utilized. In many urban settings, floriculture has shifted from simply beautifying parks and gardens to a key component of urban planning. Incorporating flowers and plants into everyday spaces from balconies to sidewalks, from office buildings to schools reflects a broader cultural shift towards greening urban life. Government-led initiatives, private-sector investments, and grassroots movements all contribute to the growing demand for more floral integration within cities. The rise of urban floriculture can be linked to a collective desire to improve both environmental quality and human health.

Benefits of Urban Floriculture

Ecological and Environmental Benefits

One of the most significant benefits of urban floriculture is its contribution to environmental sustainability. In cities where green space is limited, ornamental plants and flowers can play an essential role in mitigating some of the challenges posed by urbanization.

Reducing Heat Island Effect: Cities are known to be “heat islands,” meaning that they experience higher temperatures than surrounding rural areas due to human activities, concrete, asphalt, and lack of natural vegetation. Plants, including flowers, absorb sunlight and release moisture through transpiration, which cools the environment. Urban floriculture can help reduce the overall heat island effect, making cities more comfortable during hot summer months.

Improving Air Quality: Plants are natural air purifiers. They absorb carbon dioxide and release

oxygen, helping to combat air pollution a major issue in most urban centers. Some flowers, like marigolds and sunflowers, are particularly effective at absorbing particulate matter and harmful gases. Moreover, by increasing the number of plants and flowers within urban areas, cities can combat rising pollution levels and reduce respiratory problems among residents.

Biodiversity Enhancement: Urban floriculture plays a vital role in supporting biodiversity within city environments. By planting a variety of native and non-native flowers, urban floriculture can attract pollinators like bees, butterflies, and birds, helping to maintain healthy ecosystems in otherwise sterile urban environments. Additionally, creating green spaces with a diverse range of plants supports local wildlife and promotes ecological balance.

Psychological and Social Benefits

The psychological and social benefits of urban floriculture cannot be overstated. Numerous studies have shown that exposure to nature, even in small doses, can significantly improve mental health, reduce stress, and increase happiness.

Stress Reduction and Mental Health: Being surrounded by flowers and plants has been shown to lower stress and anxiety levels. Urban floriculture offers an opportunity to reconnect with nature, providing a calming escape from the fast-paced, often stressful, urban lifestyle. Gardens, flower-filled balconies, and green rooftops act as sanctuaries that help promote relaxation and mindfulness.

Community Engagement: Urban floriculture

initiatives can also foster a sense of community. In cities where residents may feel disconnected, community gardens, shared green spaces, and flower planting activities can bring people together, promote social interaction, and enhance civic pride. These spaces can become places for gathering, celebrating, and creating a collective identity.

Improved Quality of Life: Green spaces, particularly those enriched with flowers, can have a positive impact on the overall quality of life in urban areas. Aesthetically pleasing environments help to uplift spirits and contribute to a sense of well-being. Urban floriculture enhances the visual appeal of a city, providing both residents and visitors with an enjoyable and enriching experience.

Techniques and Innovations in Urban Floriculture

Vertical Gardens: One of the most popular trends in urban floriculture is the development of vertical gardens. These gardens make use of limited space by growing flowers and plants on vertical surfaces such as building walls, fences, and trellises. Vertical gardening offers a creative solution to the challenge of growing flowers in dense urban environments where horizontal space is scarce. Innovative vertical garden systems, such as living walls and modular planting units, allow for a wide variety of plants including flowers to thrive in otherwise unused spaces. These gardens not only improve the aesthetics of a city but also provide environmental benefits like insulation and energy savings.

Rooftop Gardens: Another innovative technique

gaining popularity is the installation of rooftop gardens. In cities where space is at a premium, rooftops offer an underutilized area that can be transformed into a lush garden space. Flowers, shrubs, and even trees can be cultivated on rooftops, turning these spaces into peaceful retreats while also providing ecological benefits such as improved air quality and reduced energy consumption. Rooftop gardens also offer a unique opportunity for urban dwellers to grow their own flowers and connect with nature in a meaningful way.

Flowering Street Furniture: Incorporating flowers into street furniture such as benches, lamp posts, and bus stops is another creative trend. Flower boxes integrated into public spaces help beautify cities while simultaneously increasing greenery. Flowering street furniture not only adds charm but can also improve air quality and contribute to a more pedestrian-friendly environment.

Smart Gardening Technologies: As technology advances, so does the practice of urban floriculture. Smart gardening technologies, such as automated irrigation systems, sensors for soil moisture levels, and even AI-driven plant care apps, are becoming increasingly popular in urban settings. These technologies help make urban floriculture more efficient, reducing water usage and ensuring that plants, including flowers, are properly cared for.

Case Studies of Urban Floriculture

The High Line, New York City: One of the most iconic examples of urban floriculture is the High Line in New York City. This elevated linear park was

built on a disused railway track and transformed into a green space that incorporates wildflowers, ornamental grasses, and a variety of native plants. The High Line has become a model for urban floral design, blending nature and urban life while promoting sustainability and biodiversity.

Singapore's Vertical Gardens: Singapore is widely regarded as a global leader in urban floriculture. The city-state has made great strides in integrating greenery into its urban infrastructure. From vertical gardens in commercial buildings to green rooftops, Singapore is a shining example of how a city can seamlessly blend modern architecture with lush floral and plant life.

Paris' Planting Initiatives: Paris has increasingly focused on integrating plants and flowers into the urban environment. The city has initiated projects like "Paris Respire" (Paris Breathes), which encourages flower planting on the streets and provides spaces for urban gardeners to create floral designs. These initiatives aim to beautify the city and improve the quality of life for its inhabitants.

Conclusion

Urban floriculture is transforming modern gardening by offering innovative, sustainable, and beautiful solutions to the challenges posed by urbanization. Whether through vertical gardens, rooftop blooms, or flowering public spaces, floriculture plays a pivotal role in enhancing the aesthetic, ecological, and psychological aspects of urban life. It offers a promising future for cities that are increasingly embracing the idea of nature as an

integral part of urban planning. The benefits of urban floriculture are multifaceted, from improving air quality and reducing the heat island effect to fostering community engagement and enhancing mental well-being. With the continued growth of urban populations and the increasing demand for greener, more sustainable cities, urban floriculture is poised to play an even more prominent role in shaping the future of urban living. As cities confront environmental challenges such as pollution, climate change, and limited green space, integrating floral and plant life into urban infrastructures becomes essential not just for aesthetic purposes, but for the overall health and well-being of their residents.

The techniques and innovations in urban floriculture from vertical gardens to rooftop greenery, provide creative solutions for maximizing limited space and integrating nature into the urban fabric. As demonstrated by successful case studies like the High Line in New York, Singapore's green initiatives, and Paris' street planting projects, urban floriculture is not just a trend but a transformative movement that is redefining how we think about and experience cities. Moreover, the adoption of smart gardening technologies further enhances the efficiency of urban floriculture. These advancements enable urban gardeners and city planners to optimize plant care, reduce resource consumption, and ensure that the plants, including flowers, thrive in sometimes challenging urban environments.

In conclusion, urban floriculture offers a wealth of opportunities for creating more livable,

sustainable, and beautiful cities. As the world continues to urbanize, the integration of flowers and plants into urban spaces will become increasingly crucial. By embracing urban floriculture, cities can not only improve their environmental sustainability but also enhance the quality of life for their inhabitants, making urban spaces healthier, happier, and more connected to nature. Urban floriculture is not just about cultivating flowers it's about cultivating a new vision for cities where nature and urban living coexist harmoniously. This vision offers hope for more sustainable, vibrant, and people-friendly urban landscapes in the future.

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Nutritional, Immunological and Pharmacological Role of Zinc in Poultry

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Introduction

Zinc (Zn) is an important trace mineral which has various roles in poultry nutrition. It serves as an essential nutrient and a metal cofactor for several enzymes. Sufficient zinc intake and absorption are required for various functions such as immunity against pathogens, growth and quality of the egg. Zinc is ubiquitous in all living organisms and acts both structurally and catalytically in metalloenzymes (Dell, 1992). Zinc metalloenzymes are recognized in all six enzyme types, which include oxidoreductase (catalysing oxidoreductions between two substrates), transferase (catalysing transfer of a group other than hydrogen), hydrolase (catalysing hydrolysis of esters, ether, peptide, glycosyl, acid anhydride, C-C, C-halide, or P-N bonds), lyase (catalysing removal of groups from substrates by mechanisms other than hydrolysis, leaving double bonds), isomerase (catalysing interconversion of optical, geometric, or positional isomers), and ligase (catalysing the linking together of two components coupled to the breaking of a pyro-phosphate bond in ATP or a similar compound) (Keilin and Mann, 1940).

Zinc in poultry nutrition

Zinc is a trace element that is necessary for normal growth and maintenance and includes among other functions bone development, feathering, enzyme structure and function and appetite regulat-

ion for all avian species (Batal, 2001).

Zinc for growth performance

Zinc is essential for growth, maintenance and other functions such as bone development, feather development, enzyme structure and function and appetite control in poultry. At the level of 0.012-0.018% on the total weight basis, Zn is commonly added as a supplement to all formulated poultry diets.

With respect to growth, zinc deficiency has shown poor growth rate because of improper nucleic acid synthesis. Chicks fed with basal diet and not supplemented with zinc grew poorly, did not feather properly, developed footpad dermatitis and could not walk normally. Chicks that were fed the same basal diet with added zinc did not develop any deficiency symptoms.

Zinc in egg quality

Quality of eggshell is an important parameter in the egg industry as its value is totally dependent on it. If eggshell quality is not good, it directly affects the hatchability. For preventing some of the harmful organism like Salmonella which is a vertically transmitting bacteria, eggshell thickness and its strength is essential. In the case of old layers, eggshell weakness is a major concern where broken egg percentage could be even more than 20% at the end of the laying period. Macro-minerals like calcium and phosphorous and vitamin D₃ are major

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nutrients which are responsible for eggshell quality in laying birds. Additionally, for the mineralization process, some enzymes are linked with macro-minerals. One of the enzymes is carbonic anhydrase, a zinc-dependent enzyme essential for supplying carbonate ions to convert calcium into calcium carbonate needed for eggshell formation in laying hens. Zinc concentration in birds is directly related to the activity of this carbonic anhydrase enzyme. Zinc and manganese are cofactors of metalloenzymes which are responsible for carbonate and mucopolysaccharides synthesis and are important in eggshell formation. Moreover, zinc, calcium and manganese can affect structural properties of eggshell by affecting on calcite crystal formation and modification of the crystallographic structure of eggshell.

Pharmacological role of zinc

Zinc at 0.012-0.018% on a total-weight basis is commonly added as a supplement to all formulated poultry diets (Batal, 2001; Leeson and Summers, 1997). Currently, there are two inorganic feed-grade zinc sources commercially used by the poultry feed industry (Batal, 2001; Wedekind and Baker, 1990): zinc oxide (ZnO : 72% Zn) and zinc sulphate monohydrate ($\text{ZnSO}_4 \cdot \text{H}_2\text{O}$: 36% Zn). Of the supplemental zinc feed, 80-90% is ZnO, which is less bioavailable for poultry than reagent-grade or feed-grade Zn sulphate (Sandoval *et al.*, 1997; Edwards, 2000). However, the sulphate (acid salt) is highly water soluble, allowing reactive metal ions to promote free-radical formation, which can facilitate reactions that lead to the breakdown of vitamins and

ultimately to the degradation of fats and oils, decreasing the nutrient value of the diet (Batal, 2001). Oxide is less reactive, but also less bioavailable (Batal, 2001). Dietary zinc is relatively nontoxic to animals and humans; both exhibit considerable tolerance to high intakes of zinc (Fosmire, 2000). However, high levels of zinc in the diet can result in reduced growth rates in chicks (Dewar, 1983), lesions of the gizzard and pancreas in laying hens (Dewar, 1983), high mortality in chicks and reduced feed intake and egg production in laying hens (Hermayer *et al.*, 1977). Zinc toxicity is responsive to supplemental copper and both iron and zinc interfere with copper and iron metabolism (Rama and Planas, 1981). Zinc interferes with iron metabolism in chicks, iron-deficient chicks are more susceptible to the effects of zinc toxicity than are iron adequate chicks (Blalock and Hill, 1988). This is because iron might induce the synthesis of metallothionein in the liver.

Immunological role of zinc

Zinc has shown many effects on the immune system. Zinc is a component of hormone thymosin (produced by the thymus cell) which is required for immunity purpose. It helps in the production of T-lymphocytes in the thymus. Zn deficiency has shown to decrease cellular immunity, thymus and spleen development. Zn is an important element of thymus gland functioning and supports in T cell maturation and differentiation by Zn-dependent thymic hormone called thymulin. Zinc impacts immunity in poultry and zinc supplementation in breeder diets has shown

to enhance immunity of their progeny.

Dietary organic zinc supplementation at 80 mg kg⁻¹ in old broilers and 40 mg kg⁻¹ in young broilers improves immunity. Dietary organic zinc supplementation at the level of 40 or 80 mg kg⁻¹ in the layer diet improves survival of *E. coli* challenged old laying hens. Similarly, immunity in broilers can be improved by the level of organic zinc in the diet. Layer birds supplemented with organic zinc had increased thymus weight and improved liveability of progeny.

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Diseases of Groundnut in Assam

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Abstract

In India, Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra are major groundnut growing states account for about 89 per cent of the total groundnut area and contribute nearly 88 percent of the total groundnut production. In Assam, groundnut is a minor oilseed crop grown during *rabi* and spring seasons mainly under rainfed conditions. However, its cultivation has gained momentum in the recent past in the state with Government initiatives. A large number of diseases are known to be associated with groundnut crop, however, only some of them cause economic losses. Among the diseases, stem rot, collar rot, tikka leaf spots, rust and bud necrosis affect the groundnut crop both in *rabi* and summer in Assam.

Introduction

Groundnut (*Arachis hypogaea* L.) is major oilseed crop in India and is grown during *kharif*, *rabi* and spring/summer seasons. Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Rajasthan and Maharashtra are major groundnut producing states contributing about 80 percent area and production in India. In Assam, total oilseed crops occupy 3.42 lakh ha of area with a production of 2.66 lakh tons and productivity of 776 kg ha⁻¹ (2022-23; Directorate of Agriculture, Govt. of Assam, Khanapara, Guwahati). Groundnut is a minor oilseed crop in Assam grown during *rabi* and spring seasons mainly under rainfed conditions with high insect-pest and disease pressure. However, its cultivation has gained momentum in the recent past in the state with Government initiatives. More than 55 pathogens

including viruses have been reported to affect groundnut. Among diseases, stem rot, collar rot, tikka leaf spots, rust and bud necrosis affect the groundnut crop both in *rabi* and summer in Assam. However, the incidence and severity of these diseases vary from season to season. Diseases reduce the pod yield of groundnut manifold and also fodder quality of haulm. Among the seed and seedling diseases, collar rot/seedling blight (*Aspergillus niger* van Tieghem), stem rot/*Sclerotium* wilt (*Sclerotium rolfsii* Sacc.), dry wilt or dry root rot (*Macrophomina phaseolina* (Tassi) Goid. = *Rhizoctonia bataticola* (Taub., Butler) have been recognized as economically important diseases. Among the foliar fungal diseases, economically important are tikka leaf spot caused by *Cercospora arachidicola* Hori (Perfect stage-*Mycosphaerella arachidis* Deighton),

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rust caused by *Puccinia arachidis* Speg. and groundnut bud necrosis disease caused by tospovirus is widespread with a wide host range and is transmitted by *Thrips palmi* (Kendre *et al.*, 2000). The major diseases of groundnut and its management practices are discussed below.

Major diseases of seed and seedling

Collar rot (Causal organism: *Aspergillus niger*): It is prevalent in almost all groundnut growing states of India and the losses in terms of mortality of plants range from 28 to 50%. The inoculum present in the soil or adherent on seed surface germinates and attacks the seeds before its germination and causes pre-emergence rotting of seeds. It also causes decaying of hypocotyls, post-emergence seedling blight, rapid wilting of entire plant or its branches. Collar region of the affected plants becomes shredded and dark brown, covered by mycelial growth and spores. Soil borne inoculum is the primary source of infection.

Stem rot (Causal organism: *Sclerotium rolfsii*):

The initial symptoms are partial or complete wilting of the stem or branches that are in contact with the infected soil. White mycelial growth with brown colour sclerotia is visible on the infected plant parts. The leaves turn brown and wilt but remain attached to the plant. It causes peg infection, pod rot and leaf blight. The pathogen has a wide host range and can colonize either living plant tissues or plant debris. Deeply buried sclerotia



survive for years or less while those near soil surface remain viable for many years. The pathogen spreads through infected soil, wind splashed rain and sclerotia.

Dry root rot/ dry wilt/ charcoal rot (Causal

organism: *Macrophomina phaseolina*): The pathogen causes severe seedling mortality resulting in patchy crop stand and thus reduces yield. The diagnostic symptom is water soaked necrotic lesion that girdles the stem just above the ground level, followed by wilting. The taproot turns black and later rots and shreds. Kernels turn black with abundant sclerotia on inner wall of the shell and surface of the testa. Infected soil, plant debris and pods serve as the source of inoculum. The sclerotia get disseminated via plant debris, soil, infected pods, shell, and kernel.

Management for collar rot, stem rot and dry root

rot: Seed treatment with 2 g carboxin or 5 g thiram or 3 g mancozeb or 2 g carbendazim per kg of kernels (Anonymous, 2015, 2021).

Foliar fungal diseases

Tikka leaf spot (Causal organism: *Cercospora*

***arachidicola*):** The disease normally occurs 30 days after sowing. Initially minute circular to sub-circular chlorotic spots develop on upper surface of leaf which later turn into brown in colour and surrounded by yellow halo. Sporulation occurs on the upper surface of leaflet. Severely infected leaves may drop off prematurely. The lesion may extend to the stem and branches. The pathogen survives through



conidia on affected plant debris in soil or through conidia being carried on the pod shell. The pathogen also survives from one season to another on volunteer groundnut crop. Conidia disseminated by wind leads to secondary infection.

Rust (Causal organism: *Puccinia arachidis*):

Initially chlorotic spots develop on the upper surface of the leaf with orange coloured pustules (uredinia), corresponding to lower surface. The pustules range from 0.5 to 1.4 mm in diameter. Severely infected leaves turn necrotic and desiccate. The kernels formed in the affected plants shrivel and remain small. The disease perpetuate through uredinio-spores. In India, groundnut crop or volunteer plants are available in one or the other parts of the country enabling the survival of uredinial stage round the year. The pathogen may also survive from season to season on self-sown groundnut plants. Spread of the disease within growing crops is facilitated by wind movement, rain splash and also by insects.

Management for tikka leaf spot and rust:

Hexaconazole 5 EC @ 0.2 % or carbendazim 50 WP @ 0.05% should be sprayed as soon as the initial symptoms are detected followed by a second spray after 15-20 days with mancozeb 75 WP @ 0.2% (Anonymous, 2015, 2021).

Groundnut bud necrosis (Groundnut bud necrosis tospovirus): This is the most important virus disease of groundnut, widely distributed and causes yield losses from 30 to 90% depending upon plant growth stage at the time of infection. The typical symptoms of the disease are terminal bud

necrosis, severe stunting and proliferation of axillary shoots. Necrosis of the bud may spread to the petiole and stem, sometimes leading to death of the plants. In late infections pod size is reduced. Seeds are often wrinkled and have mottled and discoloured testa. Groundnut bud necrosis virus is also known as Peanut bud necrosis virus (PBNV). The vector of PBNV is *Thrips palmi* which transmits in circulative and propagative manner. The 1st or 2nd stage larvae acquire the virus and transmit during adult stage. The vector is viruliferous throughout its life time nevertheless, transovarial transmission is absent. The pathogen has a wide host range and survives on ornamentals (*Zinnia*, *cosmos* and *sunflower*), weeds (*Ageratum conyzoides*, *Cassia tora*, *Acanthospermum hispidum*, *Desmodium triflorum*) and crop plants (tomato, brinjal, green gram, black gram, beans and pea). The thrips population increases rapidly in late August and September. The population builds up again during January and February and hence *rabi* season crop also suffers seriously.

Management: Cultural methods like early planting, closer spacing and intercropping with tall crop which act as a barrier for the migration of vector, helps to reduce the disease (Anonymous, 2015, 2021).

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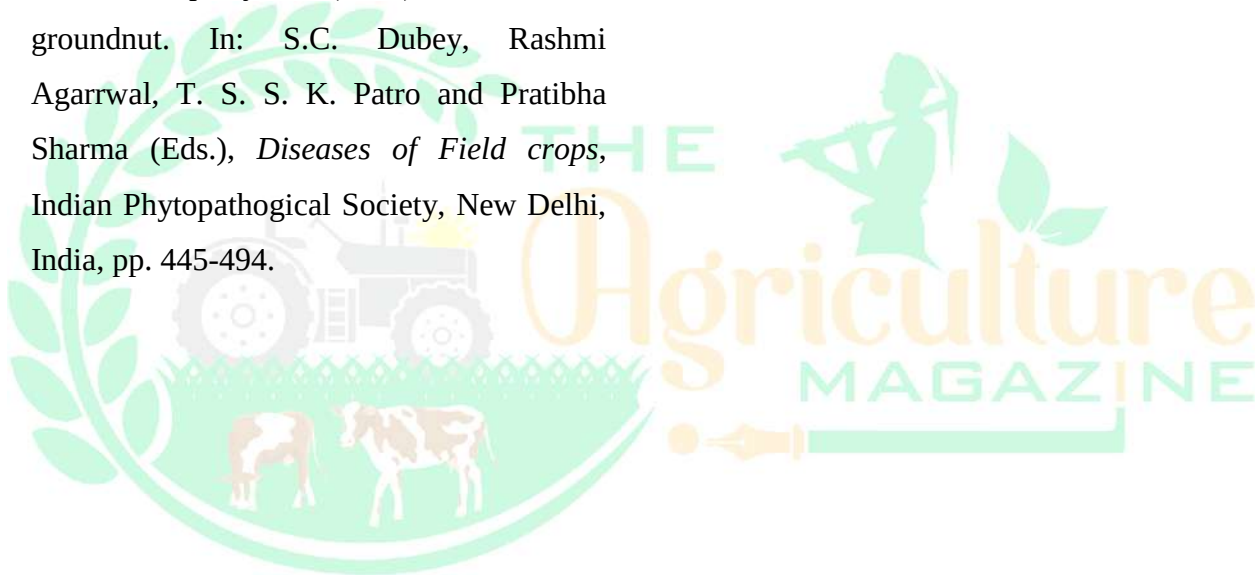
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Seed Quality Management in Radish Production

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Abstract

Radish (*Raphanus sativus*) is an important root crop in the Brassicaceae family, cultivated for both its edible roots and seeds. Seed production in radish requires careful planning, proper field management, and adherence to strict standards to ensure genetic purity and high seed quality. This guide outlines the key practices for successful radish seed production, including land preparation, sowing, irrigation, roguing, supplementary pollination, and field inspections. It emphasizes the importance of maintaining proper isolation distances to avoid contamination and specifies maximum permissible limits for off-types, diseased plants, and non-conforming roots. Additionally, it covers the stages of harvesting, seed extraction, drying, and cleaning to ensure seeds meet the required quality standards. Through effective management of environmental conditions and careful monitoring of seed purity, radish seed producers can ensure the production of high-quality seed with excellent germination rates and vigor.

Radish (*Raphanus sativus*) is a root crop that belongs to the family Brassicaceae and originates from the Mediterranean region. It has a chromosome number of $2n = 18$ and is a cross-pollinated crop relying on insect pollinators like bees and flies for fertilization. Anthesis occurs between 9:00 and 10:00 AM and is synchronized with anther dehiscence to ensure optimal pollen transfer. Pollen fertility is highest on the day of anthesis and the stigma remains receptive for up to four days to provide a suitable window for effective seed set.

Season: Radish seed production should occur in September-October in the hills and April-June in the plains, ensuring optimal growth conditions depending on the region.

Land Requirement: Select fields that have not grown radish or related crops in the past two years, unless certified to be free from seed-borne diseases. This ensures a healthy environment for seed production.

Seed Production Systems in Radish: Radish seed production follows two main systems: root-to-seed and seed-to-seed. Both methods are used depending on the crop type, climatic conditions, and production needs.

✓ **Root-to-Seed System:** This method is widely used for biennial radish types. It is common in Europe and other temperate regions. Roots are lifted in late autumn when they are mature. The tops of the plants are removed before storage.

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The roots are stored in clamps or similar conditions during winter. For annual radish types, this system is used for stock seed production. Selected roots are replanted immediately after selection. In some Asian regions, half of the root (steckling) is removed before replanting. This promotes better root growth and seed production.

- ✓ **Seed-to-Seed System:** This system is used for the final stages of seed multiplication. It is suitable for spring-sown seed crops. It does not require inspections of mature roots. This method works best for cultivars that do not need vernalization. The seed-to-seed system is simpler. It is often used for annual radish types. It ensures efficient seed production in suitable climates.

Cultural practices

Climate and Soil Requirements: Radish is a cool-season crop that thrives best in temperatures ranging from 10-25°C. It requires vernalization (exposure to low temperatures of 4-10°C) to trigger flowering and seed production. For optimal growth, radish needs well-drained loamy or sandy loam soils that are rich in organic matter. The ideal pH range for the soil is 6.0-7.5. It's crucial to avoid waterlogged soils as they can lead to root rot.

Land Preparation and Sowing: Land preparation involves plowing and harrowing the soil to achieve fine tilth. Incorporate well-rotted farmyard manure (15-20 tons ha⁻¹) during the final plowing to improve soil fertility. The sowing time for seed production is

typically September-October in temperate regions and October-November in tropical regions. The recommended seed rate is 4-6 kg ha⁻¹. Roots produced from one hectare can be transplanted to 2.5 ha, allowing efficient use of space. For spacing, maintain 30 × 15 cm for seed-to-seed production and 60 × 30 cm for root-to-seed production.

Manuring

- ✓ **First Season:** Apply 20-25 tons of farmyard manure (FYM) ha⁻¹ before field preparation. Fertilize with 75 kg nitrogen (35 kg basal + 35 kg top dressing), 50 kg phosphorus (basal) and 50 kg potash (basal).
- ✓ **Second Season (During Transplanting):** Apply 10-15 tons of FYM ha⁻¹ and 50 kg nitrogen (25 kg at pre-bolting + 25 kg before flowering), along with 50 kg phosphorus (basal).

Irrigation: Frequent irrigation is necessary during both the vegetative and reproductive phases. It is especially important to maintain sufficient moisture during flowering and seed setting to ensure good seed yield. However, over-irrigation should be avoided to prevent waterlogging and root issues.

Field Inspection for Radish Seed Production:

Field inspection is a critical step in ensuring the genetic purity and quality of radish seeds. It is conducted during two stages: the Mother Root Production Stage and the Seed Production Stage.

Mother Root Production Stage

First Inspection: This inspection is conducted 20-30 days after sowing. The primary objective is to verify the required isolation distance, identify off-types,

and evaluate other relevant factors that may affect seed quality.

Second Inspection: The second inspection takes place after the roots have been lifted. This step ensures the roots exhibit the true characteristics of the variety, confirming their suitability for seed production.

Seed Production Stage

Flowering Inspection: At least one inspection is carried out during the flowering stage. This inspection checks for proper isolation distances, identifies off-types, monitors designated diseases, and ensures compliance with seed production standards.

Supplementary Pollination: Honeybees play a crucial role as pollinating agents in radish seed production. To enhance pollination efficiency, especially in large seed fields, it is recommended to place beehives within or near the fields. This practice becomes particularly essential when temperatures drop below 15°C, as natural pollination activity may decrease under such conditions. The presence of honeybees ensures better fertilization, resulting in higher seed yield and quality.

Roguing: Roguing is a critical step in radish seed production to maintain varietal purity and quality. A minimum of three field inspections should be conducted:

- ✓ **First Inspection:** At 20-30 days after sowing.
- ✓ **Second Inspection:** When roots are lifted and replanted.
- ✓ **Third Inspection:** During the flowering stage.

Roguing involves removing undesirable plants based on:

- ✓ **Root Characteristics:** Plants with roots not conforming to the desired traits are eliminated.
- ✓ **Flower Characteristics:** Plants with atypical flowers are removed.
- ✓ **Disease Status:** Plants showing signs of disease are discarded.

Regular roguing ensures that the final seed lot is genetically pure, free from off-types, and unaffected by seed-borne diseases.

Field Standards for Radish Seed Production

To ensure high-quality seed production in radish, specific field standards are followed. These standards cover isolation distances and permissible limits for off-types, non-conforming roots, and seed-borne diseases.

General Requirements

Isolation: Seed fields must maintain a specified isolation distance to prevent contamination. The required distances are:

Contaminants	Mother Root Production Stage	Seed Production Stage
Fields of other varieties of the same species	5 meters (Foundation and Certified)	1600 m (Foundation), 1000 m (Certified)
Fields of the same variety not conforming to purity standards or rat-tail radish (<i>Raphanus caudatus</i>)	5 meters (Foundation and Certified)	1600 m (Foundation), 1000 m (Certified)

Specific Requirements: Specific standards are established to maintain varietal purity and minimize the impact of diseases. The maximum permissible levels for various factors are as follows:

Factor	Foundation Seed (%)	Certified Seed (%)
Roots not conforming to varietal characteristics	0.10 (by number)	0.20 (by number)
Off-types	0.10	0.20
Plants affected by seed-borne diseases (final inspection)	0.10	0.50

Harvesting and Processing: Radish seed production requires careful harvesting and processing to ensure high-quality seeds:

Harvesting: Plants are harvested when they are fully mature, and the siliques turn brown, indicating seed maturity. The entire plants are cut and removed from the field for further processing.

Drying: Thorough drying of siliques is essential for easy seed extraction. Proper drying reduces moisture content, preventing seed spoilage.

Seed Extraction: Seeds are separated from siliques by gently beating the plants with pliable sticks. This method ensures minimal damage to the seeds.

Drying to Safe Moisture Content: Extracted seeds are further dried to a safe moisture level of 6% to enhance storage longevity.

Cleaning: The seeds are cleaned to remove debris and broken material, ensuring a uniform and pure seed lot ready for storage or marketing.

This process ensures the production of high-quality seeds with good germination and vigor.

Seed Standards for Radish

Factor	Foundation (%)	Certified (%)
Pure Seed (Min.)	98.0	98.0
Inert Matter (Max.)	2.0	2.0
Other Crop Seeds (Max.)	5 seeds kg ⁻¹	10 seeds kg ⁻¹
Weed Seeds (Max.)	10 seeds kg ⁻¹	20 seeds kg ⁻¹
Germination (Min.)	70	70
Moisture Content (Max.)	6.0	6.0
Moisture Content (vapor-proof containers)	5.0	5.0

Conclusion

Radish seed production requires careful management of land, pollination, roguing, and field inspections to ensure high-quality seeds. Adhering to isolation distances, disease control measures, and seed standards is crucial for maintaining genetic purity and optimizing seed quality. By following these practices, producers can achieve healthy, vigorous seeds that meet certification requirements and contribute to sustainable agriculture.

Standards and Practices in Carrot Seed Production

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Abstract

Carrot (*Daucus carota* L.) is a biennial root vegetable valued for its nutritional content, particularly beta-carotene, vitamins, and fiber. Effective seed production is crucial to ensuring high-quality carrot seeds for sustainable cultivation. The process involves two primary methods: Seed-to-Seed and Root-to-Seed, each with specific advantages and limitations. Carrot is a cross-pollinated crop, requiring optimal pollination management, particularly through insect activity, to ensure seed setting. Roguing, field inspections, and adherence to field and seed standards are essential to maintain varietal purity and seed quality. Proper land preparation, fertilization, and harvesting practices further ensure seed viability. The average seed yield ranges from 800-1000 kg ha⁻¹. Adherence to quality standards, including purity, germination, and moisture content, is vital for seed certification. Carrot seed production supports improved crop performance and sustainable agricultural practices.

Carrot (*Daucus carota* L.) is a biennial root vegetable valued for its rich nutritional content, including beta-carotene, vitamins, and dietary fiber. The crop is cultivated globally and is a major source of antioxidants in the human diet. Carrot seed production is a specialized process requiring specific climatic, agronomic, and post-harvest practices to ensure high-quality seeds for consistent crop performance.

Botanical and Growth Characteristics: Carrot belongs to the Apiaceae family and has a chromosome number of $2n = 18$. The crop completes its lifecycle in two years: in the first year, it develops a fleshy root, and in the second, it produces seeds after vernalization. Carrot is a highly cross-pollinated crop, with pollination primarily facilitated

by bees and other insects.

Land Requirements: To maintain seed purity and avoid disease contamination, fields used for carrot seed production must not have grown carrots or other Apiaceae crops for at least three years. The soil should be well-drained, rich in organic matter, and have a pH of 6.0-7.0. Loamy soils are preferred for root development.

Methods of Seed Production in Carrot

Carrot seed production employs two primary methods: the Seed-to-Seed Method (in situ) and the Root-to-Seed Method (transplanting of cut roots or stecklings). Both methods have distinct advantages and are used based on the climatic conditions, crop variety, and desired seed quality.

Seed-to-Seed Method (In Situ Method): In this

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method, the carrot crop is grown and left in the field for its entire lifecycle from root formation in the first year to flowering and seed production in the second year. Carrot seeds are sown directly in the field during the appropriate season, with temperate varieties in regions like Himachal Pradesh typically sown in October and November to align with favorable climatic conditions. The roots remain undisturbed in the field throughout winter, undergoing vernalization a necessary cold period for inducing flowering. As temperatures rise in spring, the plants bolt, producing flowers and eventually seeds. Being a cross-pollinated crop, carrot relies primarily on insect-mediated pollination, particularly by bees, making pollinator activity crucial for optimal seed setting. Once the umbels mature and turn brown, indicating fully developed seeds, they are harvested to ensure seed quality and viability. The seed rate for carrot production is typically 2 to 3 kilograms per hectare. A row spacing of 50 to 90 centimeters is maintained to ensure optimal plant growth and development. To enhance germination, soaking seeds in water for 72 hours with a water change every 24 hours helps leach out inhibitors that may hinder seed sprouting.

Advantages

- ✓ Simple and requires less manual labor, as the roots do not need to be transplanted.
- ✓ Suitable for regions with mild winters where roots can survive in the field without frost damage.

Limitations

- ✓ **Roguing Challenge:** Since roots remain in the soil, they cannot be inspected for quality, making it difficult to remove off-types or diseased roots.
- ✓ **Susceptibility to Adverse Conditions:** Extreme winter conditions or excessive moisture can damage roots, affecting seed quality.

Root-to-Seed Method (Transplanting of Cut Roots/ Stecklings)

This method involves harvesting roots after the first growing season, inspecting and selecting quality roots (stecklings), and then replanting them for seed production in the second year.

Carrots are cultivated as a regular root crop during the standard growing season. Mature roots are harvested late in the first growing season after ensuring they are true-to-type and disease-free. In areas with severe winters, roots are lifted from the soil and stored in cold and ventilated conditions to avoid frost damage. In spring, stored roots are trimmed and replanted in prepared beds at appropriate spacing to support flowering and seed development. The vernalized roots flower and set seeds during the next growing season. Cross-pollination occurs with the help of insect pollinators, which is essential for proper seed setting. Mature umbels are harvested when the seeds are fully developed and turn brown. Raising stecklings in beds before transplanting allows for the removal of plants with undesirable root or foliage traits during the lifting and planting process. This ensures that only healthy and true-to-type plants are selected for seed production.

Advantages

Quality Assurance: Since roots are inspected and selected before replanting, only true-to-type and disease-free roots are used, ensuring high seed quality.

Flexibility: Allows for storage of roots, which can be beneficial in regions with harsh winters.

Limitations

Labor-Intensive: Requires additional effort to harvest, inspect, store, and replant roots.

Cost: Higher production costs due to additional labor and resources for root storage.

Comparison of Seed-to-Seed and Root-to-Seed Methods

Feature	Seed-to-Seed Method	Root-to-Seed Method
Root Inspection	Not possible	Possible
Vernalization	In situ in the field	Controlled during storage
Labor Requirement	Lower	Higher
Seed Quality	May include off-types or diseased roots	Higher quality through selection
Climatic Suitability	Regions with mild winters	Regions with harsh winters

Land Preparation and Sowing: Prepare the soil to a fine tilth by plowing and harrowing. Apply 20-25 tons of farmyard manure per hectare during land preparation. Sow carrot seeds at a depth of 1-2 cm in rows spaced 30-45 cm apart. For the root-to-seed method, transplant roots at a spacing of 60 × 45 cm.

Fertilizer Management: Provide a basal application of 60-80 kg nitrogen, 40-60 kg phosphorus (P_2O_5), and 40-60 kg potassium (K_2O) per hectare. Split the remaining nitrogen into two doses applied at 30-day intervals.

Pollination Management: Carrot is a highly cross-

pollinated crop. Adequate insect pollinators, particularly honeybees, are necessary for successful seed setting. Place bee hives near the field to enhance pollination efficiency.

Field Inspection

Mother Root Production Stage

First Inspection: Conducted 20-30 days after sowing to assess isolation, the presence of volunteer plants, outcrosses, off-types and other relevant factors.

Second Inspection: Performed after lifting the mother roots to ensure their true-to-type characteristics and confirm uniformity.

Seed Production Stage

First Inspection: Conducted before flowering to evaluate isolation, volunteer plants, outcrosses, and other crucial factors.

Second and Third Inspections: Carried out during flowering to monitor isolation, off-types, and other relevant considerations.

Fourth Inspection: Performed at maturity to verify the true nature of the umbels and ensure the quality of the seeds.

Field Standards

General requirements: Isolation

Contaminants	Minimum distance (meters)			
	Mother root production stage		Seed production stage	
	Foundation	Certified	Foundation	Certified
Fields of other varieties	5	5	1000	800
Fields of the same variety not conforming to varietal purity requirements for certification	5	5	1000	800

Specific requirements

Factor	Maximum permitted (%)*	
	Foundation	Certified
*Roots not conforming to the varietal characteristics including forked roots	0.10% (by number)	0.20% (by number)
**Off-types (plants)	0.10%	0.20%

*Maximum permitted at second inspection at mother root production stage.

**Maximum permitted at and after flowering at seed production stage

Roguing Practices in Carrot Seed Production:

Roguing is a critical practice in carrot seed production to maintain varietal purity and ensure high-quality seeds. The focus during roguing is on removing plants with undesirable traits, including root color, shape, skin, flesh characteristics, and bolting behavior. In seed-to-seed production, where the crop is grown continuously without lifting, limited roguing is performed, primarily to remove early bolting plants and those with atypical foliage. If the crop is lifted and replanted, roguing should follow the guidelines for root-to-seed production, although confirming root type may be more challenging in this system.

In root-to-seed production, roguing begins during the first growing season by eliminating plants with atypical foliage and those that bolt prematurely during root development. After the roots are lifted, they are inspected for trueness to type based on traits such as shape, size, and color. Roots with defects, including green shoulders, incorrect or off-colored shoulders (e.g., purple or green), splits, fangs, or rough surfaces, are discarded. By systematically removing undesirable plants and roots, roguing ensures the production of seeds with consistent and

desirable characteristics.

Harvesting and Processing: Carrot seeds mature unevenly, requiring multiple pickings for efficient harvesting. Seeds are collected when the secondary umbels are fully mature and brown, while tertiary umbels start turning brown. Typically, 2 to 3 pickings are needed to gather all seeds. After harvesting, seed heads are dried and threshed to separate the seeds. The seeds are then rubbed by hand to remove bristles, cleaned thoroughly, and dried to a moisture content of 8% for proper storage.

Seed Yield: The average seed yield of carrots ranges from 800-1000 kg ha⁻¹, depending on the cultivar, growing conditions, and management practices.

Seed Standards: Carrot seed standards ensure quality for planting. The parameters for foundation and certified seeds are as follows:

Factor	Foundation Seed	Certified Seed
Pure Seed (Min.)	98.0%	98.0%
Inert Matter (Max.)	2.0%	2.0%
Other Crop Seeds (Max.)	5 kg ⁻¹	10 kg ⁻¹
Weed Seeds (Max.)	5 kg ⁻¹	10 kg ⁻¹
Germination (Min.)	70%	70%
Moisture (Max.)	7.0%	7.0%

Conclusion

Carrot seed production is a detailed process requiring proper cultivar selection, field preparation, and adherence to quality standards. By utilizing appropriate seed production methods and managing pollination, fertilizer, and irrigation effectively, high-quality seeds can be produced. This ensures better crop performance and supports sustainable carrot farming practices.

Organic Farming: A Path to Sustainable Food Systems and Environmental Health

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Abstract

With growing concerns about population growth, climate change, and environmental damage, agriculture must adapt to more sustainable practices. Organic farming offers a promising alternative to conventional methods, which often rely on synthetic chemicals and harm the environment. By focusing on natural processes, biodiversity, and long-term sustainability, organic farming improves soil health, supports wildlife, and helps combat climate change. This article highlights the principles of organic farming, its environmental benefits like healthier soils and biodiversity preservation, and its positive economic and social impacts, such as producing safer, healthier food and supporting rural communities. While the transition to organic farming can be challenging due to higher costs and labour demands, its future looks bright with increasing consumer demand, supportive policies, and innovative technologies. Organic farming is more than just a way to grow food it's a pathway to healthier ecosystems, stronger rural livelihoods, and a sustainable future. As awareness and collaboration grow, organic farming has the potential to transform how we produce food while caring for the planet.

Introduction

As the global population grows and climate change intensifies environmental challenges, agriculture faces mounting pressure to meet the rising demand for food. Yet, conventional farming practices, which rely heavily on synthetic fertilizers, pesticides, and monoculture cropping, have led to soil degradation, water pollution, and biodiversity loss. Amid these issues, organic farming is emerging as a promising solution (Tscharntke *et al.*, 2021). By avoiding harmful chemicals and embracing practices that work in harmony with nature, organic farming

offers a path to creating sustainable food systems that prioritize both human health and environmental well-being (Das *et al.*, 2020). This article explores the principles, benefits, challenges, and future prospects of organic farming, highlighting its potential to restore ecological balance and promote healthier food systems.

What is Organic Farming?

Organic farming is an agricultural approach focused on sustainability, biodiversity, and ecological health. Unlike conventional farming, which depends on synthetic chemicals and genetically

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modified organisms (GMOs), organic farming uses natural methods to improve soil fertility, control pests, and support plant health. Practices such as crop rotation, composting, biological pest control, and the avoidance of synthetic inputs are integral to organic farming.

At its core, organic farming works with nature rather than against it. Farmers aim to enhance soil fertility, encourage biodiversity, and reduce the environmental footprint of farming. This approach contrasts sharply with industrial agriculture, which often prioritizes short-term profits over long-term ecological health.



<https://www.khetivyapar.com/en/organic-farming-sustainable-organic-farming-50>

Environmental Benefits of Organic Farming

The environmental benefits of organic farming are profound, particularly in terms of soil health, biodiversity preservation, and climate change mitigation (Gamage *et al.*, 2023).

Soil Health and Fertility

- ✓ Organic farming has a remarkable impact on soil health. Conventional farming, with its heavy use of chemical fertilizers and intensive tilling, often results in soil erosion, reduced organic matter, and a decline in soil microbial activity.

- ✓ Organic farming, however, focuses on enriching the soil with compost, manure, and crop residues.
- ✓ These practices help improve soil structure, enhance water retention, and increase organic carbon levels, which are essential for long-term soil health. Moreover, healthy soils are crucial for mitigating climate change.
- ✓ Organic farming systems store more carbon in the soil than conventional systems, helping to offset greenhouse gas emissions and combat global warming.

Biodiversity Preservation

- ✓ Biodiversity is another key advantage of organic farming. In conventional agriculture, monoculture cropping and extensive use of chemicals have led to a decline in plant and animal species.
- ✓ Organic farms, by contrast, are generally more diverse, with a mix of crops, cover plants, and natural habitats that support wildlife.
- ✓ Organic farming practices such as crop rotation and intercropping foster environments where beneficial insects, pollinators, and wildlife thrive.
- ✓ These practices help maintain ecological balance and reduce the reliance on harmful pesticides, which can harm pollinators like bees and butterflies. By promoting biodiversity, organic farming helps stabilize ecosystems and enhances resilience against environmental changes (Łuczka and Kalinowski, 2020).

Climate Change Mitigation

- ✓ Organic farming also plays a role in mitigating

climate change. In addition to sequestering carbon, organic farming reduces greenhouse gas emissions by eliminating synthetic fertilizers, which are energy-intensive to produce.

- ✓ Organic farming methods are typically less dependent on fossil fuels since they rely more on labour-intensive practices like hand weeding and mechanical cultivation.
- ✓ By supporting soil health and reducing environmental harm, organic farming is an essential part of the broader effort to reduce the agricultural sector's carbon footprint and address climate change (Clark, 2020).

Economic and Social Benefits of Organic Farming

- ✓ Beyond its environmental advantages, organic farming offers economic and social benefits that promote a more sustainable and equitable food system.

Healthier Food Production

- ✓ Organic farming is often linked to healthier food, as it avoids the use of synthetic chemicals like pesticides and herbicides, which are associated with health risks.
- ✓ Organic foods are grown in ways that support ecological health and are generally free from harmful residues.
- ✓ Studies suggest that organic foods may also contain higher levels of certain nutrients, such as antioxidants, which contribute to overall health.
- ✓ For consumers, choosing organic means supporting a food system that prioritizes both

human health and environmental sustainability.

Economic Viability

- ✓ Although organic farming can be more labour-intensive and costly at first due to certification fees and organic inputs, it can provide financial benefits in the long run. Organic products often fetch higher prices in the market, driven by growing demand for healthier and more eco-friendly options.
- ✓ This price premium offers organic farmers the opportunity for better incomes, particularly in niche markets.
- ✓ Additionally, organic farming stimulates local economies by supporting small-scale farmers, reducing dependence on imported chemical inputs, and encouraging sustainable practices.

Social Impact

- ✓ Organic farming also has a positive social impact. It fosters stronger communities by promoting collaboration and knowledge-sharing among farmers.
- ✓ These relationships often lead to mutual support and the exchange of best practices.
- ✓ Moreover, organic farming is more labour-intensive, creating more job opportunities in rural areas, where employment options can be limited.

Prospects of organic farming

The future of organic farming looks bright as more people seek healthier, environmentally friendly food options. Governments and organizations are stepping up with policies and support to make organic farming more accessible for farmers.

Innovations like natural pest control and precision tools are making it easier and more efficient to grow organic crops. In a world grappling with climate change, organic farming's focus on healthy soil, biodiversity, and resilience to extreme weather makes it a vital solution. Beyond its environmental benefits, it also supports rural communities by creating jobs and empowering small farmers. With growing awareness and collaboration, organic farming is on track to shape a healthier, more sustainable future for all.

Conclusion

Organic farming is more than just a method of food production; it is a vital pathway toward a sustainable and equitable agricultural system. By enhancing soil health, preserving biodiversity, and mitigating climate change, organic farming offers a holistic solution to some of the most pressing environmental challenges of our time. As demand for organic products continues to grow, it holds the potential to shape a future where food systems are both sustainable and beneficial to the planet and its people.

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A Trellis System for Climbing Plants and its Different Management Practices

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Abstract

A demo unit of trellis system was established at KVK, Bargarh for farmers learning purposes. A trellis system is a framework or structure used to support climbing plants, such as vines, in agricultural, gardening, or landscaping applications. Trellis systems can be simple or complex and are designed to improve plant health, optimize space, and make maintenance easier. Effective nutrient management is crucial in a trellis system to ensure plants receive the necessary nutrients for optimal growth and productivity. Because trellised plants grow vertically and often produce higher yields, they may have higher nutrient requirements compared to ground-level cultivation. Crop management in a trellis system involves implementing practices that maximize productivity, ensure healthy plant growth, and make efficient use of space and resources.

Introduction

The trellis system is an agricultural and horticultural practice where plants are trained to grow vertically on structures such as frames, grids, or netting. This method has been utilized for centuries to maximize space, improve crop management, and enhance yield quality. In modern agriculture, trellis systems are highly valued for their ability to optimize plant growth and facilitate efficient

resource use. At its core, the trellis system is designed to support climbing or vining plants, allowing them to grow off the ground. This vertical growth reduces competition for light, enhances air circulation, and minimizes contact with soil, which can lead to rot and pest infestation. Commonly trellised crops include fruits like grapes, passionfruit, and melons; vegetables such as tomatoes, cucumbers and beans; and ornamental plants like climbing roses

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and clematis. The trellis system offers numerous benefits. It improves plant health by reducing the incidence of soil-borne diseases and pests. Additionally, it maximizes space utilization, making it ideal for small gardens and urban farming. Trellised plants also receive better exposure to sunlight, resulting in higher-quality produce. Furthermore, this system facilitates easier harvesting and maintenance by keeping fruits and foliage at an accessible height. However, the trellis system also comes with challenges. It requires a higher initial investment for materials and construction compared to traditional farming methods. Maintenance can be labor-intensive, as plants need regular pruning, training, and monitoring. Moreover, improper design or overloading can lead to structural failure, especially in adverse weather conditions. Despite these challenges, the trellis system is widely adopted due to its versatility and effectiveness. It is employed in both small-scale gardening and large-scale farming operations, particularly in vineyards and vegetable farms. Innovations in trellis design, such as modular and mobile structures, have further expanded its applications.

Crop management in trellis system

Crop Selection

Climbers and Vines: Choose crops that naturally climb or can be trained to grow vertically. Examples include:

- ✓ **Vegetables:** Tomatoes, cucumbers, peas, beans, gourds, and squash.
- ✓ **Fruits:** Grapes, passionfruit, melons, and kiwis.

- ✓ **Ornamentals:** Climbing roses, clematis, and honeysuckle.

Growth Characteristics: Ensure the plant's growth habit and weight are suitable for the trellis system.

Trellis Design

Material and Structure: Select materials (wood, metal, or plastic) that match the crop's weight and growth habit.

Height and Spacing

- ✓ Allow adequate spacing between plants for airflow and light penetration.
- ✓ Design the height based on the crop's growth potential, making sure it's accessible for maintenance and harvesting.

Planting

Plant Density: Avoid overcrowding by adhering to recommended spacing for the crop.

Plant Orientation: Align rows to maximize sunlight exposure, typically north-south orientation in open fields.

Companion Planting: Incorporate companion plants for pest control, nutrient improvement, or space optimization.

Pruning and Training

Regular Pruning

- ✓ Remove unnecessary shoots and leaves to direct energy toward fruit and flower production.
- ✓ Eliminate diseased or damaged parts to reduce pest and disease risk.

Training Plants

- ✓ Secure vines to the trellis using ties, clips, or twine to guide their growth.

- ✓ Avoid tying too tightly to prevent damaging the stems.

Irrigation

Efficient Watering

- ✓ Use drip irrigation systems to deliver water directly to the root zone, minimizing waste and preventing wet foliage.
- ✓ Ensure consistent moisture levels, particularly during flowering and fruiting stages.

Mulching: Apply organic mulch around the base to retain moisture and reduce evaporation.

Fertilization

Targeted Nutrition

- ✓ Base fertilizer application on soil tests to meet the specific nutrient needs of the crop.
- ✓ Use nitrogen-rich fertilizers during early growth and switch to phosphorus and potassium during flowering and fruiting stages.

Fertigation: Combine irrigation with soluble fertilizers for precise nutrient delivery.

Pest and Disease Management

Integrated Pest Management (IPM)

- ✓ Monitor plants regularly for signs of pests like aphids, mites, or caterpillars.
- ✓ Use biological controls (e.g., beneficial insects like ladybugs) and cultural practices (e.g., crop rotation) to manage pests.

Disease Prevention

- ✓ Maintain good air circulation by spacing plants and pruning foliage.
- ✓ Avoid wetting leaves during irrigation to reduce fungal risks.

Crop Rotation: Rotate crops annually to prevent the buildup of soil-borne pathogens and pests.

Weed Control

Mulching: Suppress weed growth around the base of the plants using straw, wood chips, or black plastic mulch.

Manual Weeding: Regularly remove weeds to prevent competition for nutrients and water.

Harvesting

Accessibility: Trellised crops are easier to harvest due to their elevation and organization.

Timely Harvest: Harvest fruits and vegetables at the right maturity to encourage continuous production and maintain quality.

Seasonal Maintenance

Trellis Inspection: Regularly check the trellis for damage or wear, especially after storms or high winds.

Off-Season Care

- ✓ Remove old vines and plant debris to prevent disease carryover.
- ✓ Repair or replace trellis components as needed.

Maximizing Space

Intercropping: Utilize the space beneath the trellis for shade-tolerant crops or cover crops.

Succession Planting: Grow multiple crops in the same area throughout the year to maximize productivity.

Record Keeping

Growth Monitoring: Track planting dates, pruning schedules, and harvest yields to identify areas for improvement.

Pest and Disease Logs: Document issues and their solutions to refine future management practices.

Nutrient management in trellis system

Soil Preparation

Soil Testing: Conduct a soil test before planting to understand nutrient levels, pH, and organic matter content.

Amendments: Based on test results, amend the soil with organic matter, such as compost or well-rotted manure, to improve fertility and structure.

Adjust pH: Ensure the soil pH is within the optimal range (typically 6.0-7.0 for most crops) to maximize nutrient availability.

Fertilization

Base Fertilization: Apply a balanced fertilizer (e.g., NPK 10-10-10) during soil preparation to provide essential macronutrients.

Split Applications: Divide fertilizer applications into smaller doses throughout the growing season to match plant uptake and avoid leaching.

Crop-Specific Needs

Nitrogen (N): Essential for leafy growth and vine development, especially during early growth stages.

Phosphorus (P): Promotes root development and flower/fruit production.

Potassium (K): Enhances disease resistance and fruit quality, critical for trellised fruiting plants like tomatoes or cucumbers.

Organic Nutrient Sources

Compost and Manure: Provide a slow-release source of nutrients and improve soil health.

Bone Meal: A good source of phosphorus for flower

-ing and fruiting plants.

Wood Ash: Supplies potassium but should be used cautiously to avoid altering soil pH excessively.

Liquid Fertilizers: Organic teas (e.g., compost or fish emulsion) can be applied during peak growth periods for an immediate nutrient boost.

Drip Irrigation with Fertigation

Efficient Delivery: Combine trellis systems with drip irrigation to deliver water and soluble nutrients directly to the root zone.

Customizable Feeding: Use water-soluble fertilizers to meet the precise nutritional needs of the plants during different growth stages.

Monitoring Plant Health

Leaf Observation: Regularly inspect plants for signs of nutrient deficiencies or toxicities:

- ✓ Yellowing leaves (nitrogen deficiency)
- ✓ Poor flowering or fruiting (phosphorus deficiency)
- ✓ Scorched leaf edges (potassium deficiency)

Tissue Testing: Conduct leaf tissue analysis to determine nutrient levels during the growing season.

Mulching

Moisture Retention: Organic mulch (e.g., straw or wood chips) helps retain soil moisture and prevent nutrient leaching.

Nutrient Addition: As organic mulch breaks down, it adds nutrients to the soil.

Crop Rotation and Intercropping

Prevent Nutrient Depletion: Rotate crops to prevent the overuse of specific nutrients and reduce pest pressure.

Legume Intercropping: Include legumes (e.g., beans or peas) in the trellis system to fix atmospheric nitrogen into the soil.

Avoid Over-Fertilization

Balance Nutrients: Excess nutrients, particularly nitrogen, can lead to excessive foliage growth at the expense of flowers and fruits.

Environmental Concerns: Over-fertilization can lead to nutrient runoff, causing environmental harm.

Foliar Feeding

Supplemental Feeding: Apply foliar sprays of micronutrients (e.g., zinc, iron, boron) if deficiencies are detected.

Quick Absorption: Foliar feeding is especially useful during flowering and fruiting stages.

Continuous Monitoring and Adjustments

Regular Assessments: Evaluate plant growth, yield, and soil health throughout the season to adjust nutrient inputs as needed.

Long-Term Soil Health: Incorporate cover crops or green manures during the off-season to replenish nutrients and improve soil structure.

Conclusion

In conclusion, the trellis system is a sustainable and efficient agricultural practice that enhances productivity and quality. By enabling vertical growth, it not only optimizes space but also contributes to better crop management. As agriculture evolves to meet the demands of a growing population, the trellis system remains a valuable tool for maximizing yields and ensuring environmental sustainability.

Development of Novel Silkworm Diets for Enhanced Silk Production and Reduced Environmental Impact

Kiruthika C. and Bhuvana S.

Introduction

Silk production, a key component of the global textile industry, has been a major part of human history and culture for thousands of years. The silkworm (*Bombyx mori*) is the primary insect species used in sericulture to produce silk. The traditional practice of sericulture involves rearing silkworms on a diet consisting mostly of mulberry leaves, which serve as the main food source. The development of novel silkworm diets that enhance silk production while minimizing the environmental impact is crucial for sustainable sericulture practices. This article explores the advancements in silkworm nutrition and the development of alternative and sustainable diets for silkworms. It will cover the role of traditional and novel diets, the impact of diet on silk yield and quality, environmental sustainability, and the integration of new technologies to develop improved feeding strategies. The aim is to provide a comprehensive understanding of how these developments contribute to both higher silk productivity and a reduced ecological footprint.

Traditional Silkworm Diets and their Limitations

Silkworms are primarily fed mulberry leaves (*Morus alba*), which provide the necessary nutrients for growth, development, and silk production. Mulberry cultivation is energy and water-intensive

and large-scale sericulture requires vast amounts of mulberry leaves, which contribute to deforestation, soil degradation, and water scarcity in regions where sericulture is practiced intensively.

Limitations of Mulberry-based Diets

Resource Intensity: The monoculture of mulberry trees is resource-heavy, requiring substantial amounts of water, pesticides and fertilizers. Furthermore, the cultivation of mulberry trees consumes valuable arable land, often displacing other crops or natural ecosystems.

Seasonality: Mulberry trees are seasonal in their leaf production, which results in a fluctuation of feed availability. This seasonal dependency can hinder continuous sericulture operations.

High Production Costs: The labor and resource inputs required for growing and harvesting mulberry leaves translate into higher costs for silk producers, particularly in regions where land and water are scarce or expensive.

Environmental Impact: The environmental consequences of mulberry farming such as pesticide use, soil erosion, and loss of biodiversity are significant. In addition, large-scale silkworm rearing operations require a considerable amount of energy and water to maintain the silkworms and process the silk.

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Given these drawbacks, there is a growing interest in developing alternative silkworm diets that can reduce the environmental burden and improve the sustainability of the sericulture industry.

The Need for Alternative Diets

The increasing demand for silk, combined with the environmental and economic limitations of mulberry-based diets, necessitates the exploration of alternative feeding strategies. Sustainable silkworm diets could be derived from a range of organic and agro-industrial by-products, waste materials, and synthetic feeds that reduce reliance on mulberry trees while providing the necessary nutrients for optimal growth and silk production.

Key Objectives in the Development of Alternative Diets

Enhancing Silk Production: Novel diets should not only sustain silkworm growth but should also enhance the quantity and quality of silk produced. This involves improving silk thread length, strength, and luster.

Reducing Environmental Impact: Alternative diets must minimize the ecological footprint of sericulture by reducing water and land usage, lowering pesticide dependency, and utilizing agro-industrial waste products.

Cost-Effectiveness: Reducing the cost of silk production is crucial for improving the economic viability of sericulture, especially in regions where mulberry cultivation is not feasible or is too expensive.

Nutritional Adequacy: The diet should meet all of

the silkworm's nutritional needs, including proteins, carbohydrates, lipids, vitamins, and minerals, to ensure healthy growth and optimal silk production.

Development of Novel Silkworm Diets

Recent research has focused on developing alternative diets that utilize diverse materials with the potential to replace or supplement mulberry leaves. These include agricultural by-products, plants, algae, animal-based proteins and even synthetic compounds. Below are some of the most promising developments in novel silkworm diets.

Utilization of Agro-industrial By-products

Agro-industrial by-products such as wheat bran, rice bran, soybean meal, and corn stalks are being explored as potential alternatives to mulberry leaves. These by-products are often discarded as waste, yet they are rich in essential nutrients like proteins, carbohydrates, and fibers, which are crucial for silkworm development.

Rice Bran: Studies have shown that rice bran, which is a by-product of rice milling, can be a suitable substitute for mulberry leaves in silkworm diets. Rice bran contains protein, fat, and fiber, which contribute to the growth of silkworms. The use of rice bran has been linked to higher silk yield and quality compared to traditional diets.

Soybean Meal: Soybean meal, a common by-product of soybean oil extraction, is rich in high-quality protein, which is essential for silkworm growth. Research has shown that supplementing silkworm diets with soybean meal can lead to increased silk production without compromising the

overall health of the insects.

Incorporation of Alternative Plant Materials

Moringa Leaves: Moringa (*Moringa oleifera*) leaves are high in proteins, vitamins, and minerals, making them a strong candidate as an alternative feed for silkworms. Studies have demonstrated that feeding silkworm's moringa leaves can result in comparable or even improved silk yield compared to mulberry-based diets.

Sweet Potato Leaves: Sweet potato leaves are another potential source of nutrients for silkworms. These leaves are rich in proteins, carotenoids, and other essential vitamins. They have been shown to enhance silkworm growth, though they require careful preparation to optimize digestibility and nutrient availability.

Cassava Leaves: Cassava leaves contain significant amounts of protein and are being explored as a cost-effective and sustainable alternative to mulberry leaves. Cassava cultivation is widespread in many tropical and subtropical regions, making it an accessible resource for sericulture.

Use of Algae and Aquatic Plants

Algae, particularly microalgae like *Spirulina*, *Chlorella*, and *Dunaliella*, are rich in proteins, lipids, and essential amino acids, making them ideal candidates for silkworm feed.

Spirulina: *Spirulina* is known for its high protein content and has been shown to enhance silkworm growth and silk yield. Moreover, it has the added benefit of being a sustainable and rapidly growing organism that can be cultivated in controlled condi-

ons.

Water Hyacinth: Water hyacinth (*Eichhornia crassipes*) is an invasive aquatic plant that can be used as a feed source for silkworms. It has high fiber and protein content and grows abundantly in water bodies, providing an abundant and sustainable resource for feed.

Environmental Benefits of Novel Diets

Reduced Land Use: By utilizing agro-industrial by-products and waste materials, novel diets help reduce the need for large-scale mulberry plantations, thus preserving natural habitats and preventing deforestation.

Water Conservation: Many alternative feed sources, especially algae and aquatic plants, require less water to cultivate compared to mulberry trees. This can significantly reduce the water footprint of sericulture.

Lower Carbon Footprint: Using locally sourced by-products and waste materials minimizes the need for transportation and the associated greenhouse gas emissions. Additionally, some feed sources, like algae, can even help sequester carbon during cultivation.

Waste Reduction: By converting agro-industrial waste into silkworm feed, these diets provide a sustainable way to recycle waste and reduce landfill accumulation.

Conclusion

The development of novel silkworm diets is a crucial step towards enhancing silk production while minimizing environmental impact.

By exploring alternative feed sources, sericulture can reduce its dependence on resource-intensive mulberry cultivation, lower its ecological footprint, and improve the economic sustainability of silk production. With further research and technological advancements, it is likely that sustainable silkworm diets will become a key component of future sericulture practices, providing a more eco-friendly and efficient solution for the growing global demand for silk.



Hurdle Technology for Fish Preservation

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Abstract

Hurdle technology, a preservation strategy that combines multiple methods to control microbial development, increase shelf life, and preserve quality of food product. Temperature, acidity, salt, preservatives, and competitive microbes are just a few of the “hurdles” that this technique employs to improve food safety, stability, and nutritional value. Given that fish is perishable and susceptible to rapid spoilage, this technology presents an innovative approach to increase shelf life and lower the microbial burden in the seafood the industry. Although this multi-targeted strategy has been effectively used for a variety of food products worldwide, including fish species, its use in Indian fish industry is still somewhat limited.

Introduction

In India, fish consumption has risen from 4.9 kg to 8.89 kg per capita, reflecting a growth rate of 4.05% (Padiyar *et al.*, 2024). In 2023, the Andaman & Nicobar Island had the highest fish consumption, with 114 kilograms per capita, followed by Lakshadweep and Tripura (Handbook of fisheries statistics, 2023). To meet the nutritional needs of future generations, investing in aquatic food is crucial for combating malnutrition and addressing the challenges posed by climate change, ensuring both prosperity and nutritional security. The development of new processing technology is evident for combating new challenges in preservation. As we all know the fishing commodities are perishable in nature due to their biochemical composition, high microbial load and the quality of fish products are very important to the consumers

point of view. The preservation is important to minimize the growth of food poisoning micro-organism. To overcome the problem Dr. Lothar Liestner developed the concept called hurdle technology who is german food technologist. Dr. Leistner developed the concept based on the idea of using multiple preservation methods (or “hurdles”) in combination to inhibit microbial growth, prevent spoilage, and extend the shelf life of food products. The idea behind hurdle technology is that no single preservation method is sufficient on its own, but when combined, these hurdles (such as temperature, acidity, salt, and preservatives) create a synergistic effect that enhances food safety, quality, and shelf life. The preservation is based on combined application of several preservative methods (e.g., heating, chilling, drying, curing, conserving, acidification, oxygen removal, fermenting, adding preser-

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vatives, etc). These methods and their underlying principles (i.e., water activity, pH, competitive flora, preservatives, etc.) have been applied since centuries empirically. The need for fish and seafood with minimal alterations to their sensory, biochemical, and nutritional qualities has led to the development of innovative fish processing processes. As a result, hurdle technology has emerged in the seafood technology sector (Pal *et al.*, 2021). Preservation of food ensures safety against microbes, prevent food from spoiling, improve its quality control foodborne infections and intoxications which in turn increase shelf life of food and minimize financial losses.

What is Hurdle Technology?

Hurdle technology, as defined by Leistner in 1976, is “the intelligent combination of various hurdles that ensures microbial safety and stability, while maintaining the organoleptic and nutritional quality of the product, and ensuring its economic viability.” The most important hurdles used in food preservation are temperature (high or low), water activity (a_w), acidity (pH), redox potential (Eh), preservatives (e.g., nitrite, sorbate, sulfite), and competitive microorganisms (e.g., lactic acid bacteria) (Leistner *et al.*, 1981).

The microbial safety and stability of most foods are based on an application of preservation factors called “hurdles”, and the techniques applying different hurdles is known as “hurdle technology”. Hurdle technology is a multiple-barrier technology that employed multiple preservative measures, which are strategically applied, to efficiently control

the growth of microorganisms in food (Yuan, 2003). It is an important area of food microbiology which described the potentials of multiple preservation approach that act synergistically to inhibit microorganisms in foods. The concept of hurdle technology involves the optimization of preservation techniques that ensure safe products with greater sensory and nutritional quality at lower costs (Augusto *et al.*, 2018). The approach to hurdle technology involves combining traditional and novel technologies to control microbial growth in food (Ravishankar and Maks, 2007). A combination of inhibitor factors or additives at a minimal level limit pathogenic growth by providing cumulative stress that makes microbial survival difficult (Novak, 2003). Adverse effects of conventional food processing on nutrients, texture and acceptability could be minimized or eliminated by hurdle technology. Smart combinations of different hurdles ensure microbial safety, minimize energy consumption, reduce emissions, increase profit and affordability and increase overall quality (Khan *et al.*, 2017). In addition to preservation effects, hurdles used in food can improve acceptability nutritional values of foods (Abdullahi and Dandago, 2021).

Hurdle technology in Fish Preservation

The fish decompose at faster rate after being caught, spoilage progress rapidly and make them unconsumable within the shorter period of time. Preservation is known to increase their shelf life and reduce microbial load. There are many well known traditional preservation techniques, drying is said out

to be the oldest method used for preservation followed by freezing, salting, smoking and canning. The advanced technologies such as retort pouch processing (use laminated thermally processed can & pouches), high hydrostatic pressure (use high pressure to inactivate microorganism and enzymes), ozonation (use sanitation property of ozone in cold storage), irradiation (extend shelf life using gamma rays, electron beams & x-ray), Modified atmospheric packaging (use combination of CO₂, N & O₂), pulse light technology (use short pulse of strong electrical currents for short duration), organic acids (inhibit bacterial proliferation) (Kontominas *et al.* 2021). Despite the range of techniques available, the problem has not yet been adequate control. As Leistner says no single method of preservation is sufficient on its own. So to promote multifaceted and multi-targeted approach, the hurdle technology has been proposed. Hurdle technology provides benefits using multiple methods instead of rely on single method. Tsironi (2020) suggested the alternative hurdles to inhibit microbial growth in fish and fish products by utilizing homeostasis, stress reaction, metabolic exhaustion and multi-targeted preservation techniques. Hurdle technology has been utilized for fish preservation in various countries, applied to a wide range of fish species. These include *Gadus morhua* (Dalgaard *et al.*, 1998), *Anguilla anguilla* (Choulitoudi *et al.*, 2017), *Sparus aurata* (Tsironi and Taoukis 2010; Tsironi and Taoukis 2012; Tsironi and Taoukis 2014), *Reinhardtius hippoglossoides* (Mejlholm and Dalgaard, 2015),

and *Thunnus albacares* (Sofra *et al.*, 2018; Emborg and Dalgaard, 2008).

In India, the progress of hurdle technology has been observed in dairy products such as paneer, a perishable commodity, as well as in brown peda, payasam, curd rice, and dudhchurpi (a Himalayan product) (Mor *et al.* 2015). Additionally, this technology has been applied to fruits (pineapple slices), vegetables, and meat products (chicken lollipop) (Pal *et al.* 2017). However, its implementation in fish products yet to be limited. One potential application is in fish canning, where heat is applied to eliminate microorganisms, followed by sealing the fish in cans to maintain sterility. By incorporating hurdle technology, this process can be enhanced through the use of salt or other preservatives combined with vacuum sealing. This combination would ensure improved quality and extended shelf life of canned fish products. This is particularly important for popular fish varieties like tuna, sardines, and mackerel, which are not only consumed widely within India but also exported globally.

Conclusion

One of the most important problems facing the seafood industry is maintaining fish fresh and nutritious and hurdle technology offers a revolutionary solution to this problem. In addition to extending shelf life, this approach guarantees food safety, improves quality, and preserves the sensory appeal of fish products by carefully combining many preservation techniques. In India, where fish consumption is rising quickly, implementing hurdle

technology might prove revolutionary. It holds the potential to minimize spoilage, reduce microbial risks, and meet the growing demand for high-quality, safe seafood both domestically and internationally. Therefore, adopting hurdle technology is essential for ensuring the long-term sustainability and nutritional security of the seafood industry in India.

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Silver Pomfret *Pampus argenteus* as Maharashtra's State Fish

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Abstract

The Silver Pomfret (*Pampus argenteus*) has been designated as the state fish of Maharashtra, highlighting its ecological, economic, and cultural significance. This article explores the role of state symbols in India, emphasizing the importance of biodiversity conservation. The Silver Pomfret serves as a vital resource for local communities and the fishing industry, yet its population is declining due to overfishing, habitat disruption, and pollution. In response, the Maharashtra government has initiated conservation measures, including fishing restrictions and awareness campaigns. This designation not only aims to safeguard the species but also promotes sustainable practices that support the livelihoods of coastal communities. Through understanding its biological characteristics and cultural relevance, this initiative underscores the need for collaborative efforts to ensure the sustainability of marine resources.

Introduction

The significance of state symbols in India encompasses cultural identity, biodiversity awareness, historical context, and tradition. Each state in India has designated symbols that represent its diverse flora, fauna, and cultural ethos. State symbols play a crucial role in embodying the natural resources, historical significance and unique characteristics of a state, thereby fostering a sense of pride among its residents. Among these symbols, the state fish occupies a prominent position, reflecting the ecological richness and culinary traditions of the region. It is important that all the states declare their state fish and start contributing towards the conservation of those neglected species, which are in urgent need of conservation. This concept may also

be applied elsewhere for biodiversity conservation.

The varying climatic conditions have led to varied distribution of species among different states of India and the people have different preferences and cultural attachments towards different species. Sensing an opportunity to make use of this, the ICAR-National Bureau of Fish Genetic Resource, Lucknow has conceptualised the “state fish” concept as a method to conserve fish species (Sarkar *et al.* 2024). Different states of India have declared their state fish based on the abundance, preference and importance in the day to day life of the people. Out of 28 states, 21 have designated state fishes, while 3 have recognized state aquatic animals, emphasizing the importance of conservation, breeding, and cultural aspects. These efforts aim to protect biodive-

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rsity (NFDB, 2023). Maharashtra features several state symbols, including the Mango tree, Indian giant squirrel, Blue mormon butterfly, Green pigeon, and Silver pomfret as its state fish. The designation of the silver pomfret as the state fish of Maharashtra is significant in promoting a balanced and protected marine environment while conserving this economically important seafood species (Fig. 1). Notably, the silver pomfret, alongside other seafood such as hilsa and prawn, was commemorated in definitive postage stamps released by the Department of Posts, India, in 1979 and 1982 (Fig. 2). This initiative honored the fish's contributions to the local economy and seafood culture. The silver pomfret holds a vital role within the coastal environment of Maharashtra, contributing to the livelihoods of coastal communities and preserving their cultural heritage. This recognition underscores the need for sustainable practices to safeguard marine ecosystems and the communities that rely on them.



Fig. 1: State Fish of Maharashtra (*Pampus argenteus*) @ FAO



Fig. 2: Postage stamp by GoI, 1982

The Maharashtra government has officially designated the silver pomfret (*Pampus argenteus*) as the state fish, a decision prompted by growing concerns regarding its declining population in coastal waters. This announcement was made by Sudhir Mungantiwar, the state's Minister for Fisheries, during a national conference on the Kisan Credit Card. Accompanying this designation was a government resolution (GR) outlining several measures aimed at the conservation of this species. The silver pomfret is a significant seafood choice in Maharashtra, particularly among the coastal communities, and is indigenous to the coastal regions of South and Southeast Asia, as well as the Middle East. It plays a vital role in the marine food chain, contributing to the ecological balance by maintaining populations of prey species. The GR highlights the need to prevent the fishing of undersized individuals, promote the growth of mature pomfret, and address local conservation issues, all while aiming to enhance foreign currency earnings through increased seafood exports. Minister Mungantiwar emphasized the global demand for pomfret and its economic potential for local fishermen. He noted that the initiative not only addresses conservation challenges but could also lead to significant economic benefits for the fishing community. The government resolution aims to empower the fisheries department to implement conservation strategies for the silver pomfret, locally referred to as “paplet” or “sarangi”. Supporting this decision, the GR references findings from the International Union for Conservation of

Nature (IUCN), which indicate a decline in both the population and catch rates of the silver pomfret in Maharashtra. This decline is attributed to mechanized fishing practices that have resulted in the premature capture of juvenile fish, thereby exacerbating the reduction of mature populations. Fishermen's associations have voiced their concerns regarding this issue, calling for government intervention to protect the species.

Historically, silver pomfret was abundant along the coasts of Sindhudurg, Ratnagiri, Raigad, Thane, and Palghar districts; however, production figures have been troubling. According to the Marine Products Export Development Authority (MPEDA), production levels reached 17,235 tonnes in 2022, reflecting an 8.45% decrease compared to 2017. The persistent decline in pomfret stocks since the 1980s is linked to various factors, including habitat disruption caused by industrial activities such as the establishment of the Mumbai High oil production project. The Maharashtra government's decision to declare the silver pomfret as the state fish is a critical step toward addressing conservation concerns and promoting sustainable fishing practices, thereby ensuring the longevity of this economically and ecologically important species.

Taxonomy and Identification: *Pampus argenteus* belongs to the family Stromateidae and the order Scrombriformes. It is commonly known as the silver pomfret. It was first described in 1788 by the Swedish botanist Bengt Anders Euphrasén (1756-1796). It represents a significant marine resource,

particularly in the context of trawling activities in India. This species is highly sought after as a food fish globally due to its palatable qualities. As per Haedrich (1984) *Pampus argenteus* exhibits a body that is notably deep and compressed, yet relatively thick. The caudal peduncle is short, deep, and compressed, devoid of keels, and possesses firm musculature. The mouth is small, subterminal, and exhibits a downward curvature. The maxilla is immobile, covered with skin, and fused. The dentition consists of minute, uniserial, flattened teeth, characterized by a prominent central cusp accompanied by two smaller cusps, while the palate is devoid of teeth. The gill membranes are broadly fused to the isthmus, with the gill opening presenting as a vertical slit covered by a flap of skin; gill rakers comprise 2 to 3 in the upper row and 8 to 10 in the lower row on the first arch. The pectoral fins are elongated and wing-like, whereas pelvic fins are absent. The caudal fin is stiff and forked, with the lower lobe being longer than the upper lobe. The anterior rays of the median fins, particularly the anal fin, and the ventral lobe of the caudal fin are often significantly elongated and distinctly falcate. The scales are very small, cycloid (smooth), easily shed, and extend onto the bases of all fins. The lateral line is positioned high, closely following the dorsal profile and extending onto the caudal peduncle. The species displays a silvery white hue on the sides, transitioning to blue or grey on the dorsal surface. The body is adorned with numerous small black dots, particularly prominent on the snout, lower jaw, and

cheek. The fins exhibit a yellowish coloration with dark margins, while juvenile individuals are predominantly silvery.

Habitat and Distribution: The silver pomfret, is a schooling pelagic fish typically found in shallow marine environments (Fischer and Bianchi, 1984). It is widely distributed across the Indo-Pacific region, with significant populations in the coastal waters of countries such as India, Bangladesh, Myanmar, and parts of Southeast Asia. In Indian waters, it is particularly abundant along the western coast, including Maharashtra, where it is vital to local fisheries (Kuronuma and Abe, 1972; Davis and Wheeler, 1985; Froese and Pauly, 2011). The species can attain a maximum length of approximately 60 cm (Fischer and Bianchi, 1984). Adult silver pomfrets predominantly feed on ctenophores, salps, medusae, and various groups of zooplankton (Khan, 2000; Froese and Pauly, 2011). This species typically inhabits the continental shelf and is often found in deeper waters, generally between 20 to 200 meters (65 to 660 feet) deep. It tends to favor sandy or muddy bottoms, which provide suitable foraging grounds. The natural habitat and broad geographical range of the silver pomfret highlight its ecological significance and economic value to coastal communities. Understanding these biological characteristics is crucial for promoting sustainable fishing practices and ensuring the conservation of this important species.

Catch Trends: Maharashtra boasts a coastline of approximately 720 kilometers, supporting a diverse

array of marine resources. In 2023, the state recorded a per capita fish consumption rate of 2.47 kg. The pomfret fishery in Maharashtra primarily comprises three species: the silver pomfret (*Pampus argenteus*), black pomfret (*Parastromateus niger*), and Chinese pomfret (*Pampus chinensis*). Among these, *Pampus argenteus* is the most dominant species. In 2023, the total marine fish landings in Maharashtra amounted to 446,000 metric tons, with pomfret contributing 10.06% to the overall marine fish landings (DoF, 2023). The silver pomfret accounted for 40,000 metric tons from the west coast, with 18,000 metric tons originating from Maharashtra (Handbook of Fisheries Statistics, 2023). The total contribution from trawl nets was recorded at 4,162 metric tons, representing 2.46% of the total marine fish landings (DoF, 2022). Notably, the percentage share of silver pomfret in the total valuation of marine fish production in Maharashtra is 16.3% (DoF, 2022). This data underscores the economic significance of the silver pomfret within the state's fisheries sector. Thane district reported the highest fish landings in Maharashtra, totaling 8,884 tonnes in 2022. Figure 3 represents a notable decline in production compared to the 15,808 tonnes recorded in 2017.

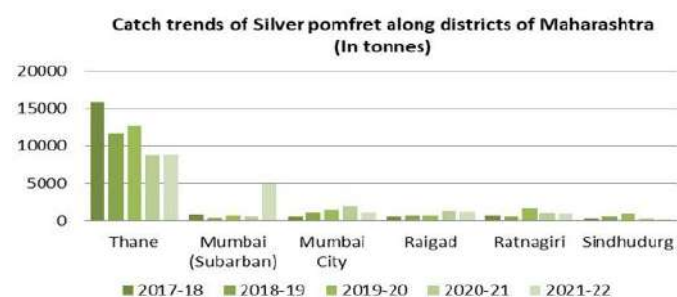


Fig. 3: Catch trends of Silver pomfret along districts of Maharashtra (In tonnes) (Source: DoF, 2023; Handbook of Fisheries Statistics, 2023)

Threats and Conservation status: Fishermen from Maharashtra gave alert within fish-eating communities, decline is attributed to rising pollution and undersized fishing before reaching full maturity and breeding age. Due to annual decrease in production members of satpati fishermen society in palghar representing the group that supply food to Mumbai and nearby coastal area are urging for special recognition of the species. This designation would enable to focused breeding programs and securing funding for its preservation. The community heightened the catch from last 35 years decline by 50 %. The size and weight of the fish have also notably decreased due to unlawful catches of undersized juvenile fish, coupled with escalating sea pollution. Changes in fishing practices and marketing dynamics has negatively affects the silver pomfret population in north western regions due to juvenile fishing. Various organizations and government bodies are promoting sustainable fishing practices among local fishermen. This includes education on responsible catch limits, the importance of protecting juvenile fish, and the use of selective fishing gear that minimizes bycatch.

Initiatives like the Marine Stewardship Council (MSC) certification encourage sustainable fishing practices by recognizing fisheries that meet certain environmental standards. In 2014, the IUCN declared silver pomfret as Vulnerable in the list of threatened species. A uniform ban on fishing will be implemented for all fishing vessels in the Indian Exclusive Economic Zone (EEZ) beyond territorial

waters along the West Coast, spanning from June 1 to July 31, 2024 (inclusive of both days), for a total duration of 61 days. This fishing ban will exempt traditional non-motorized fishing units (GoI, 2024). The minimum length size (MLS) for the silver pomfret (*Pampus argenteus*) is established at 14 cm, which represents the size at which the species reaches maturity. Implementing an MLS is crucial for maintaining healthy fish stocks and promoting sustainable fisheries management (Anulekshi *et al.* 2018).

Crafts and Gears: The fishing methods employed for pomfret fisheries typically include trawls, bag nets, and gill nets, with notable areas of abundance in Maharashtra, Gujarat and Orissa. The peak fishing season for this species is generally recognized as extending from September to January. In Indian waters, silver pomfrets are predominantly harvested using a variety of fishing techniques, including bottom trawls, gill nets, and fixed bag nets (Khan, 2000). The Fish Trawl (62 Angli disco dol), a two-seam high-opening bottom trawl net, is specifically utilized along the Ratnagiri coast for catching Ribbonfish, Squid, Croaker, and Pomfret (Sawant and Mohite, 2016). Modifications in gill netting techniques have been observed along the Satpati and Sindhudurg coasts (Waghmare *et al.*, 2018). The drift gillnets employed, with mesh sizes ranging from 140 to 155 mm (large) and 70 to 130 mm (small), account for a significant portion of pomfret landings in India (Khan, 2000). The Satpati coast is recognized as a primary fishing ground for silver

pomfrets using drift gillnets (Gladstone *et al.*, 2016). Perumal and Alagarswamy (1970) documented a significant catch of *Pampus argenteus* during a routine training voyage of the Swedish-built fishery training vessel “Bluefin”. In Gujarat, the use of Jarva (gill nets) and PankhaJal is particularly prevalent for capturing silver pomfrets along the Navsari and Veraval coast (Mittual *et al.*, 2023; Prassana and Dharmaraja, 1978; Ghosh *et al.*, 2009).

Cultural Significance: The Indo-Asia-Pacific region places considerable culinary value on the silver pomfret (*Pampus argenteus*), renowned for its distinctive flavor profile. When properly prepared, the fish exhibits a soft, buttery texture, making it highly desirable among consumers. In Indian markets, silver pomfret is often sold at a premium price, reflecting its cultural significance and local demand. Regionally, it is referred to by various names, such as “Pamplet” in Mumbai and “Vawali” in southern India, underscoring its importance within local culinary traditions. In Maharashtrian cuisine, the silver pomfret is particularly esteemed for its delicate flavor and versatility. Its popularity supports local fisheries and highlights the region's rich maritime heritage. The fish is commonly sold fresh in local markets or shipped frozen to urban centers, thereby catering to diverse consumer preferences. Several traditional dishes prominently feature silver pomfret in Maharashtrian cuisine. For instance, “Pomfret Fry” involves marinating the fish in a blend of spices, including turmeric and red chili powder, and shallow frying it to achieve a crispy exterior.

“Pomfret Curry,” a household staple, is prepared in a coconut-based gravy enriched with spices such as coriander and tamarind, typically served alongside rice or chapati. Additionally, “Stuffed Pomfret” showcases traditional cooking techniques by filling the fish with a mixture of spices and herbs before steaming or grilling it. These dishes not only reflect the culinary expertise of the region but also emphasize the integral role of silver pomfret in both everyday meals and festive celebrations.



Fig. 4: Pomfret Fry at Versova seafood festival @ VSF, 2023

The Koli community, the indigenous fishing population of Maharashtra, is recognized for its deep-rooted traditions and cultural practices related to fishing. The Versova Seafood Festival, held annually at the beginning of the year, showcases a variety of seafood delicacies, with particular emphasis on silver pomfret alongside other local favorites such as mackerel (referred to as “bangda”) and Bombay duck (bombil). This festival not only highlights the culinary significance of these fish but also celebrates the cultural heritage of the Koli community and their contributions to the region's maritime economy.

Summary

The declaration of silver pomfret (*Pampus argenteus*) as Maharashtra's state fish marks a significant step towards addressing conservation challenges while fostering economic growth within the fisheries sector. The species plays a crucial role in maintaining marine biodiversity and supporting the livelihoods of coastal communities. Sustainable management practices are essential to combat threats such as pollution, juvenile fishing, and habitat loss. By implementing effective conservation strategies and promoting awareness among local fishermen, Maharashtra aims to restore pomfret populations while enhancing the ecological integrity of its marine environments. Ultimately, this initiative serves as a model for other states, emphasizing the importance of biodiversity conservation and the interconnectedness of cultural heritage and economic sustainability in the context of natural resource management.

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Transforming Plant Breeding through Marker Assisted Selection

Saroj Verma and Deepak Gupta

Agriculture has been the backbone of human civilization for millennia, but the challenges faced by modern agriculture i.e. climate change, pest resistance and the need for higher yields require innovative solutions. Traditional breeding methods, though effective, are often time-consuming and labor-intensive. Enter Marker-Assisted Selection (MAS) a modern, precision-breeding technique that has revolutionized the selection of desirable traits in crops. MAS allows breeders to identify traits at the DNA level, significantly speeding up the process of developing improved crop varieties.

How Marker-Assisted Selection Works

MAS is a process that uses molecular markers specific sequences of DNA associated with particular traits of interest to select plants that carry the desired genes. Unlike traditional breeding, where phenotypic selection is based on visible traits, MAS allows breeders to select plants at the seedling stage, saving time and resources. Molecular markers act as proxies for traits like disease resistance, drought tolerance, or nutrient content, which can otherwise take years to identify through conventional methods.



The process of MAS involves several steps

DNA Extraction: Tissue (usually leaves) is collected from plants, and DNA is extracted. This DNA is then analyzed to identify specific molecular markers linked to the traits of interest.

Marker Screening: Once markers are identified, the breeding population is screened. Plants that possess the desired markers are selected, while those without are discarded.

Trait Selection: Breeders focus on plants that contain favorable genes linked to the markers, allowing them to develop crops with improved characteristics in fewer generations than traditional methods.

Requirements for Successful MAS: To be effective, MAS relies on certain prerequisites:

Tight Linkage: The marker must be tightly linked to the gene of interest (usually less than 5 cM) to ensure accuracy.

Large Mapping and Screening Populations: The breeding population needs to be large to ensure genetic diversity and accurate marker-trait associations.

High-Throughput Screening: Efficient screening techniques are essential for handling large populations.

Reliability and Cost-Effectiveness: MAS methods

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must be reliable and affordable to be widely adopted in agricultural systems.

Advantages of Marker-Assisted Selection in Agriculture

MAS offers numerous advantages over traditional breeding methods:

Early Selection: MAS enables the selection of traits at the seedling stage. This is a significant improvement over conventional breeding, where traits often cannot be identified until maturity.

All-Year Breeding: MAS allows breeders to work independently of seasons. By focusing on molecular markers rather than phenotypic traits, breeding programs can continue throughout the year.

Distinguishing Homozygous from Heterozygous Plants: One of the major advantages of MAS is that it allows breeders to distinguish between homozygous and heterozygous plants for specific traits, which is often difficult with traditional methods.

Simultaneous Selection for Multiple Traits: MAS enables the selection of multiple traits at once, such as drought tolerance, pest resistance, and higher nutrient content. This ability is particularly important when breeding for complex traits controlled by several genes.

More Efficient and Reliable: MAS reduces the time and resources needed for screening and selection, making the process more efficient, accurate, and cost-effective in the long run.

Challenges of Marker-Assisted Selection

Despite its many benefits, MAS is not without challenges:

High Cost and Complexity: The initial setup costs for MAS can be high, especially for breeding programs in developing countries. The need for skilled labor and advanced molecular biology tools can make implementation difficult.

Linkage Drag: This occurs when undesirable traits are co-inherited with desired ones because the genes are located close together on the same chromosome.

False Positives: Occasionally, MAS may result in false positives, where plants appear to have the desired marker but do not exhibit the corresponding trait due to other genetic factors.

Marker-Assisted Backcross Breeding (MABB)

Marker-Assisted Backcross Breeding (MABB) is an advanced breeding technique where both foreground and background selection are used in the backcrossing process. This method is particularly useful in transferring a specific gene or Quantitative Trait Locus (QTL) from one variety (the donor parent) into another (the recurrent parent) while maintaining the genetic background of the recurrent parent.

Foreground Selection

- ✓ Focuses on selecting the gene of interest (e.g., disease resistance gene) using linked molecular markers. This is essential for traits that are difficult or expensive to evaluate phenotypically.
- ✓ For example, the transfer of the opaque-2 gene in maize, which improves the nutritional quality of maize by increasing lysine content, can be facilitated using MAS.

Background Selection

- ✓ This process ensures that the genetic background of the recipient parent is retained, except for the target gene. Markers scattered throughout the genome are used to track this background.
- ✓ It enhances the recovery of the recurrent parent genome, speeding up the process of developing a variety that closely resembles the original one but with the new desirable trait.

MABB has been used successfully in breeding programs for rice, wheat, and maize, where disease resistance and drought tolerance traits were introduced without compromising yield or quality.

Gene Pyramiding: Combining Multiple Resistance Genes

Gene pyramiding involves combining multiple genes that control a single trait, particularly disease resistance. For example, in wheat, pyramiding genes for resistance to various strains of rust disease helps develop varieties with broad-spectrum resistance. With MAS, gene pyramiding is much faster and more efficient compared to traditional breeding methods, which require disease tests and progeny testing. By stacking genes using molecular markers, breeders can ensure that plants carry multiple resistance genes, providing durable resistance to pathogens and reducing the need for chemical pesticides.

Gene pyramiding has been particularly successful in rice and tomato breeding, where multiple resistance genes have been combined to provide long-lasting protection against pests and diseases, ensuring stable crop production.

Agricultural Importance of MAS

In the context of global agriculture, MAS is increasingly important for addressing key challenges:

Climate-Resilient Crops: By selecting for traits like drought and heat tolerance, MAS helps develop varieties that can thrive in the face of changing climate conditions, ensuring food security for growing populations.

Disease and Pest Resistance: MAS allows breeders to develop crops with durable resistance to pests and diseases, reducing reliance on chemical pesticides and promoting more sustainable farming practices.

Nutritional Improvement: MAS can also be used to enhance the nutritional content of crops. For example, biofortified crops like Golden Rice, enriched with Vitamin A, have been developed to address micronutrient deficiencies in developing countries.

Conclusion

Marker-Assisted Selection represents a paradigm shift in agricultural breeding, offering a more precise and efficient method for developing improved crop varieties. Whether it's through Marker-Assisted Backcross Breeding or gene pyramiding, MAS enables breeders to address critical challenges like food security, climate change, and sustainability. As the technology becomes more accessible and cost-effective, MAS will continue to play a pivotal role in shaping the future of agriculture.

Role of Conventional Breeding in Developing Stress-Resilient Crops

Teena Verma and Deepak Gupta

Abstract

The increasing impact of climate change and environmental stressors has underscored the need for crop varieties capable of withstanding diverse abiotic and biotic stresses. Conventional breeding, leveraging natural genetic resources and established breeding techniques, has played a pivotal role in developing stress-resilient crops. This approach utilizes genetic diversity from crop wild relatives, which possess traits for resilience against challenges such as drought, salinity, heat, and floods. Through rigorous screening and selection processes, breeders identify superior genotypes that perform well under stress conditions. Key breeding strategies, including hybridization and the incorporation of resistance genes, have enabled the development of high-yielding crops that can thrive in adverse environments. Notable examples include the development of flood-tolerant rice varieties, such as Swarna-Sub1 and drought-resistant maize varieties from preserved landraces. The integration of traits like osmotic adjustment, ion balance, and heat shock protein production has improved crops' ability to survive extreme conditions. Long-term breeding programs, involving multiple generations of testing and selection, ensure the stability and resilience of these varieties across different environments. As climate change continues to challenge agricultural systems, conventional breeding remains a cornerstone in ensuring food security and adapting crops to new environmental realities.

The increasing impact of climate change and environmental stressors has necessitated the development of crops capable of withstanding various stresses. Conventional breeding has been pivotal in improving stress resilience by utilizing natural genetic resources and employing well-established breeding techniques.

Utilization of Genetic Diversity

Harnessing Natural Variability: Genetic diversity within crop species and their wild relatives provides an indispensable resource for improving stress toler-

ance. Wild relatives of crops, which have evolved under harsh and variable environmental conditions, often possess unique traits for resilience against drought, salinity, pests, and diseases. For example, genes from wild rice species (*Oryza rufipogon*) have been incorporated into cultivated rice to develop varieties with enhanced drought and salinity tolerance. Such natural variability acts as a treasure trove for breeders, enabling them to address the growing challenges posed by climate change and environmental stresses.

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Screening and Selection: One of the foundational steps in conventional breeding is the identification of plants that demonstrate superior performance under stress conditions. This involves rigorous field trials and genetic screenings to evaluate traits such as drought resistance, heat tolerance, and disease resistance. Selected plants, which perform well under these conditions, are then utilized as parents in breeding programs. For instance, screening wheat germplasm for heat tolerance has led to the development of varieties that maintain grain quality even under high-temperature stress.

Hybridization for Enhanced Traits: Hybridization is a critical step in combining stress tolerance with high yield and other desirable agronomic traits. By crossing stress-tolerant varieties with high-yielding cultivars, breeders create hybrids that can thrive under adverse conditions while maintaining productivity. A prime example is the breeding of submergence-tolerant rice varieties like 'Swarna-Sub1,' which were developed by introducing submergence tolerance genes from wild relatives into high-yielding rice varieties. This strategy ensures farmers can achieve stable yields despite floods or waterlogging.

Preserving Biodiversity: The conservation of genetic diversity through the preservation of landraces, traditional varieties, and wild relatives is a cornerstone of conventional breeding. Gene banks and seed repositories play a vital role in safeguarding these genetic resources, providing a reservoir of traits that can be tapped into for future breeding programs.

For example, the preservation of drought-resistant landraces of maize in Africa has enabled the development of improved varieties tailored to arid regions. By maintaining biodiversity, breeders ensure that crops can adapt to emerging stresses and contribute to global food security.

Selection for Drought Tolerance

Drought tolerance is a vital trait for crops grown in arid and semi-arid regions, where water scarcity significantly limits agricultural productivity. Developing drought-tolerant crops through conventional breeding involves identifying and selecting genotypes that can maintain growth and yield under water-deficient conditions.

Major Traits for Drought Tolerance

Deep Root Systems: Crops with deeper root systems can access moisture from deeper soil layers, ensuring better water uptake during prolonged dry spells. Root architecture traits, such as root length and density, are prioritized during the selection process.

Efficient Water Usage: Breeders evaluate traits related to water-use efficiency (WUE), such as reduced transpiration rates and enhanced photosynthetic capacity. Plants with high WUE can produce more biomass per unit of water consumed.

Osmotic Adjustment: Drought-tolerant plants often exhibit osmotic adjustment mechanisms, allowing them to maintain cell turgor under water stress. This involves the accumulation of compatible solutes like proline and glycine betaine, which stabilize cellular structures and enzymes.

Screening Germplasm: Field trials and controlled

experiments are conducted to evaluate the performance of germplasm under drought conditions. Traits such as canopy temperature, stomatal conductance, and leaf rolling are monitored to identify potential candidates for breeding. Advanced phenotyping techniques, such as imaging systems and root scanners, have enhanced the precision of these evaluations.

Breeding for Salinity Tolerance

Soil salinity is a major abiotic stress that affects agricultural productivity worldwide, especially in irrigated and coastal areas. Excessive salt in the soil disrupts water uptake, nutrient absorption, and plant metabolism, significantly reducing crop yields. Conventional breeding for salinity tolerance focuses on selecting plants with the ability to withstand these challenges and sustain growth.

Major Traits for Salinity Tolerance:

Ion Balance: Salt-tolerant plants effectively regulate the uptake and transport of ions like sodium (Na^+) and potassium (K^+). Maintaining a high K^+/Na^+ ratio in cells is crucial to avoid ion toxicity and ensure normal physiological functions.

Osmotic Pressure Regulation: Plants adapt to saline conditions by synthesizing osmoprotectants such as proline and sugars, which help maintain cellular osmotic balance. This prevents water loss and supports metabolic activities under salt stress.

Exclusion and Compartmentalization of Salt: Salt-tolerant plants often exhibit mechanisms to exclude excess sodium at the root level or compartmentalize it into vacuoles, minimizing its

impact on sensitive cellular processes.

Role of Wild Relatives: Wild relatives of crops, which have evolved in saline environments, are invaluable sources of salinity tolerance traits. For example, wild rice species like *Oryza coarctata* and *Oryza rufipogon* possess inherent salt-tolerance mechanisms. These species are utilized in breeding programs to introduce such traits into cultivated rice varieties.

Screening and Selection: Breeders screen germplasm under saline conditions to identify genotypes with superior performance. Traits like shoot and root ion content, biomass retention, and yield under salt stress are evaluated.

Enhancement of Heat Tolerance

High temperatures pose a significant challenge to crop production, particularly during critical growth stages such as flowering and grain filling. Prolonged exposure to heat stress can impair pollen viability, reduce seed set, and ultimately lead to severe yield losses. Conventional breeding plays a crucial role in developing heat-tolerant crop varieties by targeting specific traits and leveraging natural genetic diversity.

Major Traits for Heat Tolerance

Heat Shock Protein (HSP) Production: Heat shock proteins act as molecular chaperones, protecting cellular structures and enzymes from heat-induced damage. Breeders focus on selecting genotypes with enhanced HSP production, which helps maintain cellular integrity during temperature extremes.

Altered Phenology: Adjusting the growth cycle of

crops to avoid peak heat periods is a common strategy. Early-maturing varieties, for example, can complete their reproductive phase before the onset of extreme heat, reducing exposure to stress.

Flowering and Seed Set Stability: Breeders select plants capable of maintaining pollen viability and seed setting under high temperatures. This ensures stable yields even during heat waves.

Screening and Selection: Heat tolerance is evaluated through controlled environment trials and field assessments in heat-prone regions. Traits like canopy temperature, photosynthetic efficiency, and grain filling duration are monitored to identify heat-resilient lines.

Disease and Pest Resistance

Biotic stresses, including diseases and pests, are among the leading causes of crop yield losses worldwide. Conventional breeding has been instrumental in developing disease- and pest-resistant varieties by introducing resistance genes from wild or traditional varieties into modern cultivars.

Major Strategies for Breeding Resistance

Incorporation of Resistance Genes: Resistance genes (R-genes) from wild relatives or traditional landraces are introduced into cultivated crops through hybridization and backcrossing. These genes provide the plant with the ability to recognize and respond to specific pathogens or pests.

Polygenic Resistance: In some cases, resistance to diseases and pests is controlled by multiple genes (polygenic resistance). Breeders select and combine

these genes to develop durable resistance that remains effective over multiple generations.

Enhanced Plant Defense Mechanisms: Traits that strengthen the plant's innate defense systems, such as the production of secondary metabolites or structural barriers, are incorporated into new varieties.

Screening and Selection: Breeders expose plants to targeted pathogens or pests under controlled conditions to identify resistant genotypes. Field trials in endemic areas further validate the effectiveness of resistance traits.

Flood Tolerance in Crops

Flooding is a major challenge in agriculture, especially in rice-growing regions, where submergence can severely impact crop yield and quality. Traditional rice varieties are often susceptible to waterlogging, leading to reduced productivity or complete crop failure. However, breeding programs have made significant progress in developing flood-tolerant varieties, such as the Swarna-Sub1 rice, which is equipped with the Sub1 gene for submergence tolerance. This gene allows the rice plants to survive prolonged periods of flooding by slowing down their metabolism and reducing oxygen consumption. These flood-tolerant varieties offer critical resilience to farmers in flood-prone areas, ensuring stable crop production even under adverse weather conditions.

Long-Term Breeding Programs

Conventional breeding often involves long-term efforts, requiring multiple generations of select-

ion and testing. Breeders focus on developing stable varieties that can perform well under varying stress conditions such as drought, flood, and extreme temperatures. This process includes rigorous field trials across different environments to ensure that the traits being selected for will be stable and effective in real-world conditions. The development of flood-tolerant crops, for example, requires the evaluation of varieties over multiple seasons to assess their performance under different flooding scenarios. By ensuring that crops maintain high productivity and resilience across diverse environments, long-term breeding programs provide sustainable solutions that benefit farmers in the face of climate variability and extreme weather events.

Conclusion

Conventional breeding remains a vital tool in addressing the growing challenges posed by climate change and environmental stressors on agriculture. By harnessing genetic diversity from crop wild relatives and traditional landraces, breeders have developed crop varieties with enhanced resilience to drought, salinity, heat, and flooding. Techniques such as screening, hybridization, and the incorporation of resistance genes have been instrumental in improving stress tolerance while maintaining high productivity. Long-term breeding programs ensure the stability and effectiveness of these varieties across diverse environmental conditions, contributing to sustainable agricultural practices. As climate change accelerates, conventional breeding will continue to play a crucial role in

ensuring food security, improving crop resilience, and adapting agricultural systems to an ever-changing environment. Through the preservation and use of genetic resources, future breeding efforts will be better equipped to tackle the emerging challenges of a rapidly changing climate.

Pathogenesis Related Proteins: Role in Plant Defense Response

Monisha K. R.

Introduction

Pathogenesis-related proteins, often called PR Proteins, are a structurally diverse group of plant proteins that accumulate at high levels in plants following a pathogen attack. They are widely distributed in plants in trace amounts, but are produced in much greater concentration in pathogen attack or stress. These proteins have different molecular weights, ranging from 6 to 43 kDa. They are thermostable, soluble at pH < 3, and protease-resistant, thus contributing to quantitative changes in protein levels during defense responses. Their initial discovery in tobacco (*Nicotiana tabacum*) following infection by tobacco mosaic virus (TMV) has prompted years of research and characterization of these proteins.

PRP are synthesized in response to some type of stress, their function analogous to the one postulated heat shock protein might be protect the plant from extensive damage. During hypersensitive reaction, PRP are first detectable in a ring around necrosis center. In the subsequent phase of slow lesion expansion, they reach the highest concentration at the lesion margin. They also accumulate between lesion in that inoculated leaves & may appear in lower concentration in distant non infected leaves. During a pathogen encounter, PR proteins are produced not only by the adjacent healthy cells but also in the

infected plant cells (Oliveira *et al.*, 2016).

Classification of PR proteins

The several groups of PR proteins have been classified according to their function, serological relationship, amino acid sequence, molecular weight, & certain other properties. Depending on their isoelectric points, PR proteins may be acidic or basic, although with similar functions.

PR proteins are grouped into two categories namely acidic and basic proteins based on their isoelectric points. Acidic proteins are secreted in the extracellular space or apoplast, where these are stable at a very low pH and resistant to proteases enzymes. While basic proteins are usually transported to the vacuole by a specific signal sequence located at their carboxyl end and are also sensitive to proteolytic enzymes as in case of potato and tomato PR proteins. But apoplastic or vacuolar localization of acidic and basic proteins may vary in different PR protein families. Basic proteins are triggered by jasmonic acid and ethylene pathways, whereas acidic proteins are triggered by salicylic acid-mediated pathways. PRs are not limited to photosynthetic tissues but they have been also reported in all the plant organs like leaves, flowers, roots, stems, and seedlings.

PR proteins are categorized into 17 families according to their properties and functions. They are:

- ✓ PR1 proteins (antioomycete and antifungal).

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- ✓ PR2 proteins (b-1,3-glucanases : antifungal).
- ✓ PR3 proteins (endochitinases).
- ✓ PR4 proteins (antifungal).
- ✓ PR6 proteins (proteinase inhibitors).
- ✓ Thaumatine -like proteins (antioomycete)
- ✓ PR7 proteins (endoproteinase)
- ✓ PR8 (lysozymes- Endochitinase)
- ✓ PR9 (peroxidases).
- ✓ PRP10 (ribonuclease activity- viral RNA)
- ✓ PRP11 (endochitinase)
- ✓ PRP12 (defensin - antifungal & antibacterial)
- ✓ PRP13 (thionin- antifungal & antibacterial)
- ✓ PRP14 (lipid transfer proteins)
- ✓ PRP15 (Oxalate-Oxidase)
- ✓ PRP16 (Superdismutase activities)
- ✓ PRP17 Unknown function

PRP1: These proteins have having 14 to 17 kDa molecular weight and mostly basic in nature. They are first discovered in 1970 and identified in arabidopsis, tobacco, barley, rice, maize, wheat, tomato and pepper.

Mode of action: Non-expressors of PR genes1 (NPR1): Regulate systemic acquired resistance in Arabidopsis thaliana. The interaction of nucleus-localized NPR1 with TGA transcription factors, after reduction of cysteine residues of NPR1 by salicylic acid (SA) results in activation of defense genes of PR1. PR1 have antifungal activities, against *Uromyces fabace*, *Phytophthora infestans*, *Erysiphe graminis*.

PRP2: PRP 2 proteins have β -1, 3- glucanase activity, comprises of larger and highly complex

gene families involving in pathogens defense. They have molecular weight of 33 to 44 kDa. Identified in peanut, chickpea, tobacco etc. In *Nicotiana* species, three classes of PRP2 present. Class 1 includes PR2e sub group, these are basic protein localized in cell vacuole. Class 2 includes PR2a, PR2b and PR2c sub group, these proteins are acidic protein. Class 2 includes PR2d subgroup, it is also acidic protein

Mode of action: Wounding, hormonal signals during pathogens attack: Eg- *Colletorichum lagenarium* releases ethylene it help to induced PRP2. It involves in hydrolytic cleavage of 1,3- β -D-glucosidic linkages in B-1,3-Gs, a major component of fungi cell wall. So that cell lysis & cell death occur as a result of hydrolysis of glucans present in the cell wall of fungi.

PRP3: PRP3 Proteins shows chitinase activity. Chitinase are endo β -1-4- glucosaminidase which hydrolyze the β -glycosidic bond at the reducing end of lucosaminidinides found in chitin, chitosan or peptidoglycan. Most of the chitinase having molecular mass in the range of 15 kDa and 43 kDa. These chitinase can be isolated from chickpea, cucumber and barley.

Mode of action: Chitinases hydrolyze chitin to soluble oligosaccharides, mainly, n-diacetylchitobiose (G2), which is futher hydrolyzed to G1 (N-acetylglucosamine) by GlcNAcases. Chitinases gene expressed in response to stress like cold up to -2 to -5 °C Chitinases cleaves the cell wall chitin polymers in situ, resulting in a weakened cell wall and rendering fungal cells osmotically sensitive.

PRP4: These are chitin binding proteins, having antifungal activity. Isolation from: Sugarbeet, hortensia, tobacco pepper, tomato and potato, bacteria like *Streptomyces tendae*. These proteins have molecular weight of: 9kDa to 30kDa and they are basic in nature, shows inhibitory effect against fungi *Aspergillus* species, *Cercospora beticola*, *Xanthomonas campestris* etc. Enzymatically CBP (Chitin binding protein) has not any function but it binds to insoluble chitin and enhances hydrolysis of chitin by other enzyme like chitinase.

Mode of action: Chitoooligosaccharides, sugar intermediates released during chitin hydrolysis, also pharmaceutically important. CBP, which binds to the insoluble crystalline substrate, leading to structural changes in the substrate and increased substrate accessibility. CBP21 strongly promoted hydrolysis of crystalline chitin by chitinases A and C, while it was essential for full degradation by chitinase B.

PRP5: These proteins comprise of polypeptides classes that share homology with thaumatin, sweet protein from (bennett) Benth. Isolated from barley, kiwifruit, maize. They are having molecular weight in the range of 18kDa to 25kDa and pH: 4.5 to 5.5. TLPs (Thaumatin like proteins) is absent in healthy plants. Show inhibitory effect against- *Uncinula necator*, *Phomopsis viticola*. Linusitin, have molecular weight of 25kDa, TLPs isolated from flax seeds. Shows antifungal activity against *Alternaria alternata* by the mechanism of membrane permeabilization.

Mode of action: Display significant *in vitro*

inhibition of hyphal growth and sporulation by various fungi. TLPs considered a prototype for a PRP domain. It found in rice and *Canorhabditis elegans*. The proteins are involved in systematically acquired resistance and stress response in plants. It is induced by attack by viroids, which are single-stranded unencapsulated RNA molecules that don't code for proteins.

PRP6: The possible role of proteinase inhibitors (PIs) in plant protection was investigated as early as 1947 by, Mickel and Standish. The term "protease" includes both "endopeptidases" and "exopeptidases" whereas, "proteinase" is used to describe only "endopeptidases". Several non-homologous families of PIs are recognized among the animal, microorganisms and plant kingdom. Isolated from: Leguminosae, solanaceae and gramineae. PIs are rich in cysteine and lysine, contributing to better and enhanced nutritional quality.

Mode of action: These PIs genes have practical advantages over genes encoding for complex pathway i.e. by transferring single defensive gene from one plant species to another and expressing them from their own wound inducible or constitutive promoters thereby imparting resistance against insect pests. PIs exhibit a very broad spectrum of activity including suppression of pathogenic nematodes like *Globodera tabaccum*, *G. pallida* and *Meloidogyne incognita* by CpTi. These PIs having specific for each of the four mechanistic classes of proteolytic enzymes, and based on the active amino acid in their "reaction center", are classified as serine, cysteine,

aspartic and metallo-proteases.

PRP10: PRP10 proteins are ribosome inactivating proteins (RIPs). RIPs are toxic N-glycosidases that depurinate the universally conserved sarcin loop of large rRNAs. This depurination inactivates the ribosome, thereby blocking its further participation in protein synthesis. RIPs are widely distributed among different plant genera and within a variety of different tissues. Enzymes activity of some RIPs is not limited to site-specific action on the larger rRNAs of ribosomes but extends to depurination and even nucleic acid suission of other targets. RIPs have been linked to defense by antiviral, antifungal and insecticidal properties demonstrated in vitro and in transgenic plants.

Classification of RIPs

Type 1RIP: basic proteins that share number of highly conserved active cleft residues and secondary structure within the active site region but are distinctly different in overall sequence homology and post-translationl modification.

Type 2RIP: one polypyrptide with RIP activity (Achain) is linked to a galactose binding lectin (B-chain) through a disulfide bond.

Type 3RIP: it is synthesized as inactive precursors (proRIPs) that require proteolytic processing events to occur between amino acids involved in formation of the active site. They isolated from maize, barley, sorghum.

Mode of action

Type1RIPs from *Mierabilis expansa* roots were active at microgram levels against several soil

borne bacterial species, the first such demonstration of antibacterial activity from a plant RIP in bioassays. In addition, these RIPs were active against a wide variety of both pathogenic and non pathogenic fungai including *Fusarium* and *Trichoderma* species. Type1 barely RIP was inhibitory to fungal growth, on solid media when tested against *Tricoderma reesei*. Inhibition of growth in liquid media, however, was minimal with was minimal with barley RIP alone but increased dramatically when chitinase was also included. A type2 RIP from seeds of the camphor tree *Cinnamomum camphora*, was toxic to larvae of mosquito and cotton bollworm.

PRP12 (plant defensin): The name “plant defensin” was coined by Terras and Collegues, 1995. MW: 5kDa, basic, cysteine- rich antifungal peptides ranging from 45 to 54 amino acids, and positively charged. First isolated from wheat and barley and were initially classified as a subgroup of the thionin family called the γ -thionins. The plant defensins Rs-AFP1 and Rs-AFP2 from radish are examples of potent antifungal proteins.

Mode of action: Some of them exhibit potent antifungal activity in vitro at micromolar concentration against a broad spectrum of filamentous fungi. Morphogenic antifungal defensins reduce hyphal elongation and induce hyperbranching, whereas non-morphogenic defensins reduce hyphal elongation without causing any morphological distortions. Antifungal defensin, Rs-AFP2, appears to act primarily at the cell membrane and induces rapid Ca^{++} uptack and K^{+} efflux from *Neurospora crassa*

hyphae and it may thus inhibit the growth of filamentous fungi by disrupting cytosolic Ca^{++} gradients essential for hyphal tip growth.

PRP13 (plant thionins): Thionins are small, basic plant proteins, 45-50 amino acids in length, which include 3 or 4 conserved disulfide linkages. Thionins are mainly found in seeds where they may act as a defence against consumption by animals. A barely leaf thionin that is highly toxic to plant pathogens and is involved in the mechanism of plant defence against microbial infections has also been identified. The hydrophobic protein crambin from the Abyssinian kale is also a member of the thionin family.

Mode of action: The proteins are able to inhibit digestive enzymes, bringing thionins to a select group of plant proteins synthesized in response to insect-pest. Some are capable to inhibit insect α -amylases and others could inhibit serine proteases. γ -hordothionins isolated from sorghum was the first example of a thionin.

PRP14 (Lipid-transfer proteins): LTP are basic, 9kDa protein present in high amounts in higher plants. LTPs can enhance the in vitro transfer of phospholipids between membranes and can bind acyl chains. On the basis of these properties, LTPs were participated in membrane biogenesis and regulation of the intracellular fatty acid pools. The principle of the assays is to monitor the transfer of labeled lipids from donor to acceptor membranes.

Mode of action: A shuttle mechanism has been proposed for the phosphatidylcholine - specific LTP,

which suggests the formation of a phospholipid-LTP complex that interacts with the membrane and exchanges its bound phospholipid with a phospholipid molecule from the membrane. In contrast, a strong binding of acyl chains or of lysophosphatidylcholine has been noted for several plant LTPs.

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Tuberose Cultivation: From Bulbs to Blooms

Madhana Keerthana S. and Gandreti Umadevi

Introduction

Polianthes tuberosa L., commonly known as Tuberose, belongs to the family Amaryllidaceae and is a cross-pollinated crop. It is native to Mexico and began spreading throughout the world during the 16th century. Tuberose was introduced to India via Europe during the same period. Tuberose is an important commercial crop for cut and loose flowers due to its pleasant fragrance, long vase life, high returns, and adaptability to various climates and soils. The flowers are attractive, star-shaped, waxy, and fragrant. As per the report from the Ministry of Agriculture and Farmers Welfare, Government of India, during the 2022-23 period, the total flower crop in India was cultivated in an area of 285,000 hectares, with a production of 3,097,000 metric tons. Of this, tuberose was grown in an area of 6,110 hectares, with a production of 56,520 metric tons. Tuberose blooms year-round, and its essential oil is a key component in high-grade perfumes. Humidity and temperature are the two main factors responsible for increasing or decreasing the production of tuberose. Tuberose needs full sunlight for healthy growth and maximum flower yield.

Botanical description

Tuberose is a half-hardy, erect, herbaceous perennial, and bulbous plant that stands 60-120 cm tall, with short, stout bulbs composed of scales and

leaf bases. Its fibrous roots are shallow and mostly adventitious. The plant has 6-9 grass-like basal leaves that are bright green, slightly reddish near the base, and measure about 30-45 cm in length. The foliage forms a rosette at the base, becoming wider at the top.

Tuberose spikes contain 25 ± 10 pairs of florets that open acropetally (from the base to the top). The *Polianthes* genus has three flower types: single, semi-double, and double. The single-flower type, with a chromosome count of $2n = 60$, is female fertile and used in perfumery and breeding programs. Semi-double and double types are commonly used as cut flowers. The flowers have a fragrant, tubular, waxy white perianth, with the tube bent only near the base. They feature six stamens, a 3-locular ovary, numerous ovules, and produce a capsule fruit.

Species and varieties

The genus *Polianthes* has about fifteen species, with twelve species have been reported from Mexico and Central America. Nine species have white flowers, one is white tinged with red, and two are red. Except for *Polianthes tuberosa* L., all other species grow wild. There are four varieties of tuberose, classified by the number of petal rows:

Single: Pure white flowers with one row of corolla segments, highly scented, used for loose flowers, essential oil, and floral ornaments. The seed setting

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is high.

Semi-double: Flowers with 2-3 rows of corolla segments, used for concrete extraction and cut flowers.

Double: Flowers with more than three rows of corolla segments, white or tinged with pinkish-red.

Variegated: Varieties with streaked leaves, showing silvery white or golden yellow markings.

Soil and Climatic requirement

Climate: Tuberose is well suited for cultivation in tropical to subtropical and temperate climates, preferring warm, humid conditions and full sunshine. In India, it is grown in areas with average temperatures ranging from 20°C to 30°C. The crop flowers profusely throughout the year in mild climates, but high temperatures above 40°C and frost can damage plants and flowers. Tuberose requires humidity and temperature control for optimal flower production. Long-day exposure promotes vegetative growth and earlier flowering.

Soil: Tuberose can be grown in various soils, including sandy loam and clay loam. It can tolerate soils affected by salinity and alkalinity with proper agronomic practices. The soil should be at least 45 cm deep, well-drained, friable, rich in organic matter, and retain moisture. Well-drained, loamy, or sandy soils with a pH of 6.5 to 7.5 are ideal. Avoid water stagnation, as the crop is sensitive to waterlogging. It should be planted in well-drained, aerated soil with good moisture retention. A site protected from strong winds and temperature extremes is preferable to prevent damage to flower stalks.

Propagation technique

Propagation of tuberose is commonly done by dividing mature bulbs, as it is less expensive than using whole bulbs. Bulbs with a diameter of 2.1 cm or more are suitable for planting. Large bulbs can be cut into 2-3 vertical sections, each containing a bud and part of the basal plate. The sections are treated with copper fungicide and planted vertically in a rooting medium. New bulblets form from the basal plate and, once developed, are transferred to the ground.

Planting technique

Spacing: The optimal spacing for tuberose is 30 x 20 cm or 20 x 20 cm, requiring 40,000-50,000 bulbs acre⁻¹ or 100,000-200,000 bulbs ha⁻¹. The planting depth varies from 3.0 to 7.0 cm, depending on bulb size and soil type. The depth should be 2.5 times the bulb's diameter. While planting, the bulbs are planted at the recommended plant spacing, 4-6 cm deep on the sides of the ridges. In sandy loam soil, bulbs are planted 6.0 cm deep, with the growing portion at ground level.

Bulb treatment: Dipping bulbs in a 4% thiourea solution can break their resting period. Pre-plant storage at 10°C for 30 days enhances growth and increases spike and flower yield. Treating bulbs with GA₃, etherel, or thiourea promotes early flower spike emergence and longer spikes with more florets. Bulbs should be cleaned and treated with 0.2% Bavistin for 30 minutes, followed by a 20-30 minutes dip in 0.2% Emisan, 0.3% Thiram, 0.2% Captan, or 0.2% Benlate. Dry the bulbs in the shade before

planting or storing, using systemic fungicide before planting, and contact fungicide before storage.

Nutrient Management

For optimal production, apply 20 tonnes of FYM ha⁻¹ along with 100 kg N, 50 kg P₂O₅, and 70 kg K₂O ha⁻¹. To enhance essential oil content, use 80 kg N, 60 kg P₂O₅, and 40 kg K₂O ha⁻¹. Apply half of the nitrogen and the full dose of phosphorus and potassium at planting, with the remaining nitrogen top-dressed 45 days later.

Micronutrients such as calcium, magnesium, sulphur, iron, zinc, manganese, boron, and copper play a vital role in improving growth and flowering. Foliar application of 0.5% ZnSO₄ + 0.2% FeSO₄ + 0.1% boric acid is highly effective.

Plant growth regulators like GA₃ at 50-100 ppm, applied three times (40, 55, and 60 days after planting), boost growth. Additionally, CCC at 5000 ppm or GA₃ at 1000 ppm encourages early flowering and improves flower quality.

Intercultural operations

Weeding: Regular weeding and monthly earthing-up are essential to keep plots weed-free and prevent bulb exposure. Manual weeding is effective, while chemical control using Gramaxone (3 L ha⁻¹) or Atrazine (1-3 kg ha⁻¹) as pre-emergent sprays help manage weeds. Mulching with black polythene, dried grass, or straw also suppresses weed growth.

Earthing up and staking: Earthing up to 10-15 cm when plants are 15-20 cm tall supports erect growth. Staking with bamboo or ropes prevents the lodging of flower spikes during strong winds or rains.

Irrigation: Irrigate before planting to ensure adequate moisture for sprouting. Avoid watering until bulbs sprout, then adjust based on weather twice weekly in summer and every 10 days in winter.

Micro-sprinkler irrigation offers precise water delivery that enhances bulb development, bulblet multiplication, and overall plant growth. It ensures optimal soil moisture, promoting higher yield and quality of flower spikes while keeping the flowers fresh and vibrant. By creating a favourable microclimate, it reduces heat stress and prevents waterlogging, minimizing pest and disease risks. This efficient system also maximizes water and nutrient use, making it a sustainable choice for growers. Adopting micro-sprinkler irrigation ensures better productivity and profitability in tuberose farming.

Harvesting and yield: Tuberose are commercially cultivated for flower spikes and loose flowers, primarily for the domestic market. Flowering begins 3 to 3.5 months (80-100 days) after planting, typically starting in July, with peak flowering occurring in August and September. Tuberose flowers year-round. For cut flowers, spikes are harvested when 1-2 pairs of flowers open, ideally in the morning before sunrise or late evening, using a sharp knife or secateurs to make a clean cut. A 4-6 cm portion of the base is left to allow bulb growth. Loose flowers are harvested by plucking individual blooms in the morning, by 8 a.m. Flower production in tuberose depends on cultivar, bulb size at planting, planting density, cultural practices and climatic

Pest Management

Pest/Insect	Description	Control Measures
Aphids	Tiny, soft-bodied insects, green, deep purple, or black, are found in clusters. Feed on flower buds and young leaves.	Spray 0.1% Malathion or Rogor (1 ml liter ⁻¹) every 15 days.
Bud Borer (<i>Helicoverpa armigera</i>)	Larvae bore into buds and flowers, feeding on them and causing holes.	Collect and destroy damaged buds. Use light traps. Spray monocrotophos (0.2%), Thiodan (0.5-0.8%), Methyl Parathion (0.05%), or Neem oil (1%).
Grasshoppers	Feed on young leaves and buds, especially during the rainy season, damaging foliage and flowers.	Dust with 5% Cythione/Folidol. Spray Quinalphos @ 0.05%, Malathion 0.1%, or Carbaryl @ 0.2%. Use netting to protect nurseries.
Nematodes	Cause stunted growth, reduced leaf size, and sickly flowers; roots rot due to infestations by root-knot, reniform, and greasy streak nematodes.	Apply Thimet or Furadan (20 kg ha ⁻¹), Furadon @ 2 g plant ⁻¹ , Carbofuran @ 2-5 kg ha ⁻¹ or Neem @ 1 tonne ha ⁻¹ .
Red Spider Mites	Thrives under hot, dry conditions, creating webs on the undersides of leaves. Suck sap, causing yellow streaks, discoloration, and distortion of leaves.	Spray Kelthane @ 1.2% concentration.
Rodents	Damage plants in fields by making burrows.	Use poison bait like 'Roban' to control rodents.
Thrips	Feed on leaves, flower stalks, and flowers, causing deformation and 'bunchy top' disease.	Spray Rogor or Metasystox @ 1.75-2.0 ml l ⁻¹ , 0.1% Malathion or Nuvacron (0.1%). Apply Thimet to soil.
Weevils (<i>Myloccerus</i> sp)	Nocturnal pests cause notched leaves; larvae feed on roots and bulbs.	Apply 10% BHC dust in the soil before planting. Spray Thiodon @ 2.0 mg litre ⁻¹ .

Disease management

Disease	Symptoms	Control Measures
Alternaria Leaf Spot	Caused by <i>Alternaria polyantha</i> . Brown spots with concentric rings on leaves, mainly midrib.	Spray Bordeaux mixture (0.4%), Zineb (0.5%), Mancozeb (0.2%), or Iprodione (0.2%) every 10 days.
Flower Bud Rot	Caused by <i>Erwinia</i> sp. Leads to dry rotting of buds and brown discoloration of peduncles.	Uproot and destroy infected plants. Spray Streptomycin (0.01%).
Leaf Blight (<i>Botrytis</i>)	Caused by <i>Botrytis elliptica</i> . Dark brown spots on flowers, drying of inflorescence, and infection on leaves/stalks.	Spray Carbendazim (2 g litre ⁻¹), ammoniacal copper (2%), or Greeno (0.5%) every 15 days.
Rust and Powdery Mildew	Minor diseases cause damage when severe.	Suitable fungicides as needed.
Sclerotial Wilt	Caused by <i>Sclerotium rolfsii</i> . Flaccidity, drooping, yellowing of leaves; root/tuber rotting with cottony fungal growth.	Drench soil with 0.3% Zineb.
Stem Rot	Caused by <i>Sclerotium rolfsii</i> . Mycelial growth on leaves/soil, light-green rotting spots, sclerotic brown spots. Infected plants weaken.	Drench soil with Brassicol (1%) or Zineb (20%, 30 kg ha ⁻¹). Reduce soil moisture and ensure wider spacing (45 cm x 30 cm).

conditions. Flowers are ready for harvest 3 to 3.5 months after planting. A hectare of tuberose plantation yields 4-5 lakh spikes year⁻¹ for cut flowers, or 14-15 tonnes of loose flowers. Additionally, 20-25 tonnes of bulbs and bulblets are harvested at the end of the third year.

Lifting, Curing and Storage of Bulbs: Bulbs mature after flowering when leaves dry, typically in

February-March. Irrigation is stopped, and bulbs are dug, cleaned, and graded by size. Offsets are separated for seed stock. Bulbs are cured on sieves, with optional artificial heat (27-35°C). They are treated with Bavistin or mancozeb to prevent rot. Curing at 18°C for 4-6 weeks or 30°C for 6 weeks improves bulb size. Longer storage at higher temperatures may reduce spike quality.

Conclusion

Tuberose is a valuable flower crop known for its fragrant blooms and importance in the floral industry. Its adaptability to different climates and soils makes it ideal for both cut flower production and perfumery. Successful cultivation requires attention to soil, climate, propagation, irrigation, and pest management. With its continued popularity and demand, tuberose remains an essential crop in the floriculture industry, contributing to both aesthetic and commercial benefits.



Silicon Application: A Way to Increase Nutrient Use Efficiency

Subhajeet Sarkar, Jyotirmay Roy and Arham Tater

Abstract

The use of silicon (Si) in agricultural settings has proved to be a potential means of enhancing crop yields while also enhancing nutrient use efficiency. However, the absence of standard procedures and guidelines on silicon fertilization makes the application challenging, thus making it prone to misuse, which limits its benefits. This article would explore the potential role of silicon within agricultural systems, especially on its effects: on the structural integrity of plants, nitrate uptake, metabolic activities and nitrogen cycling in both plants and soils. The article gives extensive details on the benefits this addition may bring, mentioning the challenges involved with adding silicon. Application of silicon into traditional agricultural practices are going to herald a new era in productive agriculture coupled with ecological balance. The need here is to continue researching it and exploiting its potential; build up the knowledge of how it works, so one is to set best practices for it, in order to adapt it and use it towards maximizing benefits for generations in the future.

Introduction

Agriculture research practice for improving crop yield productivity combined with nutrients-use efficiency remains among one of the sophisticated questions posed by agricultural practices within modern days. An important strategy receiving the required production from current agriculture system is Si supplementation for plants. Silicon has recently emerged as a key element in the context of critical nutrients such as nitrogen, phosphorus, and potassium, although it plays a very important role in the enhancement of resistance in plants, uptake of nutrients, and subsequently increased use efficiency of nutrients. Silicon is considered an essential element for most crops but not as an essential nutrient for most plants; rather, adequate amounts are required to ensure health and productivity. Silicon,

when applied to the foliage, has the potential to penetrate the architecture of the leaf and interfere with several physiological mechanisms. This characteristic makes the nutrient absorption and utilization very effective, thereby forming an important link between silicon application and general crop performance. An important way through which silicon enhances nutrient use efficiency is by increasing the structural integrity and vigour of plant tissues. Silicon enhances the strength of plant structures, improves resistance to biotic and abiotic stressors, and improves efficiency in nutrient uptake. For this reason, “silicon application” has emerged as a promising strategy for overcoming some limitations associated with traditional agricultural practices, especially with respect to the use of essential nutrients such as nitrogen, phosphorus and

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potassium.

Silicon sources

Silicate slag is primarily an industrial by-product, primarily produced from processing iron and other alloys. Wollastonite is the mineral, also known as calcium metasilicate, CaSiO_3 that can be regarded as a source of silicon available to the plant. Rice hulls and sugarcane bagasse are readily available sources of Si for plants. Chemical forms of potassium and sodium silicates are other readily available sources of Si. Foliar silicon contains all soluble forms of silicic acid, from monosilicic acid up to colloidal silicic acid, dissolved in seawater, river water, and in soil. Diatomite is the most important natural source of siliceous diatom remains, which are available to plants, being in close association with unicellular aquatic algae. Rice hull ash and carbonized straw and husks are some renewable sources of silicon available as fertilizers.

Table 1: Silicon fertilizer sources

Primary Si fertilizers	Si content (%)
Calcium silicate slag ($\text{CaAl}_2\text{Si}_2\text{O}_8$)	18-21
Calcium metasilicate (CaSiO_3)	31
Sodium metasilicate (NaSiO_3)	23
Quartz sand (fine grinded)	46
Salicic acid	29
Potassium silicate	18
Calcium silicate	24

Functions of silica in plants

No biochemical role has so far been identified to plants, but it was hypothesized that enzyme-Si complexes may be involved as either protective proteins during photosynthesis and enzyme activity or as regulatory proteins. Si may prevent the functioning of invertase while elevating

sucrose production due to interference in sugarcane enzymic activities (Majumder and Prakash, 2020) . Low phosphatase activity is supposed to provide enhanced supply of better high energy precursors towards sugar synthesis and optimum growth. The silica deposited on the epidermal cells of leaves and stems provides rigidity, increases strength, and resists lodging. This deposit strengthens the vascular tissues, reduces transpiration rates, and increases the possibility of water balance, thus facilitating water economy. On the other hand, low amounts of silica result in succulence and increase the rate of transpiration (water loss through the leaves), leading to a reduction in water use efficiency. Improved fruit reproduction by improved pollination of tomatoes and increased pollen fertility of cucurbits. But silicon deficiency decreases the protein and chlorophyll synthesis and increases the rate of photosynthesis as stems are stronger and hence result in more erect leaves which intercept more light. The beneficial effects of Si are due to partial remediation of toxic effects of high soil Mn^{+2} , Fe^{+2} , or Al^{+3} ; plant disease resistance; higher stalk strength and resistance to lodging. Foliar applications of silicon have shown the potential to improve cell wall fortification, leading to an increase in biotic as well as abiotic stress resistance.

Increase of Nutrient use efficiency: Silicon improves growth in roots and increases root surface area, thereby offering greater uptake of nitrogen from the soil. Applied silicon has also been proved to stimulate enzymatic activity linked with assimilation

activity resulting in the conversion of inorganic forms of available nitrogen into organic forms by organisms, which are simpler in uptake by plants. Silicon application has been known to promote mycorrhizal fungi. These are symbiotic fungi that develop relationships with the roots of plants. Fungi increase the uptake of nutrients including nitrogen. Improved soil microbiome promotes efficiency in nutrient cycling, further increasing NUE. Silicon application can modulate the expression of nitrogen transporters and assimilatory enzymes, thereby optimizing the internal nitrogen economy of plants. Silicon amendment application enhanced the leaf chlorophyll index, agronomic efficiency, and N-uptake in maize and wheat plants, which positively impacted the shoot and root development resulting in a higher grain yield. In addition, if Si application was done, then N fertilization in wheat and maize could be reduced from 195-200 to 100 kg N ha⁻¹ and 180-185 to 100 kg N ha⁻¹, respectively (Galindo *et al.*, 2021). Silicon application has been reported to enhance phosphorus nutrition and uptake in the plants.

Silicon enhances phosphorus use efficiency by reducing phosphorus fixation in the soil (Zhang *et al.*, 2019). Silicon addition to the soil has been shown to alter the chemistry of the soil and to increase the solubility of phosphorus, hence making it more available for the plants. Silicon is thus a promoter of nutrient availability, and by limiting the adsorption of phosphorus onto soil particles, it encourages root development and enhances phosphorus uptake.

It also increases phosphorus availability and uptake by competing for the fixation sites that exist in the soil. This increased resistance enables plants to sustain higher physiological performance and nutrient uptake even in adverse conditions. Among the many roles silicon plays in enhancing nutrient use efficiency, one of the most important contributions is to stomatal conductance. Improved stomatal conductance results in increased transpiration rates, which facilitates nutrient transfer from the soil into the plant system. The use of silicon enhances root growth and, consequently, allows for greater soil volume exploitation for the uptake of nutrients. Increased root system leads to better adsorption of potassium in the soil, which ultimately increases potassium use efficiency (KUE). Silicon is helpful in stabilizing the cell membrane significantly. Silicon also helps in silica deposition inside the cell walls, which in turn strengthens the structural integrity to reduce leakage of potassium ions into the cells. It thereby maintains the important nutrient within plant tissues and maximizes its usage. The presence of silicon has been proven to improve the osmotic potential of plants, thereby helping it take up water better and transport nutrients better. Silicon application has been reported to be associated with higher chlorophyll content and improved photosynthetic efficiency. Improved photosynthetic rate leads to an increase in carbohydrate production that requires a higher uptake of potassium for various metabolic activities, thus increasing KUE. Silicon has been documented to make plants more tolerant to

various abiotic stresses, such as salinity and drought. By alleviating the stress factors, silicon enables plants to make better use of potassium under stressed conditions, thus increasing KUE. Application of silicon under saline conditions resulted in a much higher production of dry matter in *Prosopis juliflora* correlated with the improved uptake of potassium as reported by Liang (1999).

Challenges Associated with Silicon Application

Silicon used in agriculture comes with a lot of advantages but also creates many problems. One of the main problems is the inconsistency in availability of silicon related to the different classifications of soils and pH levels, which leads to erratic reactions from plants. In addition, silicon effectiveness varies across crop species, and this requires targeted research to know which crops would benefit the most, a process that can be resource-intensive. The lack of uniform practices and protocols concerning silicon fertilization exacerbates its application challenges, leading to potential misapplications and restricting its benefits. It is crucial for stakeholders to have access to precise, scientifically-grounded guidelines regarding the timing, dosage, and methods of application. Additionally, there are possible trade-offs involved, as elevated silicon concentrations may impede the absorption of vital micronutrients, underscoring the necessity for a comprehensive nutrient management strategy to enhance advantages while mitigating adverse interactions.

The Future of Silicon Application in Sustainable

Agriculture

Better Nutrient Use Efficiency through Silicon will only be attained if research focuses on explaining specific crop responses to the element and mechanisms by which silicon acts to modify nutrient flow at the plant and soil interface. Management strategies should therefore be developed based on local soils conditions and crop types together with awareness programs for farmers on the benefits of silicon and how to handle it appropriately. It means incorporating silicon research in agricultural policies and funding initiatives, which in return will help to standardize practice towards better nutrition efficiency and sustainability in agriculture by acceptance of silicon across the world.

Conclusion

The utilization of silicon through foliar means has been one of the major opportunities for enhancing nutrient use efficiency in agricultural systems. Strengthening structural plant integrity, enhancing nutrient absorption, optimizing metabolic processes, and providing resilience to environmental stress have made silicon an indispensable component in the quest to enhance productivity in agriculture. The introduction of silicon in conventional agricultural practices may signal the beginning of a new era in sustainable agriculture, increasing yields without compromising ecological balance. The agricultural industry must continue to research and exploit the potential of silicon, promote a more holistic understanding of its mechanisms, and formulate best practices for application in order to optimize its

advantages for future generations.

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Meet *Thrips parvispinus*: The Tiny Pest with a Big Impact on Crops

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Abstract

Thrips parvispinus is a notorious pest that endangers key crops such as chili, capsicum, eggplant, and tomatoes. Its feeding on plant tissues, combined with its ability to transmit plant viruses like Tomato Spotted Wilt Virus (TSWV), results in significant yield reductions, lower crop quality, and severe economic losses. This pest reproduces rapidly, completing its life cycle in just 10-14 days, enabling it to form large infestations that can destroy up to 80% of crops in heavily affected fields. Its spread is facilitated by climate change and global trade, with infestations reported in Southeast Asia, India, and tropical regions. Effective control requires an Integrated Pest Management (IPM) strategy, incorporating quarantine, field sanitation, natural predators like mites and parasitoid wasps, and microbial agents like entomopathogenic fungi. Responsible use of chemical insecticides is also essential. A combined approach is crucial to protect food security and maintain the sustainable production of these economically important crops.

Introduction

“Can an insect of size of a grain of sand generate millions of dollars' worth of economic destruction?”

It can, and it does, indeed. Introducing *Thrips parvispinus*, a small yet potent pest that seriously jeopardizes agriculture worldwide. This little insect causes disproportionate harm to high-value crops including eggplant, capsicum, pepper, and other vegetables. Its infestations have caused devastating crop losses from Southeast Asia to India; in badly infected farms, these losses have occasionally reached 80% (Prasannakumar *et al.*, 2024). Farmers and legislators are becoming increasingly concerned about this new pest's quick geographic spread.



Adult *Thrips parvispinus*. Photo source: <https://www.thrips-id.com/en/thrips-parvispinus/>

The significance of *Thrips parvispinus* extends far beyond its size. It has become one of the most economically damaging pests in horticulture. A study on its impact on chili crops found that infestations resulted in significant fruit loss and, in extreme cases, total crop failure (Keerthi *et al.*, 2024). With the rise of international agricultural

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trade, its ability to spread to new regions poses a global economic threat. For example, capsicum and chili farmers in Southeast Asia and India report losses that compel some to abandon their crops entirely (Marimuthu *et al.*, 2023). This insect damages crops by feeding on plant tissues, especially flowers and young fruits. The result is distorted fruits, early flower drops, and discoloured or scarred vegetables, reducing the commercial value of crops (Raghavendra *et al.*, 2023). By consuming plant tissues, particularly blooms and immature fruits, this bug harms agriculture. The outcome lowers the commercial value of crops by producing deformed fruits, early blossom drops, and discoloured or scarred vegetables (Raghavendra *et al.*, 2023). A study published in *Phytoparasitica* claims that *Thrips parvispinus*'s feeding activities on chili flowers result in enormous flower drops, which significantly affects production (Raghavendra *et al.*, 2023). Infesting a range of horticultural plants, such as eggplant, capsicum, and other vegetables, the pest's effects are not limited to a single crop. In addition to directly harming crops, it serves as a vector for tospoviruses, which in turn cause other crop diseases (Ghosh *et al.*, 2017). It is especially harmful because it serves as both a pest and a disease vector. Direct feeding and viral disease transmission work together to increase crop loss and make effective control measures even more urgent. The possibility of its spreading to new areas is a major worry due to the growth in international agricultural trade. Containment attempts are made more difficult by the fact that

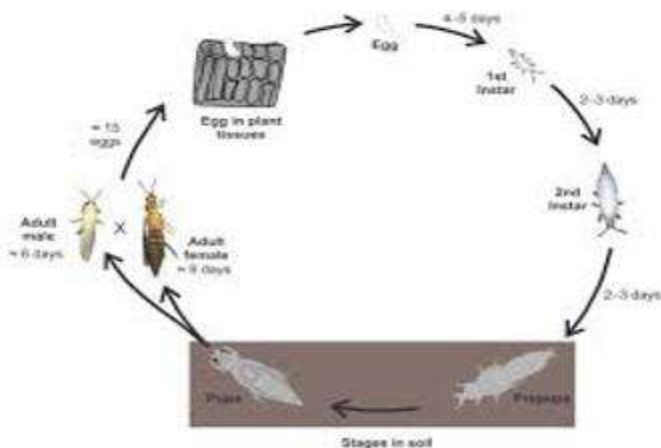
the pest has been observed in a variety of cropping systems, including tropical poly-crop ecosystems (Marimuthu *et al.*, 2023). According to recent research, climate change may cause its geographic spread to grow even more, endangering crops all across the world (Mukherjee *et al.*, 2023). This article's goal is to inform farmers, scientists, and decision-makers on its biology, effects, and dissemination. Increase knowledge of the pest's potential to interfere with international food supply chains, particularly for valuable crops like eggplant, capsicum, and chili. Offer pest management and control alternatives, such as sustainable agricultural methods, biological control choices, and integrated pest management (IPM) techniques.

Taxonomy, Appearance and Life Cycle

It belongs to Order: Thysanoptera, Family: Thripidae

This classification places *Thrips parvispinus* among other economically important thrips species like *Thrips tabaci* and *Frankliniella occidentalis*, both of which are notorious for their role in crop damage and disease transmission (Ghosh *et al.*, 2017). The appearance of *Thrips parvispinus* is characterized by: Adults are small, typically less than 1mm in length. The body of the adult is often pale yellow or light brown, while the larvae are usually a lighter, creamy-white colour. The insect's body is elongated with narrow wings fringed with fine hairs, a key identifying trait of most Thysanoptera. The head is conical, and the antennae are segmented, assisting in identifying this species (Vono *et al.*, 2022). These small but distinctive morphological

features make it possible to differentiate *T. parvispinus* from other similar species like *Thrips tabaci* or *Frankliniella occidentalis*. However, the use of microscopic examination and molecular identification tools is often necessary due to the similarity in appearance across different thrips species (Ghosh *et al.*, 2017).



Life cycle of *Thrips parvispinus* (Ahmed *et al.*, 2023)

The life cycle of *Thrips parvispinus* consists of six distinct stages. The egg stage involves the female depositing eggs into plant tissue, leaving scars or discolorations (Nguyen *et al.*, 2024). In the first instar larva, the larvae feed on plant surfaces, causing silvery or scarring. The second instar larva continues feeding and later burrows into soil or plant debris to pupate. During the pre-pupal stage, feeding stops, and the larva prepares for transformation. The pupal stage occurs underground, where the larva develops into an adult, sheltered from predators and weather (Ghosh *et al.*, 2017). Finally, in the adult stage, the thrips resumes feeding, mating, and egg-laying, spreading to new plants. The entire life cycle lasts 10 to 14 days, with warm temperatures accelerating development (Nguyen *et al.*, 2024). This

rapid cycle allows *T. parvispinus* to establish large populations quickly, making it a persistent agricultural pest.

Why Does *Thrips parvispinus* Matter?

A highly polyphagous pest, *Thrips parvispinus* infests a variety of economically significant crops, resulting in notable losses in yield and quality. In chili (*Capsicum annum*), where it feeds on flowers, it has the most detrimental effects, resulting in early flower drop, deformed fruits, and decreased fruit yield (Vono *et al.*, 2022). The tomato (*Solanum lycopersicum*) is similarly impacted, resulting in post-harvest losses and decreased market value due to flower and immature fruit deformity and scarring. Damage to ornamental plants reduces their marketability for export (Marimuthu *et al.*, 2023). Cucurbits, eggplants, and other vegetables are also attacked; feeding activity reduces their commercial value and causes scarring. *T. parvispinus* is a serious danger to crop output worldwide because of its capacity for rapid reproduction once established, which makes pest control very difficult. *Thrips parvispinus* causes significant financial losses. Infestations in tropical and subtropical locations have resulted in yield reductions of up to 80% in affected fields, where capsicum and pepper are important cash crops (Vono *et al.*, 2022). Farmers, exporters, and national economies that depend on agricultural exports are all affected economically. According to research by Mukherjee *et al.* (2023), in some areas, the total yearly economic loss brought on by thrips infections across several crops can surp-

ass \$50 million. Direct feeding damage, lower yields, and higher production expenses as a result of pest management practices are all blamed for this loss. The rejection of subpar produce from export markets results in additional revenue losses for producers and exporters, which has a substantial indirect economic impact. Because it is a vector for plant viruses, especially Orthotospoviruses, which lower crop yields and damage plant health, *Thrips parvispinus* is a serious agricultural pest. It spreads diseases like Groundnut Bud Necrosis Virus (GBNV), which affects groundnut plants and lowers yield, and Tomato Spotted Wilt Virus (TSWV), which deforms and discolours crops like tomatoes, chilies, and ornamental plants, and it directly damages crops through feeding (Ghosh *et al.*, 2017). Direct feeding and virus transmission combine to increase crop losses. For example, TSWV outbreaks in tomato fields have resulted in crop rejections in export markets, particularly in Europe where quality standards are stringent. Owing to its broad host range, quick reproductive cycle, and function as a virus vector, *T. parvispinus* is a serious threat to world agriculture, causing large financial losses and decreased crop value. Protecting food security and agricultural economies requires a thorough understanding of its effects and control strategies.

Signs and Symptoms of Infestation

It takes careful monitoring to find *Thrips parvispinus* infestations in the field because the pest is small and hard to see up close. On delicate stems, flower buds, and blooms where thrips usually feed

and deposit their eggs infestation symptoms are most noticeable. When thrips remove cellular fluids from the plant, it results in aberrant leaf growth, which is a common symptom of leaf twisting and distortion (Marimuthu *et al.*, 2023). When cell contents are removed from leaves, air fills the space, resulting in silvery or glossy spots (Khatun *et al.*, 2024). Thrips cause scarring and discolouration on fruits like tomatoes and chilies, which lowers their market value (Marimuthu *et al.*, 2023). Additionally, especially in chili crops, thrips that feed on flowers can result in early blossom drop, which impedes fruit development and drastically affects yields (Vono *et al.*, 2022).

Field Monitoring and Detection Tools

Timely discovery and management of its populations depend on efficient monitoring. For early detection, sticky traps in blue or yellow are frequently utilized; blue traps are more successful at attracting thrips (Marimuthu *et al.*, 2023). Although it might be time-consuming, visual examinations of young leaves, flowers, and fruits aid in spotting early symptoms including silvery patches, malformed leaves, and scarred fruits (Rajesh *et al.*, 2024). Due to the pest's small size, it is necessary to employ magnifying instruments such hand lenses or microscopes in order to examine important characteristics like body colour and fringed wings (Vono *et al.*, 2022). Recent developments include automated detection systems that use image analysis and machine learning to speed up the identifying process by examining photos of sticky traps (Khatun *et al.*,

2024). Thrips can also be found in plant tissue as larvae, eggs, and adults through manual sampling and microscopic dissection of flowers and foliage (Marimuthu *et al.*, 2023). In order to minimize production costs, reduce crop losses, and apply pest management measures, early detection is essential.

Control and Management

A comprehensive approach combining chemical, biological and preventative control methods is needed to manage *Thrips parvispinus*. In addition to limiting financial losses, this integrated approach lowers pest populations and slows the emergence of chemical resistance. Stopping the introduction and spread of the insect requires preventive actions. Quarantine procedures are required to prevent the spread of contaminated plant materials, especially for plants that are imported (Ataide *et al.*, 2024). To avoid unintended infections, farmers should only use certified pest-free planting materials, according to Gagnon *et al.* (2024). When possible breeding grounds are removed through field cleanliness, such as removing weeds and agricultural trash, thrips are unable to live on other host plants (Marimuthu *et al.*, 2023). Physical barriers like insect-proof screens and fine mesh nets are put in place in nurseries and greenhouses to keep pests out and save valuable crops like capsicum and decorative plants (Kim *et al.*, 2018). By using biological management instead of synthetic pesticides, *Thrips parvispinus* can be managed in a sustainable manner. Predatory mites, such *Amblyseius swirskii* and *Amblyseius cucumeris*, are frequently employed in greenhouse settings and

consume the larvae and eggs of thrips (Beretta *et al.*, 2024). In order to reduce the population of thrips, parasitoid wasps, such as *Ceraninus menes*, attack their larvae and feed on the thrips themselves (Coy-Barrera and Rodríguez, 2023). Particularly in humid environments that encourage fungal growth, entomopathogenic fungi such as *Beauveria bassiana* and *Metarhizium anisopliae* infect and kill thrips (Adly and Sanad, 2024). Furthermore, botanical extracts such as mint, eucalyptus, and neem oils work as natural repellents or prevent thrips from laying eggs (Antonopoulou *et al.*, 2023). Although biological management provides a sustainable and environmentally beneficial option, it may take some time for predator and parasitoid populations to form.

Chemical control is still an essential part of managing *Thrips parvispinus*, especially when the infestation is severe. Nevertheless, an excessive dependence on pesticides may lead to resistance and inadvertent damage to beneficial organisms. In order to prevent resistance, common insecticides like spinosad, abamectin, and cyantraniliprole must be used in combination with various modes of action (Ataide *et al.*, 2024). Imidacloprid and other systemic insecticides can be absorbed by plants, rendering their tissues poisonous to thrips, particularly in crops like capsicum and pepper (Vono *et al.*, 2022). Farmers are urged to adhere to the Insecticide Resistance Action Committee's (IRAC) recommendations and reduce the frequency of their spraying. This strategy lowers expenses, safeguards non-target creatures, and lessens the impact on the

environment (Summerfield *et al.*, 2024).

Conclusion

Thrips parvispinus control requires a combination of preventive, biological, and chemical methods. Clean planting supplies, field hygiene, quarantine procedures are crucial. Biological controllers like predatory mites and parasitoid wasps offer environmentally friendly alternatives. Chemical controls, like pesticide rotation and application frequency, are used to prevent resistance. Integrated Pest Management (IPM) reduces pesticide use, protects crop health, and minimizes financial losses.

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The Secret to Optimal Health: An Understanding of Balanced Diet

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Abstract

In order to maintain optimal health and wellness, it is imperative that the body receives the nutrients it requires from a balanced diet. This article discusses the elements of a balanced diet, how important it is to keep one's physical and mental health, doable ways to incorporate it into day-to-day activities and offers guidance on creating good eating habits. The disadvantages of dietary deficiencies are also covered. Individuals who understand the significance of a balanced diet can make educated food choices that will enhance their quality of life and lead to better health results. Optimal health is a goal that many strive to achieve, and understanding the concept of a balanced diet is crucial in this pursuit. A balanced diet is defined as one that provides the necessary nutrients in the right proportions to support overall health and well-being. By recognizing the significance of nutrient diversity and moderation, individuals can take charge of their health through informed dietary choices.

Introduction

Health as a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity (WHO, 1946). This concept recognizes that health is influenced by a variety of social factors, including economic stability, education, social and community context, health care access, and neighbourhood environment (Social Determinants of Health, 2024). A balanced diet should include a variety of foods from all food groups, ensuring adequate intake of essential nutrients (WHO, 2010). A balanced diet as one that includes a variety of foods from all food groups, ensuring that individuals receive the necessary nutri-

ents for optimal health (U.S. Department of Agriculture, 2020). A balanced diet has become increasingly difficult to maintain in the fast-paced world of today. It is more crucial than ever to understand and follow the guidelines of a balanced diet in a setting where processed foods and convenience items are easily accessible. Maintaining a balanced diet is crucial. A mindful diet can enhance one's physical and mental well-being and lead a more colourful, energetic life. It provides the necessary nutrients for the body. It must be efficient, aid in the prevention of illness, and promote general physical and mental well-being. A varied diet with sensible serving sizes ensures that individuals receive adequ-

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ate amounts of fats, proteins, carbohydrates, vitamins, and minerals. This is known as a balanced diet. The 2017 National Health Policy advocated for a “Focus on Preventive and Promotive Health Care” and highlighted seven priority areas for enhancing the environment for health through social determinants of health initiatives. “Balanced and Healthy Diets” was one of these focused areas (National Health Policy - 2017). Population growth, demographic shifts, fast urbanization, and changes in lifestyle all contribute to the spread of bad food habits and physical inactivity, which leads to diet-related chronic diseases. The low nutritional value, high salt content, and the levels of saturated and trans fats found in fast food are likely contributing factors to the increasing rates of hypercholesterolemia, hypertension, type II diabetes, obesity, and cardiovascular diseases in Western societies (Jahan *et al.*, 2020).

We can say that there is a direct relationship between food and our bodies. Everything we ingest through food on a daily basis has an immediate effect on our bodies. A balanced diet is fundamental to maintaining optimal body function and overall health. It offers the vital nutrients vitamins, minerals, proteins, carbs, and healthy fats that the body needs for energy production, growth, and repair. Every nutrient has a distinct purpose. For example, proteins are essential for tissue growth and repair, carbohydrates are the body's main source of energy, and fats support hormone production and cellular function. A balanced diet helps regulate body weight,

supports the immune system, and reduces the risk of chronic diseases such as diabetes, heart disease, and obesity. A balanced diet promotes physical vitality, mental clarity, and emotional well-being by guaranteeing that the body receives a sufficient and diverse supply of nutrients. It cultivates this harmonious relationship between food consumption and physical well-being. In addition to highlighting the advantages of consuming a variety of food groups, the concept of a balanced diet also highlights the significance of portion control and moderation. It is well established that a diverse diet helps prevent nutrient deficiencies, fosters growth and development, and reduces the risk of chronic illnesses like obesity, diabetes, and cardiovascular issues. Thus, the functions of our bodies and the results of our health are directly impacted by the food we eat.

Elements of a Balanced Diet

Carbohydrates are the body's primary energy source. Foods high in carbs include fruits, vegetables, and whole grains. Whole wheat bread, oats, and brown rice are a few of these items. They also provide essential fiber, which aids in digestion and encourages good weight maintenance.

Proteins: Found in plant and animal sources (such as legumes, beans, nuts, and seeds) and animal sources (such as meat, fish, and dairy), proteins are necessary for the development, maintenance, and repair of body tissues. A comprehensive amino acid profile is ensured by including a range of protein sources.

Fats: Good fats are necessary for energy and help in the absorption of several vitamins (A, D, E, and K).

Good fats can be found in nuts, seeds, avocados, olive oil, and fatty seafood like salmon. The usual sources of trans and saturated fats in processed foods should be minimized.

Minerals and vitamins: These micronutrients are essential for a number of body processes, such as the production of energy, healthy bones and immunological response. A broad range of these nutrients can be obtained by eating a colourful assortment of fruits and vegetables.

Water: Although it is sometimes disregarded, water is crucial for sustaining metabolic processes and staying hydrated. It is essential for general health to consume enough water each day.

Stay active: A minimum of 60 minutes of moderate to vigorous-intensity exercise should be encouraged on a daily basis. More than 60 minutes of physical activity involves enhanced fitness and health. These activities should be done three times a week or more to include muscle and bone strengthening.



Figure 1: Healthy Food Plate for the day, totalling 2000 Kcal

The Advantages of a Balanced Diet

Weight management: Eating a variety of nutrient-dense foods in moderate portions helps people maintain a healthy weight and prevent obesity.

Lower Risk of Chronic Illnesses: A balanced diet helps lower the risk of developing diabetes, heart disease, some cancers, and other chronic conditions. Foods like fruits, vegetables, and whole grains that are high in antioxidants and have anti-inflammatory qualities have a protective effect.

Better Mental Health: The brain's health is greatly influenced by nutrients. A well-balanced diet has the potential to improve mental health in general, mood, and cognitive performance.

Enhanced Energy Levels: Eating a healthy diet gives you the energy you need for everyday tasks and can help you perform better physically overall.

Improved nutrients intake: Providing the appropriate balance of essential nutrients in the correct proportions.

How to Eat a Balanced Diet by Following These Useful Tips

Portion control: The ideal composition of a nutritious meal plate is 50% fruits and vegetables, 25% grains, 25% protein source, and maintaining balance and avoiding overeating can be achieved by being aware of serving sizes and making necessary portion adjustments.

Variety is Key: To guarantee a complete nutrient intake, try to eat a broad variety of foods from all food groups.

Plan Your Meals: Making healthier food choices

Elements		Food source	Work	Deficiency or excess symptoms
Carbohydrates		Potatoes, jaggery, bananas, and whole grains	Energy generation	Weakness results from deficiency, and obesity is caused by overabundance.
Protein		Pulses, Egg, Meat, Mushroom, Soybean	Muscle or body building	Kwashiorkor disease is brought on by deficiencies. Excess causes the body to get agitated.
Fat		ghee, oil, meat	Energy generation and the composition of the body	Weakness stems from insufficiency, whereas excess leads to obesity.
Vitamin A (Retinol)		Dark green leafy and yellow/orange vegetables, yellow fruits	Immunity, growth, reproduction, and vision	Night blindness is a result of deficiency.
Vitamin B	Thiamine (Vitamin B ₁)	Leafy greens, pork, and whole and enriched grains	Energy metabolism	Problems with neurological function
	Riboflavin (Vitamin B ₂)	Milk products, whole and enriched grain products	Convert protein, lipids, and carbs into glucose to produce energy.	Skin and mouth inflammation
	Niacin (Vitamin B ₃)	Protein-rich foods, whole and enriched grain products	increasing the efficiency of digestion, the body's ability to properly absorb dietary juices, and the removal of waste from the intestines	Pellagra, digestive tract problems, fatigue, insomnia, apathy, and later confusion and memory loss
	Pantothenic acid (Vitamin B ₅)	Virtually all meals, but particularly meats, avocados, and broccoli	Metabolism of proteins, fats, and carbohydrates	Upper respiratory infections, scorching feet, agitation, vomiting, and stomach aches
	Pyridoxine or pyridoxal or pyridoxamine (Vitamin B ₆)	Foods high in protein	Metabolism of fats and proteins	Microcytic anaemia, anomalies in electroencephalography, and tongue swelling or glossitis
	Folate or folic acid (Vitamin B ₉)	Fortified grain products, legumes, vegetables	Aids in cellular DNA synthesis and B ₁₂ activation	Weakness, exhaustion, mouth sores and neurological problems
	Cyanocobalmine (Vitamin B ₁₂)	Fish, meat, poultry, eggs, and dairy products	Promotes the synthesis of new DNA, activates folate, and shields nerve cells	Weak muscles, numbness, dizziness, nausea, difficulty walking, exhaustion, and elevated heart rate
Vitamin C (Ascorbic acid)		Lemon, Amla, and Tomato	Immune system, collagen formation, antioxidants, and healthy gums	Deficit leads to scurvy
Vitamin D (Calciferol)		Sunlight, dry fruits, liver, eggs, and fatty fish	Growth and preservation of bones, as well as calcium absorption	Insufficient bone mass results in osteomalacia, calcium imbalance, and rickets.
Vitamin E (Tocopherol)		Wheat germ, fruits, vegetables, and cucumber	Healthy procreation, antioxidant; shields the membranes of cells	Fertility is hampered by deficiencies. breakdown of red blood cells and injury to the nerves
Vitamin K (Phylloquinone)		Liver, dark green vegetables, fenugreek, milk, and spinach	Formation of blood clots	Deficit does not cause blood clots to form.
Minerals	Calcium	Foods fortified with calcium, such as soy products, dairy products like milk, yoghurt, and cheese, and, to a lesser extent, some leafy green vegetables, nuts and seeds	Develop and preserve a robust heart, bones, muscles, and nervous system.	Causing numbness and tingling in your fingers, weak nails, sluggish hair growth, frail, thin skin, muscle soreness, and spasms.

Minerals	Phosphorus	Meats and poultry, fish, eggs, dairy products, nuts, legumes, vegetables, and grains	Enzyme activation, bone and tooth formation	Muscle aches and cramps, problems with cognition, your fingers are numb and tingly.
	Iodine	Fenugreek, iodized salt	Thyroid gland	Fatigue, weight gain, and swollen neck
	Iron	Brinjal, spinach, green leafy vegetables	Formation of hemoglobin	Lack results in blood loss.
	Copper	Potatoes, cashew nuts, oysters, mushrooms, and sunflower seeds	Red blood cell synthesis and maintenance of neuronal cells, immunological system, and antioxidant	Low white blood cell count, irregular heartbeat, anaemia, low body temperature, osteoporosis, bone fractures, loss of skin pigmentation, and thyroid issues
	Zink	Meat, fish, oysters, and shellfish	Contributes to the immune system, cell proliferation, division, wound healing, and carbohydrate breakdown.	Inflammation, gastrointestinal problems, sexual dysfunction, and stunted growth
Water			Temperature regulator, lubricant/shock absorber, transportation vehicle, and chemical reaction medium	low to non-existent urine production, a weak and fast pulse, sunken eyes, dry lips, poor skin turgor, and cold hands and feet

and resisting the urge to eat fast food or unhealthy snacks can both be accomplished by preparing meals in advance.

Observe Your Body: Acknowledge the signs of hunger and fullness sent by your body, and eat when you're hungry and stop when you're satisfied.

Conclusion

A balanced diet is essential for preserving health and warding off illness. People can enjoy a healthier lifestyle and improve their well-being by including a variety of foods and nutrients in their daily meals. A balanced diet must be achieved and maintained through nutrition education and thoughtful food selection. His secrets to optimal health lie in the understanding and practice of a balanced diet. By embracing a variety of nutrient-rich foods and practicing mindful eating, individuals can significantly enhance their health and well-being. The journey to a balanced diet is not about achieving perfection but rather making informed

choices that contribute to long-term wellness. As we move forward in our health journeys, let us prioritize nutrition and cultivate habits that promote a healthier, happier life.

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Abscissic Acid Mediated Defense against *Tetranychus urticae*

Priyadharshini V. and Ayyamperumal M.

Abstract

The two-spotted spider mite, *Tetranychus urticae*, is a significant agricultural pest that causes substantial damage to crops worldwide. Plants employ various defense mechanisms to combat herbivory, including the phytohormone abscisic acid (ABA). ABA plays a crucial role in regulating stomatal aperture, a process that can influence plant susceptibility to piercing-sucking insects like mites. Upon mite infestation, plants accumulate ABA, leading to stomatal closure and limiting mite access to plant tissues. This study investigates the role of ABA in plant defense against *T. urticae* and explores the underlying mechanisms. By understanding the complex interplay between ABA, stomatal behavior, and herbivory, researchers can develop novel strategies to enhance plant resistance to this destructive pest.

Introduction

Tetranychus urticae, commonly known as the two-spotted spider mite, is a tiny, yet destructive pest that inflicts damage on over 180 plant species worldwide. These mites, easily spread by wind or human activity, thrive on the undersides of leaves. Using their piercing mouthparts, they puncture the leaf's epidermis, leading to tissue collapse and the formation of unsightly bronze, chlorotic, or white patches. Severe infestations can result in extensive webbing, which further hinders plant growth and productivity.



Abscissic acid (ABA) is a crucial plant hormone that regulates stomatal aperture (Kuromori

et al., 2018), a vital process for gas exchange, photosynthesis, and responses to environmental stress. When plants are under duress, such as from drought, salinity, or herbivory, ABA levels increase, triggering stomatal closure to conserve water (Christmann *et al.*, 2006; Lim *et al.*, 2015). Interestingly, ABA signaling can influence plant-herbivore interactions. ABA-deficient plants are more susceptible to herbivory, suggesting that stomatal closure may play a role in defense. Piercing-sucking insects, like aphids and mites, often exploit open stomata as entry points to access plant tissues. By manipulating stomatal behavior, herbivores can gain a feeding advantage and potentially suppress plant defenses. The complex interplay between ABA, stomata, and herbivory highlights the intricate

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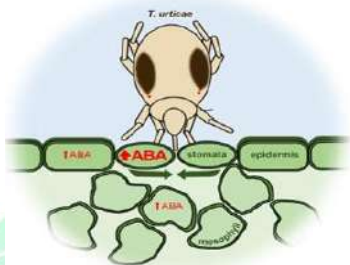
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strategies employed by plants and insects in their ongoing evolutionary arms race.

ABA accumulation upon mite infestation

When mite infestations cause ABA to accumulate in leaves, a high-resolution biosensor called nlsABACUS2-400n is used to pinpoint the specific cells where ABA levels rise significantly (Rowe *et al.*, 2022).

This biosensor is effectively expressed in various cell types, including internal and epidermal cells, allowing researchers to analyze ABA accumulation in different regions of the leaf. By comparing infested and control plants, it was observed that ABA concentrations increased in all cell types upon infestation. To further understand the cellular distribution of ABA, a nuclear morphology classifier was employed. This tool identified five distinct cell types: vascular bundle cells, pavement cells, spongy mesophyll cells, stomata, and bundle sheath cells. Notably, stomatal and vascular bundle cells exhibited the highest ABA levels, although all cell types showed increased ABA accumulation in response to infestation. To assess the impact of mite feeding on cell viability, researchers examined the number of nuclei in infested and non-infested leaves. While the overall number of nuclei varied between the two groups, a significant decrease in mesophyll cell nuclei was observed in infested plants. This finding supports the hypothesis that mites feed on spongy mesophyll cells, leading to cell death.



Role of abscisic acid (ABA) in plant defense against mites

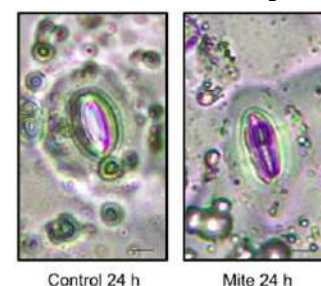
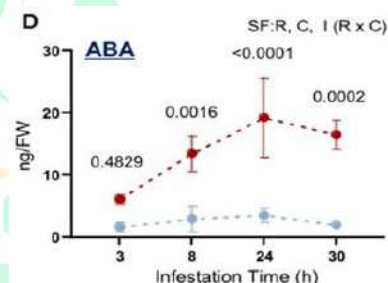
ABA can have a complex and sometimes contradictory role in plant defense against herbivores. While it can enhance defense responses by amplifying jasmonic acid (JA) signaling (Dinh *et al.*, 2013; Aleman *et al.*, 2016) and promoting stomatal closure, it can also compromise defenses by increasing susceptibility to certain herbivores.

Mite feeding triggers ABA synthesis in vascular cells, which then translocates to other cell types. This increase in ABA can lead to stomatal closure within 24 hours of infestation, restricting access for mites and reducing damage to leaf tissues.

Interestingly, ABA can also interact with JA signaling pathways to amplify defense responses.

However, the interplay between ABA, JA and salicylic acid (SA) signaling can be intricate. While SA and methyl-JA can promote stomatal closure, other jasmonates, like JA-Ile, can induce stomatal opening.

To further explore the role of ABA in plant defense, researchers have employed genetic and pharmacological approaches to manipulate ABA levels and signaling. By targeting ABA-triggered stomatal closure, it has been shown that this mechanism can effectively



prevent mite feeding and reduce leaf damage. Pre-treatment of plants with ABA can enhance their resistance to mite infestation by inducing stomatal closure. In contrast, ABA-deficient mutants are more susceptible to herbivory by caterpillars. This suggests that ABA plays a crucial role in defense against these herbivores, potentially by limiting their access to plant tissues through stomatal closure.

Overall, the role of ABA in plant defense is multifaceted and depends on various factors, including the type of herbivore, the specific plant species and the environmental conditions. Understanding the complex interactions between ABA and other signaling pathways is essential for developing effective strategies to enhance plant resistance to herbivores.

Conclusion

ABA-induced stomatal closure is a powerful defense mechanism plants employ against mites. However, several key questions remain unanswered. Which specific mite signals trigger this defense response in plants? Are there counter-signals from mites that can suppress this response? Additionally, it is crucial to evaluate the effectiveness of this defense mechanism against various mite species, particularly *T. urticae*. By addressing these questions, researchers can lay the groundwork for developing strategies to enhance plant resistance to these harmful pests by manipulating stomatal aperture and density.

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Sugarcane Flowering and Hybridization Program: A Brief Overview

Vijeta Gupta and Sudhir Sharma

Sugarcane (*Saccharum officinarum*) is a major crop for sugar and biofuel production. Hybridization programs in sugarcane are essential for improving traits such as yield, disease resistance and environmental stress tolerance. Flowering is the foundation of these hybridization programs, as it enables crossbreeding between genetically distinct plants to create superior varieties.

Sugarcane Flowering

Flowering in sugarcane is typically a late-season phenomenon, occurring when the plant reaches maturity. Flowering is influenced by environmental factors such as temperature, photoperiod and soil nutrients, along with genetic factors. In controlled breeding environments, flowering is often induced by manipulating these factors.

Inflorescence: Sugarcane flowers form a panicle, composed of many spikelets. The flowers are wind-pollinated and successful pollination leads to seed production.

Induced Flowering: In breeding programs, flowering is artificially induced using techniques like temperature manipulation, light management and the application of plant growth regulators.

Hybridization Process

Hybridization in sugarcane is a deliberate cross between two genetically distinct parents either within a species or from different species e.g.

Saccharum officinarum × *Saccharum spontaneum*.

The goal is to combine desirable traits from both parents such as high yield, high sucrose content and disease resistance.

Parent Selection: Parents with complementary traits (e.g., high sucrose content and pest resistance) are selected for crossing.

Cross-Pollination: Pollen from the male parent is transferred to the female flowers of the female parent. Cross can be bi-parental cross, general cross (GC) or polycross (PC).

Seed Development: Seeds from the hybridized plants are collected to create the F₁ generation. These seeds are grown and evaluated for superior traits.

Advances in Hybridization Techniques

Molecular Marker-Assisted Selection (MAS):

MAS utilizes DNA markers linked to traits like disease resistance, drought tolerance or high sugar content. This method accelerates the breeding process by identifying promising hybrids early in the selection cycle.

Genetic Engineering: Genetic modifications, such as gene editing (e.g., CRISPR-Cas9), are increasingly used to introduce specific traits like pest resistance or improved sugar yield. Transgenic approaches allow for more precise trait development without traditional hybridization.

Genomic Selection: High-throughput sequencing

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allows breeders to analyze the sugarcane genome, identifying loci associated with key traits. This helps in selecting parents that will produce the best hybrids in fewer generations.

Challenges in Hybridization

Low Seed Fertility: Many modern sugarcane varieties have low seed fertility, which complicates the hybridization process.

Genetic Narrowing: Commercial sugarcane varieties are often derived from a limited gene pool, restricting the introduction of new traits.

Environmental Sensitivity: Flowering and hybridization require specific environmental conditions, which can vary based on geographic location and climate.

Future Prospects

With continued advancements in genomics and biotechnology, sugarcane breeding programs are poised to overcome these challenges. Future efforts will focus on climate resilience, higher biomass production and biofuel optimization, ensuring that sugarcane remains a sustainable and productive crop for the future.

In summary, sugarcane flowering and hybridization programs are essential for developing new, high-performing sugarcane varieties. Through the integration of molecular tools and advanced breeding techniques, the potential for creating more resilient and high-yielding sugarcane varieties is expanding.

Potent Pulse-Green Gram and its Nutritional Benefits

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Introduction

Pulses, also referred to as 'poor man's meat' and rich man's vegetable, are members of the Leguminosae family, which has approximately 670 genera, over 21,000 species and 39 tribes. However, a recent phylogenetic analysis based on extensive DNA studies found 727 genera, 19,327 species, and 36 tribes. The legumes of the Papilionidae or Faboidae subfamily are divided into five tribes: Phaseoleae, Viciae, Cicereae, Aeschynomeneae, and Gemistae (Summerfield *et al.*, 1985). The first three tribes encompass the vast majority of grain legume species.



Green gram (*Vigna radiata* (L.) Wilczek) ($2n=22$) is the world's third most important pulse crop, grown extensively in many regions of the world. It belongs to the Fabaceae family and is the grain legume in Asia. It is grown in the tropics and subtropics and is self-pollinating, having a genome size of 579 Mbp (Arumuganathan and Earle, 1991). It has high levels of protein and is low in flatulence-causing components. As a result, green gram seeds are chosen for feeding newborns and individuals recovering from illness. The seeds have a higher lysine content than any other bean seeds. The seeds are processed and eaten as cooked whole beans or

splits (dhals), sprouts, immature seeds, and flour, which are used in a variety of cuisines. Pulses play an essential function in our existence. The word "Pulse" comes from the Latin word "Puls," which means "pottage" or boiled seeds used to make porridge or thick soups. Green gram is more popularly known in India than mung bean (Chatterjee and Randhawa, 1952), as are golden gram, chicksawpea, and Oreganpea. Pulses are the cheapest source of dietary proteins, with 24% of highly digestible protein and amount, which is almost two-thirds of the protein content of soybeans, twice that of wheat, and three times that of rice (Thirumaran and Seralathan, 1988). Regular green gram eating may help manage chronic diseases including as diabetes, cancer, hypertension and heart disease.

India is the world's leading producer of green gram, which is grown in practically in every state. It is planted on around 31.03 million hectares, producing 27.69 million tons at a productivity of 892 kg ha⁻¹ and accounting for 10% of total pulse production. According to the Government of India's fourth advance projections, green gram production will be 3.15 million tonnes in 2021-22 (Agricultural Statistics at Glance, 2022). As a result, further actions are required to boost pulse output and productivity in the country.

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Integrated Taxonomic Information System (ITIS) for Green Gram

The taxonomic hierarchy of green gram as per the (ITIS) Integrated Taxonomic Information System-report:

Kingdom	<i>Plantae</i>
Subkingdom	<i>Viridiplantae</i> (green plants)
Infrakingdom	<i>Streptophyta</i> (land plants)
Superdivision	<i>Embryophyta</i>
Division	<i>Tracheophyta</i> (vascular plants, tracheophytes)
Subdivision	<i>Spermatophytina</i> (spermatophytes, seed plants, phanerogames)
Class	<i>Magnoliopsida</i>
Superorder	<i>Rosanae</i>
Order	<i>Fabales</i>
Family	<i>Fabaceae</i>
Genus	<i>Vigna</i>
Species	<i>Vigna radiata</i> (L.) R. Wilczek

Nutritional Composition of Green Gram

Green gram is high in protein, carbohydrate, dietary fiber, vitamins, and minerals, with a low-fat content. Because it is high in protein, it might be viewed as a meat substitute for vegans. Aside from being a healthy food, green gram has possible health benefits such as antioxidant, anti-cancer, anti-inflammatory, and hypolipidemic properties (Lewis 2005). Green gram possesses prebiotic and nutraceutical effects. It contains a significant amount of galactooligosaccharides, which can stimulate the growth of good gut flora. Different researchers have already developed useful meals derived from green gram, such as mung bean milk and non-dairy probiotic drinks. It can also be employed as a carrier to transport probiotic microorganisms into the gut.

Besides from these applications, green gram is used in cosmetics, land reclamation, and in other meals such as jams, jellies, and noodles. Green gram

is a common element in traditional Chinese health meals. Because it is high in proteins, carbohydrates, dietary fiber, vitamins, and minerals and low in fat. Because it is high in protein, it can be considered a meat alternative for vegetarians. In addition to being a healthy food, green gram has possible health benefits such as antioxidant, anticancer, antioxidant, anti-inflammatory, and hypolipidemic properties.

Furthermore, mung bean protein is easily digested when compared to protein found in other legumes. Consumption of mung beans mixed with cereals has been shown to greatly improve protein quality, as cereals are high in Sulphur-containing amino acids but low in lysine. A 3:4 ratio of mung bean protein to rice protein was identified as the best for ingestion in terms of chemical amino acid content.



The protein digestibility of the rice-mung bean combination diet was shown to be 84.4% of that of the rice-meat combination diet in newborns, which can practically meet human protein requirements. And plant-source proteins may help to minimize land occupation and greenhouse gas emissions when compared to animal-source proteins, resulting in a better balance of dietary preferences and environmental conservation. Anti-nutritional elements in mung beans may reduce the biological value of their nutrients. Phytic acid, for example, can bind to iron, zinc, calcium, and magnesium, all of which are essential divalent cations (Polhill *et al.*, 1981).

The resulting insoluble complexes can impede mineral absorption and utilization in the small intestine. However, various processing processes, such as fermentation, germination, dehulling, and cooking, can diminish or eliminate the anti-nutritional component.

After germination, phytic acid level in mung beans decreased by 76%, while zinc and iron bioavailability values improved to 3.0 and 2.4 times greater than raw mung beans, respectively. As a result, the mung bean's antinutritional qualities do not prevent it from being consumed.



Fig. 1: Nutritional composition of green gram

Conclusion

The mung bean is rich in nutrients and bioactive substances, including polyphenols, polysaccharides, and polypeptides, and it has a variety of pharmacological effects. The in vitro and in-vivo studies presented in this review provide support for the theory that the mung bean has been linked to health benefits such as hypoglycemic and hypolipidemic effects, as well as antihypertensive, anticancer, anti-melanogenesis, hepatoprotective, and immunomodulatory properties. Because of its health and nutritional benefits, mung bean-based functional goods and nutraceuticals could be considered an alternative food not just in Asian

countries, but also in other countries. However, significant gaps remain in our understanding of the mung bean's bioactive chemicals and biological activity. Although vitexin and is vitexin have been identified as the main functional components in many published studies, more research is needed to uncover other major functional components relevant to health benefits and highlight the mung bean's synergistic multi-component effects on biological functions. Furthermore, the mung bean is typically processed prior to ingestion, which includes mechanical force, heat treatment, and a biotechnical procedure. As a result of the various methods of processing, the functional properties of the mung bean will alter. However, the type of processing given to the grain has a direct impact on its functionality. There is currently a limited understanding of how food processing processes alter the physiochemical properties of the mung bean, and the effects of various mung bean fractions on important health outcomes.

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Miyawaki Planting Technique for Improving the Green Agerage

Varun Saini

Introduction

Research says that 4 billion years ago, Earth witnessed development of large intricate structures called organisms and about 2.5 billion years ago, *Homo sapiens* evolved from apes. This was change of course. Till the time our ancestors went ahead and undergo agriculture revolution some 10,000 years ago, *sapiens* lived by hunting and gathering in forests. In order to develop farms to grow limited species of food, *Homo sapiens* started destroying natural forests. This would eventually bring the community down in the rabbit hole of industrialization and urbanization. Little did anyone know that it is going to be difficult to go back to basics of any organism's living requirement of fresh air. In present world, we are facing the situation where growth in terms of technology has become as important as breathing and contradictory to historic era, fresh air has become "expensive".

Today, the world is constantly moving forward on the road of developments, technologies and building planet of concretes. However, at the same time, we humans are moving backward on the path of staying close to nature and sticking to our roots. Factories, engines and machines continue to pour out dangerous polluted air which residents are compelled to breathe. A report published by World Health Organization clearly states that as the popula-

tion increases, the planet gets hotter- leading to increase in greenhouse effect, ultimately falling in the trap of vicious cycle of global warming. Taking prime example of capital region Delhi, the "luxury" of breathing fresh air is now limited to few days of the year (Singh and Saini, 2019). In order to beautify urban arrangements, most of the places are planted with non-native species which generally have higher environmental requirements. Moreover, urban green environment developed under peer pressure goes unplanned leading to its mismanagement. Having said this, it is no exaggeration to state that the basis of human life is threatened (Miyawaki, 2004).

In the ideal world, urbanization and ecosystem management have to go hand-in-hand for longer benefits. The very basic need of existence being physically and mentally sound life can be fulfilled by natural vegetation restoration. Here lies the greatest difficulty of reinstating extinct species and taxa, which is next to impossible task. However, what can be quoted as minimum aid to vegetative restoration is growing native species of the habitat (Miyawaki, 2004). Since the evolution of Earth, it took billions of years in making of "Green planet", which has been destroyed in few hundred years. Now, taking equal time of some 500 years to grow temperate forests with similar life forms and some 200-300 years to develop tropical forests does not

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make sense especially when humans are in rat race of becoming super power every second. Hence, a noble sociophytologist named Akira Miyawaki came up with the concept of reforestation in urban habitat. The specialty of the concept lies in the least time taken and high growth rate registered by species planted. Henceforth, this article emphasizes on the concept which is now famously recognized as “Miyawaki forest” backed by few magnificent case studies recorded till date.

The Idea that revolves around the creation of Miyawaki forest is based on the following concepts as discussed below:

Natural restoration: Creation of a Miyawaki forest mainly is an intentional activity linked to initiation or acceleration of natural recovery of any ecosystem with respect to its health, integrity and sustainability (Aronson *et al.*, 2002).

Ecological Succession: In comparison with natural forest cycle the species which results as climax is always preceded by pioneer communities and this process requires decades. The Miyawaki technique involves omission of this decade long process by providing a multistratal quasi-natural forest that can reach climax stage in a short span of time.

Plant community and Potential Natural Vegetation: In the Miyawaki technique the local species are grouped into groups and various species combinations are studied to check for effectiveness based on phytosociological analysis and a potential vegetation is drawn based on the concepts of ecological climax.

Cooperation: The local existence of species is not due to abiotic conditions and competition alone but the interactions and cooperation amongst the species is also responsible for stabilization of forest.

The Benefits of developing an area using the Miyawaki forest technique may yield similar benefits of natural vegetation which may described as follows:

- ✓ Temperature reduction
- ✓ Air quality maintenance and pollution clustering
- ✓ Noise reduction
- ✓ Health and well being
- ✓ Biodiversity balance
- ✓ Soil stability
- ✓ CO₂ sequestration
- ✓ Aesthetic beauty



Fig. 1: A typical site raised with Miyawaki technique

Miyawaki Forest: Concept

The concept of Miyawaki forest revolves around the land restoration, which involves reconstruction of native biota in a sustainable form. For the development of temperate forest in natural ecosystem way, 100 to 200 years of time is predicted. In case of tropical forest, this time period increases up to 500 years. In many situations, it is not possible or desirable to wait for natural recovery (Miyawaki and Galloy, 1993). Other than two popular and tradit-

ional methods of tree planting viz., monoculture of needle leaved trees for lumber production and trees for beautification, there is one more kind of tree plantation developed which is based on ecological studies.

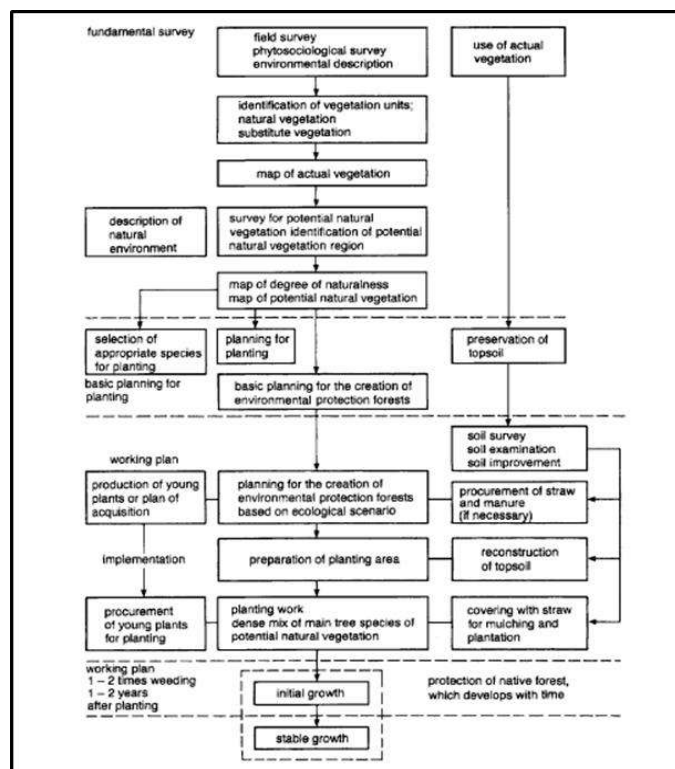


Fig. 2: Concept of Miyawaki Forest

Miyawaki forest is based on its four step procedure, which in reality acts as foundation pillars of restoration. The first and foremost step includes selection of tree species. If the main tree species is badly chosen, it will be difficult to regenerate native forests which develop as time goes by. The major advantage of selecting native tree species is proper acclimatization to the environment and speedy growth. Thorough field vegetation survey (relevés) provides approximate native species, which is equal to census of green environments. After this, similar species are grouped, species combinations are made

using relevés and character species chart is made. The character species are used to decide phytosociological units and further on hierarchical vegetation community system is decided. Apart from this system, potential natural vegetation is measured.

In absence of secondary vegetation, all the species that naturally exists as well as the potential of land to sustain the vegetation based on soil topography, profile and land utilization is termed as potential natural vegetation. At last, the major species from potential natural vegetation and companion species are finalized (Miyawaki, 1999). In second step, seedlings of selected species are developed.

According to the method, seeds are collected from its natural habitat and are planted in pots. Temperate species take one and half year to two years to reach desirable transplanting size, while tropical species are ready in six to eight months. Pot planting gives easy transplanting access. Moreover, strong root system is the key to successful survival of plants (Miyawaki and Galloy, 1993). Meanwhile, the soil at forest site is prepared for transplanting. Healthy top soil contributes most of the shares in rapid growth and development of the forest. Especially in ecosystem restoration, it is mandatory to furnish upper 30-50 cm layer of soil by manuring, ploughing and mixing (Miyawaki, 1999).

Now is the time to transplant seedlings. Companion species are mixed with main one and planted as densely as possible. However, the recorded rate of dense planting is two to three plants m^{-2} (Miyawaki, 1999). The major advantage of dense

plantation lies in competition between tree species for space and sunlight. In order to grow, plants tend to reach as high as possible in absence of horizontal space, leading to extensive vertical growth imitating dense forest. Last but not the least part is covering soil with the mulch. Mulching not only covers the soil, but also prevents soil runoff, evaporation of moisture. Moreover, it maintains soil temperature and thus providing underground ecosystem proper environment to flourish. Two to three years after planting, proper care and management is imperative. Later than that trees manage to reach height of 2-3 m and cover the floor. The lack of sunlight under the canopy prevents weed growth. Similarly, moisture is retained and forest becomes self-sustainable (Miyawaki, 1999). In a natural forest cycle, annual plants on barren land are succeeded by perennial grass, sun-tolerant shrubs, light-demanding, fast-growing trees, and finally natural forests (Clements, 1916). Biocoenotic relationships involve auto regulations between species, favoring a dynamic equilibrium and avoiding any further silvicultural practice and need no insecticides or herbicides (Schirone *et al.*, 2010).

Future Prospects

Rapid urbanization, population growth and rural to urban migration have resulted in fast decline of forest cover and green spaces in urban centers and cities around the world. This has resulted in alarming situation for health and ecosystem both. Miyawaki technique is hence and affordable, low-tech based, maintenance free and rapid method of growing

natural vegetation on degraded lands. This not only helps in increasing forest cover and vegetation cover in urban areas but also provides for various benefits viz. beautification, abating climatic change etc. The Government of India has announced Nagar Van scheme to develop 200 urban Forest in the country in next five years with focus on PPP mode and collaboration of forest departments, Municipal bodies, NGO's which paves way to adapt this technique. Due to low cost and low maintenance requirement this technique is finding resonance amongst the organizations and individuals with several examples and case studies arising in the local media in the recent years.



Fig. 3: Newspaper article cuttings common nowadays with local success stories of Miyawaki Technique highlighting the importance and popularity gained.

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Novel Bio-fungicides from Weed Plants: Unlocking the Potential of *Ageratum conyzoides* L. and *Parthenium hysterophorus* L. for Control of *Phytophthora capsici* in *Capsicum annuum* and Sustainable Agriculture

Rajeev Kumar, Seweta Srivastava and Aspak

In the quest for sustainable agricultural solutions, researchers have been exploring eco-friendly options to combat devastating plant pathogens. Among these, *Phytophthora capsici* has emerged as a particularly challenging pathogen, affecting a range of economically valuable crops, notably *Capsicum annuum* (bell pepper), worldwide. The pathogen causes severe blight and rot, leading to considerable yield losses. Given the harmful environmental impacts and resistance issues associated with conventional fungicides, our research team has turned to nature's untapped resources weed plants to develop innovative biofungicides.

Why Bio-Fungicides?

Bio-fungicides, derived from natural sources such as plant extracts and beneficial microorganisms, offer promising alternatives to synthetic fungicides. They are typically biodegradable, less toxic to non-target organisms, and pose fewer risks to the environment and human health. In recent years, bio-fungicides have gained significant attention for their efficacy in managing various plant diseases while aligning with sustainable agriculture goals.

Targeting *Phytophthora capsici*: A Major Threat to

Capsicum Cultivation

Phytophthora capsici is a soil-borne pathogen that thrives in warm and moist conditions, attacking the roots, stems, leaves, and fruits of *Capsicum annuum*. Traditional control methods have proven insufficient due to the pathogen's adaptability and the growing resistance to synthetic chemicals. In response to these challenges, we have turned our attention to two invasive weed species with potential antifungal properties: *Ageratum conyzoides* and *Parthenium hysterophorus*.

Weed Plants as a Source of Bio-Fungicidal Agents

Weed plants are typically regarded as a nuisance, competing with crops for nutrients and water, and sometimes being toxic to livestock. However, certain weeds possess unique bioactive compounds that make them suitable for developing natural pesticides and fungicides. Specifically, *Ageratum conyzoides* and *Parthenium hysterophorus* are rich in secondary metabolites natural compounds with antimicrobial properties that have shown potential for controlling a range of fungal pathogens.

***Ageratum conyzoides*:** A Potent Antifungal Herb

Commonly known as billygoat-weed, *Ageratum*

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Conyzoides is rich in essential oils, alkaloids, flavonoids, and other bioactive compounds. Previous studies have documented its antifungal and antibacterial properties, which are attributed primarily to its high content of bioactive compounds like precocene, ageratochromene, and other essential oils. These compounds disrupt fungal cell membranes and inhibit pathogen development, making them suitable candidates for controlling *Phytophthora capsici* in a natural and environmentally friendly way.

Parthenium hysterophorus: Transforming an Invasive Menace into an Agricultural Ally

Parthenium hysterophorus, also known as congress grass, is an invasive weed notorious for causing allergic reactions and outcompeting native vegetation. Despite its invasive nature, *Parthenium* contains an impressive array of phytochemicals, including sesquiterpene lactones, which are known to have strong antimicrobial properties. Our research has focused on harnessing these compounds for their antifungal potential, specifically targeting *P. capsici* in *Capsicum annuum*.

Developing a Novel Bio-Fungicide Formulation

Our study involved the extraction of leaf components from *Ageratum conyzoides* and *Parthenium hysterophorus* using environmentally friendly solvents. The resulting extracts were then tested for their efficacy against *P. capsici* under laboratory and greenhouse conditions. By optimizing the concentration of active compounds, we developed a bio-fungicidal formulation that not only

inhibited the growth of *P. capsici* but also showed no adverse effects on the growth and yield of *Capsicum annuum* plants.

Preliminary results have shown promising outcomes, with the bio-fungicide demonstrating a comparable efficacy to some conventional fungicides. Moreover, the formulation has the advantage of being biodegradable and poses minimal risk to beneficial soil organisms, which are essential for maintaining soil health and nutrient cycling.



Benefits of Using *Ageratum* and *Parthenium* Based Bio-Fungicides

Environmental Safety: Derived from plant sources, these bio-fungicides break down naturally in the soil, reducing chemical buildup and pollution.

Reduced Resistance Development: Unlike synthetic fungicides, which can lead to pathogen resistance, bio-fungicides based on complex plant extracts make it more difficult for pathogens to develop resistance.

Cost-Effective: The utilization of invasive weeds as a raw material for bio-fungicides adds value to these

unwanted plants, offering a low-cost alternative to synthetic chemicals.

Enhanced Crop Safety: Bio-fungicides are generally less phytotoxic, meaning they are safer for crop plants, thus ensuring better yield and quality of produce.

Sustainable and Organic Farming: Bio-fungicides align with organic farming principles and help promote sustainable agriculture, appealing to environmentally conscious consumers.

Conclusion and Future Directions

Our research into developing bio-fungicides from *Ageratum conyzoides* and *Parthenium hysterophorus* highlights the untapped potential of weed plants as valuable resources for sustainable agriculture. This novel formulation offers a promising, eco-friendly solution for managing *Phytophthora capsici* in *Capsicum annuum*, providing farmers with an alternative to traditional fungicides. Moving forward, we have conduct field trials to evaluate the long-term efficacy and economic feasibility of this bio-fungicide, with the aim of making it accessible to farmers and contributing to a more sustainable agricultural system. As we continue to explore nature's resources, this work is a testament to the benefits of looking beyond conventional methods and embracing innovative, natural solutions for crop protection. Through such efforts, we move closer to a future where agriculture is not only productive but also harmonious with the environment.

Soil in Crisis: The Unseen Cost of Fertilizer Overuse

Sugavaneshwaran K. and Abithaa P.

Introduction

For centuries, human civilization has relied on agriculture to sustain its populations. The process known as “Soil degradation” results in a decrease in the soil's ability to generate products, such as crops and fodder, as well as services, such as controlling water and nutrients. The opposite of soil quality is soil deterioration. Due to its detrimental effects on production, the health of people and animals, and the quality of the air and water, particularly at the local, regional, and global levels, soil degradation is a major concern in the modern era (Patle *et al.*, 2019). Soil degradation can be physical, chemical or biological degradation that altogether affects the soil's productivity. Chemical degradation happens due to over utilization of fertilizers or usage of pesticides.

With the rise of industrial agriculture and global food production systems, fertilizers have become one of the cornerstones of modern farming. They promise high crop yields, allowing farmers to meet the ever-growing demand for food. However, this reliance on chemical fertilizers is slowly taking a toll on the very soil that sustains our crops. Overuse of these fertilizers is leading to the degradation of soil health, reducing its fertility, and threatening long-term food security. This article explores how overusing fertilizers harms our soil and the environ-

ment and discusses potential solutions to address this critical issue.

The Essential Role of Fertilizers in Agriculture

Fertilizers are substances that supply essential nutrients to plants, most notably nitrogen (N), phosphorus (P) and potassium (K). These elements play a crucial role in plant growth, influencing everything from root development to flowering and fruit production. Nitrogen promotes lush, green growth, phosphorus helps with root and flower formation, and potassium strengthens plants' ability to resist diseases.

The Green Revolution of the 20th century, which saw the widespread adoption of high-yielding crop varieties and synthetic fertilizers, significantly increased food production across the globe. Without fertilizers, modern agriculture could not have supported the global population growth of the past century. However, as with many technologies, the benefits come with unintended consequences, especially when the application of fertilizers goes unchecked. The fact that the most limiting element ultimately determines crop productivity helps to at least partially explain the high amount of fertilizer used (Nijland *et al.*, 2008). All farmers must agree, nevertheless, that the advantages of using more fertilizer outweigh the disadvantages, especially because they are not held personally responsible for

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environmental harm (Wesenbeeck *et al.*, 2021). Overuse of fertilizer results in excesses of nitrogen (N) and phosphate oxide (P_2O_5) which can seriously pollute the air, water, and soil. More precisely, toxic nitrates are formed in groundwater as a result of excessive N and P concentrations (Ju *et al.*, 2006). The problem of agricultural nutrient loss is difficult to solve if farm profitability and production are to be sustained and even raised. More creativity is required to extract and recover the nitrogen (N) and phosphorus (P) that catchments may contain in sufficient amounts to support algal blooms and murky waters for decades to come (Withers *et al.*, 2014).

The Dangers of Overusing Fertilizers

While fertilizers are vital for growing crops, using them excessively can have a number of negative consequences on soil health and the environment.

Nutrient Imbalance and Soil Depletion: Overuse of macro nutrients like N, P, K results in deficiency of micronutrients. Excessive use of synthetic fertilizers degrades the microbial population of the soil that acts as a store house for steady supply of nutrients. Fertilizers makes the soil acidic due to which nutrients like calcium and magnesium are found deficient.

Soil Acidification: Soil acidification happens because of natural process like breakdown of organic matter, but is accelerated by anthropogenic activities like excessive use of fertilizers. Among the fertilizers, Nitrogen based fertilizers contribute much

to soil acidification. Process like nitrification that produces hydrogen ions makes the soil acidic. Sulphur and phosphatic fertilizers are also found to contribute to soil acidification.

Eutrophication and Water Pollution: Eutrophication is the enrichment of waterbody with nutrients like nitrogen and phosphorus, due to runoff from the agricultural fields. These nutrients are essential plant nutrients supplied by synthetic fertilizers contribute to water pollution and growth of algal blooms in the waterbodies. Thus, depleting the available oxygen and disrupting the biodiversity of the aquatic ecosystem.

Soil Compaction and Reduced Water Infiltration:

Over fertilization with high salt concentrated fertilizers leads to surface crusting, which prevents the water to infiltrate into the soil. Compacted soil reduces soil aeration and root growth.

The Global Consequences of Fertilizer Mismanagement

The impact of fertilizer overuse is not confined to individual farms it has far-reaching consequences for the environment and human health. Globally, excessive fertilizer use contributes to a range of environmental problems, including:

Climate Change: Nitrous oxide (N_2O), a potent greenhouse gas, is released from fertilized soils, contributing to global warming. Over-fertilization of fields, especially with nitrogen-based fertilizers, leads to higher emissions of nitrous oxide (Huang *et al.*, 2004), which has a global warming potential 300 times that of carbon dioxide.

Declining Biodiversity: The degradation of soil and water ecosystems can harm biodiversity. As soils become less hospitable to beneficial microorganisms and plants and demand for oxygen increases. Algal blooms due to excessive nutrients disrupts the water ecosystem.

Food Security Risks: In the long term, overusing fertilizers can compromise the sustainability of agriculture. Soil depletion, reduced crop yields, and environmental damage threaten food security, particularly in regions that rely heavily on chemical inputs.

Solutions: A Path toward Sustainable Farming

Given the severe consequences of overusing fertilizers, what can be done to mitigate the damage? There are several strategies that farmers, policy-makers, and consumers can adopt to restore soil health and ensure the long-term sustainability of agriculture.

Integrated Nutrient Management (INM): By combining organic and inorganic fertilizers like combining green manure with chemical fertilizers, overuse of synthetic fertilizers is reduced thus reducing soil salinization, soil acidification and soil compaction. Use of compost and organic fertilizers enhances the physical properties of soil like soil structure, soil aeration and soil infiltration. Thus, improves overall nutrient use efficiency.

Adopting Organic Fertilizers: Organic fertilizers contribute to increase the soil organic matter which enhances the soil microbial activity that plays a key role in nutrient cycling, soil aeration, water infiltration

and soil aggregation. Water bodies are less prone to pollution from non-point sources like agriculture.

Precision Agriculture: Applying the inputs like fertilizers in right amounts and at right timing helps in minimizing nutrient loss to the environment. Using technologies like drones to apply fertilizers as foliar spray helps to prevent soil degradation and it is absorbed directly by the leaves.

Soil Testing and Monitoring: Analysing soil samples to determine the nutrient levels and regular monitoring of fertilizer application and soil management practices will prevent over-fertilization. Soil testing moreover finds the deficiency of nutrients and allows for targeted application rather than blindfold application.

Crop Rotation and Agroecological Practices: Crop rotation helps in promoting soil health and biodiversity. Addition of legumes helps to fix nitrogen from the atmosphere. Deep-rooted crops break the sub-surface hardpan and promote soil aeration and soil infiltration. Agro-ecological practices like intercropping, cover cropping and mulching prevent the buildup of pest and diseases and enhance soil organic matter.

Conclusion

One of the most visible environmental impacts of fertilizer overuse is the pollution of nearby water bodies. When farmers apply too much fertilizer, it often runs off the land, carried by rainfall or irrigation. This runoff can carry large amounts of nitrogen and phosphorus into rivers, lakes, and oceans, causing nutrient pollution (Sapkota *et al.*,

2022). The overuse of fertilizers is a pressing issue that threatens the health of our soils, the environment, and food security. While fertilizers are essential for modern agriculture, their excessive use can lead to nutrient imbalances, soil acidification, water pollution, and the depletion of soil health. To safeguard the future of farming, we must shift toward more sustainable practices, including integrated nutrient management, organic fertilization, precision agriculture, and soil conservation. By taking these steps, we can ensure that our soils remain fertile and productive for generations to come. More grain yield with less fertilizer use by applying site-specific nutrient management (SSNM) based on fertilizer application, in comparison to blanket N application and other nutrient approaches (Rahman *et al.*, 2018).

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Crop Yield Estimation Using Satellite Remote Sensing

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Introduction

Food and energy need in everyday life is inevitable and the demand will keep growing as the world's population and average income rise. The demand for cereals alone for food and animal feed worldwide is predicted to reach 2.8 billion (B) tons annually by 2030, which is 50% more than it was in 2000 (Lobell *et al.*, 2009). Agriculture is seen viable if a successful crop year produces a high yield, which essentially attracts remunerative prices. As a result, farmers need to anticipate crop yield in advance for farm-level planning and to make strategic choices about marketing, storage, and other areas. Both the public and commercial sectors place equal importance on establishing different policies concerning the domestic food supply, international food trade, imports, and exports. Therefore, there is a great demand for accurate and effective forecasting techniques for a number of agricultural-related factors, most notably crop output (Dharmaraja *et al.*, 2020).

The use of remote sensing (RS)-based methods has been steadily increasing recently; satellite data, with its spatial coverage, temporal and spectral resolutions, timely availability to users, and affordability, provide substantial advantages for evaluating agricultural yield and production throughout the cropping season. Remote sensing

devices are widely used for yield prediction and crop growth monitoring (Kumhálová *et al.*, 2017).

Satellite remote sensing

Satellite remote sensing have great ability to contribute in crop yield as well as crop area estimation worldwide as used by Kannan *et al.* (2021). The ability to retrieve geo-spatial data on a broad scale makes satellite-based remote sensing an appropriate and economical method required for crop monitoring at the regional and national levels (Setiyono *et al.*, 2019). The European Space Agency's (ESA) Sentinel satellite series has made extremely important data for agriculture publicly available due to its spectral, geographical, and temporal resolution. A data set can give information on crop growth and condition up to once every week in cloud-free situations, enabling inferences on factors including biomass, plant density, and yield.

Satellite-based yield estimation in crops is commonly performed using various Earth observation satellites that collect data on vegetation, soil conditions, and weather patterns. These satellites help in estimating crop yield by monitoring the growth, health, and productivity of crops. Some of the satellites used for crop yield estimation are given in Table 1.

Sentinel-1 (ESA): It is a Synthetic Aperture Radar (SAR) is used to monitor crop health, vegetation, and

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Table 1: Satellites used for yield estimation and their organizations

Satellite	Organization
Sentinel-1	European Space Agency (ESA)
Sentinel-2	European Space Agency (ESA)
Landsat Series	NASA/USGS
WorldView-3	Maxar Technologies
TerraSAR-X	German Aerospace Center (DLR)
MODIS	NASA
RADARSAT-2	Canadian Space Agency (CSA)
GOSAT	Japan Aerospace Exploration Agency (JAXA)

soil moisture; it is particularly helpful in all types of weather. Sentinel-1 is employed to monitor vegetation growth, land cover, and soil moisture all of which are crucial elements in yield prediction.

Sentinel-2 (ESA): Provides high-resolution multispectral imagery for crop monitoring, detecting vegetation stress, and assessing plant health. Sentinel-2's optical imagery helps track crop phenology, detect diseases, and estimate yield based on vegetation indices (like NDVI).

Landsat Series (NASA/USGS): Provides multi-spectral imagery for long-term monitoring of crops, soil conditions, and land use. Landsat satellites have been instrumental for historical data analysis in crop yield predictions. Their imagery helps assess vegetation health and monitor seasonal changes in crops.

WorldView-3 (Maxar Technologies): High-resolution optical imagery for monitoring agricultural land, detecting crop health, and estimating yield. WorldView-3 provides detailed imagery that can help monitor individual fields and detect anomalies related to crop stress or growth, which is useful for yield forecasting.

TerraSAR-X (DLR): It has Synthetic Aperture Radar (SAR) data for monitoring crop conditions, soil moisture, and flood risk, which can impact yields. TerraSAR-X provides high-resolution radar images that help estimate soil moisture content and vegetation biomass, essential for yield predictions.

MODIS (NASA): It has Moderate-resolution imaging for monitoring vegetation and land surface temperature, which helps in understanding crop health and predicting yields. MODIS provides global coverage and is used to derive vegetation indices, such as NDVI, which are correlated with crop health and yield estimates.

RADARSAT-2 (CSA): It has Synthetic Aperture Radar (SAR) for monitoring agricultural fields, especially in regions with frequent cloud cover. RADARSAT-2 is used for detecting crop growth, soil moisture, and assessing flood risks, all of which contribute to crop yield estimation.

GOSAT (JAXA): Provides remote sensing data on atmospheric carbon dioxide, which can help assess agricultural productivity indirectly. GOSAT's data can contribute to yield predictions by monitoring greenhouse gas emissions that are associated with crop production.

These satellites provide critical data that help scientists, farmers, and policymakers monitor and predict crop yields, ensuring food security and better agricultural planning.

Methodology of Yield estimation using Satellite remote sensing

Satellite Data Acquisition: Collect satellite imagery

from various sources (e.g., Landsat, Sentinel, MODIS). Ensure images have appropriate resolution and temporal coverage.

Preprocessing of Satellite Data

- ✓ Geometric correction
- ✓ Radiometric correction
- ✓ Atmospheric correction
- ✓ Cloud masking
- ✓ Image mosaicking

Vegetation Index Calculation: Calculate vegetation indices (e.g., NDVI, EVI, SAVI) to assess plant health and vigor.

Field Boundary Identification: Use high-resolution imagery or classification techniques to identify crop field boundaries.

Crop Type Classification: Classify crops using supervised or unsupervised classification methods (e.g., machine learning, SVM, random forest).

Growth Stage Monitoring: Track the phenology of crops using multi-temporal satellite data to monitor growth stages (e.g., germination, flowering, maturity).

Biomass Estimation: Estimate biomass using vegetation indices, regression models, or empirical relationships between remote sensing data and field observations.

Yield Prediction Model Development: Develop yield prediction models using historical data, ground truth data, and satellite-derived parameters. - Use machine learning models, statistical models, or crop growth models.

Yield Estimation: Estimate crop yield based on the

developed model and satellite-derived data. Integrate additional parameters like weather, soil conditions, and irrigation.

Validation and Accuracy Assessment: Validate yield estimates with ground truth data (e.g., crop cutting experiments or field surveys). Assess the accuracy of the predictions using statistical metrics like RMSE, R^2 .

Final Yield Map Generation: Generate yield maps for different regions using satellite data for spatially explicit yield predictions.

Insights

- ✓ Optical data have advantages of coinciding with the crop phenological parameters than the SAR data.
- ✓ Optical data have disadvantages of cloud and shadow hindrances.
- ✓ MODIS have high temporal resolution with more frequent coverage of the crops.
- ✓ Vegetation indices are helpful in monitoring the crop yield but integration of many indices can provide better results.

Advantages

- ✓ Spatial coverage is high
- ✓ Frequent and Timely data collection
- ✓ Cost effective
- ✓ Non invasive
- ✓ Non-Destructive
- ✓ Improved accuracy
- ✓ Scalable and reproducible
- ✓ Real time monitoring
- ✓ Supports Precision agriculture

Conclusion

In conclusion, with major benefits over conventional techniques, satellite remote sensing has emerged as a crucial instrument for precise agricultural output estimation. For efficient yield forecasting, this technique uses a range of Earth observation satellites, such as Sentinel, Landsat, and MODIS, to give extensive, large-scale data on crop health, growth phases, and environmental variables. The accuracy and consistency of yield forecasts are improved by combining vegetative indices, such as NDVI and EVI, with machine learning algorithms and ground-truth validation. For large-scale agricultural management, satellite-based crop yield estimation is especially useful because it is non-invasive, economical, and able to conduct regular, real-time monitoring. By facilitating prompt interventions to maximize inputs and raise crop output, it also aids precision agriculture. Furthermore, it offers a distinct advantage in global agricultural planning due to its capacity to monitor crops over large areas and in remote locations, particularly for areas with restricted access to ground-based data. Satellite remote sensing will become more and more important in guaranteeing food security and sustainable agriculture as the world's food demand rises. Its capacity to provide precise, scalable, and useful insights will facilitate improved farming, policy, and resource management decision-making, promoting more intelligent agricultural methods and assisting in addressing the difficulties of future food production.

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Revolutionizing Sustainable Agriculture through Genome Editing

Chirag P. Chandramaniya and Nilesh Chauhan

Introduction

Agriculture faces the challenge of meeting growing and diversifying food demands while contending with the impacts of climate change and a rapidly increasing global population. Sustainable agriculture encompasses farming practices that fulfill current demands for food, fiber, and biofuels while preserving the resources and ecosystems necessary to ensure future generations can meet their needs. It focuses on achieving a balance between environmental health, social equity and economic viability to ensure sustainable agricultural productivity and the preservation of ecosystems for the future. Developing crops with improved higher yields, nutrient efficiency and stress tolerance is essential for sustainable agriculture. Leveraging advanced biotechnologies to enhance crop productivity and nutritional quality will play a crucial role in meeting global food demands while preserving environmental resources. Genome editing empowers breeders to make precise sequence modifications at specific loci, enabling targeted improvement of traits in crops to address agricultural challenges. CRISPR/Cas9-based genome editing has revolutionized plant research over the past decade due to its simplicity, cost-effectiveness and efficiency, sparking widespread enthusiasm among plant scientists (Zhan *et al.*, 2021). CRISPR/Cas9 is a nuclease that induces

double-stranded DNA breaks at target sites guided by a complementary RNA sequence (gRNA). These breaks are typically repaired through error-prone nonhomologous end joining (NHEJ), resulting in insertions or deletions (indel mutations) (Cong *et al.*, 2013) or DNA sequence replacement via homology-directed DNA repair (Lu *et al.*, 2020). Building on this principle, several CRISPR/Cas9-derived genome-editing technologies, such as base editing and prime editing, have been developed and successfully applied in crop genome editing. These advanced techniques allow for more precise and efficient modifications, further enhancing the potential for crop improvement (Molla *et al.*, 2021).

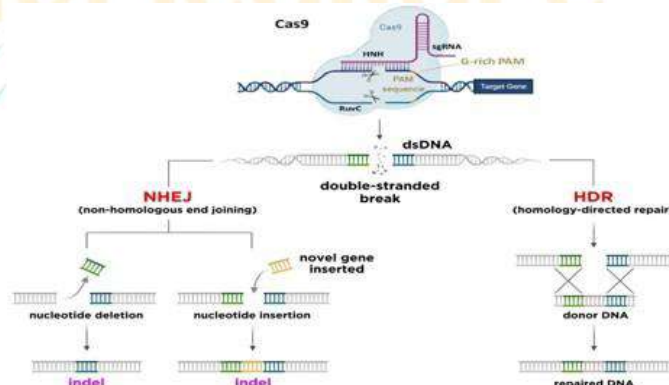


Fig. 1: Principle CRISPR/Cas9

These tools enable precise, efficient, and targeted modifications to a plant's genome, facilitating the development of crops that can thrive in challenging environments, reduce reliance on chemical inputs, and help meet the growing global demand for food security. While genome-editing

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biotechnologies hold significant promise for crop breeding, they also generate controversy and face regulatory challenges, particularly regarding safety, ethical concerns, and varying international policies. This article seeks to gather original research papers and reviews on recent advancements in plant genome editing, along with an overview of the regulatory status and policies across different countries. Key ideas of the collected articles that contributed to the topic “Revolutionizing Sustainable Agriculture through Genome Editing” are summarized.

Applications of Genome Editing in Sustainable Agriculture

Developing Climate-Resilient Crops

Drought Tolerance: Editing genes like *DREB* or *NAC* improves water-use efficiency and drought tolerance in crops such as wheat and rice.

Heat Resistance: Modifications to heat-responsive genes like *HSFA1* allow crops to maintain productivity under high temperatures.

Improving Nutritional Value

Biofortification

- ✓ **Golden Rice:** Enhanced with provitamin A to combat vitamin A deficiency.
- ✓ Genome-edited cassava with increased iron and zinc levels addresses micronutrient deficiencies.

Enhancing Crop Yield and Productivity

- ✓ Edits in genes regulating photosynthesis efficiency, such as *Rubisco*, boost plant growth and yield potential.
- ✓ Modification of flowering time and seed size genes (e.g., *GW2*, *GS3*) optimizes yield in cereals

like rice and maize.

Pest and Disease Resistance

Pathogen Resistance: Editing susceptibility genes like *MLO* in wheat and barley confers resistance to powdery mildew.

Insect Resistance: CRISPR-edited cotton resists bollworms, reducing reliance on chemical pesticides.

Virus Resistance: Editing plant genomes to target viral replication genes, such as in cassava (CMD) and bananas (BBTV), protects crops from devastating diseases.

Reducing Chemical Dependency

Nitrogen Use Efficiency: Genome editing of *NLP* and *NRT* genes in crops like rice and maize improves nitrogen uptake, reducing fertilizer use.

Herbicide Tolerance: Precise edits in genes like *ALS* allow crops to tolerate herbicides, enabling efficient weed control without soil disturbance.

De Novo Domestication

- ✓ Using genome editing to domesticate wild relatives of crops (e.g., wild tomatoes, quinoa) retains their stress tolerance and resilience while enhancing traits like yield, taste, and nutritional value.
- ✓ This approach expands the pool of cultivable crops and diversifies farming systems.

Mitigating Greenhouse Gas Emissions

- ✓ Genome-edited rice with reduced methane emissions from rice.
- ✓ Crops engineered for higher carbon sequestration, contributing to climate mitigation efforts.

Challenges and Considerations

Table 1: Examples of successful applications

Crop	Problem Addressed	Solution (CRISPR Target)	Impact
Tomato	Short shelf life due to over-ripening, leading to post-harvest losses.	Edited genes like <i>SIMYB12</i> and <i>RIN</i> to regulate ripening.	Reduced food waste, maintained flavor/nutritional quality, increased economic returns for farmers and exporters.
Wheat	Yield losses due to Powdery Mildew, requiring intensive fungicide applications.	Disabled <i>MLO</i> gene to block mildew susceptibility.	Durable, broad-spectrum resistance; reduced fungicide use, lowering costs and environmental impact.
Banana (<i>Golden Banana</i>)	Vitamin A deficiency in regions relying on bananas as a staple food.	Enhanced carotenoid biosynthesis genes.	Combats Vitamin A deficiency, improves public health, and reduces healthcare costs.
Maize (<i>WEMA Project</i>)	Yield losses due to drought, especially in sub-Saharan Africa.	Edited <i>DREB2A</i> gene to improve drought tolerance.	Stable yields under water stress; supports food security in climate-vulnerable regions.
Potatoes	Devastation by Late Blight disease, leading to high fungicide use.	Introduced resistance gene <i>Rpi-vnt1</i> .	Long-lasting resistance, reduced fungicide dependency, and increased yields.
Wheat (<i>Low-Gluten Wheat</i>)	Millions affected by gluten sensitivity and celiac disease.	Modified α -gliadin family genes to reduce gluten.	Safer wheat products for gluten-sensitive individuals; expands dietary options and enhances consumer health.
Rice	Reduced productivity in saline soils, common in coastal/arid regions.	Edited <i>OsRR22</i> gene for salt tolerance.	Increased productivity in saline soils; expanded arable land and improved food security.
Banana (<i>Disease-Resistant</i>)	Losses due to Panama disease caused by <i>Fusarium oxysporum</i> TR4.	Modified <i>RGA2</i> and knocked out <i>S</i> -genes.	TR4-resistant varieties; lower losses, reduced fungicide use, and stable production benefiting over 400 million people relying on bananas.

Regulatory Frameworks: Variations in the acceptance and regulation of genome-edited crops globally can limit adoption.

Public Perception: Misinformation about genome editing may hinder its acceptance by consumers and policymakers.

Access and Equity: Smallholder farmers in developing countries need support to access and benefit from this technology.

Conclusion

In summary, plant genome editing has made significant advancements in editing efficiency, breeding applications and the development of regulatory frameworks, positioning it as a powerful tool for enhancing agricultural sustainability and productivity. This special issue covers different facets of the

advances in plant genome editing and highlights the impactful potential of CRISPR/Cas9 systems for sustainable agriculture. CRISPR/Cas9-based plant genome editing has been successfully employed to promote basic research and improve agricultural outcomes, such as increasing crop yield and improving grain quality seed oil composition and disease resistance. Many countries (e.g., the United States, China, Canada, Brazil, Argentina, and Japan) have passed legislation allowing genome-edited crops for commercial cultivation. Further improving public trust and solving policy and governance problems at a broader level will enable plant genome editing to contribute more to agricultural sustainability and global food security. Genome editing offers unparalleled potential for transforming agricu-

lture into a sustainable and resilient system. By addressing critical challenges like climate change, food security, and environmental degradation, it is a key driver for the future of sustainable agriculture.

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Botanical Discription and Economic Importance of Ginger

S. Ranjith Raja Ram and S. R. Venkatachalam

Introduction

Ginger (*Zingibera officinale*) is one of the most popular spices in the world and widely used as a spice and a folk medicine. Fiery spice has been a signature ingredient in Asian cuisine since ancient times. Today, it is frequently used in medicines, food, and cosmetics across the globe. Indians and Chinese are believed to have produced ginger as a tonic root for over 5000 years to treat many ailments, and this plant is now cultivated throughout the humid tropics, with India being the largest producer. It is propagated through rhizomes. Ginger is cultivated in almost all the states of India. The Major ginger growing states are Kerala, West Bengal and North Eastern Region. About 3 lakhs tones of ginger are being produced annually from 47,641 ha land and the northeast region is emerging as India's organic ginger hub. It grows well in medium temperature regions and moisture in the air. Ginger cultivated 1500 meters above sea level. But it grows well in 300 meters to 900 meters above the sea level. Alluvial gravel mixed red soil is also suitable for ginger cultivation.

Common name: Ginger (English), Ingee (Tamil), Adrak (Hindi).

Scientific name: *Zingibera officinale*

Family: Zingiberaceae

Wild species: Asarumcanadense

Chromosome number: 2n=22

Origin of the crop: Southeast Asia.

Distribution of the crop: Pacific Island, Hawaii, South India, Sri Lanka

Habit: Perennial

Habitat: Tropical and subtropical forests of Southeast Asia.

Root system: Adventitious, rarely fibrous.

Stem: Rhizome-tuberous, aerial, braked, leafy, short or elongated. In curcuma the aerial system is very short or even absent, sometimes formed by the rolled-up leaf sheaths.

Leaf: Exstipulate, petiolate or sessile, entire, elliptical or linear or lanceolate, apex acute or obtus. Leaf base sheathing in some curcuma.

Flower: Flowers usually large in size and brightly coloured, aromatic, Bracteate, Pedicellate or Sessile, Complete flower, Bisexual, Epigynous, Zygmorphi, irregular, calyx and corolla are distinct, Calyx Sepals 3, gamosepalous, tubular or spathe like generally 3-thoothed,. In globba the calyx tube is very short, odd sepal anterior.

Corolla: Petals 3, free or less united, tubular or funnel-shaped corolla, three-lobed, lobes, unequal,

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linear or broad. In *Roscoea* the corolla tube is long and slender with upper lobe broad, cucullate, and erect, the two lateral lobes spreading and narrower. Corolla tube as long as or longer than the calyx tube.

Androecium: Stamens six, arranged in two whorls, the posterior stamen or the inner whorl is fertile and epipetalous and antipetalous, the other two stamens of the inner whorl are sterile and mostly petaloid and are fused together to form the petaloid lip or labellum, which may be two or three lobed. The anterior stamen of the outer whorl is always absent, the other two may be absent) or may be present as large leafy staminodes right and left of the fertile stamen.

Gynoecium: Tricarpellary, syncarpous, inferior, trilobular with axile placentation, ovules many and superposed in each loculus, in *Globba* the ovary is unilocular with parietal placentation in *monocostus* the ovary is bilocular with parietal placentation. In *Haplochorema* the ovary is unilocular with a few basal ovules. Ovules are usually anatropous or semi-anatropous. Style one, simple, usually slender, stigma simple and capitate or three lobed.

Fruit: Loculicidal capsule, opening by three valves.

Seed: Endospermic.

Floral formula: $\%, K_{(3)}, C_{(3)}, A_1, \overline{G(3)}_{or} \overline{(2)}$

Pollination: Entomophilous.

Types of ginger

There are several types of ginger baby ginger, blue Hawaiian ginger, white ginger, yellow ginger, alpinia ginger, beehive ginger, butterfly lily ginger, dancing ladies ginger, globba ginger, hidden ginger,

moth ginger, red ginger, shell ginger, spiral ginger, torch ginger, zingiber ginger. The inflorescences bear pale yellow with purple flowers and arise directly from the rhizome on separate shoots. Ginger is a rainfed crop. It cultivated dependent on the rainfall. Thus, the crop planting should be done in the first week of April. In west coast, ginger planted month of May after a summer rain. But in places with good irrigation facilities and can be planted until mid to late February and March.

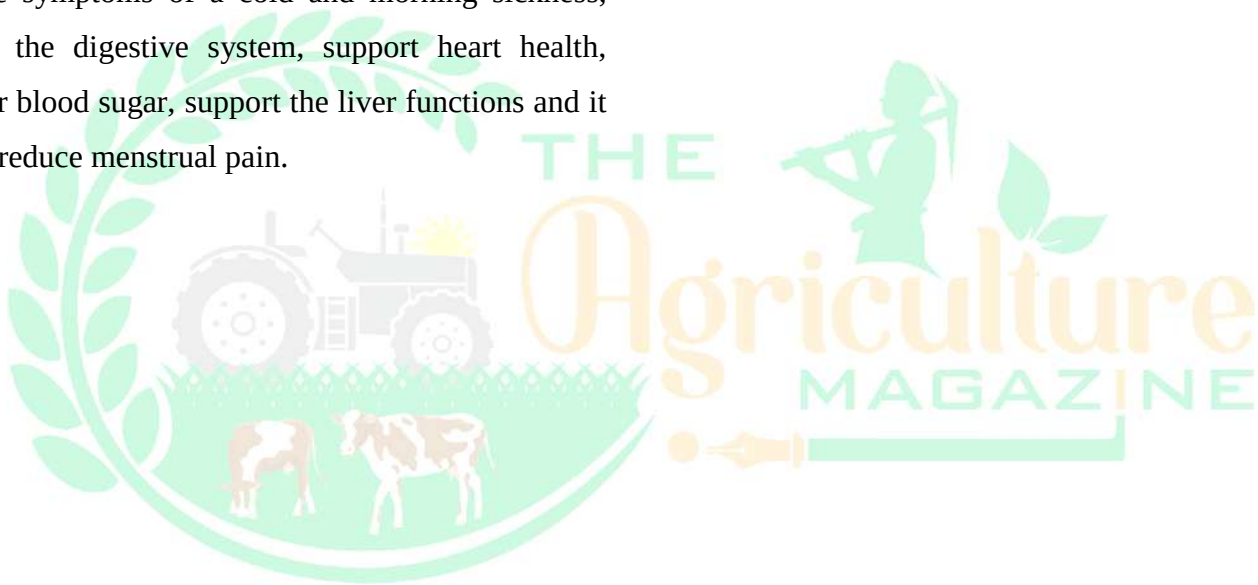
Intercropping

Ginger absorbs the large amount of nutrients in the soil. So ginger should not be cultivated the same land continuously in the same land. So it should be cultivated with a variety of other crops, rotation of Tapioca, Beans, Chow-Chow and other Vegetables. Ginger can be cultivated as a single crop or intercrop with Maize, Soyabean, Groundnut, Tomato, Bhendi coffee, orange, banana etc. Tuber rot disease is the most important disease in ginger it may see in poor drainage areas of stagnant water found in this disease. The disease is transmitted through the soil and seed tubers.

Economic importance

Ginger is an important commercial spice crop and cash crop in many countries. It is used in cooking, confectionery, beverages and medicine. Here are some economic aspects of ginger: The top ginger producing countries in the world are India, China, Nepal, Indonesia, Nigeria, Thailand, Bangladesh, Japan, Cameroon, and the Philippines are the top ten ginger-producing countries.

In 2017, India accounted for 34% of the world's ginger production. In 2021, India exported \$109.88 million worth of ginger. Ginger production can be affected by biotic stress, climatic fluctuations, and food price instability are challenges. In Ethiopia, ginger production and distribution is a key driver of economic growth and poverty alleviation. Ginger contains antioxidants and anti-inflammatory properties, eating ginger can break down fermentation, relive constipation, other causes of intestinal gas, relive symptoms of a cold and morning sickness, calm the digestive system, support heart health, lower blood sugar, support the liver functions and it may reduce menstrual pain.



Assessing the Efficacy of Natural Farming: Yield and Sustainability in Northeast India

Ricky Ronghang, Amrutha T., A. K. Mohanty, Divya P. and A. K. Singha

Abstract

Natural Farming (NF) emerges as a promising sustainable agricultural practice in response to growing global food demands and environmental concerns. This study evaluates the efficacy of NF in Northeast India (NER), focusing on its impact on yield, sustainability, and socio-economic outcomes. NF integrates traditional knowledge with modern practices, emphasizing soil restoration, biodiversity conservation, and reduced chemical dependence, aligning with agroecological principles. India's Green Revolution, while ensuring food security, led to significant environmental degradation. The COVID-19 pandemic further highlighted the vulnerabilities of conventional farming systems, accelerating the shift towards nature-driven solutions. NF holds significant potential in the biodiverse NER, offering a sustainable pathway for agricultural development. Natural Farming offers a promising pathway for sustainable agricultural development in Northeast India. By integrating traditional knowledge with modern scientific principles, NF can enhance agricultural productivity, improve soil health, and reduce environmental impact. Through a detailed analysis of crop yields, soil health, economic viability, and social impacts, this study demonstrates how NF can enhance productivity, reduce environmental footprints, and support rural livelihoods. By leveraging local bio-resources, NF fosters community resilience and aligns with global calls for sustainable development. This research underscores the potential of NF to transform agriculture in the NER, serving as a model for other regions seeking sustainable farming solutions.

Introduction

To meet the growing global population's food demands, production must increase by 60% by 2050 (FAO, 2009), which puts immense pressure on the environment, resulting in significant degradation. This need for increased food production is particularly evident in India, which ranked 177th out of 180 countries in the 2018 Environmental Performance Index (EPI), underscoring the urgent need for sustainable agricultural practices.

In response to this challenge, Natural Farming (NF), also known as Eco-Agriculture, has emerged as a promising solution. NF integrates traditional and modern farming methods to address environmental health, public well-being, and community resilience (Mishra, 2018). Sustainable agriculture, as outlined by the World Bank (2017), aims to meet current food demands while safeguarding the needs of future generations. The growing global awareness of environmental issues,

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such as resource conservation and biodiversity protection, has led to a wider adoption of eco-friendly practices. In India, the Green Revolution played a key role in achieving food security but also resulted in significant environmental harm and soil depletion. The COVID-19 pandemic further highlighted the importance of shifting to more sustainable agricultural methods. Economist Mihir Shah (2022) has advocated for agroecology to ensure long-term sustainability in farming. Prime Minister Modi echoed this sentiment in 2021, urging a transition from chemical-intensive farming to nature-driven solutions. This aligns with agroecological principles that promote soil restoration, crop diversification, and reduced water dependence. Although Natural Farming and Organic Farming are often used interchangeably, the former focuses on bio-inputs derived from local ecosystems, while the latter adheres to specific product certification standards. Both methods aim to reduce external inputs and promote sustainable, environmentally responsible farming.

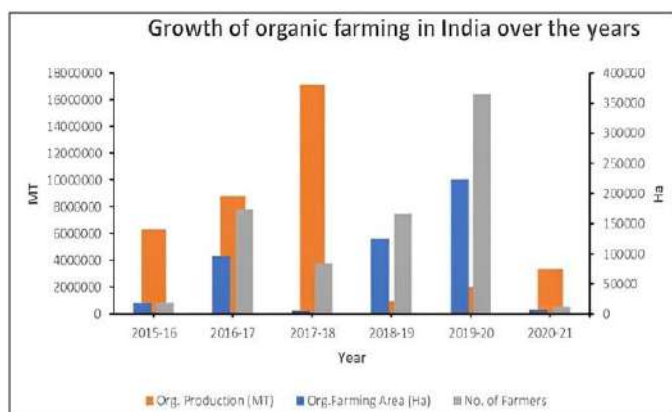


Fig. 1: Growth of organic farming in India over the years (Source: NCOF report)

The rise in organic farming in India is evident

in the steady increase in organic production, farming area, and the number of farmers involved, particularly from 2015-16 to 2020-21 (Fig 1). This growth suggests a growing interest in organic practices, driven by factors such as increased consumer demand, government support, and heightened awareness of the benefits of sustainable agriculture.

Benefits of Natural Farming

Natural Farming (NF) enhances agricultural productivity by optimizing labour, soil health, and equipment use while avoiding chemical fertilizers and pesticides. Studies indicate that NF can achieve similar yields to conventional farming, but with greater long-term sustainability through practices like diverse cropping systems. These systems benefit both ecology and finances by reducing the environmental impact and providing a steady income for farmers. Additionally, NF significantly lowers production costs, especially by reducing the need for expensive fertilizers, which only account for a small percentage of material costs compared to conventional systems. By eliminating harmful chemicals, NF minimizes health risks for farmers and consumers. Crops produced through NF tend to have higher nutritional content and fewer toxins, contributing to better health outcomes, including lower rates of certain diseases. Furthermore, NF creates rural employment opportunities in bio-input production, marketing, and other related activities, thereby fostering economic growth and promoting gender equality. This system also restores soil health, enhan-

ces productivity, and supports environmental conservation, particularly in regions prone to extreme weather.

NF helps conserve water through techniques that improve soil moisture retention and water management. In areas experiencing water scarcity, these methods are especially beneficial for sustaining crops, such as those in paddy cultivation. Additionally, NF rejuvenates soil by encouraging the growth of beneficial microorganisms and using natural inputs like Jivamrit, which improves soil fertility and reduces the need for chemical fertilizers. The integration of livestock, particularly indigenous cows, further supports sustainability by enhancing soil health and reducing external input dependency, contributing to a balanced and eco-friendly farming system.

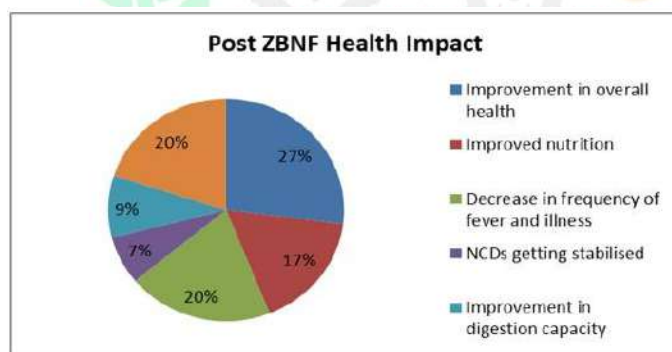


Fig. 2: Perception of HHs on Health post NF consumption (Source: Assessment of Post NF effects on the Health & Nutrition profile of households December, 2019)

The ZBNF program, an example of NF, has shown positive health outcomes. The pie chart demonstrates that 27% of participants reported improvements in overall health, with significant gains in nutrition and digestion capacity. The program also helped stabilize non-communicable

diseases (NCDs) such as heart disease and diabetes (17%), and reduced the frequency of fevers and illnesses, showcasing the broad health benefits of NF practices. In terms of fertilizer use, Table 1 of recovery rates for Urea, DAP, SSP, and MOP across three crops (Rice, Groundnut, and Maize) shows that Urea and DAP generally have higher recovery rates, meaning better fertilizer use efficiency. Rice exhibited the highest recovery rate for Urea, while Groundnut showed the best recovery for DAP. Conversely, MOP had the lowest recovery rates in all crops, underlining the importance of selecting the right fertilizer for each crop to optimize efficiency and minimize environmental impact.

Table 1: Fertilizer Use Efficiency for Rice, Groundnut and Maize

Fertilizer	Rice	Groundnut	Maize
Urea	99.2	69.5	84.9
DAP	98.5	90.9	78.4
SSP	82.9	58.3	79.8
MOP	99.8	47.7	24.6

*Source: Can Zero Budget Natural Farming Save Input Costs and Fertilizer Subsidies- Evidence from Andhra Pradesh, January 2020.

Natural Farming in Northeast India

The North Eastern Region (NER) of India holds considerable potential for organic agriculture, yet its full capacity remains underutilized. With benefits like proximity to Southeast Asian markets and a variety of exotic produce, NER can become a significant hub for organic agribusiness, attracting premium prices for its products. To harness this potential, the Ministry of Agriculture launched the Mission Organic Value Chain Development for the Northeastern Region (MOVCD) in 2017. This initiative aims to promote organic farming through a

value-chain approach. Currently, 177 Farmer Producer Organizations (FPOs) are involved in organic production in the NER. Many organic clusters have been established under the Paramparagat Krishi Vikas Yojana (PKVY) scheme, which ensures transparency, quality assurance, and the promotion of sustainable agricultural practices. These initiatives provide a strong foundation for the region to evolve into a global leader in organic farming, driving economic growth, employment, and environmental sustainability.

Table 2 summarizing the status of organic farming in eight Indian states shows the progress in organic farming across these regions. Sikkim currently leads in terms of the existing organic area, reflecting its strong commitment to organic agriculture. Arunachal Pradesh has the largest area currently transitioning to organic practices, indicating a focus on expanding organic farming. Mizoram stands out with the highest total area under both organic farming and conversion, demonstrating a comprehensive approach that combines established organic areas with ongoing efforts to increase organic cultivation.

Table 2: Organic Farming Statistics for Northeast India (Source: APEDA, 2022-23)

Sl. No.	State Name	Organic Area (in ha)	Conversion area (in ha)	Total area (in ha)
1.	Sikkim	74647.31	1082.34	75729.66
2.	Meghalaya	34816.3	3560.09	38376.39
3.	Assam	6719.27	11751.57	18470.84
4.	Nagaland	7384.96	7405.42	14790.38
5.	Manipur	4419.25	8305.67	12724.92
6.	Arunachal Pradesh	265.37	12848.74	13114.12
7.	Mizoram	40.45	12998.44	13038.89
8.	Tripura	203.56	6317.75	6521.31

NITI Aayog's Role in Promoting Natural Farming

Natural farming is a chemical-free, agroecological method that integrates crops, trees, and livestock while maintaining biodiversity. In India, it is promoted through the Bharatiya Prakritik Krishi Paddhati Programme (BPKP), which is part of the Paramparagat Krishi Vikas Yojana (PKVY). BPKP encourages indigenous practices like biomass recycling, cow dung and urine formulations, soil aeration, and the exclusion of synthetic chemicals. This method reduces dependence on purchased inputs, easing the credit burden on smallholder farmers. Studies show that natural farming under BPKP enhances production, sustainability, water efficiency, and soil health. It is also cost-effective and promotes rural development. Approximately 2.5 million farmers in India practice regenerative agriculture, and the area under organic farming, including natural farming, is expected to reach 2 million hectares in the next five years, with 1.2 million hectares under BPKP.

National level consultation on BPKP-Natural farming- held on 29th & 30th September 2020

NITI Aayog organized a two-day virtual consultation on the principles and practices of Bhartiya Prakritik Krishi Padhati (BPKP)-Natural Farming from September 29-30, 2020. Chaired by the Vice Chairman of NITI Aayog, the event brought together over 600 participants, including officials from central and state agriculture ministries, agricultural scientists, vice-chancellors, subject-

matter experts, faculty from agricultural universities, Krishi Vigyan Kendra representatives, NGOs, farmers' associations, and agri-entrepreneurs. International participants included representatives from FAO, UN, and ICRAF. The consultation aimed to discuss the potential and challenges of adopting natural farming in India.



Fig. 3: NITI Aayog Consultation on Natural Farming (Source: Bhartiya Prakritik Krishi Padhati (BPKP)-Natural Farming from September 29-30, 2020)

The meeting on Natural farming- way forward held on 9th October 2020

A follow-up meeting to the National-level consultation on BPKP-Natural Farming, held on 29th-30th September 2020, took place on 9th October 2020. Chaired by the Vice-Chairman of NITI Aayog, the virtual meeting focused on advancing natural farming by gathering empirical evidence, scientific validations, and preparing success stories from states like Andhra Pradesh, Karnataka, Gujarat, and Himachal Pradesh. Key participants included NITI Aayog's Member of Agriculture, the Director-General of ICAR, officials from the Ministry of Agriculture & Farmers Welfare, the Deputy Director-General of ICRAF, and representatives from Krishi Vigyan Kendras (KVKs).

Lecture Series on Natural Farming

On 18th November 2020, the Agriculture Vertical hosted a virtual lecture on “Sustainable Agroecological Systems,” presented by Dr. Bruno Dorin, Senior Researcher at Centre De Sciences Humaines. Chaired by Dr. Rajiv Kumar, Vice Chairman of NITI Aayog, the event saw 71 participants, including key figures like Prof. Ramesh Chand, Member of NITI Aayog (Agriculture), Dr. Rakesh Sarwal, State Agriculture Secretaries, ICAR officials, FAO representatives, and scientists from State Agriculture Universities and Krishi Vigyan Kendras (KVKs).

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Innovative Dairy Processing: Boosting Efficiency and Quality

Vikash Kumar, M. P. S. Yadav and Kuldeep

Dairy processing has come a long way from traditional methods to a sophisticated system that leverages technology to enhance efficiency and quality. The evolution in this sector has made dairy products safer, more affordable, and widely available to meet the needs of an ever-growing global population. From automation to quality control innovations, dairy technology is reshaping the industry, providing benefits to producers, consumers and the environment. This article explores some of the most recent advancements in dairy processing and highlights how they are transforming the sector.

Enhancements in Milk Production and Processing

In the modern dairy industry, efficiency and quality are paramount. Technological advances have streamlined production processes, allowing dairy farms and processing plants to operate with minimal waste and maximum output. Automation, one of the most significant developments, has reduced labor costs and improved product consistency. Automated milking systems, for instance, are now widely used to increase milking efficiency while reducing stress on animals, which ultimately leads to higher-quality milk. These systems allow cows to be milked at their convenience, minimizing human interference and

enhancing animal welfare. Another critical advancement is the use of data analytics in milk processing. Sensors placed on cows or within processing equipment can track numerous factors, including milk yield, quality, and overall animal health. This data provides insights that help optimize feeding schedules, adjust milking protocols, and monitor for signs of illness or stress. Dairy farmers can make informed decisions that boost productivity and maintain product quality by leveraging data.

Pasteurization and Ultra-High-Temperature Processing

Pasteurization is an essential process in dairy, as it kills pathogens and extends the shelf life of milk and other dairy products. However, traditional pasteurization processes require considerable energy and can sometimes alter the taste or texture of the final product. Innovations in pasteurization, such as ultra-high-temperature (UHT) processing, have significantly improved the preservation of both taste and nutritional quality while ensuring safety. UHT processing heats milk to 135°C or higher for just a few seconds, effectively killing bacteria and allowing the product to stay fresh for extended periods without refrigeration. This method is particularly beneficial for regions with limited access

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to refrigeration, as it provides a reliable means of preserving milk and dairy products in tropical or remote areas. Moreover, UHT processing reduces energy consumption, making it a more sustainable option than traditional methods.

Membrane Filtration Technology

One of the most exciting innovations in dairy processing is membrane filtration, which allows for the precise separation of milk components. Using this technology, milk can be filtered to retain specific proteins, fats, or minerals, depending on the desired end product. Membrane filtration is commonly used in producing high-protein dairy products, such as Greek yoghurt and protein-enriched milk, as well as in lactose-free milk production. The advantages of membrane filtration extend beyond product customization; it also contributes to waste reduction. By retaining valuable nutrients that might otherwise be lost, this technology maximizes the use of raw materials. Furthermore, membrane filtration processes are highly selective, so they consume less energy than conventional methods. This combination of efficiency and versatility makes membrane filtration a cornerstone of modern dairy processing technology.

Quality Control and Safety Assurance

As consumers become more health-conscious, quality control and safety have taken center stage in dairy processing. Technological advancements have enabled real-time quality monitoring, ensuring that dairy products meet stringent standards before they reach store shelves. Machine learning

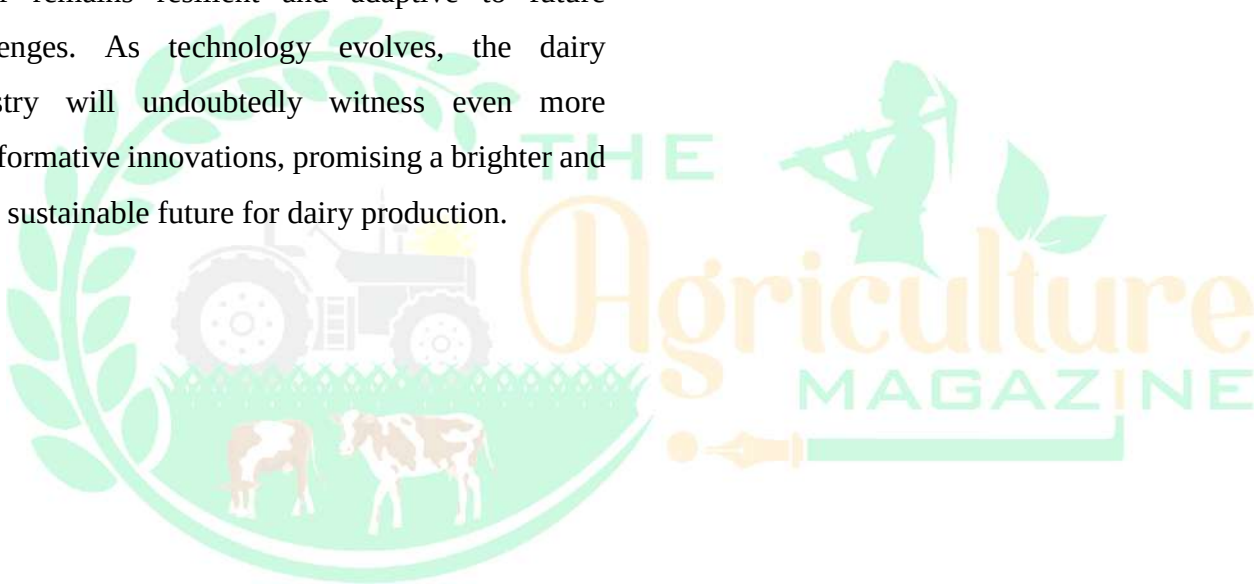
algorithms, for example, can detect anomalies in milk composition or contaminants during processing, providing an extra layer of protection against foodborne illnesses. Rapid microbiological testing is another area where innovation is playing a vital role. Traditional microbiological testing methods often require hours or even days to yield results, but modern rapid tests can detect pathogens like *E. coli* or *Salmonella* in minutes. These technologies allow processors to identify and address potential issues quickly, minimizing the risk of contamination and enhancing consumer confidence in dairy products.

Environmental Impact and Sustainability

While efficiency and quality are essential, sustainability is becoming increasingly important in the dairy industry. Dairy processing requires considerable water and energy resources, and traditional methods have a substantial environmental footprint. Modern innovations, however, are helping to reduce these impacts. For instance, waste-to-energy solutions capture methane from dairy waste and convert it into biofuel, powering equipment within processing plants. This reduces reliance on fossil fuels and decreases greenhouse gas emissions. Additionally, the industry is adopting water recycling systems to minimize waste. Many dairy processing plants now have closed-loop water systems that allow water to be purified and reused multiple times within the facility. These systems significantly reduce water consumption, aligning the dairy industry with broader sustainability goals.

Conclusion

Dairy processing technology innovations improve efficiency and product quality and pave the way for a more sustainable future. By adopting automated systems, advanced pasteurization, membrane filtration, and rigorous quality control, the dairy industry can meet the demands of modern consumers while minimizing its environmental footprint. These advancements showcase how technology can support both industry growth and environmental responsibility, ensuring that the dairy sector remains resilient and adaptive to future challenges. As technology evolves, the dairy industry will undoubtedly witness even more transformative innovations, promising a brighter and more sustainable future for dairy production.



Assessment on Role of Natural Enemies in Reducing Pest Populations

L. S. Chaudhary and M. R. Siddhapara

Introduction

Biological control is the use of living organisms viz., predators, parasitoids and pathogens to suppress the population of a pest species, thereby reducing its damage to crops, ecosystems or human health. Conventional pest management heavily relies on chemical pesticides, which can cause environmental harm, pesticide resistance, and toxicity to non-target organisms. Growing concerns over the environmental and health impacts of chemicals have led to increased interest in sustainable pest control strategies, including the use of natural enemies.

Predators: A free-living organism throughout its life, it kills its prey, is usually larger than its prey and requires more than prey to complete its development

Characteristics

- ✓ A free-living organism throughout its life cycle and usually with long life cycle
- ✓ Requires several preys to complete its development
- ✓ Larger than its prey
- ✓ Kill their prey immediately
- ✓ Usually both immature and adult stages are predatory, except some cases eg. Blister beetle larvae feeds eggs of grasshopper, whereas the adult feeds on flowers.

Special adoption

- ✓ Fast flying capacity is found in most of the flying

- ✓ predators for chasing and capturing the prey
- ✓ Rapid pounce upon the prey while at flight eg. Robberfly
- ✓ Trapping: Antlion grubs and ground beetle grubs construct conical and vertical pits, respectively
- ✓ Stinging predators: Few wasps sting and paralyse the caterpillar and store them as food for the young ones without decay due to the antibiotic property of the venom injected by the wasp while stinging.

Predators of Agricultural Importance

Group	Organism	Predatory stage
Arachnids	Spiders, Scorpion and mites	Nymph and adult
Insects	Dragon fly	Nymph and adult
	Preying mantis	Nymph and adult
	Aphid lion or green lace wing bug	Grubs
	Mud wasp, Digger wasp and Ants	Adult
	Blue butterfly	Caterpillar
	Robber fly	Adult
	Hover fly	Maggots
	Lady bird beetle & Ground beetle	Grubs and Adult
	Tiger beetle	Grubs and Adult
	Assassin bugs, Pentatomid bugs and Mirid bugs	Grubs and Adult
Fishes	<i>Gambusia affinis</i> , <i>Fundulus</i> sp and <i>Halochilus</i> sp	Nymph and adult
Birds	King crow, mynah, woodpecker etc.	Insectivorous birds

Order and Family	Name	Prey Insect
Coleoptera		
Coccinellidae	<i>Coccinella septumpunctata</i> , <i>C. rependa</i>	Aphids
	<i>Scymnus coccivora</i>	Grape vine mealy bug

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Order and Family	Name	Prey Insect
Coleoptera		
Coccinellidae	<i>Menochilus sexmaculata</i>	Mealy bugs and Scales
	<i>Rodolia cadinalis</i>	Cottony Cushion Scale
	<i>Chilocorus nigritus</i>	Tapioca Scales
	<i>Cryptolaemus montrouzieri</i>	Grape vine mealy bug
Carabidae	<i>Parena laticincta</i>	BHC
	<i>Opiomea</i> sp., <i>Paederus fuscipes</i>	Rice BPH and leaf folder
Cicindellidae	Tiger beetle	Soil Dwelling insects
Hemiptera		
Reduviidae	<i>Rhinocoris fuscipes</i>	<i>H. armigera</i>
	<i>Platyeris laevicollis</i>	Coconut rhinoceros beetle
Miridae	<i>Cryptorhinus lividipennis</i>	Rice hoppers
Veliide	<i>Microvelia atrolineata</i>	Rice leaf and plant hopper
Neuroptera		
Chrysopidae	<i>Chrysoperla carnea</i>	Aphids, Scales, bollworms
Mymeliontidae	<i>Myrmelion</i> Sp.	Ants and soil dwelling insects

Parasitoid: A parasitoid is an insect parasite of an arthropod which is parasitic in immature stages and adults are free living.

Characteristics

- ✓ Adult parasitoid seek out their host in the environment using a variety of olfactory and tactile cues from the host and its habitat visual.
- ✓ Female lays eggs in, on or near the host.
- ✓ Parasitoids larvae feed on host tissue, but may not kill their host until they develop to adult stage.
- ✓ Adult parasitoid requires food such as honeydew, nectar, pollen, host body fluids and water.

Ideal qualities of a parasitoid

- ✓ High Host searching capacity
- ✓ Having a narrowly limited host range

- ✓ Having a life cycle shorter than that of pest
- ✓ Potential rate of increase
- ✓ Able to survive in all habitats
- ✓ Able to culture easily in the laboratory
- ✓ Able to quickly reduce the pest population
- ✓ Absence of superparasitism and multiparasitism

Parasitoids of Agricultural Importance

Type	Name	Targeted host
Egg parasitoid	<i>Trichogramma chilonis</i>	Sugarcane internode borer, cotton bollworm and rice leaf folder
	<i>T. japonicum</i>	Rice YSB
	<i>Telenomus rowani</i>	
	<i>T. remus</i>	Tabacco caterpillar
	<i>Evania appendigaster</i>	Cockroach
	<i>Tetrastichus pyrrillae</i>	<i>Pyrilla perpusilla</i>
Egg-larval parasitoid	<i>Chelonus blackburni</i>	Cotton Spotted bollworm
	<i>Copidosoma koehleri</i>	PTM
Larval parasitoid	<i>Bracon hebetor</i>	BHC
	<i>B. brevicornis</i>	
	<i>Eriborus trochanteratus</i>	
	<i>Spogossia bassiana</i>	
	<i>Apanteles plutella</i>	DBM
	<i>Campoletis chloridae</i>	<i>H. armigera</i>
	<i>Platygaster oryzae</i>	Rice gall midge
	<i>Sturmiopsis interens</i>	Sugarcane shoot borer
Larval-pupal parasitoid	<i>Isotima javensis</i>	Top shoot borer
Pupal parasitoid	<i>Brachymeria nephandidis</i>	BHC
	<i>Tetrastichus Israeli</i>	
	<i>Trichospilus pupivora</i>	
Nymphal and adult parasitoid	<i>Aphelinus mali</i>	Apple wooly aphid
	<i>Encarsia formosa</i>	Whitefly
	<i>Epiricnia melanoleuca</i>	<i>Pyrilla perpusilla</i>

Pathogens

- ✓ The control of pests by the use of micro-organisms such as viruses, bacteria, protozoa, fungi, rickettsia and nematodes or their products is known as microbial control.
- ✓ These microbes can be grouped as ingested microbes (bacteria, viruses, rickettsia and proto-

zoa) which enter insect body along with food (like stomach insecticide) and penetrating microbes (nematode and fungi) that enter by penetrating the integument (like contact insecticide).

Desirable attributes

- ✓ Pathogen should be highly virulent, able to cause disease in short period and spread from one insect to another.
- ✓ Host specificity
- ✓ Cost effective and economical.
- ✓ Harmless to other forms of life (Safe to non-target organisms and man)
- ✓ Rapid prevention of pest feeding

Important history related to natural enemies to suppress pest population

- ✓ The first natural enemy to be introduced by man from one country to another was an Indian mynah, *Acridotheres tristis*, was introduced in Mauritius in 1762 to control the red locust.
- ✓ The first successful attempt was made in 1888 by C. V. Riley, a U. S. Govt. Entomologist, when Vedalia beetle, *Rodolia cardenalis* was introduced from Australia to California, for the control of cottony-cushion scale, *Icerya purchase*, on citrus.
- ✓ In India, the earliest attempt at introduction of a natural enemy was made in 1898 when coccinellid, *Cryptolaemus montrozieri*, from Australia and released against the coffee green scale, *Coccus viridis*. It was established but failed to control the scale.

- ✓ The value of ladybird beetle, green lace wing and other predators has been recognized since mid-19th century.
- ✓ The apple wooly aphid, *Eriosoma lanigera*, was effectively controlled by introduction of *Aphelinus mali* in the vallies (Coonoor), from Punjab in 1925.
- ✓ The coconut black headed caterpillar, *Opisina arenosela*, was controlled by employing its natural enemies, *Trichospilus pupivora* (pupal parasitoid), *Goniozus nephantidis* (larval parasitoid), *Bracon brevicornis* (larval parasitoid) in Tamil Nadu.
- ✓ The sugarcane pyrilla, *Pyrilla perpusilla* (nymphal and adult parasitoid) was controlled in South Gujarat by introducing *Fulgoresia (Epiricania) melanoleuca* from Haryana in 1982 and till it is effective.
- ✓ The San Jose scale, (*Quadraspidotus perniciosus*), was successfully controlled in the western Himalayas by the introduction of *Encarsia perniciosi* from China in 1960.
- ✓ The prickly pear, (*Opuntia inermis*), in Australia controlled by introduction of pyralid moth, (*Cactoblastis cactorum*), from Argentiniana in 1925.

Augmentative biocontrol in India

Rice: Release of mirid bug @ 100 bugs or 50-75 eggs m⁻² at 10 days intervals have been found effective for the control of brown planthopper. Inundative releases of exotic *Trichogramma japonicum* at 50000 ha⁻¹ during egg laying period of

Entomopathogenic pathogens of Agricultural Importance

Type of Bioagent	Species	Effective against
Bacteria	<i>Bacillus thuringiensis</i>	Lepidopteran larvae
	<i>B.t. var. kurstaki</i>	
	<i>B.t. var. israelensis</i>	Diptera (larval stages of mosquitoes and black flies)
	<i>B.t. var. gallerine</i>	Lepidoptera (Wax moth)
	<i>B.t. var. tenebrionis</i>	Coleopteran (Beetles and weevils) larvae
	<i>B.t. var. sandiego</i>	
	<i>B.t. var. aizawai</i>	Lepidopteran larvae
Viruses	<i>Bacillus popilliae</i>	Coleoptera (Scarabaeidae) “milky disease”
	Ha NPV	<i>Helicoverpa armigera</i>
	Sl NPV	<i>Spodoptera litura</i>
	Sf NPV	<i>Spodoptera frugiperda</i>
Fungus	GV	Sugarcane early shoot borer
	<i>Beauveria bassiana</i>	Lepidopteran larvae, sucking pests (aphids, whiteflies, and mealy bugs) and orthopterans (grasshoppers, locusts, and crickets)
Fungus	<i>Metarhizium anisopliae</i>	White grubs, coconut rhinoceros beetle, groundnut cut worm, rice brown plant hopper, diamond back moth and early shoot borer, top shoot borer and internode borer of sugarcane
	<i>Verticillium lecanii</i>	<i>Coccus viridis</i> , whitefly, thrips, and aphids
	<i>Hirsutella thompsonii</i>	Phytophagous mites (citrus rust mite, two spotted red spider mite)
	<i>Neozygites floridana</i>	
	<i>Nomuraca rileyi</i>	Green clover worm, cabbage looper, cabbage worm, armyworms, corn earworm, and tobacco budworm
Nematodes	<i>Paecilomyces lilacinus</i>	Plant parasitic nematodes in the soil
	<i>Steinernema carpocapse</i> , <i>S. scapterisci</i> , <i>S. masoodi</i>	Lepidopteran larvae
	<i>S. feltiae</i>	Dipteran larvae
Protozoa	<i>Heterorhabditis indica</i>	White grub, Galleria
	<i>Paranosema locustae</i>	Grasshoppers, locusts and crickets
	<i>Nosema melolonthae</i>	Chaffer beetles
	<i>Vairimorpha necatrix</i>	Armyworms and cabbage looper
Protozoa	<i>Farinocystis triboli</i>	Red flour beetle

Pests	Biotic Agents	Dosage ha ⁻¹	Frequency of application	Application methods
<i>Chilo spp.</i>	<i>T. chilonis</i>	50,000 eggs	10 days interval, starting from 30 D old crop	Staple parasitized egg card bits on lower leaf
<i>Pyrilla perpusilla</i>	<i>Epiricania melanoleuca</i>	1500 adult larvae ⁻¹	Initiated before onset of monsoon	Egg masses/cocoon spread in selected spots
<i>Scirpophaga incertulas</i>	<i>T. japonicum</i>	100000 eggs	30 DAT accordingly	Adult release / staple parasitized egg card bits
<i>Nilaparvata lugens</i>	<i>Cryptorhinus lividipennis</i>	100 adult & 50-70 nymphs m ⁻²	On noticing the incidence	Released on hopper infested spots
<i>Opisina arenosella</i>	<i>Goniozus nephantidis</i>	5000 adults	Need based or for each generation	Adult release
<i>Eriosoma lanigerum</i>	<i>Aphelinus mali</i>	1000 adults infested ⁻¹ tree	Once, infestation noticed	Adult release
<i>Cydia pomonella</i>	<i>T. embryophagum</i>	2000 adults tree ⁻¹	Weekly interval	Adult release

rice stem borer reduced borer damage and increased crop yield.

Horticultural crops: Augmentative and inoculative release of two exotic parasitoids, *Encarsia perniciosi*

and *Aphytis* spp. *Proclia* group @ 2000 per infested tree have given promising results for the suppression of sanjose scale on apples.

Plantation crops: Inundative release of native

Some Pests and their Common Natural Enemies

Pests	Natural Enemies					
	Lace wings	Lady beetles	Parasitic flies	Parasitic wasps	Predatory mites	Other Groups and Examples
Aphids	✓	✓		✓		Entomopathogenic fungi, Syrphid fly larvae
Caterpillars	✓		✓	✓		Entomopathogenic fungi, bacteria and viruses,
Cottony Cushion Scale		✓	✓			<i>Cryptochaetum iceryae</i> and Vedalia beetle
Lace Bugs	✓	✓		✓		Assassin bugs and pirate bugs, spiders
Mealybugs	✓	✓		✓		
Psyllids	✓	✓		✓		Pirate bugs
Scales	✓	✓		✓	✓	Aphytis, Encarsia, and <i>Metaphycus</i> spp
Thrips	✓			✓	✓	Minute pirate bugs, predatory thrips
Whitefly	✓	✓		✓		Bigeyed bugs and minute pirate bugs, spiders

parasitoids, *Goniozus nephantidis* and *Bracon brevicornis* at 3000 and 4500 ha⁻¹, respectively, has given encouraging results for the management of *Opisina arenosella* on coconut. The inoculative release coccinellid, *Curinus coeruleus*, against subabul psyllid, *Heteropsylla cubana* has proved very effective in the management of this pest.

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Agri-Entrepreneurship: Opportunities and Challenges

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Introduction

Agri entrepreneurship refers to using business skills and innovation in agriculture, to improve farming techniques, outputs, products, as well as deals with other sector challenges through innovative and improvements. Support for (youth) agri entrepreneurship is growing due to the successful entrepreneur contribute to sustainable food systems, employment, income generation, and positive social change, including gender and youth empowerment in low-income (rural) regions.



Agri-entrepreneurship is a subset of entrepreneurship that relates to the agricultural sector and is characterised by its link to the environment. Unlike conventional entrepreneurship, agri entrepreneurship is closely influenced by specific business, environmental, economic and social factors. Significant dynamics that influence agri entrepreneurship include climate vulnerability, smallholder farmer dominance, power imbalances, long and complex value chains, and quality control and markets, which shape doing business in the agri sector.

Agricultural Entrepreneurship involves starting and running a business in the agriculture sector. It combines the principles of entrepreneurship with the practice of farming or agricultural production. The goal is to add value to the agricultural supply chain, enhance productivity, and create sustainable solutions to meet growing global demand for food, fiber, and other agricultural products.



Need and Importance of Agri-Entrepreneurship

Traditionally, farmers are ignorant of scientific agriculture and effective Agri-management systems. Thus, they are unable to deal with delayed monsoons, drought, crop debts, fake seeds and shortage of fertilizer, as a result opt to commit suicide. Hence, the managerial, technical and innovative skills of entrepreneurship applied in the field of agriculture may build a well-trained Agri-entrepreneur who becomes a role model to all such depressed farmers. Agri-entrepreneurship has the prospect of social and economic development, for example, employment generation, poverty reduction, improvements in nutrition, health and overall food

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security in the national economy especially in rural areas. In the face of growing unemployment and poverty in rural areas, there is urgency of entrepreneurship in agriculture for more productivity and profitability. Agri-entrepreneurship can be used as chief remedy for the solution of this complexity such as lower the burden of agriculture, produce employment opportunities for rural youth, control migration from rural to urban areas, boost national income, sustain industrial development in rural areas and cut down the pressure on urban cities. Agri-entrepreneurship is greatly affected by the economic situation, education and culture. Agri-entrepreneurship is important for national economy in following ways 1) It helps in achieving productivity profit by small farmers and amalgamating them into local, national and international markets. 2) It helps in decrease in food costs, and provides highquality diets to the rural and urban poor in the country. 3) It accelerates growth, diversifying income and develops entrepreneurial opportunities in both rural and urban areas.

Agricultural entrepreneurs are involved in different activities such as

Agribusiness Ventures

Crop Production: Growing high-demand crops or organic produce.

Livestock Farming: Rearing animals for meat, dairy, or other products.

Aquaculture & Fish Farming: Cultivating aquatic organisms such as fish, shellfish, or algae.

Agroforestry: Combining agriculture and forestry to

improve land use and promote sustainable practices.

Value-Added Products

- ✓ Creating processed goods like jams, juices, cheese and sauces from raw agricultural products.
- ✓ Starting businesses around organic products, such as organic fertilizers, seeds, and even eco-friendly packaging solutions.

Agro-Technology & Innovation

- ✓ Developing and implementing new technologies that increase productivity or efficiency in farming.
- ✓ Drones for monitoring crops, AI for crop management, or smart irrigation systems.

Agro-Tourism: Establishing farm-based tourist attractions, such as farm stays, agricultural tours, and educational programs for the public.

Agricultural Services

- ✓ Providing services such as crop consulting, farm management, or agricultural equipment rental.
- ✓ Offering distribution and logistics services that help farmers get their products to market.

Components of Agricultural Entrepreneurship

Market Research

- ✓ Understanding the demand for agricultural products, both locally and internationally.
- ✓ Identifying markets and emerging trends, such as plants- based foods, sustainable agriculture or vertical farming.

Innovation & Technology

- ✓ Using modern tools like sensors, drones, and data analytics to optimize production & reduce costs.

- ✓ Adopting precision farming techniques, such as GPS-guided machinery or climate-controlled greenhouses.

Sustainability

- ✓ Developing eco-friendly farming practices and sustainable resource management.
- ✓ Emphasizing organic farming, water conservation and soil health.

Networking & Partnerships

- ✓ Collaborating with other farmers, suppliers, government agencies, and NGOs to share knowledge, access funding, or develop joint ventures.
- ✓ Building relationships with customers through branding, marketing, and offering transparency in how products are produced.

Financial Management

- ✓ Managing cash flow, securing funding or investment, and making strategic financial decisions.
- ✓ Understanding the cost structure of agricultural businesses, including the cost of inputs like seeds, equipment, and labor.

Opportunities in Agricultural Entrepreneurship

Organic Farming: As demand for organic produce increases, entrepreneurs have the opportunity to tap into the organic food market.

Agri-Tech Startups: Innovating in precision agriculture, automation and sustainable technologies.

Alternative Proteins: With the rise of plant-based and lab-grown meat products, there is room for

entrepreneurs to get involved in this emerging field.

Supply Chain Solutions: Streamlining logistics to reduce food waste, enhance distribution, and increase access to markets for small-scale farmers.

Challenges Agricultural Entrepreneurship

Capital Intensity: Agriculture businesses can require significant upfront investment in land, equipment, and technology.

Weather Dependency: Farming is highly dependent on weather conditions, which can lead to uncertainties.

Market Fluctuations: Agricultural prices can be volatile due to changing market conditions, which can affect profitability

Regulatory Hurdles: Navigating agricultural regulations, including food safety standards, environmental laws, and subsidies, can be complex



Skills for Agricultural Entrepreneurs

Knowledge of Agriculture: A deep understanding of farming techniques, livestock care, and crop management is essential.

Business Acumen: Skills in marketing, financial management, and operations management are critical to building a sustainable enterprise.

Innovation & Problem-Solving: The ability to think creatively and innovate to overcome challenges or tap into new market opportunities.

Sustainability Mindset: As consumers demand

more eco-friendly practices, agricultural.

Motivation for Agribusiness Start-Ups

As we discussed above the challenges and problems encountered by agri-entrepreneurs, then the question arise is that what prompts them to start their own business? These entrepreneurs before entering in this venture assess other job opportunities and impact of that on their family.

- ✓ The major motivation for agri-entrepreneurs is to increase household income and expand primary agriculture business in order that additional family members can be engaged. In other words, Agri-entrepreneurship may be a source of good living.
- ✓ It is good for individuals who do not have other career options. Some wants to take advantage of unique resources and use them for competitive advantage in business operations.
- ✓ Small farmers can remain economically feasible on expanding their activities and selling value-added products. For increasing the likelihood that consumer will purchase their costly products and provide sufficient profit, product novelty must be maintained. Entrepreneurs must be attuned to sustainable farming and ethical practices

Conclusion

Agricultural entrepreneurship offers exciting opportunities for those interested in making an impact in the global food system while also contributing to economic growth in rural and developing areas. With the right combination of passion for agriculture, business skills, and innovative thinking,

agricultural entrepreneurs can thrive while addressing key issues like food security, sustainability, and climate change.

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Emerging Insect Pests in Makhana Crop and their Management Strategies

Sunil Kumar Mandal and Sanjay Kumar

Abstract

Makhana (*Euryale ferox* Salisb) also known as Gorgon nut or Flox nut, Prickly water lily is an important aquatic fruit crop in India (including Bihar) and a good source of Carbohydrate, protein and minerals. It is cultivated over an area of 20,000 hectares in Bihar which constitutes about 80 percent of the Makhana crop in India, but the production (3.19 lakh quintals) and productivity (21.25 q ha⁻¹) of Makhana crop is low due to many constraints, of which aphid (*Rhopalosiphum nymphaeae* L), case worms (*Elophila depunctalis* G. and *Elophila crisonalis* W.) rib borer (*Chironomous spp*) and gastropods causes 17.04 to 23.67 percent loss in seed yield. These insects attack almost all parts of makhana plants viz; leaf, leaf rib, petiole, shoot, fibrous root, flower, fruits etc. under the changing cropping patterns and intensification of the crop emerge as major constraints in getting maximum yield. Further, some of the pest like leaf bug and sighara beetle emerged as minor pest and in future intensifications and changing cropping patterns may aggravate their population and infestation.

Introduction

Makhana, gorgon nut, fox nut (*Euryale ferox* Salisb) also known as black diamond of the wet land and is a perinial herbaceous aquatic cash crop with gigantic prickly floating leaves belonging to the family Nymphaeaceae. Makhana is one of the important underutilized aquatic food crops next to deep-water rice and water chesnut (Pramanik *etal*, 2013). The plant is a native to South-East Asia and widely prevalent in tropical and subtropical regions accomplished with humid to sub-humid environment (Jha *et al.*, 1991). It is mainly cultivated as a source of starch and protein (Puste, 2004) in wetlands having water depth of about 0.5-3.0 meter or even more. Makhana is a good source of carbohydrate, protein and minerals. The popped kernels (g per 100

mg) are having 12.8 moisture, 76.9 carbohydrate, 9.7 protein, 0.1 fat, 0.5 total minerals, 0.02 calcium, 0.9 phosphorus, 0.0014 iron has chemical constituents (Jha and Prasad, 1996). Biochemical analysis of Makhana seeds revealed 61% carbohydrate, 15.6% protein, 12.1% moisture, 7.6% fibre, 1.8% ash and 1.35% fat. The seeds were found to contain 12% aminoacids, which are histidine, leucine, isoleucine, glutamic acid, lysine, tyrosine, valine, aspartic, threonine, alanine, methionine and orginine (Alfasane *etal*, 2008). Traditionally, it is grown in stagnantperennial water bodies like ponds, land-depressions, oxbow lakes, swamps and ditches, but now a days, the area under this crop is increasing in low land rice field condition. Makhana cultivated over an area of 20,000 hectares in Bihar which

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Table 1: Major Insect-Pests of Makhana Crop

Sl. No.	Common Name	Scientific Name	Family	Order	Damaging stage	Plant parts
1.	Aphid	<i>Rhopalosiphum nymphaeae</i>	Aphididae	Homoptera	Nymph & Adult	Leaves
2.	Root borer	<i>Donacia delesserti</i>	Chrysomelidae	Coleoptera	Grub and Adult	Flowers, leaves, roots
3.	Rib borer	<i>Chironomus spp.</i>	Chironomidae	Diptera	Larvae	Leaves, pods
4.	Leaf sucking bug	<i>Pleau litruata</i>	Pleidae	Hemiptera	Nymph & Adult	Leaves
5.	Case worm	<i>Elophila depuntalis</i> and <i>E. crisonalis</i>	Pyralidae	Lepidoptera	Larvae	Leaves
6.	Singhara beetle	<i>Galerucella birmanica</i>	Chrysomelidae	Coleoptera	Grubs and Adults	Leaves
7.	Gastropods (Mollusca's)	Unidentified	-	-	Adult	Leaves and petioles

Table 2: Natural Enemies of Aphid in Makhana Crops

Sl. No.	Common Name	Scientific Name	Family	Order	Period of activities
1.	Lady bird beetle	<i>Coccinella septumpunctata</i>	Coccinellidae	Coleoptera	Jan. to Mid April
2.	Lady bird beetle	<i>Scymnus spp.</i>	Coccinellidae	Coleoptera	Jan. to Mid April
3.	Lady bird beetle	<i>Menochilus sexmaculatus</i>	Coccinellidae	Coleoptera	Jan. to Mid April
4.	Lady bird beetle	<i>Brumus spp.</i>	Coccinellidae	Coleoptera	Feb. to March

constitutes about 80 percent of the makhana crop in the country with their production and productivity of 3.19 lakh quintal and 21.25 q ha⁻¹, respectively (Minten *et al.*, 2014). The production and productivity of makhana crop is low due to many constraints of which insect pests are of major limiting factors. Out of four dozen insect species were found associated with makhana crop (Mishra *et al.*, 1989). The emerging insect pests *viz.* aphid (*Rhopalosiphum nymphaeae* L.), case worms (*Elophila depuntalis* G and *Elophila crisonalis* W), Rib borer (*Chironomus spp.*), leaf sucking bug (*plea litruta* f.), Root borer (*Donacia delesserti*), Singhara beetle (*Galerucella birmanica*) and Gastropods which causes 17.04 to 23.67 percent loss in seed yield (Kalra and Sharma, 1996). These insect pests attack almost all parts of makhana plants like leaf, leaf rib, petiole, shoot, fibrous roots, flowers, fruits *etc.* under the changing cropping patterns and intensification of the crop emerge as major constraints in getting maximum

seed yield. Till now, no any recommended management practices are available with the makhana cultivation to cope-up with the menace of insect-pests. For management of these pests, the basic prerequisite is to have a good knowledge on important characteristics and feeding behaviour of the pests which has been discussed in Table 1-2.

Six insect pests and different species of gastropod especially Mollusca's were damage makhana crop (Table 1). These pests were mainly damaging younger as well as older root, leaf, leaf vein/rib, flowers, petioles and fruits of makhana plants. A part from direct injury, the damaged leaves plants⁻¹ are predispose to the secondary growth of pathogens, fast decay, pre-mature damage and significant yield loss. Though most of the pests are emerging / potential pests, but due to the adoption and intensification of makhana crop from pond to low land rice field, number of the pests pose threats and emerges as major and minor pests.

Aphid (*Rhopalosiphum nymphaeae* L.): Both nymph and adult suck the sap from upper surface of leaves. Under heavy infestation, the affected part of leaves turn yellow / rust red, fast decay and which results in reduction in crop yield. Cloudy weather together with western winds enhance the aphid infestation. The peak activity of aphid is from February to March and it sharply declined and disappeared in the month of April.

Case worms (*Elophila depunctalis* W and *E. crisonalis* W.): The young larvae feed by scarping the leaf surface either in middle or at the margin. The larva makes an oval case out of the portion of the leaf cut out from it and remains inside it, moving with the case on the leaves. The larva of case worms as one of the major pests of makhana which causes heavy damage and significant reduction in the crop yield. The case worm appeared in February on the crop with peak activity from March to June and their population declined in July.

Rib borer (*Chironomous spp.*): The larvae of chironomid were appeared in developed ribs under the leaf surface. The larvae are easily move inside the aerenchymatous cavities of ribs of the leaves and causes rapid destruction. The colour of affected leaves changes to yellow, decay fast and affects the crop yields. The Rib borer appeared in February and showed increasing trend up to July and their incidence are continued till the harvest of the crop in the month of August. The incidence of chironomid larvae becomes minimum in February, but it showed increasing trends from March onwards and

continued till July. However, the population goes down from August onwards.

Leaf sucking bug (*Plea litruata* F.): Both the nymph and adult of the pest suck the cell sap from the under surface of the tender leaves, shoots and roots of the crop. The population of this pest appeared in the month of January in nursery and showed increasing trends from mid-February with the maximum population in March to April. The pest showed declining trends and disappeared in May. The population of bug is also show minimum on leaves, tender shoots and roots of makhana plants.

Singhara beetle (*Galerucella birmanica* Jacoby): Grub and adult damages the younger and mature leaves, even some times petiole and integument of the fruits. Grubs are more destructive than adults. The beetle population appeared in last week of March and showed increasing trends in April with the maximum population in May. The beetle also showed declining trends from May end and disappeared in June.

Gastropods: Different species of Mollusca's especially Gastropods are found throughout the crop growth season with increasing trend from February to April and the maximum population are found in May to July. The incidence is also found till the harvest of the crop in the month of August. This is one of the most notorious emerging pest of makhana crop and the outnumber the other insect pests. They lay eggs on fibrous root and leaves. The adults remain attached with under surface of the leaves, shoots and fibrous roots. They feed on plant tissue

of the plant and caused fast decay of affected plants. This is a menace in makhana crop as it is found in entire crop growth period and led to significant yield reduction

Natural enemies of aphid: Four coccinellids beetle is found feeding on aphid (Table 2) in makhana crop. The maximum population of these coccinellids beetle appeared in March. Among these beetle, *Scymnus spp.* are found more population than other the beetles viz., *Coccinella septempunctata*, *Minochilus sexmaculaues* and *Brumus spp.* The *Scymnus spp.* is also more effective predator of aphid than compared to others.

Eco-friendly management practices

Now a day, no any recommended pest management practices are available with the makhana cultivation to cope-up with the menace of insect pests. Chemical insecticides should not be used against insect pests. Since, water may be polluted in reservoirs, ponds and low laying terrain, because of which may be harmful than benefits. Generally, use of biological products should be encouraged to control the pests. Chemical insecticides may be used under the supervision of plant protection specialist for control these pests. If fish farming with makhana, chemical insecticide should not be used absolutely.

The following management measures are given below

- ✓ Foliar spraying of neem/cinnamon leaf extract 5 percent (5 gm L⁻¹ of water) or Neem oil 0.3 percent (0.3 gm per 10 litre of water) for control of aphids.

- ✓ Spraying of leaf extract 5 percent for control of caseworm and also use light traps for control of adult caseworm.
- ✓ Soil application of Neem cake @ 25 kg ha⁻¹ at the time of field preparation for control of root borer.
- ✓ In case of severe infestation of aphid / case worm, spraying of Imidacloprid 17.8 S.L. @ 1 ml 3 L⁻¹ of water or Dimethoate 30 EC @ 2 ml L⁻¹ of water at 15-20 days of interval if necessary.
- ✓ Soil application of carbofuran 3G @ 33 kg ha⁻¹ at the time of field preparation for control of root borer (In endemic area).

Conclusion

It may be concluded that aphid, case worm, ribborer and gastropods under the changing cropping pattern and intensification of crop emerges as major constraints in getting maximum yield. Further, some of the pest like leaf bug and singhara beetle emerged as minor pest and in future intensification and changing cropping pattern may aggravate this population and intensification. Now a day, paucity of information, as no detail work is reported on the pest status in makhana crop. Hence, eco-friendly management tactics are needed for the effective control measures of the insect pests in Makhana crop to realize maximum quality yield potential.

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Major Insect Pests of Tomato and their Management

Sunil Kumar Mandal and Sanjay Kumar

Abstract

Tomato crop is attacked by many insect pests during all the growth stages, which causing severe yield losses and even sometimes complete crop failure. There are distinct management strategies viz., cultural, biological and judicious application of chemical insecticides against the pests attacking in tomato crops for the minimizing the pest intensity and achieving better quality with the maximum fruit yield.

Introduction

Tomato, *Lycopersicon esculentum* Mill is most popular and widely grown vegetable in the world and with ranking second to potato (Bose and Som, 1986). It is grown successfully throughout India and the fruit available in cities and local market almost all the year round. In India, it is cultivated for table as well as processing purpose in about 8.64 million hectares with a total production of about 20.62 million tonnes (Ag-Statistic). Tomato is also rich in medicinal value. The pulp and the juice help in digestion by promoting gastric secretions and also act as blood purifier. It is cooked as a vegetable alone or mixed with potato and brinjal, but sometimes also mixed with pulses. When it is ripe, it also taken raw or made into Salad, soups, preserves, pickles, sauce, ketchup and many other products. Tomato fruits are rich in vitamin C followed by vitamin A, B₁ and B₂ (Nath, 1976). It is one of the most common and important part of human diet because of its specific and high nutritive value.

Tomato plants are attacked in nature by a number of insect pests mites and other non-insect pests, which reduce its yield and spoil the quality of fruits. Amongst fruit borer, serpentine leaf miner, leaf eating caterpillar, white fly, thrips and fruit sucking moth are considered as major and regular pests of tomato crops in India.

Fruit borer, *Helicoverpa armigera* Hubner: The fruit borer is the polyphagous pest and most destructive pest of tomato in India. It also attacks gram, cotton, pea, chilli, okra, maize, groundnut, pigeonpea, bean, soyabean and large number of ornamental plants. This is a serious pest of gram and named as gram pod borer. Tomato is the most preferred host of this pest next to chickpea and pigeonpea (Garg, 1987).

Identification: Adults moths are medium sized, Stout, browns in colour with a wing span of about 30-44 cm. Forewings are olive green to pale brown in colour with a dark brown circular spot in the centre and indistinct double waved antemedial Hindwings

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are pale smoky white with a broad black outer border. The stout (forcible) caterpillars are greenish or brownish with longitudinal bands alternatively dark and pale. The pale bands on the lateral side of the body are conspicuous. The full grown larva is 40 mm long and has short fine hair on its body.

Bionomics: The female moths start emerging during February. The female lays about 1000 or more eggs singly on the tender parts of the plants. Young larvae feed on tender foliage for sometimes and ultimately bore into the fruits. After getting full grown in the 14-24 days, they descend into the soil and pupate. Life-cycle is completed in 4-6 weeks. The pest has 8 generations in a year and remains inactive during severe hot and cold months.

Damage symptoms: The caterpillars initially feed on the tender foliage, flower buds and flowers for few days. After fruiting, they bore large, clear, circular holes into fruits and feed on the pulp. The caterpillar either feeds on a single fruit or migrates from one fruit to another and a single caterpillar may eat and destroy 2 to 8 fruits. Infested fruits become unfit for consumption. The granular frass of caterpillar is easily seen on the plant.

Management practices

- ✓ Deep ploughing the field after harvest to expose the hibernating pupae to their natural enemies and sun.
- ✓ Hand Collection and destruction of larvae from the field can be useful in early stage of the pest infestation.
- ✓ Regular collection and destruction of damaged fruits from the pest infested field.
- ✓ Light trap (@ 25 trap ha⁻¹) can be used as a means of surveillance and control of the moths.
- ✓ Pheromone traps @ 5 traps ha⁻¹ can be installed in the field for monitoring and 8-10 traps ha⁻¹ for the control of fruit borer, monitor top three leaves for *Helicoverpa* eggs.
- ✓ Tomato varieties with high hairiness of the peduncle comparatively less damaged by the fruit borer. These hairiness varieties are Arkavikas, Pusa-Gaurav, Pusa- Earley Dwarf etc (Chandrakar *et al.*, 1998).
- ✓ Adopt wide spacing of 60 cm x 45 cm for common varieties and 90 cm x 60 cm for hybrids.
- ✓ African marigold can be transplanted as a trap crop (A row of marigold after every 14 rows of tomato). About 80 percent of the resident and immigrant *H. armigera* moths are known to colonize on marigold crops. Larvae feed on the flowers. Larval migration from the marigold to intercropped tomato is not recorded (Srinivasan, 1998).
- ✓ Release of *Trichogramma chilonis* @ 1.0 lakh ha⁻¹ at six times from flower initiation at 15 days interval.
- ✓ Spray of HaNPV @ 250 LE ha⁻¹ in the early stage of the pest appearance at least 3 times at 10-15 days interval in evening hours on observing the eggs or early instar larvae.
- ✓ The combined application of egg parasitoid, *Trichogramma pretiosum* (1 lakh ha⁻¹) and *Bacillus thuringiensis* var. Kestaki (1 kg formul-

ated materials ha^{-1}) was found effective for suppression of this pest (Gupta and Babu, 1998).

- ✓ The effected crop can be sprayed with Indoxacarb 15.5 SC @ 2 ml L^{-1} or Chlorantraniliporle 18.5 SC @ 0.15 ml or Flubendiamide 20WG @ 0.20 gm L^{-1} or Novaluron 10 EC @ 1.0 ml L^{-1} of water as and when required.
- ✓ Field sanitation.
- ✓ Erecting of bird perches @ 50 ha^{-1} for encouraging predatory birds such as king crow, mynah etc.
- ✓ Rotate the tomato crops with non-host cereal crops, curbit and cruciferous vegetables.
- ✓ Spray Azadirachtin 1% (10,000 PPM) @ $2-3 \text{ ml L}^{-1}$ of water.

Leaf eating caterpillar; *Spodoptera litura* Fab:

This is one of the important polyphagous pest of tomato and other vegetable crops, pulses, oilseeds, and cotton which distributed throughout the country.

Identification: The adult moth is stout measuring 22 mm long and 40 mm across the wing spread. The forewings have beautiful golden and greyish-brown patterns with wavy white markings and hindwings are white with brown margins. Full grown larvae measured 35-40 mm in length and varies in colour from dark-black to white with several dark spots and yellowish green dorsal stripe with lateral white bands.

Bionomics: Female lays 250-300 eggs at lower surface of the leaves in cluster. Eggs massess remain covered with buff coloured hairs and they hatch in approximately 3-5 days. It goes through six instars.

The larval and pupal stage last for 15-30 and 7-15 days, respectively. Pupalation occurs within the soil. Pest breeds throughout the year. Moths are nocturnal and mostly active at night. Adults have a lifespan of 7-10 days. The entire life cycle completed 32-60 days and having 8 generation in a year.

Damage symptoms: The young caterpillars are gregarious and scarpthe chlorophyll content of leaf lamina which giving it a papery white appearance and they become voracious feeders with making irregular holes on the leaves. Later skeletonization leaving only veins and petioles with heavy defoliation. The caterpillars feed soft stem of tomato plants. Matured larvae damage small and big fruits, which become unfit for human consumption and gave no market value. The hybrid tomato (cv. Avinash) sustained high damage of about 27 per cent (Patnaik, 1998).

Management practices: Same as *H. armigera*

Serpentine Leaf Miner, *Liriomyza trifoli* Bur.:

This pest is also highly polyphagous in nature and serious pest of tomato, cotton, ridge gourd, brinjal, cucumber, tomato and other vegetables.

Identification: The adult is a pale yellowish fly and 1.5 mm in length. A fully grown maggot is 3 mm long. Apodous maggot cannot move from one leaf to another.

Bionomics: Female lay eggs on the upper surface of leaves. Eggs are little and orange in colour. Pupation takes place in the soil, but sometimes on leaves inside a thin loose mesh of silken cocoons. The egg, maggot, pupal and adult period are 4, 7, 7 and 15-30

days, respectively. Warm weather conditions are favourable for multiplication.

Damage symptoms: Leaves with serpentine mines due to the mining of maggots. Drying and dropping of leaves in severe attack of this pest.

Management practices

- ✓ Avoid excess use of nitrogenous fertilizers/ judicious use of nitrogenous fertilizer.
- ✓ Tomato with beans as intercrop reduce leaf miner attack.
- ✓ Grow attract plants as carrot, sunflower, French bean *etc* for predatory thrips.
- ✓ Installation of yellow traps or cards @ 25 ha⁻¹.
- ✓ Conserve predators viz. lacewing bug, lady bird beetle, spiders, fire ants *etc*.
- ✓ Remove infested leaves in early infestation period or at the time of planting or within a week of transplanting.
- ✓ Apply neem cake @ 250 kg ha⁻¹ at planting period and repeat after 25 days after 1st application.
- ✓ Spray NSKE 4% at DAPS.
- ✓ Spray chemical insecticides viz. Indoxacarb 15.5 SC @ 2 ml L⁻¹ or Nuvaluron 10 EC @ 1.0 ml L⁻¹ of water.

Whitefly, *Bemisia tabaci* Genn: Whitefly is reported from many wild and cultivated of host plants in India. It is a serious pest of tomato and also vector of tomato leaf curl virus (T.L.C.V.) inflicting severe loss of fruit yield. The pest is more active during the dry season (warm weather condition) and its activity decreases with the onset of rains.

Identification: The adults are tiny winged insects having light yellow body of 1 mm length dusted with a white waxy bloom. They have 2 pairs of pure white wings and 3 pairs of prominent long legs. The nymphs are louse like sluggish creatures, which cluster together in the under surface of leaves. The last instar nymph (called pupa) is about 4-7 mm long and red eyes of the adult can be seen through the transparent of integument during this stage.

Bionomics: This pest breeds throughout the year. The female moth lays about 100 eggs singly on the underside of the leaves. The nymphs on emergence move for some times, but soon fix their mouth parts in the plant tissue and suck the cell-sep. Once settled, they do not move. All nymphal instars are greenish white, oval, scale like and some what spiny. On getting full grown, they transform into pupae at the same site, which ultimately give rise to adult in about 2-4 weeks. The total life cycle is completed in 14-107 days depending on the season and there are about 12 generations in a year.

Damage symptoms: Both nymphs and adults suck the sap from leaves of the plants and lower their vitality. Tiny white scale like creatures on the underside of leaves are visible. Once the plant is disturbed, a cloud of tiny adults flutter out and resettle rapidly. Black sooty mould develops on the honeydew excreted by whiteflies on the affected leaves and thus whiteflies infested plants look sick. It is a vector of viral diseases in okra, tomato, chilli *etc*.

Management practices

- ✓ Raising nursery in protected condition (with net of sufficient mesh size to prevent the entry.
- ✓ Select seeds from disease free healthy plants for sowing.
- ✓ In the nursery, all the infested plant should be removed carefully and destroyed. Seedling infested with the viral disease should not be used for transplanting.
- ✓ Six rows of maize / sorghum / sunhemp around tomato field act as a barrier crop to prevent tomato leaf curl virus.
- ✓ Adoption of resistant / tolerant varieties.
- ✓ Grow repellent plants: Peppermint.
- ✓ Grow attractant plants for predatorythrips: Ferench bean
- ✓ Yellow sticky traps / cards @ 25 ha⁻¹ may reduce the whiteflies population.
- ✓ Spray NSKE 5% or Azadirachtin 5% (W/W) @ 2 ml L⁻¹ of water.
- ✓ Before transplanting dip the roots of seedling for 15 minutes in Imidacloprid 17.8 SL @ 60-70 ml per 200 litre of water for management of leaf curl virus.
- ✓ Spray the following insecticides when needed for managing the pests.
 - ✚ Dimethoate 30 EC: 2 ml L⁻¹
 - ✚ Imidacloprid 17.8 SL: 0.25 ml L⁻¹
 - ✚ Thiomethoxam 25 WG: 0.33 ml L⁻¹
 - ✚ Spiromesifen 22.9 SC: 1 ml L⁻¹

Leaf hopper: *Amrasca biguttula biguttula* Ishida:

The pest also attack tomato and cause considerable reduction in yield. Besides tomato, cottons, okra,

potato and brinjalare also attacked.

Identification: Nymphs are light green and are very active. Adults small, slender, pale-green with minute black spot on hind part of each forewings.

Bionomics: The pest breeds throughout the year. The female adult lays about 30-50 eggs singly inside the vein under leaf surface. Egg stage is 4-10 days. Nymphs full grown in 7-21 days and passing through six stage. Adult longevity is 5-7 weeks and complete in several generation in a year.

Damage symptoms: The nymphs and adults suck Juice from the undersurface of the leaves. The margin of infested leaves become brown and later curlon and dries up. In case of severe infestation plants look like a diseased one. The infested plants bear small sized fruits with less numbers, thus reduced yield. This pest also acts as a vector for spreading viral diseases in the plant.

Management practices

- ✓ Soil application of neemcake @ 250 kg ha⁻¹.
- ✓ Judicions use of nitrogenus fertilizer.
- ✓ Avoid close space planting.
- ✓ Spraying the following insecticides
 - ✚ Imidacloprid 17.8 SL @ 0.25 ml L⁻¹
 - ✚ Thiomethoxam 25 WG @ 0.33 ml L⁻¹
 - ✚ Dimethoate 30 EC @ 2 ml L⁻¹

Red spider mite: *Tetranychus spp.*: This polyphagous pest is known to feed on more than 100 species of plants including tomato, cucrbits, brinjal and okra. *Tetranichus neocaledonicus* and *T. Cinnabarinus* Boid are common species found in tomato crop.

Identification: Nymphs are light brown or yellowish brown and have two eye spots and four pairs of legs, while the adult is reddish, greyish green or light brown without dark spots having with small size.

Bionomics: The female mite start laying eggs under webs. The eggs are hatched in 2-6 days, and are transferred in to nymphs in 3 to 4 days. They are fully fed within 4-9 days after passing through two stages. The life- cycle is completed in 9-20 days in two spotted red mite and 4 to 10 days in the redvegetable mite. The pest has about 30-32 generation in a year.

Damage symptoms: Nymphs and adults of these mites lacerate the leaves from the lower surface and suck sap, resulting white patches at feeding sites between main veins. The infested leaves become reddish-brown and bronzy, wither and dry away. A severe infestation affects the flower and fruit which ultimately fruit setting reduced.

Management practices

- ✓ Clip of the affected leaves and burn or bury these in soil.
- ✓ Grow healthy crops, avoid water and nutrient stress.
- ✓ Keep the field free of weeds.
- ✓ Keep perennial hedge such of pigeonpea, which encourage predatory mites.
- ✓ Conserve the natural enemies: Predatory mite, predatory thrips, coccinellidbeetls, mirid bug etc.
- ✓ Spray NSKE (5%) at the initial stage of mite infestation.
- ✓ In case of severe infestation spraying the

following acaricides:

- ✚ Dicofol 18.5 EC @ 2.5 ml L⁻¹ of water
- ✚ Propargite 57 EC @ 2.0 ml L⁻¹ of water
- ✚ Flumite / Flufenazine 20 SC @ 0.5 ml L⁻¹ of water
- ✚ Spiromesifen 22.9 SC @ 0.75 ml L⁻¹ of water

Conclusion

Tomato is the most choist vegetables among the people in the country and also consumed directly fresh fruits for salad and other table purposes. But many insect-pests were attacked on tomato crops during its different growth stages and cause reducing the fruit yield as well as quality. Hence, consequently there is urgent needs for eco-friendly management strategies against these pests and save human health, natural enemies of the pests and environment.

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Socio-Economic Analysis of Apiculture Enterprise in Alluvial Zone of West Bengal: A Case Study

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Abstract

This study was framed to evaluate the socio-personal profile of the successful beekeepers and the economic analysis of the system in the alluvial zone of West Bengal. Three categories of beekeepers were prepared on the basis of number of colonies *i.e.* 10-50 (small scale enterprise), 51-100 (medium scale enterprise) and more than 100 colonies (large scale enterprise). The analysis of the socio-personal characteristics of the respondents revealed that the majority of the successful beekeepers were in age group of 18-30 years and maximum beekeepers were from OBC category background. The results depicted that the majority of beekeepers were from farming background and they took beekeeping as subsidiary occupation. However, unemployed youth were engaged with migratory apiculture and they adopt beekeeping as their main occupation. The average honey production per colony was worked out to be 31.50 kg, 34.14 kg and 35.17 kg and average net return was of rupees 52163.33, 150157.14 and 275525.00 in small scale, medium scale and large scale enterprise, respectively. It was evident from the results that the net return of beekeepers increased with the increase in the number of colonies.

Introduction

Indian land holdings are getting fragmented and emerging small holdings are becoming unviable. Further, increasing input cost and low yields are resulting in poor income to the farmers. The farming system in India has changed after the implementation of Krishi Vigyan Kendra (KVK) throughout India. This institutional arrangement focused on bottom up approach in implementation of extension and research strategies at village level. While the unemployment among rural youth also demands immediate attention. Training and capacity building

is integral part of KVK system and many farmers, rural youth, and SHGs were provided training, demonstrations and exposure visit on improved agricultural technologies and new agri-enterprises to promote small scale enterprises to enhance the income and to generate employment. At present, beekeeping is becoming a promising occupation for commercialization of agriculture and liberalization of economy. It covers entire scope of honey bee resources, bee products, beekeeping practices, pollination services and their interface with business systems and environment integrity. Beekeeping does

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not bring any pressure on agriculture land and it produces honey, bee-wax, pollen, from the flowers which otherwise dry up in nature and go waste. If the favorable conditions prevail the level of beekeeping can be increased to semi-commercial or commercial level. Therefore, KVK North 24 PGs, Ashokenagar is providing the opportunity to farmers to start new enterprise, “Apiculture” through its diversification strategy. Many farmers adopted this apiculture technology and started as small scale enterprises. So, a careful analysis of the factors responsible for the success of these farmers is necessary. If these factors are documented and analyzed carefully, it would give some in sight and can be applied to other farmers’ situation. Documentation of strategies followed by the farmers and their management techniques would be highly useful for other farmers. This type of investigation was also important in context of policy making regarding beekeeping. Hence, the present study was undertaken with the objective to study the socio-personal profile of the successful beekeepers and the economic analysis of apiculture enterprise in the alluvial region of West Bengal.

Materials and Methods

The current study was conducted in North 24 Parganas district of West Bengal during the year 2020. North 24 PGs Krishi Vigyan Kendra, Ashokenagar conducted total seven numbers of training courses on beekeeping enterprise during the years 2016-19. Total 120 rural (Table 1) youth and farmers from 10 different blocks of the districts were trained in these courses. The trainees were given

practical training through method demonstrations on bee box preparation, colony management practices, honey extraction and caning of honey. Out of these 120 trainees, 25 continuous adopters of beekeeping were selected for the present study. Three categories of these selected beekeepers were prepared on the basis of number of colonies *i.e.* 10-50 (small scale enterprise), 51-100 (medium scale enterprise) and more than 100 colonies (large scale enterprise). An interview schedule was developed to collect the data regarding socio-economic profile of the respondents and economics of beekeeping enterprise. Data were collected from all the 25 successful beekeepers using personal interview schedule. The data from individual farmer was arranged from the lowest to the highest, based on number of colonies. The data collected from the respondents were tabulated and analyzed by using frequency and percentage. The socio economic profile of the trainees was studied in terms of gender, age, education, category, caste, land holding, social participation and occupation.

Table 1: Distribution of beekeepers

Sl. No.	Block	Numbers of Beekeepers
1.	Habra 1	11
2.	Habra 2	13
3.	Barasat	13
4.	Baduria	10
5.	Deganga	13
6.	Swarupnagar	8
7.	Gaighata	20
8.	Bongaon	11
9.	Bagda	10
10.	Bashirhat	11
Total		120

Results and Discussion

Socio-economic profile of the respondents: It was found that majority of the successful beekeepers

Table 2: Socio-economic profile of the respondents

Sl. No.	Attribute	Number	Percentage	Sl. No.	Attribute	Number	Percentage
1.	Gender			6.	Family size		
	Male	89	74.17		=< 4 members	64	53.33
	Female	31	25.83		> 4 members	56	46.67
2.	Age			7.	Family type		
	18-30	62	51.67		Joint	38	31.67
	31-60	58	48.33		Nuclear	82	68.33
3.	Caste			8.	Education		
	SC	39	32.50		Primary	29	24.17
	OBC	57	47.50		Matric	41	34.17
	GEN	24	20.00		Graduate	50	41.67
	ST	0	0.00				
4.	Land holding			9.	Occupational status		
	Landless	17	14.17		Farming + Beekeeping	74	61.67
	Marginal (<1.0 ha)	71	59.17		Service + Beekeeping	21	17.50
	Small (1.0 - 2.0 ha)	21	17.50		Only Bee keeping	25	20.83
	Medium (2.0 ha - 10 ha)	11	9.17				
5.	Social participation						
	Members of SHGs	89	74.17				
	Member of panchayat	3	2.50				
	Others	28	23.33				

were in 18-30 years age group (51.67 %) and remaining (48.33 %) were in the age group of 31-60 years old (Table 2). Out of 120 beekeepers, 32.50, 47.50 and 20 % lies in SC, OBC and General Categories, respectively. 34.17 % of the beekeepers were having education up to metric level, whereas, 41.67 % of respondents were having education up to graduation level. It was also found that they live in nuclear family (68.33 %) and 53.33 % beekeepers have up to four members in their family. The successful beekeepers were from marginal category (59.17 %). While 17.50 % of beekeepers were small category farmers having land holding less than 2 ha and 9.17 % and 14.17 % were medium and landless category farmers, respectively. The majority (61.67 %) was having farming as major occupation along with beekeeping followed by only beekeeping (20.83 %) and service + beekeeping (17.50 %) respectively. It might be due to unemployment of the youth and

they had adopted beekeeping as their main occupation.

Motive to start Apiculture

The data presented in the Table 3 shows that the main motive of beekeepers is of better future (90.83 %), to take loan (63.33 %) and recognition in family and society (52.50 %). While, some of them also expressed economic independence (45.83 %) and advantage of government schemes (37.50 %).

Table 3: Motive to start Apiculture in groups

Sl. No.	Reasons	Frequency	Percentage (%)
1.	To become economically independent	55	45.83
2.	For recognition in family and society	63	52.50
3.	For better future	109	90.83
4.	To take advantage of government initiatives	45	37.50
5.	To get loans	76	63.33

Participants' gain in knowledge

It was observed that the beekeepers were inconstant touch with the experts of the KVK for

gaining recent knowledge regarding beekeeping. The scores gained in different aspects of apiculture were categorized in low, medium and high level of knowledge gain (Table 4). It was found that 65.83 % of the participants gained medium level of knowledge followed by high (20 %) and 14.17 % low on the vocation and opined for further training on the aspects of beekeeping. The low to medium level in knowledge gain shows that the participants are not fully trained, and there is scope for skill up gradation.

Table 4: Gain in knowledge

Sl. No.	Categories	Participants Number	Percentage (%)
1.	Low	17	14.17
2.	Medium	79	65.83
3.	High	24	20.00
Total		120	100

Economics of beekeeping enterprise

Major expenditure was involved on the purchase of bee boxes, colonies, honey extracting machine, gloves, veil and other tools. Beekeepers got income from sale of honey, wax and pollen. The economics of the apiculture based on the information collected from individual beekeepers have been calculated.

Small scale be-keeping enterprise

The number of colonies varied from 10 to 50 in this group. The data presented in the Table 5, it was revealed that total 12 numbers of bee-keepers were practicing beekeeping on small scale. The average numbers of colonies were 28.75. The average honey production per colony was worked out to be 31.50 kg. The net returns varied from rupees 16350.00 to 108630.00 with an average of rupees 52163.33. One farmer of this group were selling the

honey after processing, resulting in high average sale rate than others.

Medium scale beekeeping enterprise

The data (Table 6) indicated that 7 numbers of beekeepers lies on medium scale enterprise having 51-100 colonies. The average numbers of colonies were 83.57 and average honey production was 34.14 kg colony⁻¹. Income of the beekeepers in medium scale enterprise varied from rupees 117900.00 to 186240.00. The average income of this group was rupees 150157.14.

Large scale beekeeping enterprise

Perusal of the data presented in the Table 7, revealed that 6 numbers of beekeepers belong to large scale enterprise (>100 colonies). The average numbers of colonies in this group were 187.50. While, the average honey production per colony was 35.17 kg. The average selling rate was rupees 73.83 per kg of honey. The income of this group varied from rupees 128250.00 to 399600.00. The low sale rate realization was due to sale of raw honey by all the beekeepers.

Beekeeping is a highly profitable agricultural enterprise and suitable for self employment for men and women because of its low initial cost. If a budding entrepreneur is interested in some business, is supported by Government organization by providing technical and financial guidance, can be very successful in his/her business. Beekeeping can be tried as an enterprise wherever opportunities are available. Poor rural people in remote villages can be motivated, trained and supported to become agri-

Table 5: Average net returns per year for individual beekeeper in small scale beekeeping enterprise (10-50 colonies)

Respondents	No. of colonies	Average honey production (kg colony ⁻¹)	Average sell rate (Rs. kg ⁻¹)	Gross cost (Rs.)	Gross return (Rs.)	Net return (Rs.)
R1	10	33	89	11500.00	29370.00	17870.00
R2	10	30	94	11850.00	28200.00	16350.00
R3	15	35	99	17250.00	51975.00	34725.00
R4	15	29	109	16850.00	47415.00	30565.00
R5	20	35	94	23000.00	65800.00	42800.00
R6	25	29	84	28750.00	60900.00	32150.00
R7	30	34	79	34500.00	80580.00	46080.00
R8	35	26	89	40250.00	80990.00	40740.00
R9	40	28	100	46000.00	112000.00	66000.00
R10	45	36	99	51750.00	160380.00	108630.00
R11	50	32	94	57500.00	150400.00	92900.00
R12	50	31	99	56300.00	153450.00	97150.00
Mean	28.75	31.50	94.08	32958.33	85121.67	52163.33

Table 6: Average net returns per year for individual beekeeper in medium scale beekeeping enterprise (51-100 colonies)

Respondents	No. of colonies	Average honey production (kg colony ⁻¹)	Average sell rate (Rs. kg ⁻¹)	Gross cost (Rs.)	Gross return (Rs.)	Net return (Rs.)
R13	60	35	89	69000.00	186900.00	117900.00
R14	75	32	91	86250.00	218400.00	132150.00
R15	80	37	94	92000.00	278240.00	186240.00
R16	85	31	84	97750.00	221340.00	123590.00
R17	90	37	83	103500.00	276390.00	172890.00
R18	95	31	84	109250.00	247380.00	138130.00
R19	100	36	82	115000.00	295200.00	180200.00
Mean	83.57	34.14	86.71	96107.14	246264.29	150157.14

Table 7: Average net returns per year for individual beekeeper in large scale (> 100 boxes) beekeeping enterprises (>100 colonies)

Respondents	No. of colonies	Average honey production (kg colony ⁻¹)	Average sell rate (Rs. kg ⁻¹)	Gross cost (Rs.)	Gross return (Rs.)	Net return (Rs.)
R20	135	30	70	155250.00	283500.00	128250.00
R21	140	36	75	161000.00	378000.00	217000.00
R22	175	39	74	201250.00	505050.00	303800.00
R23	200	34	75	230000.00	510000.00	280000.00
R24	225	38	77	258750.00	658350.00	399600.00
R25	250	34	72	287500.00	612000.00	324500.00
Mean	187.50	35.17	73.83	215625.00	491150.00	275525.00

entrepreneurs through institutions like KVKs.

Liming of Acid Soils

Mrinal Choudhary, Britan Rahman and Pompy Deka

Soil reaction or pH is the measurement of hydrogen ion concentration in soil-water suspension. Though the value of pH ranges from 0 to 14, soils vary in reaction from below pH 3.5 to above 9.5. It is important to note that though pH 7 is considered as neutral, soils having pH values between 6.6 and 7.3 are considered neutral for practical purposes. The Table 1 shows different groups of soil depending on their pH values.

Table 1: Grouping of soils based on the range of corresponding pH values

Soil reaction	Range of pH values
Extremely acidic	<4.5
Very strongly acidic	4.5-5.0
Strongly acidic	5.1-5.5
Medium acidic	5.6-6.0
Slightly acidic	6.1-6.5
Neutral	6.6-7.3
Mildly alkaline	7.4-7.8
Moderately alkaline	7.9-8.4
Strongly alkaline	8.5-9.0
Very strongly alkaline	9.1 and higher

pH is the single most important parameters that determines nutrient availability to the plants. It also affects the growth, development and activities of soil microorganisms which in turn results in varying rate of organic matter decomposition. In short, it can be said that soil fertility is mostly regulated by soil pH. Soil reaction varies widely from region to region depending upon the soil constituents, parent materials, climatic conditions, management practices etc.

Optimum range of pH for different plants

As stated earlier, soils vary in reaction from below pH 3.5 to above pH 9.5. However, only a few plants grow well over such a wide range of soil pH. Most of the plants thrive well only within narrow limits. It has been observed that the most satisfactory performance of the plants is usually found in the pH range of 5.5 to 7.5. It is within this range that most of the cultivated crops like cereals, pulses, oilseeds, vegetables etc. performed best. A large number of field crops have their optimum ranges around pH 6.5. The approximate optimum pH ranges of the major field crops are given in the Table 2.

Table 2: Optimum range of soil pH for different field crops

Cereals	pH	Pulse/legumes	pH	Other crops	pH
Rice	5.0-6.5	Field beans	6.0-7.5	Sugarbeet	6.5-8.0
Wheat	5.5-7.5	Lima beans	6.0-7.0	Cotton	6.0-7.5
Maize	5.5-7.5	Velvet beans	5.5-7.0	Linseed	5.0-7.0
Oats	5.0-7.5	Berseem	6.0-7.5	Potato	4.8-6.5
Barley	6.5-8.0	Lucerne	6.2-7.8	Sweet potato	5.8-6.0
Jowar	5.5-7.5	Peas	6.0-7.5	Sunflower	6.0-7.5
Rye	5.0-7.0	Soybean	6.0-7.0	Tobacco	5.5-7.5
		Cowpea	5.0-6.5	Sugarcane	6.0-8.0
		Groundnut	5.3-6.6	Turnip	5.5-6.8
		Gram	6.0-7.5		

One should not get the idea that a crop grow well only in a very specific and narrow range of pH as stated above. The range of reaction under which crops grow satisfactorily is fairly wide, provided the physical condition of the soil is ideal and there is sufficient organic matter, available plant nutrients

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etc. The common field crops like cereals, pulses, oilseeds, and many fodder crops can be grown successfully on soils ranging from moderately to mildly alkaline conditions. Similarly, potatoes grow well in strongly acidic to neutral soil. On the other hand, many plantation crops like tea, rubber, coffee and fruit crops like blueberries and cranberries, thrive well on strongly acidic soils.

Liming of acidic soils

Any compound containing calcium alone or both calcium and magnesium, when added to the soil is capable of reducing the acidity of the soil is known as liming material. In true sense lime refers only to calcium oxide (CaO), but for agricultural purposes it is used to include various other materials like calcium carbonate, calcium hydroxide, calcium-magnesium carbonate, calcium silicate slag etc.

Necessity of liming

Though liming materials are a source of calcium, it differs from other chemical fertilizers use to supply plant nutrients. In addition to providing calcium, it has other beneficial effects on soils such as:

- ✓ Liming materials reduces soil acidity.
- ✓ The favorable environment created by the increase in soil pH upon application of lime encourages beneficial soil bacteria. Thus bacterial decomposition of organic matter is stimulated and nutrient availability is ensured. Further, lime enhances fixation of nitrogen by symbiotic and free-living bacteria.
- ✓ In acidic soils, P_2O_5 is fixed as iron and alumi-

um phosphates. Increased pH due to lime application reduces the solubility of iron and aluminium and therefore less phosphorus is held in these unavailable forms and makes phosphorus more available.

- ✓ Lime increases the availability of other plant nutrients like potash and molybdenum.
- ✓ In addition to calcium, lime magnesium also when dolomite is applied.
- ✓ Besides the chemical effects, regular application of lime also improves the physical condition of the soil such as decreasing the bulk density, increasing infiltration capacity and the rate of percolation of water.

Factors Affecting Lime Requirements

Lime requirement is defined as the amount of liming material, as calcium carbonate equivalent, required to change a volume of soil to a specific state with respect to pH or soluble Al content. However, in economic terms, lime requirement can be defined as the quantity of liming material required to produce maximum economic yield of crops cultivated on acid soils. Quantity of lime required to produce maximum economic yields of crops grown on acid soils is determined by soil properties, liming material quality, management practices, cropping systems, crop species or genotypes within species, calcium and magnesium interaction with other nutrients, and economic considerations.

Quality of liming material: Quality of liming material is very important in correcting soil acidity. Chemical analysis of the liming material gives its

composition. A liming material containing both calcium and magnesium is desirable for correcting soil acidity and improving contents of Ca and Mg of the soil. Two important characteristics that determine lime material quality are its neutralizing power or reactivity and fineness. The chemical effectiveness of agricultural limestone is measured by its CaCO_3 equivalence. If neutralizing value is lower than CaCO_3 , a higher quantity of liming material is required and vice-versa. The neutralizing power or value of a liming material is defined as the acid-neutralizing capacity of the material by weight in relation to CaCO_3 .

Soil texture: The relative proportions of sand, silt, and clay in a given soil determine soil texture, a basic physical property of the soil that remains unchanged by cultural and management practices. Soil texture determines the buffering capacity of a soil, which refers to the ability of the solid phase soil materials to resist changes in ion concentrations in the solution phase. For liming purposes, the resistance of the soil solution to changes in pH is a main component of soil buffer power. Oxisols contain predominantly iron and aluminum oxide minerals and kaolinite and have characteristically low to moderately low cation exchange capacity, but they also have high buffering capacity. Hence, Oxisols require large amount of liming materials to raise soil pH to a desired level for maximum crop yields.

Soil fertility: Quantity of nutrient present in the soil is defined in terms of soil fertility, and, generally, soil analysis is used as a criterion to make fertilizer reco-

mmendations for field crops. High fertility soils in terms of exchangeable Ca^{2+} , Mg^{2+} , and K^+ require less lime than those with lower soil fertility. When Ca^{2+} , Mg^{2+} , and K^+ contents are higher, a lower lime rate is required, because of higher levels of these basic cations in the soil, meaning relatively higher base saturation and higher pH than with lower levels of these cations.

Crop rotation: Crop rotation is defined as a planned sequence of crops growing in a regularly recurring succession on the same area of land, as contrasted to continuous culture of one crop or growing a variable sequence of crops. Continuous cultivation of a given crop on the same land may reduce productivity. The decline in crop productivity is associated with a number of factors such as decrease in soil fertility, infestation by weeds, insects, and diseases, loss of soil by erosion, reduction in soil biological diversity and build-up of allelopathy etc. The ability of legumes to fix atmospheric nitrogen was a major reason for crop rotation. Phosphorus deficiency or unavailability is a major yield-limiting factor in Oxisols, and in the Central Great Plains of the United States, crop rotations have been reported to improve P-use efficiency.

Use of organic manures: Organic manures are products from the processing of animal or vegetable substances that contain reasonable amount of plant nutrients to be of value as fertilizers. Plant- and animal-based organic byproducts may substitute for commercial fertilizers and enhance chemical and biological attributes of soil quality in agricultural

production systems. Use of organic manures can also affect lime requirement of a crop. Organic matter increases the soil's ability to hold and make available essential plant nutrients and to resist the natural tendency of soil to become acidic. Furthermore, addition of organic manures to acid soils has been shown to increase soil pH, decrease Al saturation, and thereby improve conditions for plant growth.

Type of liming materials

The ground limestone, burnt lime and hydrated lime are the most common agricultural liming materials. Among these three forms of liming materials, ground limestone is most extensively applied to the soil in various countries.

Ground limestone: The term limestone refers to rock consisting chiefly of calcium carbonate (CaCO_3) or calcium and magnesium carbonate [$\text{CaMg}(\text{CO}_3)_2$]. When magnesium carbonate is present, the material is called dolomite limestone. When lime is applied to an acidic soil, a part of calcium carbonate is dissolved in soil solution and combines with carbonic acid to form calcium bicarbonate. Calcium bicarbonate in solution form reacts with the soil colloids, freely evolving carbon dioxide. While some portion of the limestone goes into solution, a part of the applied limestone comes in close contact with the soil colloids. Under these circumstances, the adsorption of calcium with soil colloids also occurs, carbon dioxide is freely evolved. The absorption of the calcium and magnesium raises the percentage base saturation of colloidal complex, correspondingly pushing up the

pH of the soil solution. The quality of ground limestone and its value as a soil amendment depends on both its chemical composition and its degree of fineness.

Burnt lime: It is also known as quick-lime, oxide of lime, caustic lime or stone lime. When limestone is heated to over 800°C , the calcium carbonate decomposes, yielding calcium oxide. The purity of burnt lime sold for agricultural purposes is variable, ranging from 85 to 98 per cent. When burnt lime (CaO) is added to any acid soil, it changes to bicarbonate form as it goes into solution. Calcium bicarbonate thus formed reacts with the soil colloids and calcium ions are adsorbed in the colloidal complex.

Slaked lime: It is also known as hydrated lime or hydroxide of lime. It is produced by adding water to burnt lime. The final product marketed as agricultural lime is a whitish-grey powder which is caustic and alkaline. When slaked lime is added to an acid soil, it combines with carbonic acid to form calcium bicarbonate in soil complex.

Comparative efficiency of liming materials

All forms of liming materials are not equally effective in correcting soil acidity. The effectiveness or efficiency of any liming material depends on the following factors:

- ✓ The chemical composition of the material expressed in terms of calcium carbonate equivalent known as neutralizing value (NV).
- ✓ The purity of the liming materials.
- ✓ The degree of fineness of the material.

Calcium Carbonate Equivalent or Neutralizing

Value (NV): The efficiency of various liming material is measured against pure calcium carbonate which is taken as the standard. The neutralizing value of CaCO_3 is considered to be 100 per cent. Neutralizing Value (NV) or CaCO_3 equivalent of a liming material (say, burnt lime, CaO) is worked out as the ratio between the molecular weights of CaCO_3 and CaO and expressed in percentage. The neutralizing values of commonly used liming materials are shown in the Table 3.

Table 3: Neutralizing values of the pure forms of commonly used liming materials

Material	Chemical composition	Neutralizing value
Limestone	CaCO_3	100%
Burnt lime	CaO	179%
Slaked lime	Ca(OH)_2	136%
Dolomite	$\text{CaMg(CO}_3)_2$	109%

Purity of the material: The purity of the chemical composition determines the effectiveness of liming materials. For example, if ground limestone contains 95 per cent of CaCO_3 , the neutralizing value of the material will be 95 per cent.

Degree of fineness of the material: It is well known that finer the material is ground, the more rapidly it goes into solution, and more effective it is. Therefore, degree of fineness is equally important because the speed with which a liming material reacts with an acid soil depends upon its fineness. The fineness is measured in terms of the ability of a material to pass through a 60-mesh sieve and the material passing through such a sieve is allotted 100 per cent efficiency rating. Similarly, materials passing through a 20 but not a 60-mesh sieve is

allotted 60 per cent and materials passing through a 8 but not a 20-mesh sieve is allotted 20 per cent efficiency rating.

Rate of Lime Application

The rate of application of lime depends upon many factors. Some of the important factors that determine the application rate of liming materials are as follows:

Intensity of the soil acidity: For strongly acid soils, more liming material will be required compared to slightly acidic soils.

Cation exchange capacity of the soil: A specific lime requirement depends upon the cation exchange capacity of each soil. The greater the cation exchange capacity, the greater the amount of lime required to raise the pH from one value to another.

Texture of the soil: In general lime requirement is more in heavy soils compared to light soils. Thus, sandy soils require less lime compared to silt loam and clay loam.

Type of crops: Usually leguminous crops including pulses benefit most by the application of lime since they do not thrive on strongly acid soils. They also require comparatively larger amount nutrients like Ca and Mg. On the other hand, lesser quantity of lime should be applied for potato as the fungus which causes scab disease is inactive in strongly acidic soil but may develop vigorously in moderately acidic or alkaline soils.

Purity of the liming material: The purer the liming material, the lesser the quantity required.

Type of liming material: Since the neutralizing

value of calcium carbonate is taken as 100, the amount of burnt lime required for application will be less.

Fineness of particle size: The finer the liming material, the more effective it will be.

Method of lime application

After determining the lime requirement based on proper soil test, the following general principles should be observed in applying lime:

- ✓ Lime should be applied well ahead of sowing and before ploughing or if applied on ploughed land, it should be thoroughly mixed with the soil.
- ✓ When the quantity of lime to be applied is large, instead of one heavy application it should be applied as small quantities in two or three equal splits.
- ✓ On strongly acidic soils, where three to six tonnes of lime are required, half the quantity should be applied before ploughing and the remaining half applied and mixed with soil after ploughing.
- ✓ When the lime requirement is up to two tonnes per hectare, the entire amount should be applied at a time and mixed with soil one or two weeks before sowing the crop.

Disadvantages of Overliming

Adequate lime rate is essential not only for maximum economic return but also for maintaining appropriate nutrient balance for crop production. Overliming effects are more pronounced on coarse-textured soils than on fine-textured soils. Fine-textured soils have high buffering capacity; hence, changes in chemical properties due to liming are not

as pronounced as for coarse-textured soils. Overliming can create deficiencies of micronutrients like Fe, Mn, Zn, Cu, and B. These nutrients are usually adsorbed on to sesquioxide soil surfaces. Uptake of these micronutrients has been significantly decreased at higher pH levels. Iron deficiency in upland rice is commonly observed with pH higher than 6.5. Similarly, shoot dry matter, grain yield, and number of panicles in upland rice were significantly decreased with increasing pH in the range of 4.6-6.8.

Conclusion

Liming is essential for maintaining the soil health in the long run. It not only decreases the soil acidity but also creates a better soil environment for proper root growth as well as optimal activities of the beneficial microbial species. Application of good quality liming material in correct amount and method ensures enhanced crop yield. Farmers should desist from overliming as it is not only wastage of money but also hampers the crop performance.

Prospects of Using Host Defense Elicitors in Postharvest Disease Management of Cut Flowers

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Abstract

The review addresses the growing public concern about the environmental and social risks associated with synthetic fungicides, motivating the search for more sustainable alternatives to protect cut-flowers and fresh produce from pathogens. Focusing on postharvest management of cut-flowers, the paper explores natural disease resistance (NDR) and its potential activation through environmentally friendly chemical elicitors. Key findings reveal that plant natural disease resistance comprises both constitutive and induced defense mechanisms. Induced defenses include the hypersensitive response, local and systemic acquired resistance, and induced systemic resistance. These defense mechanisms vary in their natural elicitors, signaling pathways, and resulting defensive compounds. *Botrytis cinerea* emerges as the most significant pathogen affecting cut-flowers, causing various symptoms including petal specking, flower blight, and accelerated abscission. While exogenous treatments with defense elicitors like methyl jasmonate and benzothiadiazole show potential for fungal suppression, their practical efficacy remains limited. The review highlights significant challenges in translating laboratory findings to practical applications. Most existing research focuses on model plants grown in controlled environments, whereas commercial cut-flowers are diverse in botanical structure and physiological characteristics. To develop effective postharvest disease management strategies, extensive research is needed to understand how production conditions and postharvest practices influence plant defense responses.

Introduction

Cut-flowers and ornamental plants represent more than aesthetic beauty; they are a significant economic sector within horticulture. The industry generates substantial financial value not only at the

farm level but also through value-adding processes like creating bouquets. These plants are typically complex, consisting of multiple organs including stems, leaves, and highly perishable floral structures. Flower development is a nuanced process influenced

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by environmental factors like temperature and photoperiod. It progresses from bud formation to flowering, pollination, and eventual senescence. Different plant varieties exhibit varying respiration and ethylene production patterns, ranging from climacteric to non-climacteric types. The global cut-flower trade traditionally relies on low-temperature, high-humidity storage to slow flower deterioration. However, these conditions, while effective in delaying senescence, can inadvertently create an environment conducive to fungal pathogens like *Botrytis cinerea*. Typically, *Botrytis* infection begins in the field and develops post-harvest, negatively impacting flower appearance and accelerating senescence. As global demand for high-quality floral products increases, the industry faces growing challenges in postharvest disease management. Synthetic fungicides, once a primary solution, are becoming problematic. Overuse has led to fungicide resistance among pathogen populations and raised significant human and environmental health concerns. In response, the industry is exploring alternative approaches, such as pre- or postharvest treatments that can elicit natural disease resistance. These methods aim to leverage the plant's inherent defense mechanisms using safe chemical, biological, or physical interventions, presenting a potentially more sustainable disease management strategy.

Major diseases

Only a limited number of bacteria, such as *Xanthomonas* and *Erwinia*, are significant pathogens of ornamental crops. However, ornamental plants are

widely affected by numerous disease-causing fungi, both before and after harvest. Pot-grown and field-grown plants are susceptible to necrotrophic fungi, such as *Botrytis*, *Alternaria*, and *Colletotrichum*, as well as biotrophic fungi responsible for diseases like downy mildew (*Peronospora*) and powdery mildew (*Erysiphe*). Fungal pathogens are responsible for various issues, including root rot (*Phytophthora*, *Pythium* and *Rhizoctonia*), wilt (*Fusarium*), and leaf or petal spots, as well as flower blight (*Alternaria*, *Botrytis*). Among these, *Botrytis cinerea* is particularly problematic for the postharvest cut-flower industry. Another notable pathogen affecting harvested cut flowers is *Alternaria alternata*.

Induced defence in natural disease resistance

Recognition of pathogen infection and signal transduction

The activation of defense responses in plants relies on the recognition of pathogens by the host. This recognition is mediated through a system involving pathogen-derived elicitors, host plant receptors, and signal transduction pathways that trigger the production of defense compounds. Defense activation occurs when elicitors bind to receptors during an incompatible host-pathogen interaction. Signals can be transmitted within or between cells to activate genes responsible for producing defense compounds, such as antifungal chemicals (e.g., phenolics) and enzymes (e.g., pathogenesis-related [PR] proteins). Key endogenous transducers involved in this process include protein kinases, calcium ions, phospholipases, and

hydrogen peroxide. Specific signaling molecules for systemic resistance include salicylic acid (SA), jasmonic acid (JA), and ethylene (ET). Additionally, defense signaling pathways can be stimulated by exogenous treatments using natural or synthetic substances, such as 2,6-dichloroisonicotinic acid (INA).

Hypersensitive response: The hypersensitive response (HR) is a swift defense mechanism in plants characterized by localized cell death. This response occurs during an incompatible interaction between a specific host and pathogen, preventing the pathogen from infecting or colonizing the host. While the HR may not always be visibly apparent due to its action being confined to a single or few cells, it effectively isolates the pathogen within the dead tissue. The recognition of elicitors triggers a cascade of cellular HR reactions at the site of infection, leading to the accumulation of reactive oxygen species (ROS), such as superoxide, hydrogen peroxide and hydroxyl radicals, around the infection site. This rapid oxidative burst serves to arrest pathogen growth effectively.

Local acquired resistance: Hypersensitive response (HR) triggers the activation of host defense mechanisms in surrounding cells, a phenomenon known as local acquired resistance (LAR). LAR is characterized by the accumulation of antifungal compounds and defense enzymes and provides broad-spectrum protection against pathogens, similar to HR. Secondary metabolites, including phenolics, phytoalexins, and lignin-based polymers, rapidly

accumulate in response to pathogen infection. For instance, an increase in chlorogenic acid, a phenolic compound, was observed in potato tubers treated with arachidonic acid, an HR elicitor. Phenolics are also crucial for disease resistance, such as in kiwifruit leaves against *Botrytis cinerea*. Phytoalexins, synthesized de novo, reach toxic levels in healthy cells surrounding infected areas, inhibiting fungal growth by disrupting germ tube elongation and fungal cell membranes, thereby maintaining cellular integrity. A comprehensive review by Grayer and Harborne identified phytoalexins in 31 families of flowering plants. Pathogenesis-related (PR) proteins are diverse plant proteins induced under pathogen stress or other biotic and abiotic stress conditions. Their transcription is regulated by signaling molecules like salicylic acid (SA), xylanase, ethylene (ET), systemin, and jasmonic acid (JA). PR proteins exhibit either direct antifungal activity or contribute indirectly to host defenses, such as reinforcing cell walls or aiding pathogen recognition. Initially discovered in *Tomato Mosaic Virus*-infected tobacco, at least 14 PR protein families have been identified, including PR-1 (antioomycete and antifungal), PR-2 (β -1,3-glucanases), PR-3 (chitinases), PR-4 (antifungal), PR-5 (thaumatin-like), PR-6 (proteinase inhibitors), and PR-9 (peroxidases). PR proteins accumulate significantly in response to pathogen attack, as evidenced by a 10,000-fold increase in PR-1 levels in tobacco infected by oomycetes. Salicylic acid (SA), a phenolic compound accumulates at pathogen

induced necrotic sites and is also transported to distal healthy tissues through the phloem. SA accumulation elevates endogenous hydrogen peroxide levels, which acts as a secondary messenger to activate defense gene expression. Studies on plants transformed with the *nahG* gene, encoding the SA-degrading enzyme salicylate hydroxylase, demonstrated reduced SA accumulation, leading to suppression of both localized and systemic acquired resistance. This highlights the indispensable role of SA in the expression of LAR.

Systemic acquired resistance: Induced resistance in plants typically exhibits systemic characteristics, meaning defense responses are activated not only at the site of infection but also in distant tissues. Systemic acquired resistance (SAR) equips plants to withstand subsequent infections. For instance, Cameron et al. observed that two days after inoculating a single *Arabidopsis thaliana* leaf with avirulent *Pseudomonas syringae* pv. tomato, resistance was induced in other leaves when challenged with avirulent *P. syringae* pv. maculicola. SAR offers durable and broad-spectrum protection against a variety of pathogens and parasites and is prevalent across numerous plant species. While SAR shares similarities with local acquired resistance (LAR) in providing broad-spectrum resistance, its enhanced defense capacity relies on a systemic signal, unlike LAR. Salicylic acid (SA) plays a pivotal role as a signaling molecule in SAR. Additionally, lipid-based molecules have been proposed as mobile signals in SAR. Research in

tobacco indicates that SA can bind to enzymes like catalase, while SA-binding proteins may facilitate lipid peroxidation. The peroxidation products are instrumental in activating SAR-related genes. A critical component of SA signal transduction in *Arabidopsis* is the NPR1 protein. This protein acts as a positive regulator of defense gene expression, enabling SAR activation. NPR1 functions by translocating to the nucleus, where it interacts with basic leucine zipper transcription factors to initiate the SAR response.

Other elicitors, including non-chemical: Chitosan, in addition to its direct fungicidal properties, acts as an elicitor of host defense mechanisms and is effective in controlling various postharvest diseases in fruits and vegetables. For instance, applying a 0.1% chitosan spray to cucumber plants 4 or 24 hours prior to inoculation with *Botrytis cinerea* significantly reduced grey mold development by 82% and 87%, respectively. Similarly, a GA₃ pulsing treatment (20 mg L⁻¹ for 24 hours) suppressed *B. cinerea* in detached rose petals of the cultivars Mercedes and Sonata. Since GA₃ concentrations used in the study did not exhibit direct toxicity to fungal growth in vitro, it was proposed that GA₃ functions by activating the plant's natural defense mechanisms. Physical elicitation methods, such as heat treatments and UV-C irradiation, are also widely employed to combat diseases in agricultural products. Heat treatments, beyond their direct impact on postharvest pathogens, can stimulate host resistance. For example, exposing barley leaves to

heat (50°C for 60 seconds) triggered the production of superoxide anions and hydrogen peroxide, thereby inducing resistance against *Blumeria graminis* f.sp. *hordei*.

Grapefruit fruit pretreated with hot water brushing at 62°C for 20 seconds demonstrated induced resistance to *Penicillium digitatum* within 1-3 days. This treatment resulted in the accumulation of chitinase and β -1,3-glucanase in the fruit. Short-wave ultraviolet radiation (UV-C, 190-280 nm) has also proven effective in controlling diseases in various fruits and vegetables. For example, UV-C irradiation of tobacco plants (254 nm; 70 μ W cm⁻²) increased salicylic acid (SA) levels approximately ninefold compared to the control, leading to the accumulation of PR proteins and enhanced resistance to Tobacco Mosaic Virus (TMV). Similarly, citrus fruit treated with UV-C exhibited higher concentrations of the phytoalexin scoparone in their flavedo. UV-C treatment of tomatoes induced resistance to *Rhizopus stolonifer*, correlating with elevated tomatin levels. Additionally, harvested peach fruits treated with UV-C showed enhanced activities of chitinase, glucanase, and PAL enzymes. Biological elicitors also show potential for controlling postharvest diseases in cut flowers and fruits. Dip treatments with *Aureobasidium pullulans* cell suspension improved the antifungal activity in strawberry fruit skin tissue, rendering it more resistant to *Botrytis cinerea* infection. Application of *Cryptococcus saitoana* (10⁸ CFU mL⁻¹) induced systemic resistance in fresh apples by increasing

chitinase and β -1,3-glucanase activity, thereby providing protection against *B. cinerea*. Harpin, a protein elicitor derived from the apple fire blight bacterium *Erwinia amylovora*, is marketed as 'Messenger' and has been used to prevent decay caused by *Trichothecium roseum* in stored Hami melons. Harpin is thought to activate various signaling pathways in different plant-pathogen systems, potentially leading to either compatible or incompatible interactions.

Conclusion and future directions

The use of chemical elicitors to enhance natural disease resistance (NDR) in cut flowers for managing postharvest diseases is still in its early stages. Despite limited research in this area, early findings indicate that inducing host defense mechanisms in harvested cut flowers and ornamentals could serve as an alternative to synthetic fungicides. However, for this approach to be practically implemented, it will require more detailed investigation at molecular, biochemical, and physiological levels, especially considering the limited funding available for research on commercial floriculture crops. Studies reviewed suggest that the efficacy of chemical elicitors against postharvest pathogens varies widely. Some treatments show no effect (e.g., camellia), minimal effect (e.g., wax-flower), variable results (e.g., freesia), or substantial success (e.g., rose). However, elicitor treatments can also have adverse side effects, such as accelerating senescence, inducing abscission, or causing phytotoxicity. Variability in outcomes and side effects

may result from genotype-by-environment ($G \times E$) interactions, as the effectiveness and timing of NDR responses are likely influenced by plant genotype, climate, management practices, and exposure to abiotic or biotic stresses. Additionally, the inherent capacity for NDR may decline postharvest due to ongoing developmental and senescence processes. The potential for combining chemical elicitors to improve outcomes remains largely untapped. Similarly, there is significant scope to explore the use of physical elicitors (e.g., UV-C) and biological elicitors (e.g., *Aureobasidium* spp.) either individually or in combination. Research could also focus on ancillary treatments to mitigate adverse side effects of elicitors. For instance, while combining the chemical elicitor MeJA with STS pulsing was intended to prevent ethylene-mediated flower abscission in Geraldton waxflower, it inadvertently increased the severity of *Botrytis* disease. Priming of NDR presents another promising area of study. Priming involves preparing plants to mount stronger and faster defense responses following an initial elicitor treatment. This could occur through biotic or chemical elicitors such as SA, BTH, or INA, enabling plants to respond more robustly to subsequent pathogen challenges or stressors. For example, priming with MeJA via pulsing followed by spraying enhanced suppression of *Botrytis cinerea* on cut roses. Similarly, combining pre- and postharvest MeJA treatments on Geraldton waxflower decreased *B. cinerea* severity. Inducing systemic resistance using plant-growth-promoting

rhizobacteria (PGPRs) before harvest is another potentially valuable strategy for improving pathogen defense in cut flowers. This approach, along with integrated use of chemical, physical, and biological elicitors, holds promise for more sustainable disease management in the floriculture industry.

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Impact of the Natural Resources in Economic Growth of India

Neha Dwivedi and Ankita Sahu

How Natural Resources Impact the Economic Growth of India

A country's empowerment is largely dependent on its economic growth. One of the most important drivers of economic growth is a nation's natural resource base. Many different businesses employ natural resources as raw materials, such as iron, copper, nickel, lithium, etc. The foundation of heavy industries, which open the door for the development of other industries, is iron and steel. Coal, oil, and other natural resources are the main sources of energy for both the residential and commercial sectors. Analysing the relationship between a nation's natural resource base and economic growth becomes essential in light of all these factors. Natural resources play a vital role in shaping the economic growth of nations, and India, with its diverse geography and rich endowment of resources, is no exception. From fertile plains and expansive coastlines to mineral-rich mountains and dense forests, India's natural wealth has historically driven its agricultural, industrial, and service sectors. However, the management and utilization of these resources significantly influence their contribution to sustained economic growth.

Agriculture and Food Security

Agriculture has traditionally been the backbone of India's economy, employing close to

half of its workforce and making up about 18% of its GDP. India is one of the world's top producers of rice, wheat, and pulses due to its rich soil, plentiful water supplies from rivers like the Ganges and Brahmaputra, and a temperate climate. In addition to guaranteeing food security, this agricultural abundance boosts sectors vital to the rural economy, such as dairy, sugar, and textiles. However, there are serious concerns associated with issues like soil erosion, climate change, and excessive groundwater use. Maintaining this sector's contribution to economic growth requires effective resource management and sustainable agriculture practices.

Mineral Resources and Industrial Development

India is endowed with an array of mineral resources, coal, iron ore, bauxite, limestone, and other mineral resources are among the many that India possesses and are vital to its economic development. The mining industry supports sectors like steel, cement, and electricity and accounts for about 2.5 per cent of India's GDP. For example, more than 70% of India's electricity is generated by coal, highlighting the fuel's significance in boosting industrial output. The government's drive for independence, especially through programs like "Make in India," has increased demand for minerals grown in the country. Nevertheless, the industry has to contend with issues including illicit mining, envir-

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onmental damage, and poor infrastructure. Its full potential can be realized by addressing these problems with regulatory changes and technical breakthroughs.

Energy Resources and Economic Power

For India to achieve its economic goals, energy resources such as coal, oil, natural gas, and renewable sources are essential. The nation is positioned as a global leader in renewable energy due to its enormous potential for solar and wind energy as well as its hydropower capabilities. As India looks to lessen its reliance on imported oil, which puts pressure on its foreign exchange reserves, this adjustment is crucial. In addition to supporting global climate goals, initiatives to increase renewable energy capacity also generate jobs, draw in foreign capital and promote technological advancement. The government's determination to use energy resources to boost economic growth is demonstrated by its aggressive goals, which include reaching 500 GW of non-fossil fuel capacity by 2030.

Forest and Biodiversity: A Double-Edged Sword

Through forestry, ecotourism, and ecosystem services like carbon sequestration and water purification, India's forests and biodiversity play a major role in the country's economy. Timber and medicinal plants are examples of forest goods that sustain rural industries and livelihoods. However, ecological balance and economic stability are at risk due to unchecked exploitation and deforestation. Achieving equilibrium between preservation and use is essential. The goal of programs like eco-sensitive

zones, wildlife sanctuaries, and afforestation efforts is to guarantee the sustainable use of these natural resources.

Water Resources and Infrastructure

India's water resources support agriculture, drinking water and hydropower generation. Efficient management is critical as demand continues to outstrip supply, especially in urban and industrial sectors. Large-scale projects like river interlinking and the Jal Jeevan Mission aim to address water scarcity and boost economic activities.

Challenges and the Way Forward

While natural resources contribute significantly to India's economic growth, their mismanagement and overexploitation can lead to environmental degradation, social conflicts, and economic losses. Policies promoting resource efficiency, technological innovations, and equitable distribution are crucial. The transition to a green economy presents India with an opportunity to redefine how it uses its natural resources. By integrating sustainability into its growth model, India can ensure that its resource wealth becomes a catalyst for long-term, inclusive economic development.

Natural Resources Plays a critical role in economic growth of a nation in following ways

Foundation for Industries: Natural resources supply vital raw materials for a number of businesses, including manufacturing, mining, and agriculture. Job creation and industrial growth can be enhanced by having access to these resources.

Revenue from Exports: Natural resource-rich

nations can make a substantial profit from exports. To further encourage economic growth, this money might be reinvested on health, education, and infrastructure.

Attraction for Investments: Rich natural resources have the potential to draw FDI as businesses look to take use of them. Both employment creation and technological breakthroughs may result from this.

Source of Energy: Coal, gas, and oil are essential resources for the generation of energy. Reliable energy sources are essential for sustaining economic activity and powering industry.

Food Security: Food production is directly influenced by agricultural resources, which also have an effect on local economies and the stability of the country as a whole.

Building Infrastructure: Infrastructure like ports and highways are frequently built as a result of resource extraction, which can enhance market accessibility and ease trade.

Social Development: Natural resource management done right can raise living standards and finance social services. On the other hand, poor management can result in environmental damage and conflict.

Challenges: But there are drawbacks to relying too much on natural resources, such the “resource curse,” which can cause nations to expand more slowly, become corrupt, or become embroiled in conflict. Diversification and sustainable management are crucial for long-term economic growth.

Conclusion

India's natural resources are integral to its

economic ambitions. From fueling industries to sustaining agriculture and driving renewable energy, these resources hold the key to a prosperous future. However, their effective management, coupled with forward-looking policies, will determine their true impact on India's growth trajectory. As the nation strides toward becoming a \$5 trillion economy, harnessing its natural wealth responsibly is not just an economic imperative but a moral obligation to future generations.

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Advancing Sustainability in Agriculture through Genetic Engineering

Nitin Doda, Priyanka, Minakshi Nehra and Deepak Gupta

Genetic engineering has transformed modern agriculture, enabling precise modifications to plant genomes for improved productivity, enhanced nutritional quality, and resilience to biotic and abiotic stresses. This technology offers innovative solutions to global agricultural challenges, including food security, environmental sustainability, and climate change adaptation. Genetically engineered crops reduce reliance on chemical inputs, promote conservation agriculture, and lower production costs for farmers. However, the adoption of these advancements is often hindered by regulatory complexities, public skepticism, and limited accessibility for small-scale farmers. Emerging tools such as CRISPR-Cas9 and synthetic biology hold immense potential to expand the scope and precision of genetic engineering. By addressing these challenges and fostering collaboration among scientists, policy-makers and stakeholders, genetic engineering can play a pivotal role in achieving sustainable food systems that meet the needs of current and future generations.

The advent of genetic engineering in crop improvement has revolutionized agriculture, offering unprecedented opportunities to enhance crop productivity, resilience, and nutritional value.

By manipulating plant genetic material through biotechnology, genetic engineering introduces desirable traits that conventional breeding methods cannot achieve. This innovative technology holds immense potential to address pressing global agricultural challenges, including food security, climate change, and sustainable resource utilization.

Genetic engineering enables the development of crop varieties with enhanced traits such as increased yield, improved nutritional content, and resistance to biotic (pests and diseases) and abiotic stresses (drought, salinity, and heat). For instance, genetically engineered crops like *Bt* cotton and *Bt* maize have demonstrated significant reductions in pesticide use, resulting in environmental benefits and improved farmer health.

Sustainable agriculture aims to meet the needs of the present without compromising future generations. A significant benefit of genetically engineered crops is their potential to minimize the environmental impact of agriculture. Herbicide-tolerant crops, for example, encourage the adoption of conservation agriculture practices that improve soil health and reduce greenhouse gas emissions. Similarly, pest-resistant crops reduce reliance on chemical pesticides, mitigating their adverse effects

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on biodiversity and non-target organisms. This reduction not only supports environmental sustainability but also enhances economic sustainability by lowering production costs for farmers.

Modern Techniques in Crop Genetic Engineering

CRISPR-Cas9: CRISPR-Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats and CRISPR-Associated Proteins) is a groundbreaking technology in genetic engineering due to its simplicity, precision, and versatility. Initially discovered as an adaptive immune system in bacteria, it has been adapted for genome editing. The system uses guide RNA to direct the Cas9 nuclease to specific DNA sequences, introducing double-strand breaks. These breaks are repaired by the cell's natural mechanisms, either through Non-Homologous End Joining (NHEJ) or Homology-Directed Repair (HDR), enabling targeted gene modifications.

Applications in Crop Improvement

Disease Resistance: Researchers have developed rice varieties with enhanced resistance to bacterial blight by editing susceptibility genes using CRISPR-Cas9.

Enhanced Yield: Modifications in genes controlling plant architecture and photosynthesis efficiency have resulted in higher-yielding crops.

Nutritional Enhancement: CRISPR has been used to fortify crops with essential nutrients, such as increasing the vitamin A content in rice.

RNA Interference (RNAi)

RNA interference is a gene silencing technique that uses small RNA molecules to inhibit gene

expression. It operates by degrading messenger RNA (mRNA) corresponding to specific genes, thereby preventing protein synthesis. This method utilizes double-stranded RNA (dsRNA) or small interfering RNA (siRNA) molecules that guide the degradation of target mRNA.

Applications in Crop Improvement

Pest Resistance: RNAi has been employed to develop crops resistant to pests such as corn rootworm and bollworm by silencing genes essential for pest survival.

Disease Resistance: RNAi-based strategies have been used to confer resistance to viral diseases, such as the development of virus-resistant papaya targeting the Papaya Ring Spot Virus genome.

Quality Enhancement: RNAi has been utilized to improve traits such as fruit ripening and starch composition in crops like potatoes and bananas.

Transgenic Methods

Transgenic methods involve the introduction of foreign genes into plant genomes to confer new traits. Common approaches include:

Agrobacterium Tumefaciens-Mediated Transformation: This exploits the natural ability of *Agrobacterium tumefaciens* to transfer DNA into plant cells, integrating foreign genes into the plant genome.

Biolistic (Gene Gun) Method: This technique physically delivers DNA-coated particles into plant tissues to facilitate gene integration.

Applications in Crop Improvement

Insect Resistance: *Bt* crops, such as *Bt* cotton and *Bt*

maize, contain genes from *Bacillus thuringiensis* that produce insecticidal proteins.

Herbicide Tolerance: Crops engineered for herbicide tolerance enable farmers to control weeds more effectively while adopting conservation agriculture practices.

Stress Tolerance: Transgenic rice varieties with enhanced drought and salinity tolerance have been developed to address challenges posed by climate change.

Gene Silencing Techniques

Gene silencing encompasses methods that inhibit gene expression at transcriptional or post-transcriptional levels. Technologies include:

Antisense RNA: Introduces RNA sequences complementary to target mRNA, blocking its translation into proteins.

MicroRNA and DNA Methylation: These techniques regulate gene expression and are used in crop improvement.

Applications in Crop Improvement

Delayed Ripening: The Flavr Savr tomato, which delays ripening by silencing the polygalacturonase gene responsible for cell wall degradation, was one of the first genetically engineered crops to enter the market.

Nutritional Improvement: Gene silencing has been used to increase beneficial compounds in crops, such as enhancing antioxidant levels in tomatoes and berries.

Benefits of Genetic Engineering in Sustainable Agriculture

Enhanced Crop Productivity: Genetic engineering has enabled the development of high-yielding crops, contributing to increased food production. This is particularly important in addressing the challenges of feeding a growing global population.

Improved Nutritional Quality: Biofortification through genetic engineering has enhanced the nutritional content of crops. Examples include Golden Rice, fortified with vitamin A, and biofortified bananas rich in iron and zinc.

Reduced Environmental Impact: Genetically engineered crops reduce the reliance on chemical inputs, such as pesticides and herbicides, minimizing their negative effects on soil, water, and biodiversity. Herbicide-tolerant crops also facilitate no-till farming, reducing soil erosion and greenhouse gas emissions.

Resilience to Climate Change: Crops engineered for tolerance to drought, salinity, and extreme temperatures provide solutions to challenges posed by climate change. These traits enhance food security in regions prone to adverse climatic conditions.

Economic Benefits for Farmers: Genetically engineered crops lower production costs by reducing the need for inputs like pesticides and fertilizers. Higher yields and better-quality produce further enhance profitability for farmers.

Challenges in Genetic Engineering for Sustainable Agriculture

Regulatory and Ethical Concerns: The adoption of genetically engineered crops is often hindered by complex regulatory frameworks and ethical debates

surrounding the use of biotechnology in agriculture.

Public Perception and Acceptance: Misinformation and lack of awareness contribute to public skepticism about genetically modified organisms (GMOs). Education and transparent communication are crucial to addressing these concerns.

Biosafety and Environmental Risks: Potential risks, such as gene flow to wild relatives and unintended effects on non-target organisms, need to be carefully evaluated and mitigated.

Access and Equity: Small-scale farmers in developing countries may face challenges in accessing genetically engineered seeds due to high costs and limited availability.

Future Directions and Innovations

Integration with Other Technologies: The combination of genetic engineering with other advanced technologies, such as artificial intelligence (AI) and precision agriculture, can further enhance agricultural sustainability.

Development of Multi-Trait Crops: Future efforts should focus on engineering crops with multiple beneficial traits, such as drought tolerance, pest resistance, and enhanced nutritional content, to maximize their impact.

Genome Editing Beyond CRISPR: Emerging genome editing technologies, such as prime editing and base editing, offer greater precision and flexibility, paving the way for more targeted crop improvements.

Synthetic Biology in Agriculture: Synthetic biology enables the design of novel biological systems

and pathways, opening new possibilities for sustainable agricultural solutions.

Conclusion

Genetic engineering has revolutionized agriculture, offering precise solutions to challenges like productivity, nutritional enhancement, and stress resilience while promoting environmental and economic sustainability. Despite hurdles such as regulation and public perception, ongoing innovations like synthetic biology promise to amplify its impact. With collaborative efforts, this technology can ensure a sustainable agricultural future, meeting global food demands and safeguarding resources for generations to come.

Biofortification in Agriculture: Advancing Nutritional Security

Priyanka, Nitin Doda, Minakshi Nehra and Deepak Gupta

Abstract

Biofortification is a critical strategy aimed at addressing global malnutrition by enhancing the nutritional quality of staple crops. This technique involves the fortification of food crops with essential vitamins and minerals, either through traditional breeding or genetic engineering. By increasing the concentration of micronutrients in crops, biofortification offers a sustainable solution to nutrient deficiencies, especially in regions where dietary diversity is limited. This article explores the process of biofortification, its methods, key examples, challenges, and its potential role in global nutrition security. Furthermore, it examines the implications of genetic engineering in biofortification and its benefits and limitations.

Introduction

Global malnutrition remains one of the most persistent challenges facing humanity. Despite significant progress in many areas, undernutrition and deficiencies in essential micronutrients, such as iron, vitamin A, and zinc, continue to affect millions, particularly in low-income countries. Biofortification enhancing the nutrient content of crops is emerging as a promising strategy to combat micronutrient malnutrition. By improving the nutritional value of widely consumed staple crops, biofortification offers a sustainable and cost-effective solution. Biofortification can be achieved through two primary approaches: traditional plant breeding and modern genetic engineering techniques. These methods aim to increase the concentration of vital nutrients like vitamins and minerals in the edible

parts of plants. This article will delve into the various biofortification strategies, highlight key examples of biofortified crops, and explore the benefits and challenges of these approaches.

What is Biofortification?

Biofortification refers to the process of increasing the nutrient content of food crops through conventional breeding techniques, agronomic practices and more recently, genetic engineering. Unlike fortification, which involves adding nutrients to food after harvest, biofortification occurs during the plant's growth phase, making it a more sustainable and cost-effective method to improve the nutritional value of crops.

Biofortification can target various micronutrients such as iron, zinc, and vitamins like A and E. This approach focuses on enhancing crops that are

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commonly consumed by populations at risk of nutrient deficiencies. Biofortified crops can help reduce the prevalence of hidden hunger, which occurs when individuals have an insufficient intake of essential vitamins and minerals despite an adequate overall calorie intake.

Types of Biofortification

Micronutrient Biofortification: This type of biofortification focuses on increasing the levels of essential micronutrients like iron, zinc, and vitamins A and D in crops that form the staple diet of populations.

Macronutrient Biofortification: While less common, some biofortification efforts aim to increase macronutrients like proteins, fats, or carbohydrates in crops.

Biofortified Crops for Specific Health Benefits: Certain biofortified crops may target the enhancement of specific health benefits, such as improving immune function, reducing the risk of birth defects, or enhancing cognitive development.

Biofortification Techniques

Biofortification can be achieved through various techniques, each offering distinct advantages and challenges. These methods range from traditional breeding techniques, which have been used for centuries, to more advanced methods such as genetic engineering and gene editing.

Traditional Plant Breeding

Traditional breeding involves the crossing of plant varieties to combine desirable traits, including enhanced nutritional content. This process can take

many generations to achieve the desired nutrient concentration. Breeders select plants that exhibit higher levels of specific nutrients and cross them to produce offspring with improved nutritional profiles. This approach has been successfully used for biofortification in crops such as cassava and corn.

Examples of Traditional Biofortification

Beta-Carotene in Cassava: Through conventional breeding, cassava has been developed with higher levels of beta-carotene, a precursor of vitamin A. This biofortified cassava provides a potential solution to vitamin A deficiency in regions where cassava is a staple food.

Golden Rice: Golden rice is one of the most well-known examples of biofortification using genetic engineering, which is discussed in the following section. It was created to produce and accumulate higher levels of provitamin A (beta-carotene) in rice grains.

Genetic Engineering and Genetic Modification

Genetic engineering involves the modification of an organism's DNA to introduce specific traits that may not naturally occur. This can include transferring genes from unrelated species to enhance the crop's nutritional profile. Modern biotechnology tools such as gene editing, CRISPR, and transgenic technology have made it possible to introduce genes that enhance the bioavailability of micronutrients like iron, zinc, and vitamins A and E.

Examples of Genetic Engineering for Biofortification

Golden Rice: As mentioned earlier, golden rice was genetically engineered to produce beta-carotene in the rice grain, helping combat vitamin A deficiency in developing countries.

Iron-Biofortified Beans and Cowpeas: Researchers have used genetic engineering techniques to increase the iron content in beans and cowpeas. These legumes are staples in many parts of the world, and iron biofortification is essential to combat anemia.

Zinc-Biofortified Wheat: Wheat, a major staple food in many countries, has been genetically engineered to increase its zinc content, addressing zinc deficiency.

Gene Editing Techniques: CRISPR-Cas9

Gene editing technologies, such as CRISPR-Cas9, are revolutionizing the potential for biofortification. Unlike traditional genetic engineering, which involves inserting foreign genes, gene editing can be used to modify existing genes in crops. This technology has been used to enhance the nutritional content of several crops by altering genes that control the synthesis and accumulation of nutrients.

Benefits of Biofortification

Biofortification offers numerous benefits, particularly for addressing micronutrient deficiencies in developing countries. Some of the key advantages include:

Improved Nutritional Status: Biofortified crops are designed to deliver higher concentrations of essential vitamins and minerals. For example, Golden Rice provides a source of provitamin A,

helping to address vitamin A deficiency, which is a leading cause of blindness in children and immune deficiencies. Similarly, iron-biofortified beans and cowpeas can help reduce the prevalence of iron deficiency anemia.

Sustainable Approach to Fighting Malnutrition:

Unlike other interventions like food fortification, which requires ongoing external inputs, biofortification is a sustainable solution because the enhanced nutrients are inherent in the crops themselves. This makes biofortification a long-term strategy for improving nutrition, especially in regions where malnutrition is prevalent.

Increased Access to Nutrients: Biofortified crops are often grown and consumed locally, meaning that people who may not have access to fortified foods or supplements can still benefit from improved nutrition. Since the crops are widely available, biofortification can help address nutritional deficiencies at a population level.

Low Cost: Once biofortified crops are developed, they are typically low-cost compared to other nutritional interventions like supplements or fortified foods. This makes biofortification an attractive option for resource-poor populations who might not be able to afford more expensive interventions.

Potential for Climate Resilience: Some biofortified crops are not only more nutritious but also more resilient to environmental stresses like drought, pests, and diseases. This can contribute to food security by ensuring a stable supply of nutrient-rich crops even under adverse conditions.

Challenges and Limitations of Biofortification

While biofortification has the potential to make a significant impact on global nutrition, several challenges and limitations must be addressed to ensure its success.

Yield Penalty: In some cases, biofortified crops may experience a yield penalty, meaning that the enhanced nutritional content may come at the cost of reduced crop productivity. This could require more land to produce the same amount of food, which may not be feasible in regions with limited arable land.

Genetic Uniformity: Biofortification may lead to genetic uniformity, which can increase the risk of vulnerability to pests, diseases, and changing environmental conditions. This is particularly a concern with genetically modified crops, where the use of a single variety could make entire crops susceptible to new challenges.

Limited to Single Nutrients: While biofortification has made significant strides in enhancing specific nutrients like vitamin A, iron, and zinc, it has not yet addressed the full range of micronutrient deficiencies faced by populations. Other nutrients like iodine, vitamin D, and calcium remain largely outside the scope of current biofortification efforts.

Public Perception and Acceptance: Public skepticism toward genetically modified organisms (GMOs) remains a significant barrier to the widespread adoption of biofortified crops. In many parts of the world, especially in Europe, there is resistance to GMOs, which can limit the acceptance of genetically engineered biofortified crops.

Regulatory Hurdles: The approval process for genetically engineered crops can be lengthy and complex. Regulatory agencies in different countries have different standards for assessing the safety of GMOs, and this can delay the availability of biofortified crops to those who need them most.

Conclusion

Biofortification is a promising approach to addressing malnutrition by enhancing the nutritional quality of staple crops. Through traditional breeding and genetic engineering, crops can be fortified with essential vitamins and minerals to help combat deficiencies in vulnerable populations. While the benefits of biofortification are clear, several challenges remain, including yield penalties, genetic uniformity, and public acceptance. Nevertheless, with continued research and development, biofortification has the potential to play a key role in achieving global nutritional security and improving health outcomes for millions of people worldwide.

Advances and Innovations in Stone Fruit Cultivar Development

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Abstract

Despite the availability of hundreds of stone fruit (*Prunus* spp.) cultivars for the fresh market, the industry continues to demand new cultivars to meet evolving requirements. Over the past two decades, there has been a notable shift toward private breeding programs as public sector support for these long-term initiatives declines. Consequently, fewer public breeding programs exist, and many rely on royalty payments to protect and partially fund their releases. Several trends are shaping the development of new stone fruit cultivars. These include the need for smaller or more manageable tree architectures, reduced use of agricultural chemicals, expansion of production into milder winter zones for year-round availability, diversification of fruit types in the market, and increasing consumer awareness of the health benefits of fruit consumption. Additionally, there is a growing demand for improved and more consistent fruit quality and enhanced postharvest characteristics to support global marketing. Breeding programs worldwide are adapting to these trends, aiming to develop cultivars that meet the changing needs of the global market.

Introduction

There are hundreds of cultivars of peach, nectarine (*Prunus persica*), plum (*P. salicina* and hybrids), apricot (*P. armeniaca*), and cherry (*P. avium* and *P. cerasus*) cultivated in the U.S. and globally. For instance, nurseries in the southeastern U.S. typically list between 50 to 150 peach and nectarine cultivars, while the California Tree Fruit Agreement (CTFA) identifies 80-85 major peach cultivars and an equal number of nectarine cultivars.

The USDA Handbook by W.R. Okie (1998) describes 700 peach and nectarine cultivars, and the Brooks and Olmo Register of Fruit and Nut Varieties (ASHS, 1997) lists approximately 300 nectarine and 1,000 peach cultivars. These figures pertain only to North America. Globally, breeders release about 100 peach and nectarine, 20 apricot, 30 plum, and 20 cherry cultivars annually. Do we need all these cultivars? No, as many are now obsolete. However, new cultivars are still necessary due to evolving

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markets, changing production systems, and shifting orchard locations. Who develops these cultivars? Roughly 50% of peach, nectarine, and Japanese plum cultivars are developed in the U.S. Europe, primarily France and Italy, accounts for about 30% of the cultivars. Smaller contributions come from South Africa, Australia, Asia (mainly China and Japan), and Latin America (mainly Mexico and Brazil). These proportions have remained steady over the past two decades. However, breeding activity is increasing in Asia, Australia, and Latin America, with a more global approach to testing and marketing new cultivars from established programs.

There are eight major trends that are molding the present breeding programs in various ways. These are:

- ✓ Decrease in public breeding programs
- ✓ Changing tree architecture
- ✓ Increased concerns about the use of agricultural chemicals
- ✓ Expansion of production zones
- ✓ Diversification of fruit types
- ✓ Increased interest in the health benefits of fruit
- ✓ Increased demand for fruit quality
- ✓ Need for better postharvest traits

Decrease in public breeding programs

Public peach and nectarine breeding programs have seen a decline in their contribution to new cultivar releases, dropping from 45% to 31% since 1980, while private breeding programs have taken on a larger role. In the U.S., around 50% of public stone fruit breeding programs have shut down since 1970.

The remaining programs no longer release new cultivars without protection; instead, they fund their efforts through patenting releases and partnering with private entities for testing and marketing. While these collaborations are effective, they have reduced germplasm exchange among public programs. Private breeding programs in the U.S. allocate less than 10% of their budgets to germplasm development and genetic research, whereas public programs invest over 60% of their resources in these areas. Consequently, the closure of public breeding programs has also led to a reduction in basic research on germplasm development, genetics, and breeding technology, which are predominantly supported by government grants. Efforts to address this shortfall have included increased funding for the national germplasm system due to lobbying by the American Seed Trade Association, benefiting the stone fruit industry. However, genomic and related research in fruit crops still lags behind agronomic crops. Since grant success often depends on industry backing, the stone fruit industry must actively advocate for consistent and increased governmental funding to secure the long-term success of breeding programs.

Changing tree architecture

Rising labor costs in developed nations have pushed agricultural research in three main directions: modifying tree size, developing simpler training methods, and mechanizing fruit tree production. Significant progress has been made in developing new training systems, using chemicals to control growth, and creating rootstocks that regulate growth

over the past two decades. Researchers are pursuing two genetic strategies to address these challenges. The first involves developing dwarfing rootstocks, which has proven successful with apple trees. This approach is now showing promise with stone fruits like plums, peaches, and cherries, offering both smaller tree size and earlier fruit production when budded. The second strategy focuses on modifying the tree's natural architecture. This ranges from selecting trees with better branching patterns and increased spur formation to developing varieties with completely new growth patterns. These new varieties include dwarf, semi-dwarf, compact, pillar, and weeping forms. However, each new tree architecture requires its own specialized training system. The successful commercialization of these new varieties will depend on packaging them together with appropriate training methods to ensure optimal growth and production.

Increased concerns about the use of agricultural chemicals

Growing concerns about worker safety, environmental protection, and consumer health have led to stricter government regulations on agricultural chemicals and pushed for alternative pest control methods. Consumer surveys have shown increasing worry about pesticide residues on stone fruits, reflected in the expanding organic produce market. This trend suggests more rigorous residue testing and greater accountability for producers in the future. In response, extensive research has focused on integrated pest and disease management to reduce

chemical usage in stone fruit production. A key approach involves breeding plants for genetic resistance to various diseases and pests. Several active breeding programs worldwide target specific threats:

- ✓ Brown rot resistance (in California, Mexico, Brazil, Italy)
- ✓ Powdery mildew resistance (Mexico, France, Italy)
- ✓ Aphid resistance (France, Italy)
- ✓ Bacterial leaf spot resistance (southeastern US, humid South America, Asia)
- ✓ Plum pox virus resistance (Europe)

Additionally, rootstock breeding programs focus on developing resistance to nematodes, peach tree short life, root rot, and various soil-related challenges. Biotechnology has emerged as a promising tool in this field. Scientists have made significant progress in identifying molecular markers for resistance genes, particularly for nematodes and powdery mildew. While the practical application of these markers in breeding programs is still developing, some success has been achieved - notably a plum pox-resistant European plum cultivar currently undergoing field testing. However, the transformation of stone fruit remains technically challenging. While transformed cultivars could potentially reduce pesticide use, public acceptance of such genetically modified fruits remains uncertain.

Expansion of production zones

The drive for year-round produce availability in global markets has sparked research in two main

areas: developing low-chill cultivars with quick fruit development, and coordinating production between northern and southern hemispheres. In the United States, low-chill stone fruit breeding programs focus on creating early-ripening varieties to capture premium prices in the early fruit market. Latin American programs, while also developing early varieties, have taken a broader approach by releasing mid-season and late-ripening cultivars to support their local produce and processing industries. This research has successfully expanded peach production into subtropical and tropical regions. While some of this fruit enters the international market, the vast majority (90-95%) is consumed locally. For global market purposes, breeders focus on developing varieties that ripen in April and May in the northern hemisphere and October to mid-December in the southern hemisphere. However, there remains a significant need for mid and late-season cultivars to supply local markets throughout the growing season.

Diversification of fruit types

Historically, different regions have shown distinct preferences for peach types: Chinese and Japanese markets favor low-acid white peaches, North American consumers prefer yellow-fleshed acid varieties, while Spanish and Latin American markets traditionally choose non-melting yellow-orange peaches. However, globalization and changing consumer demands are blurring these traditional preferences, leading to more diverse peach varieties appearing in markets worldwide. The U.S. supermarket produce section has undergone

significant transformation over the past 50 years, offering a much wider variety of products. Where yellow-fleshed acid peaches once dominated and nectarines were uncommon, today nectarines account for about half of California's fresh "peach" production. The market now includes white- and yellow-flesh varieties, low-acid and high-acid types, flat (pantao) peaches, and soon will feature red- and orange-fleshed varieties. However, this diversity has created some consumer confusion. For example, some customers buy white peaches or nectarines expecting a low-acid flavor but receive a high-acid variety instead. This situation highlights the need for better product differentiation and naming conventions. While some breeders have developed naming systems to distinguish different fruit types (like Italy's "Ghiaccio" series of white, high-sugar, low-acid peaches), these technical naming protocols haven't generally carried over into marketing names that would help consumers make informed choices.

Increased interest in the health benefits of fruit

As public awareness of the health benefits of fruits grows, along with recommendations for a colorful diet, there's potential for developing new fruit varieties specifically bred for enhanced health properties. Research has shown that various compounds found in peaches have beneficial antioxidant properties:

- ✓ Carotenoids (orange/yellow pigments)
- ✓ Anthocyanins (red pigments)
- ✓ General phenolics (colorless compounds)

These compounds have demonstrated protec-

tive effects against various health conditions including inflammation, cancer, atherosclerosis, and other circulatory problems. While the “healthy-for-you” marketing approach is being used actively to promote fresh produce consumption, no stone fruit varieties have yet been specifically developed to maximize these beneficial phytochemicals. Such health-enhanced cultivars could create new market opportunities, both for fresh consumption and for processing into natural extracts that could serve as sources of antioxidants, antimicrobials, and natural colorants.

Increased demand for fruit quality

While U.S. non-citrus fresh fruit consumption increased 17.2% from 1980 to 2003, with an expected additional 8% growth by 2020, stone fruit consumption has remained flat or declined over the past two decades. This trend is attributed partly to increased competition from other fruits and minimally processed products, but primarily to inconsistent fruit quality. Stone fruit quality is notably less consistent than other fruits like pomes or grapes. Consumer surveys across Southeast Asia, the U.S., and Europe highlight poor or inconsistent quality as a major deterrent to purchasing peaches. In France, a striking 80% of consumers reported dissatisfaction with peach consistency. The issue isn't with external appearance, which is standardized through packing, but with internal qualities like firmness, soluble solids, and acidity. To address this, new nondestructive testing methods using acoustical and near-infrared systems have been developed for

packing lines, allowing individual fruit quality assessment. However, fruit quality remains complex, influenced by both growing conditions and genetics. Firmness is crucial for handling and marketing. While most high-chill fresh-market breeding programs have traditionally focused on melting flesh types, programs in Mexico and Brazil have worked with non-melting flesh varieties. This firmer flesh allows fruit to be harvested when tree-ripe yet remain firm enough for marketing - a practice common in Latin America and Spain for centuries. Recent developments include fresh market peaches with non-melting flesh, such as 'UFGold', 'UFPrince', and 'Crimson Lady'. New varieties also feature semi-free- to free-stone forms with non-melting flesh, addressing potential fresh market concerns while offering benefits for processing markets.

Conclusions

Peaches and other stone fruits are marketed in various forms worldwide, reflecting regional preferences. Recent marketing strategies emphasize developing innovative varieties and products to diversify regional markets. This has led to an expanded concept of stone fruits, encompassing a broader spectrum of colors, shapes, sizes and flavors. The growth of stone fruit consumption hinges on effective marketing, consistent quality and affordability. Key trends shaping stone fruit consumption include globalization and the demand for year-round availability, rising labor costs, diversification in produce offerings, increasing awareness of the fruits' health benefits, and concerns about pesticide use and

bacterial contamination. These factors have spurred interest in production systems aimed at extending the harvest season, reducing chemical inputs, and ensuring consistent fruit quality. In response to these challenges, breeders are dedicating efforts to creating cultivars with superior fruit quality, enhanced postharvest characteristics, greater resistance to diseases and pests, higher concentrations of health-promoting phytochemicals, a wider variety of fruit types, optimized tree architecture for easier cultivation, and adaptability to subtropical and tropical climates.

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Medicinal Use of Silk Thread: A Natural Wonder in Healing and Treatment

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Introduction

Silk, one of nature's most remarkable fibers, is well-known for its luxurious texture and durability. However, beyond its popularity in the fashion industry, silk has an array of medicinal uses, particularly in the form of silk thread. The unique properties of silk thread, especially its biocompatibility, strength, and hypoallergenic nature, make it an invaluable resource in modern medicine. This article explores the fascinating medicinal uses of silk thread, from wound suturing to advanced tissue engineering.

Silk Thread in Wound Suturing

One of the earliest and most prevalent uses of silk thread in medicine is in surgical suturing. The natural tensile strength and flexibility of silk make it ideal for stitching wounds, particularly in delicate areas. Silk sutures have been used for centuries due to their effectiveness in holding tissue together and promoting natural healing. The advantages of silk in wound suturing include:

Tensile Strength: Silk threads are strong enough to hold tissue firmly in place, preventing separation and allowing the wound to heal seamlessly.

Minimal Tissue Reaction: Silk causes a minimal immune response, reducing the risk of inflammation or infection at the wound site.

Easy Handling: Silk threads are smooth and easy to tie, allowing surgeons to work with precision and ease.

However, silk sutures are typically non-absorbable, meaning they require removal after the wound has healed. Advances in surgical practices have led to the development of biodegradable silk sutures, which dissolve over time and eliminate the need for removal, enhancing patient comfort.

Silk as a Scaffold in Tissue Engineering

Silk thread has garnered significant attention in the field of tissue engineering and regenerative medicine. Its natural properties make it a highly compatible material for creating scaffolds that aid in tissue repair and regeneration. In particular, silk thread is used to fabricate structures that support the growth of new cells and tissues, making it useful in healing and reconstructing damaged organs and tissues.

Silk scaffolds are commonly used for:

Bone Regeneration: Silk threads are combined with other materials to create scaffolds that support bone regeneration in cases of fractures or bone diseases.

Cartilage Repair: In joint injuries or degenerative diseases like osteoarthritis, silk-based scaffolds provide a framework for cartilage cells to grow and restore joint function.

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Skin Regeneration: Silk threads can aid in wound healing and skin regeneration, particularly for burns or severe lacerations, by promoting the growth of healthy skin tissue.

Silk Sutures in Ophthalmic Surgery

Ophthalmic surgeries, such as corneal transplants and cataract surgeries, require sutures that are both fine and biocompatible, as the eye is extremely sensitive to foreign materials. Silk thread meets these requirements, making it a preferred choice in many delicate eye surgeries. The benefits of silk sutures in ophthalmology include:

Gentle on Eye Tissues: Silk's smooth texture causes minimal trauma to eye tissues, reducing post-operative inflammation.

Precision in Placement: The flexibility and strength of silk allow for precise placement in delicate tissues, crucial for successful eye surgeries.

Ease of Removal: Silk sutures are easy to remove, which is essential in surgeries where absorbable sutures might not be suitable.

Silk Fibroin in Drug Delivery Systems

Silk fibroin, a protein derived from silk, is increasingly used in drug delivery systems due to its biocompatibility and biodegradability. Silk fibroin can be processed into nanoparticles, films, or gels that deliver drugs directly to target areas within the body. This innovative use of silk thread-derived fibroin in medicine allows for controlled release of medications, enhancing treatment effectiveness and reducing side effects.

Applications of silk fibroin in drug delivery include:

Cancer Treatment: Silk-based nanoparticles are designed to carry anticancer drugs directly to tumors, minimizing the impact on surrounding healthy cells.

Wound Healing: Silk fibroin gels infused with antibiotics can be applied to wounds, releasing medication gradually to prevent infection.

Diabetes Management: Insulin delivery systems incorporating silk fibroin provide a steady release of insulin, improving blood glucose control in diabetic patients.

Silk in Nerve Regeneration

Nerve damage, often due to injury or disease, presents a challenging scenario for regenerative medicine. Recent studies have shown that silk threads, particularly those treated to enhance bioactivity, can support nerve regeneration. Silk thread-based conduits provide a structure that guides the growth of neurons, allowing damaged nerves to regenerate along a defined pathway.

Advantages of silk threads in nerve regeneration include:

Biocompatibility: Silk does not cause adverse immune reactions, which is critical in nerve tissue.

Flexibility: Silk threads adapt to the body's movements, maintaining integrity in mobile areas like limbs.

Support for Axonal Growth: Silk scaffolds encourage axonal growth, assisting in nerve repair and functional recovery.

Future of Silk Thread in Medicine

As research advances, the versatility and safety of silk thread continue to unfold, showing

potential in emerging medical applications such as 3D-printed tissue structures, artificial ligaments, and bioactive wound dressings. With silk's remarkable properties and ability to integrate into the body naturally, it is likely that new therapeutic uses of silk thread will continue to emerge in both conventional and experimental medicine.

Conclusion

The medicinal uses of silk thread extend far beyond traditional suturing. Its unique properties, including biocompatibility, strength, and flexibility, make silk thread a valuable resource in wound healing, tissue engineering, drug delivery, and nerve regeneration. With ongoing research and development, the full potential of silk thread in medicine is only beginning to be realized, making it a fascinating subject of study and innovation.

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Scientific Cultivation of Sapota

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Introduction

The tropical fruit crop sapota (*Manilkara zapota*), called chikoo, is prized for its sweet flavor, high nutritional value, and commercial viability. It is a native of Central America and a member of the Sapotaceae family. Ripe fruits have a sweet taste and a beautiful range of colors, making them perfect dessert fruits. In contrast, immature fruits are hard, gummy, and high in tannin (astringent) (Jadhav *et al.*, 2018). Sapota trees are evergreens that live long and have branches that drop and a round canopy. The first sapota plantation is said to have been founded in the Maharashtra village of Gholwad in 1898. It then made its way to some places in both southern and western India (Jayachandran *et al.*, 2023).

Area and Production: However, it is currently mostly grown in Mexico, India, the Philippines, Vietnam, Malaysia, Indonesia, Thailand, Sri Lanka, and Bangladesh. It was once widely grown in the tropics, primarily in Central and South America (Lim, 2013). It is grown on 0.78 lakh hectares of land

in India, producing 0.86 million MT annually (Anonymous, 2021-22).

Climatic and Soil Requirements

Climate: It thrives in tropical and subtropical climates with temperatures between 10°C and 38°C. Stays away from areas that are prone to frost.

Soil: Prefers well-drained sandy loam soils with a pH range of 6.5 to 8. It is inappropriate to use heavy soils with inadequate drainage.

Varieties

Varieties: Kalipatti, Kirtibarathi Cricket Ball and Ayyangar are widely cultivated for their yield and quality.

CO-1: Hybrid variety cross between Cricket ball and Oval, developed from TNAU, Coimbatore. The medium-sized, long, oval fruits have a sweet flavor and reddish-brown flesh.

CO-3: Hybrid variety cross between Cricket Ball × Vavivalasa, suitable for HDP

PKM-2: Hybrid variety cross between Guthi × Kirtibarathi.

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PKM-3: Hybrid variety cross between Guthi × Cricket ball, suitable for HDP

DHS-1: Hybrid variety cross between Kalipatti and Cricket ball released from UAS, Dharwad, Karnataka.

DHS-2: Hybrid variety cross between Kalipatti and Cricket ball at UAS, Dharwad.

CO-2: Developed by clonal selection from Baramasi, developed at TNAU, Coimbatore.

PKM-1: It is a clonal selection and developed in 1981 from HC&RI, Periyakulam, TNAU.

PKM-4: It is a clonal selection from PKM-1 and suitable for high density planting.

Propagation

Sapota is propagated primarily through grafting and air layering. Grafting is preferred for maintaining genetic purity, and air layering is used to propagate high-quality plants. Seed propagation is not recommended as it may lead to variations in fruit quality.

Rootstock: Commercially, Rayan/ Khirni/ Pala (*Manilkara hexandra*) are used as rootstocks for grafting.

Planting

Land Preparation: After deep plowing, leveling is done.

Pit Size: A mixture of soil, organic manure, and fertilizers is placed into 60 x 60 x 60 cm pits.

Spacing: Trees are planted at a spacing of 8 x 8 meters for optimum growth.

Irrigation

Young plants need to be watered often.

During dry spells, mature plants require irrigation, particularly when they are fruiting. For effective water use, drip irrigation is advised.

Manuring and Fertilization

Organic Manure: FYM 10-15 kg of plant⁻¹ annually

Chemical Fertilizers: Doses of potassium, phosphorus and nitrogen (500 g N, 250 g P and 250 g K tree⁻¹ year⁻¹) are advised.

Training and Pruning

Training young plants to a central leader system ensures proper canopy development. Pruning involves removing dead, diseased, and overcrowded branches.

Physiological disorders

Misshapen fruit: In certain circumstances, the tree bears crooked fruits. A fruit's shape is determined by how many seeds it contains. Oblong fruits are the result of high temperatures and rainfall during flowering.

Sun scorching: In sapota, it is another physiological condition. Extreme sunlight causes improper ripening of fruits. In the winter, it develops cockiness (Jayachandran *et al.*, 2023)

Corky tissue: Occurs in summer months due to drought stress (Shivashankar *et al.*, 2014).

Pest and Disease Management

Common Pests

Sapota seed borer: Controlled using neem-based insecticides.

Scale insects: Managed with horticultural oils.

Diseases: Leaf spot and sooty mold are treated with fungicides like carbendazim or copper-based formul-

ations.

Harvesting: Harvesting occurs seven to nine months after flowering, when the fruits are light brown and yield slightly to the touch. To prevent damage, harvesting should be done by hand.

Yield: Fruit production peaks between the seventh and fifteenth years after planting, with fruit yield beginning three to four years later. In ideal conditions, a mature tree yields 80-150 kg of fruit per year.

Post-Harvest Management: Ethylene gas or room temperature storage are two methods for ripening fruits. Market value is increased through appropriate grading, packaging, and storage.

Conclusion

Scientific cultivation of sapota involves implementing cutting-edge farming techniques, including proper variety selection, optimal managing the soil, watering methods, pest control, and management of nutrients. By following these guidelines, farmers may achieve greater yields and better fruit taste. Furthermore, implementing eco-friendly and sustainable methods guarantees the long-term viability of sapota farming. Consequently, sapota has emerged as a lucrative crop for tropical farmers, making a substantial contribution to both domestic and international markets.

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Effect of Puddling Wetland Rice on Soil Properties

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Introduction

Puddling refers to breaking down soil aggregates at near saturation into ultimate soil particles. The mechanical reduction in the apparent specific volume of soil is found due to puddling. Only soils with more than 20 per cent of clay particles are prone to puddling. The destruction of the aggregated condition of the soil by mechanical manipulation within a narrow range of moisture contents above and below field capacity (0.3 bar), so that soil aggregates lose their identity and the soil is converted into a structurally more or less homogeneous mass of ultimate particles. Throughout Southeast Asia puddling is used to prepare soil for lowland rice. It involves cultivation of the soil after it has been softened by flooding for several days and creates a layer of soft mud which often overlies a dense plough pad. Puddling and the maintenance of flooded conditions create favourable conditions for rice by aiding weed control, making seedling transplanting easier, creating reduced conditions which improve soil fertility and reducing deep percolation of the standing water in which rice is grown but in terms of the degree of alteration of soil structure, puddling is a rather extreme form of tillage, because it results in aggregate breakdown and the destruction of macropores. Puddling or wet tillage coupled with submerged conditions are responsible

for making drastic effects on soil physical characteristics of rice soils. These effects can be continued either for short or long time. During rice-rice or rice-wheat cropping sequence the system undergoes transition from saturated to unsaturated conditions. While this happens, the soil physical properties again undergo changes. Puddling and subsequent flooding differentiate lowland rice soils chemically and pedologically from other arable soils. Puddling, intensive wetland cultivation, breaks the natural aggregates to finer fractions. It decreases the apparent specific volume and hydraulic conductivity, creates an anaerobic environment and affects redox (Eh) and soil pH values.

Influence of puddling on soil properties

Puddling influences physical, chemical and biological soil properties which in turn influence rice growth. The primary result of puddling is the destruction of soil aggregates. A puddled soil consists essentially of a two phase *i.e.* solid-liquid system. Individual clay particles or clusters thereof are oriented in parallel rows and are surrounded by capillary pores saturated with water. The degree of aggregates destruction is difficult to quantify because drying is necessary to measure aggregation. Non capillary pores are essentially eliminated in the process of puddling. About 91-100 per cent of the volume occupied by such pores is destroyed by pud-

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dling in a silty loam soil. Immediately after puddling a saturated soil, the apparent specific gravity or bulk density is less than that of original soil because of the larger total pore volume occupied by water. With time however, the bulk density of the flooded soil increases probably because of a slow settling of the clays. Saturated hydraulic conductivity (K_s) of surface soil measured at harvest of rice crop was significantly reduced over farmers practice when puddling was done by a helical blade puddler and power tiller operated case wheel and rotavator. Reduction of K_s value may be due to elimination of transmission pores due to intense puddling by puddler and power tiller. Puddling also decreases the percolation rate of water by up to 92 per cent depending on the depth and intensity of puddling and soil texture. Soils with higher organic matter content responds more to puddling in terms of reduction in percolation rate. A puddling depth of 10 cm at high intensity of puddling is more effective in reducing the rate of settling of suspended particles and percolation rate of water. Percolation losses of water decreases with medium-puddling in the range 54-58 per cent, but it remained unaffected by increased puddling intensity as well as puddling depth. Percolation rate (PR) decreases with time in both medium and high puddling intensity but it increases with increasing depth of ponding water. Thus, puddling reduces percolation losses of water in rice fields, the extent of reduction being a function of intensity and depth of puddling. Course textured soils and soils with high organic matter respond more

to puddling in terms of reducing percolation losses of water. There is greater cracking on puddled soils than on non-puddled soils during soil drying, and that this is associated with a faster rate of drying in the puddled soil. Puddling has both short and long term effects on soil and rice growth.

Short Term Effects

Soil structure: Puddling destroys aggregates and peds. Wetting dry soils cause uneven swelling in aggregates and explosion of trapped air. The aggregates are slaked. Aggregates, depending on their stability, will be partially or completely destroyed 'if they are submerged and objected to repeated' ploughing, harrowing or other puddling. The puddled layer is neither structurally nor chemically uniform, but there is little information on stratification within puddled soil.

Bulk density and soil strength: The effect of puddling on bulk density depends on soil aggregation before puddling. If puddling produces a parallel, loosely packed structure from a well aggregated open structure, then bulk density increases. But puddling can also produce a more open structure, and hence decrease bulk density. Puddling decreases the shear strength of the surface layers. In general, shear strength decreases with moisture content and increases with bulk density.

Soil porosity: In a puddled soil, individual clay particles or particle clusters are in parallel rows within water-saturated capillary pores. The effect of puddling on porosity depends on the soil particle orientation in the puddled layer. If a more open

structure results from puddling, total porosity will increase.

Gas exchange: In a submerged puddled soil, gas exchange, especially of O_2 between soil and atmosphere is strictly restricted. Oxygen concentration decreases and CO_2 concentration increases.

Water retention and movement: Water retention in puddled soils always exceeds that in unpuddled soils. Puddled soils dry more slowly than unpuddled soils, probably because the higher unsaturated hydraulic conductivity of puddled soils can keep surface soil wet during evaporation by supplying water from lower layers.

Long term effects

Formation of hardpan: Long term puddling forms a hardpan in the subsoil below the puddled layer. Subsurface hardpans develop from physical compaction and precipitation of Fe, Mn and Si. Chemically cemented pans are formed in the oxidized subsoil, usually 15 to 20 cm deep, by precipitation of Fe, Mn and Si from upper reduced soil layers. Continuously submerged soils have excessively reduced conditions, Fe- and Mn-pans form very slowly.

Ferrollysis: Ferrollysis is the process of clay decomposition and transformation under the influence of periodic reduction of iron oxides to ferrous ions (Fe^{2+}). Ferrollysis comprises various component process. Some operating in reduced conditions (wet season) alternating with other operating in oxidizing conditions (dry season). Ferrollysis is not desirable for rice crop growth.

Ferrollysis can be stopped in different ways:

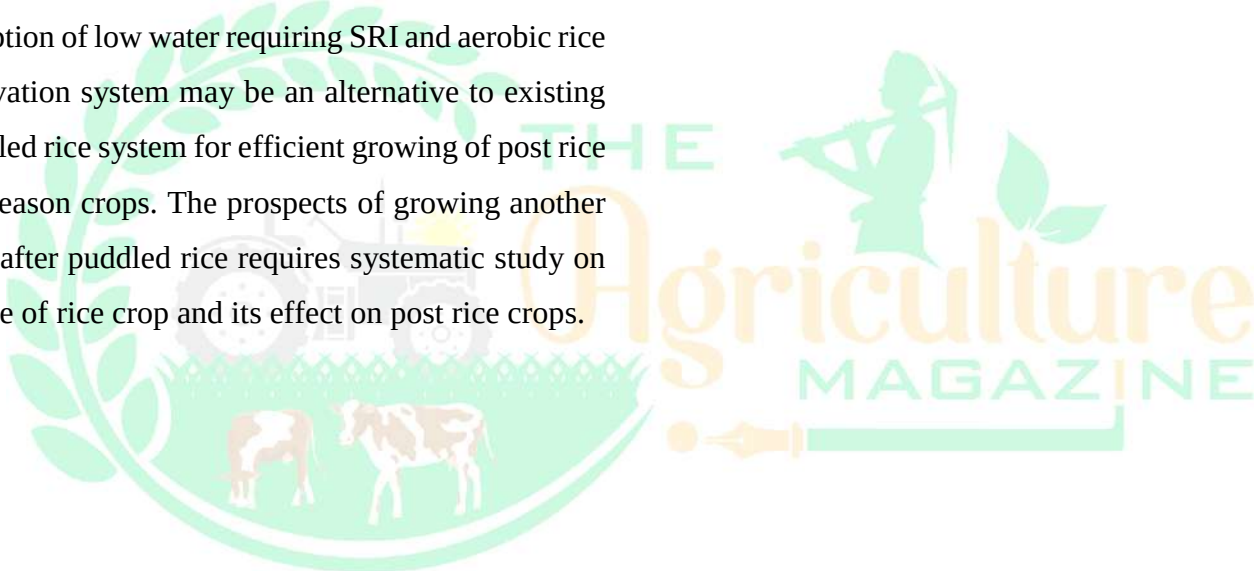
- ✓ By eliminating the oxidation phase
- ✓ By eliminating the reduction phase. This can be done by rapid leaching which would entail great losses of nitrogen and other nutrients or by shifting to up land rice.
- ✓ By raising the dry season (oxidized) pH by liming
- ✓ By replacing the basic cations lost' either through fertilizing or liming or base rich irrigation water etc.

All these measures are partially effective, since clay decomposition takes place rapidly in the first few days after air entry and since the re-supply and even distribution of bases is generally a slower process.

Conclusion

Continuous inclusion of lowland puddled rice in a cropping sequence year after year results in the development of hard subsurface layers, which act as a hydraulic barrier and impede water movement. Water retention in puddled soils is always higher than the non-puddled soil. However, when the submerged puddle soils revert back to upland non-puddle condition, its water retention falls. Crop establishment was shown to be the most limiting factor for post-rice crop production followed by the extraction of soil water, which is a function of root growth. Puddling is needed only to the required level that improved growth of rice and will also deteriorate less the soil physical condition as compared to more intense puddling. Breakdown of hard pan by deep

ploughing after every 3-4 years for better post rice crop. Post rice crops with the ability of their roots to penetrate hard sub-soils would better explorer of available soil water. Nutrient and microbial deficiencies of puddled soil correction could be done by proper fertilization, application of organic matter and bio-fertilizers for better post rice crops. Sufficient rice straw should be incorporated to the plough layer to maintain soil organic carbon and then to improve soil puddle ability and the recovery of pore structure with wetting and drying cycles. Adoption of low water requiring SRI and aerobic rice cultivation system may be an alternative to existing puddled rice system for efficient growing of post rice dry season crops. The prospects of growing another crop after puddled rice requires systematic study on tillage of rice crop and its effect on post rice crops.



Mass Multiplication of *Trichogramma* on Artificial Diet

Ratnakar V., Srinivasnaik S. and Bharati Narayan Bhat

Introduction

- ✓ *Trichogramma* wasps are tiny hymenopterous egg parasitoids widely used in biological control programs worldwide. The huge quantities of insects necessary for inundative releases are mainly produced on factitious hosts like *Ephestia kuehniella* (Zeller) (Lepidoptera: Pyralidae), or on silkworms.
- ✓ In order to simplify production, increase its flexibility, and potentially reduce cost, studies on artificial media for the development of the parasitoids have been ongoing for many years. Some successes were obtained, mainly with artificial media containing insect extracts such as pupal hemolymph from Lepidoptera.
- ✓ To define new artificial media devoid of insect components or improve the performances of existing ones, a better knowledge of parasitoid nutrition would be useful
- ✓ *Trichogramma* research accelerated the development of “industrial entomology.”
- ✓ Before the USSR ended, about 32 million hectares of agricultural and forest land were treated with *Trichogramma* annually.
- ✓ Daily, 4-5 million *Trichogramma* were produced in eggs of *Sitotroga cerealella*.

- ✓ Currently, 15 million ha are treated in more than 40 countries.
- ✓ *Trichogramma* spp. parasitize more than 400 harmful insect species.

Artificial Diet and Automated *In Vitro* Rearing of *Trichogramma*

- ✓ The Chinese first developed *in vitro* rearing of *Trichogramma* for commercial production.
- ✓ They used oligidic diets containing 27-50% silkworm haemolymph plus other ingredients
- ✓ They reared *T. dendrolimi*, *T. chilonis*, *T. cacoeciae*, *T. evanescens*, *T. ostrinae*, and *T. japonicum*.
- ✓ Biological Control units of USDA, ARS at Mississippi and Texas developed *in vitro* rearing of *T. minutum* and *T. pretiosum*.

The Diet for *Trichogramma In Vitro* Rearing

Components	Percentage
7% Yeast Extract solution	10.0
Free Amine III	5.0
10% suspension of nonfat dry milk	15.0
Chicken egg yolk	25.0
Chicken embryo extract	15.0
<i>Manduca sexta</i> egg liquid	30.0

Mass Production of Artificial Host Egg Cards

A computer controlled machine automatically completes all five egg production processes:

- ✓ Setting-up the synthetic membrane,
- ✓ Forming the “egg shells,”

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- ✓ Injecting the artificial medium into the shells,
- ✓ Sealing the double-layered membrane, and
- ✓ Separating the egg cards.
- ✓ The production capacity of the machine is 1,200 egg-cards hour⁻¹, which can be used to produce 6-7 x 10⁶ *Trichogramma*.
- ✓ About 5x10⁶ *Trichogramma* can be reared on one liter of the oligidic diet

Future Advancements in Artificial Diets for Mass Rearing *Trichogramma*

- ✓ The current diet is impractical because it requires liquid from *Manduca sexta* eggs.
- ✓ A high percentage of larvae reared *in vitro* are deformed.
- ✓ Larvae feed principally on solid, highly concentrated foods so their diet should be semi-solid, not liquid.
- ✓ Improvements in artificial diets can be made by studying the feeding behavior of *Trichogramma* larvae.
- ✓ Artificial diets for mass rearing high quality *Trichogramma* will enable development of automated mass rearing systems.

Impact of Climate Change on Agriculture

R. Amulya, Manmeet Kaur and R. K. Verma

Introduction

Climate change is increasingly recognized as one of the most significant challenges facing agriculture globally. As temperatures rise, weather patterns shift, and extreme events like droughts, floods, and storms become more frequent and intense, agriculture is experiencing profound impacts. The agricultural sector, which is heavily dependent on stable climatic conditions, faces threats to crop yields, food security and livelihoods, especially in regions that are already vulnerable. Changes in temperature, precipitation and atmospheric CO₂ concentrations can alter growing seasons, reduce water availability and increase the prevalence of pests and diseases. These shifts not only affect the quantity and quality of food production but also exacerbate socio-economic inequalities, particularly in developing countries where agriculture forms the backbone of the economy. This issue requires urgent attention and adaptive strategies to mitigate the adverse effects of climate change on agriculture, while also fostering resilient agricultural systems that can continue to feed a growing global population.

Discussion

Changes seen in agriculture from the past 2 decades

From 2000 to 2024, agriculture has undergone significant changes due to the impacts of climate change. These changes are seen in various ways, from shifts in crop production patterns to the increasing frequency of extreme weather events. Below are some of the key observed changes in agriculture during this period:

Shifts in Crop Yields and Growing Seasons

Temperature Changes: Rising temperatures have led to altered growing seasons. In some regions, the growing season has shortened due to higher temperatures, while in others, it has lengthened, but often with unpredictable weather patterns.

Decline in Yields: In many areas, particularly in tropical and subtropical regions, crop yields have been negatively impacted by increasing temperatures and water stress. Crops like maize, wheat, and rice, which are highly sensitive to temperature, have seen reduced productivity in some regions.

Regional Shifts in Crop Production: Some crops, such as certain types of grains, have moved to higher latitudes or altitudes where temperatures were previously too low for optimal growth. Conversely,

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regions that are already hot have become less suitable for traditional crops.

Changes in Precipitation Patterns

Increased Frequency of Droughts: Prolonged dry spells and more severe droughts have become more common, particularly in areas like Sub-Saharan Africa, southern Europe, and parts of Australia. These droughts reduce water availability for irrigation, leading to crop failures and lower yields.

Heavy Rainfall and Flooding: On the flip side, many areas have experienced an increase in intense rainfall events, leading to flooding. Flooding damages crops, erodes soil, and disrupts planting cycles. This has been especially damaging to rice and other flood-prone crops.

Increased Frequency of Extreme Weather Events

Heatwaves: More frequent and intense heatwaves have stressed crops and livestock. Heat stress can damage crops directly, reduce yields, and affect livestock productivity, particularly in regions where farmers rely on rainfed agriculture.

Storms and Hurricanes: Tropical storms, hurricanes, and cyclones have intensified, causing widespread damage to crops, infrastructure, and livelihoods. Regions like the Caribbean, Southeast Asia, and the Gulf of Mexico have seen an increase in storm-related disruptions to agriculture.

Pest and Disease Dynamics

Expanded Pest Ranges: Warmer temperatures have allowed pests and diseases to expand into new areas. Insects like the fall armyworm have spread to regions where they were once uncommon, threatening maize

and other crops. Additionally, climate change affects the life cycles of pests, allowing them to breed and proliferate more rapidly.

Crop Disease: Fungal diseases, such as wheat rusts and rice blight, have also seen changes in their distribution patterns, driven by the changing climate. Warmer, wetter conditions have created more favorable environments for some pathogens.

Soil Degradation and Erosion

Drought and Heat Stress: Soil erosion and degradation have intensified due to drought and heavy rainfall events. This has been particularly problematic in regions where agriculture depends on dryland farming. The degradation of soil fertility and structure has made it harder to maintain high yields.

Loss of Soil Moisture: As the climate has become more erratic, regions have experienced loss of soil moisture due to increased evaporation, reducing the ability to sustain crops without irrigation.

Water Scarcity

Reduced Water Availability: Climate change has led to reduced availability of fresh water for irrigation in many regions. Areas that are already water-stressed, such as parts of India, the Middle East, and North Africa, are facing increasing challenges to secure enough water for agricultural production.

Changing Water Patterns: Melting glaciers, changing river flows, and altered rainfall patterns have impacted water availability for irrigation and drinking, affecting crop production in some regions.

Agricultural Migration and Livelihoods

Displacement of Farmers: Climate change-induced changes in weather patterns have made some areas less suitable for agriculture, forcing farmers to migrate to new regions in search of more fertile land and water. This has led to increased competition for land and water resources, contributing to social and economic instability in some areas.

Impacts on Livestock: In addition to crop farming, livestock farming has also been severely impacted. Changes in grazing land quality due to drought, heat stress, and water shortages have made it harder to maintain healthy livestock populations. This affects food supply chains, particularly in rural areas dependent on livestock.

Changes in Agricultural Practices

Shift to More Resilient Crops: In response to climate impacts, some farmers have started switching to more resilient or drought-tolerant crop varieties. For example, crops like drought-resistant maize, sorghum, and millet are being promoted in water-scarce regions.

Adoption of Sustainable Practices: There's been a growing shift towards sustainable agricultural practices, such as agroforestry, no-till farming, and water-efficient irrigation systems, as farmers look to adapt to changing conditions.

Impact on Fisheries

Rising Ocean Temperatures: Warmer oceans have altered marine ecosystems, affecting fish populations and the livelihoods of those dependent on fishing. This has had indirect effects on agricultural communities that rely on fish as a protein source or income.

Shifts in Fishing Grounds: As fish populations migrate due to temperature changes, local fishing industries have seen declines, which can affect food security in coastal communities.

Adaptive and mitigation practices

To address the impacts of climate change on agriculture and enhance resilience, a variety of adaptive and mitigation practices can be implemented. These practices aim to help farmers and agricultural systems cope with the changing climate while maintaining or improving food production. Here are key resilience practices that can be applied:

Climate-Resilient Crop Varieties

Drought-Resistant Crops: Developing and promoting drought-tolerant crop varieties, such as drought-resistant maize, rice, and sorghum, can help maintain yields in areas experiencing reduced rainfall or more frequent droughts.

Heat-Tolerant Crops: Breeding crops that can withstand higher temperatures, such as heat-resistant wheat and tomatoes, is another strategy for maintaining productivity in hotter climates.

Pest-Resistant Varieties: Introducing genetically modified or naturally bred crops that are resistant to pests and diseases can reduce losses due to climate-induced pest outbreaks.

Improved Water Management

Efficient Irrigation Systems: Implementing water-efficient irrigation technologies, such as drip irrigation or sprinkler systems, can optimize water use and reduce the dependence on unpredictable rainfall. This is especially crucial in water-scarce

areas.

Rainwater Harvesting: Farmers can invest in rainwater harvesting systems to collect and store water during rainy periods, ensuring a reliable water supply during dry spells.

Water Conservation Techniques: Techniques like mulching, which reduces evaporation, and soil moisture management can help conserve water and maintain adequate moisture levels in the soil.

Agroecological Practices

Agroforestry: Integrating trees into agricultural landscapes (agroforestry) helps reduce soil erosion, enhance biodiversity, and improve soil fertility. Trees also provide shade, which can protect crops from extreme heat.

Diversified Farming Systems: Growing a mix of crops (polyculture) instead of monoculture can reduce the risk of crop failure due to climate-related factors. Crop rotation and intercropping also help improve soil health and reduce the vulnerability to pests and diseases.

Cover Cropping: Planting cover crops during the off-season can help protect the soil from erosion, improve its structure, and enhance soil moisture retention.

Soil Conservation and Management

No-Till or Reduced Tillage Farming: This practice minimizes soil disturbance, which helps retain moisture, reduce erosion, and improve soil health. It also enhances carbon sequestration, mitigating climate change.

Composting and Organic Matter: Adding organic

matter to the soil, such as compost or manure, can improve soil structure, fertility, and water retention, making it more resilient to climate stress.

Terracing and Contour Farming: In hilly areas, creating terraces or following contour lines when planting can reduce soil erosion, slow down water runoff, and protect against landslides during heavy rains.

Sustainable Livestock Management

Improved Grazing Management: Rotational grazing and maintaining optimal stocking rates can prevent overgrazing, which degrades land and reduces resilience to droughts and heatwaves.

Livestock Breeding for Resilience: Breeding livestock that are better adapted to heat stress, drought, or disease can help farmers maintain productivity in the face of climate extremes.

Enhanced Animal Health Management: Vaccination and better disease control measures can prevent the spread of livestock diseases exacerbated by climate change, such as those associated with heat stress and changing pest patterns.

Climate-Smart Agriculture (CSA)

Weather Forecasting and Early Warning Systems

: Access to timely and accurate weather forecasts and early warning systems can help farmers plan their activities better and prepare for extreme events like droughts, floods, or storms.

Climate-Smart Practices: These practices combine adaptation and mitigation strategies. For example, CSA includes integrating climate-resilient crops, improving soil health, managing water efficiently,

and enhancing biodiversity to build long-term resilience.

Sustainable Pest and Disease Management

Integrated Pest Management (IPM): IPM combines biological, mechanical, and chemical control methods to minimize pesticide use, which can be particularly important as pests evolve in response to climate change.

Biological Control: Introducing natural predators or pathogens to control pest populations can help maintain ecological balance and reduce reliance on chemical pesticides, which can harm the environment and biodiversity.

Diversification of Income Sources

Non-Agricultural Activities: Encouraging farmers to diversify into other income-generating activities, such as agro-tourism, processing, or small-scale crafts, can reduce dependence on agriculture and buffer against crop failures.

Aquaculture and Fisheries: In regions with access to water bodies, aquaculture (fish farming) can be an alternative livelihood, reducing the impact of climate-related disruptions to agriculture.

Policy Support and Access to Resources

Climate Insurance: Crop insurance, especially weather-indexed insurance, can help farmers recover from losses caused by extreme weather events like droughts or floods. This can also provide a financial safety net.

Government and International Support: Governments and international organizations can provide funding for climate adaptation projects, promote

climate-resilient infrastructure, and offer training to farmers on climate-smart agricultural practices.

Farmer Education and Extension Services:

Providing farmers with the knowledge and tools to adopt resilience practices through extension services and community-based programs can accelerate adaptation.

Carbon Sequestration and Mitigation

Agroforestry and Carbon Farming: Planting trees and adopting practices that sequester carbon in soils can help mitigate the effects of climate change while improving agricultural productivity.

Greenhouse Gas Reduction: Sustainable livestock and manure management practices can reduce methane and nitrous oxide emissions, both potent greenhouse gases, contributing to broader climate change mitigation efforts.

Technology and Innovation

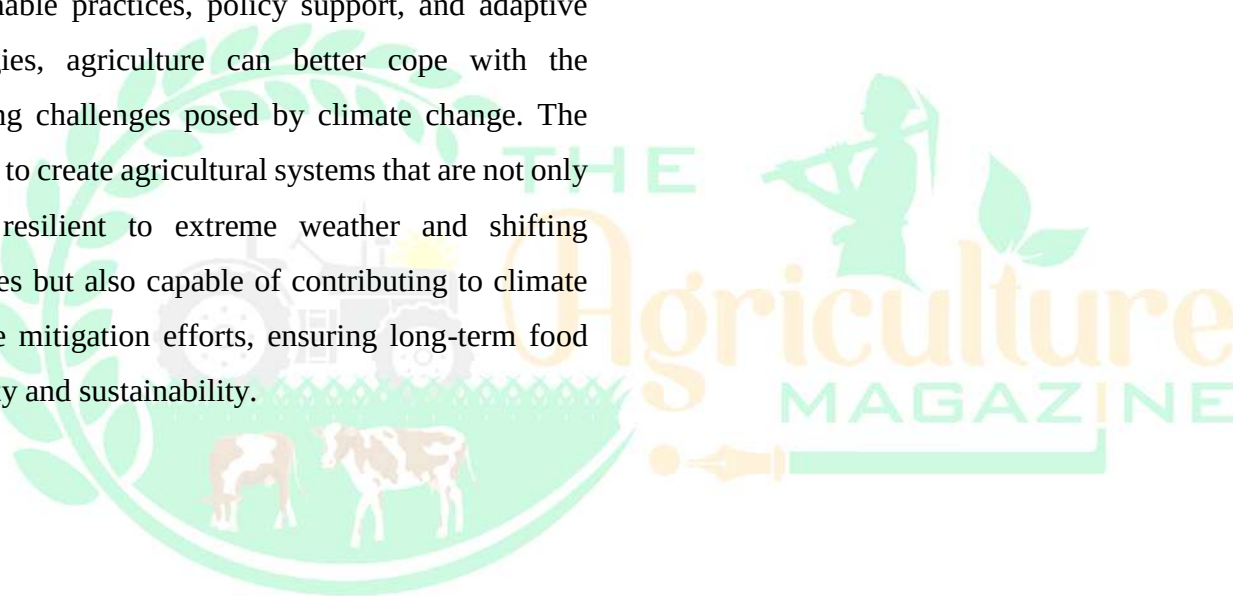
Precision Agriculture: The use of data-driven technologies, such as remote sensing, drones, and GPS, helps farmers optimize input use (water, fertilizers, pesticides) and make informed decisions, leading to more sustainable and efficient farming.

Genetic Engineering: Advanced genetic research can develop crops and livestock breeds that are more resilient to climate stresses, pests, and diseases, contributing to increased productivity in a changing climate.

Conclusion

From the past 2 decades, climate change has led to increasingly unpredictable weather patterns, reducing agricultural productivity in certain regions

while altering the viability of farming in others. This has created both challenges and opportunities, urging the adoption of adaptive agricultural practices to safeguard global food security in the face of a rapidly changing climate. As climate change continues to progress, these changes are expected to intensify, making it critical to develop strategies for climate-resilient agriculture. Building resilience in agriculture requires a comprehensive, multi-pronged approach. By combining technological innovation, sustainable practices, policy support, and adaptive strategies, agriculture can better cope with the growing challenges posed by climate change. The goal is to create agricultural systems that are not only more resilient to extreme weather and shifting climates but also capable of contributing to climate change mitigation efforts, ensuring long-term food security and sustainability.



Genetic Engineering for Herbicide-Tolerant Crops

Guddi Takar and Deepak Gupta

Abstract

Herbicide-tolerant (HT) crops, developed through genetic engineering, have revolutionized agriculture by enabling effective weed management, increased productivity, and reduced environmental impact. These crops use mechanisms like glyphosate and glufosinate resistance, achieved by modifying key enzymes. Benefits include improved yields, reduced tillage, and cost-effective farming, though challenges like herbicide-resistant weeds and environmental concerns persist. Advanced tools like CRISPR/Cas9 and RNAi offer precise and efficient development of HT traits, paving the way for future innovations integrating herbicide tolerance with other stress resistance traits for sustainable agriculture. The advent of genetic engineering has revolutionized modern agriculture, providing innovative solutions to enhance crop productivity and sustainability. Among these advancements, the development of herbicide-tolerant (HT) crops stands out as a milestone, enabling farmers to effectively manage weeds while minimizing crop damage.

The Science behind Herbicide Tolerance

Herbicides are chemical substances designed to eliminate or inhibit the growth of unwanted plants (weeds) that compete with crops for resources. Traditional herbicides often lack selectivity, leading to the potential damage of crops. Genetic engineering has addressed this issue by introducing specific genes into crops, conferring resistance to particular herbicides. The foundation of HT crops lies in the manipulation of metabolic pathways and enzymatic activity to ensure selectivity.

Mechanisms of Herbicide Tolerance

The two most commonly utilized herbicide tolerance systems are:

Glyphosate Tolerance: Glyphosate, a broad-spectr

um herbicide, targets the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSP S) involved in the shikimate pathway, essential for plant growth. HT crops engineered with a modified EPSPS enzyme or an alternative pathway can withstand glyphosate application, allowing weeds to be controlled without harming the crop. The genes encoding modified EPSPS enzymes often come from bacteria, such as *Agrobacterium tumefaciens*. These modifications prevent glyphosate from binding effectively to the enzyme, ensuring continued metabolic activity in the plant.

Glufosinate Tolerance: Glufosinate inhibits the enzyme glutamine synthetase, disrupting nitrogen metabolism and leading to plant death. HT crops

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expressing the bar or pat genes encode an enzyme that detoxifies glufosinate, making the crops resistant. These genes originate from the soil bacterium *Streptomyces hygroscopicus* and function by acetylating glufosinate, rendering it non-toxic.

Benefits of Herbicide-Tolerant Crops

The introduction of HT crops has brought several advantages to agricultural practices, contributing to both economic and environmental improvements.

Improved Weed Management: HT crops enable farmers to apply herbicides without damaging their primary crop, leading to more efficient weed control. Effective weed management is essential to prevent resource competition, ensuring higher yields.

Enhanced Productivity: By reducing weed competition, HT crops allow for increased nutrient, water, and sunlight availability, boosting yields. Studies have shown yield improvements of up to 20% in crops like soybeans and corn in regions with high weed pressure.

Reduction in Tillage: The use of HT crops supports no-till or conservation tillage practices, which help reduce soil erosion, improve soil health, and enhance carbon sequestration. No-till practices also save labor and fuel, reducing greenhouse gas emissions.

Cost-Effectiveness: Simplified weed management translates into lower labor and fuel costs, making farming operations more economical. A streamlined weed control process reduces the need for multiple herbicide applications, further cutting costs.

Flexibility: HT crops allow farmers to time herb-

icide applications based on the weed's growth stages, enhancing effectiveness. This flexibility in timing is particularly beneficial in regions with unpredictable weather patterns.

Environmental Benefits: Reduced reliance on mechanical weeding and fewer herbicide applications can lower the overall environmental footprint of agricultural operations. Conservation tillage associated with HT crops also helps maintain biodiversity in soil ecosystems.

Challenges and Concerns

Despite their numerous benefits, HT crops are not without challenges. These issues encompass biological, environmental and socio-economic dimensions.

Herbicide Resistance in Weeds: Continuous reliance on a single herbicide can lead to the evolution of resistant weed populations, reducing the long-term effectiveness of HT crops. "Superweeds" resistant to glyphosate have been reported in several countries, necessitating integrated weed management strategies.

Environmental Impacts: Increased herbicide usage can lead to runoff, affecting non-target organisms and ecosystems. Aquatic ecosystems are particularly vulnerable to herbicide contamination, which can disrupt food webs and water quality.

Biodiversity Loss: Over-reliance on HT crops may contribute to the decline in weed species diversity, impacting food chains. Beneficial insects, birds, and other organisms that depend on diverse weed populations may face habitat loss.

Regulatory and Social Acceptance: Public concerns over genetically modified organisms (GMOs) and stringent regulatory frameworks can hinder the adoption of HT crops. Misinformation and lack of awareness about the safety and benefits of GMOs often exacerbate resistance among consumers and policymakers.

Monoculture Practices: The adoption of HT crops often aligns with large-scale monoculture farming, which can increase vulnerability to pests and diseases. Monocultures also exacerbate soil nutrient depletion and reduce agricultural resilience to climate change.

Future Directions

As the agricultural sector faces increasing challenges, the future of HT crops lies in innovation and integration.

Stacked Traits: Combining herbicide tolerance with other traits like pest resistance, drought tolerance, and nitrogen use efficiency can offer holistic solutions to agricultural challenges. Stacked traits allow farmers to address multiple constraints simultaneously, improving resilience and sustainability.

Integrated Weed Management: A combination of HT crops, crop rotation, mechanical weeding, and diverse herbicide use can mitigate resistance development. Integrated approaches reduce the risk of herbicide over-reliance and promote long-term agricultural sustainability.

Biotechnology Advancements

CRISPR/Cas9 and other gene-editing techno-

logies hold the potential to develop next-generation herbicide-tolerant (HT) crops with improved specificity, efficiency, and safety. These tools enable precise modifications of plant genomes, offering several advantages over traditional genetic engineering techniques. Unlike transgenic approaches that introduce foreign DNA into the genome, CRISPR/Cas9 and similar methods make targeted edits, such as altering a single nucleotide or deleting small segments of DNA, which can lead to herbicide tolerance without triggering extensive regulatory scrutiny in some jurisdictions.

Different Types of Genetic Engineering Tools Used in Herbicide Resistance

CRISPR/Cas Systems: The CRISPR/Cas family, particularly CRISPR/Cas9 and CRISPR/Cas12, is widely used for developing herbicide-resistant crops. These tools enable:

Gene Knockouts: Disrupting genes that make plants susceptible to herbicides.

Base Editing: Precise changes to nucleotides to create tolerance.

Prime Editing: Introducing more complex modifications without causing DNA breaks. Example: Altering the EPSPS enzyme to resist glyphosate.

RNA Interference (RNAi): RNAi technology involves silencing specific genes associated with herbicide susceptibility. Double-stranded RNA molecules are introduced to target and degrade messenger RNA (mRNA), effectively turning off the gene. Example: Silencing of genes related to the detoxification pathway of herbicides.

Zinc Finger Nucleases (ZFNs): ZFNs are engineered proteins that bind to specific DNA sequences and create double-stranded breaks. These breaks are repaired by the plant's natural mechanisms, leading to mutations that can confer herbicide resistance. Example: Modifying genes in maize to resist ALS-inhibiting herbicides.

Transcription Activator-Like Effector Nucleases (TALENs): TALENs function similarly to ZFNs but are easier to design and more specific. They are used to precisely modify herbicide target genes, enhancing crop resistance. Example: Editing genes in rice for resistance to bispyribac-sodium.

Agrobacterium-Mediated Transformation: This classic method involves using the bacterium *Agrobacterium tumefaciens* to insert herbicide-resistance genes into the plant genome. This approach is often used for transgenic crops. Example: Introducing bar or pat genes for glufosinate resistance.

Biolistic (Gene Gun) Method: In this technique, DNA-coated particles are physically shot into plant cells to introduce herbicide-resistance genes. This method is useful for crops less amenable to *Agrobacterium* transformation. Example: Developing glyphosate-resistant cotton and maize.

Mutagenesis: Chemical or physical mutagens induce random mutations, some of which confer herbicide resistance. Modern techniques like Targeting Induced Local Lesions in Genomes (TILLING) combine mutagenesis with high-throughput screening for desired traits. Example: Identifying mutations

in ALS or EPSPS genes for herbicide resistance.

Advantages of Gene Editing for Herbicide Tolerance

Precision: Gene-editing technologies allow scientists to target specific genes responsible for herbicide sensitivity and modify them without affecting other parts of the genome, reducing unintended consequences.

Speed: The streamlined nature of gene editing accelerates the development of HT crops compared to traditional breeding or transgenic approaches.

Reduced Regulatory Hurdles: Since gene-edited crops often do not contain foreign DNA, they are perceived as “non-GMO” in several regulatory systems, making them easier to commercialize and more acceptable to consumers.

Broader Applicability: Gene editing can be applied to a wide range of crops, including those with complex genomes, enabling the development of HT traits in minor or specialty crops such as vegetables, fruits, and pulses.

Recent Developments

Modified EPSPS Enzymes: Researchers have used CRISPR/Cas9 to engineer variants of the EPSPS enzyme with increased resistance to glyphosate. These modifications improve the efficacy of herbicide tolerance while minimizing yield penalties.

Regulatory Element Modulation: By editing regulatory regions of key genes, scientists have fine-tuned the expression of herbicide tolerance traits to optimize plant performance under varying environmental conditions.

Multiplexed Editing: Recent advances enable the simultaneous editing of multiple genes, allowing the combination of herbicide tolerance with other beneficial traits such as drought resistance or pest tolerance.

Conclusion

Herbicide-tolerant crops have become a cornerstone of modern agriculture, offering effective weed management, enhanced productivity, and environmental benefits. While challenges such as herbicide resistance in weeds and environmental concerns remain, advancements in genetic engineering and gene-editing technologies like CRISPR/Cas9 provide innovative solutions to address these issues. The integration of HT traits with other beneficial characteristics, such as pest resistance and drought tolerance, holds promise for sustainable agricultural practices. As the demand for efficient and resilient farming systems grows, the continued development and responsible use of HT crops will play a critical role in ensuring global food security and environmental sustainability.

Enhancing Crop Yield through Genetic Modification

Minakshi Nehra, Priyanka, Nitin Doda and Deepak Gupta

Abstract

Genetic modification (GM) offers innovative solutions to enhance crop yields and address global food security challenges. By introducing traits like increased productivity, pest resistance, and tolerance to environmental stresses, GM technologies such as CRISPR/Cas9 and Marker-Assisted Breeding enable precise genetic improvements. Strategies include optimizing photosynthesis, regulating growth hormones, and improving crop resistance to pests, diseases, and abiotic stresses. Additionally, GM facilitates biofortification to combat nutritional deficiencies. However, challenges such as gene silencing, regulatory hurdles, and socio-economic barriers remain. Overcoming these issues is crucial for the widespread adoption of GM technologies to ensure sustainable agricultural growth. The escalating demand for food driven by rapid population growth presents a formidable challenge for global agriculture. Traditional farming practices and conventional breeding methods, though effective to a degree, are insufficient to meet this growing need sustainably. Genetic modification (GM) has emerged as a transformative approach in crop science, offering innovative solutions to enhance crop yields while addressing environmental and economic constraints. Genetic modification involves altering an organism's DNA to introduce desirable traits such as increased yield potential, resistance to pests and diseases, tolerance to abiotic stresses, and improved nutritional content. Since the introduction of the first GM crops in the mid-1990s, the technology has evolved significantly, enabling scientists to develop more precise and effective modifications.

What is Genetic Modification?

Genetic modification refers to the process of manipulating an organism's genetic material to introduce, enhance, or suppress specific traits. This process employs modern biotechnological tools, including recombinant DNA technology, CRISPR/Cas9 genome editing, and Agrobacterium-mediated transformation. These methods enable precise alterations at the genetic level, offering immense

potential for crop improvement and agricultural advancements. Transgenic crops are plants that contain genes from different species, enabling them to exhibit novel traits such as pest resistance or drought tolerance. Gene editing techniques, such as CRISPR/Cas9, facilitate targeted modifications within an organism's genome without necessarily introducing foreign DNA, allowing for rapid and precise genetic improvements.

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Marker-Assisted Breeding (MAB) integrates genetic markers with traditional breeding techniques, enhancing the precision and efficiency of selecting desirable traits in crop improvement programs.

Major Approaches in Genetic Modification for Yield Improvement

Introduction of Yield-Enhancing Genes

One of the primary goals of genetic modification is to boost crop yields by optimizing physiological and metabolic processes.

Photosynthesis Optimization: Improving photosynthetic efficiency is a critical target for yield enhancement. For instance, introducing genes involved in the C₄ photosynthetic pathway into C₃ crops like rice has shown promise in increasing carbon fixation and biomass production. By engineering the expression of enzymes such as phosphoenolpyruvate carboxylase (PEPC) and pyruvate orthophosphate dikinase (PPDK), researchers aim to mimic the high efficiency of C₄ plants like maize.

Hormonal Regulation: Growth hormones like gibberellins (GA) and auxins play pivotal roles in plant development. By manipulating genes involved in hormone biosynthesis, signaling, or degradation, plants can be engineered to exhibit enhanced growth, reduced lodging, and improved yield. For example, downregulation of GA biosynthesis genes can produce semi-dwarf varieties with higher resistance to lodging.

Resistance to Biotic Stresses

Biotic stress factors such as pests and

diseases significantly impact crop yields. Genetic modification offers precise solutions to enhance plant resistance.

Pest Resistance: The incorporation of *Bacillus thuringiensis* (Bt) genes has revolutionized pest management. Bt crops produce insecticidal proteins that target specific pests, such as bollworms in cotton and stem borers in maize, without harming non-target organisms. These modifications reduce the need for chemical pesticides, making farming more sustainable.

Disease Resistance: Genetic engineering for disease resistance often involves introducing genes for viral coat proteins, which provide plants with immunity to specific viruses. For bacterial and fungal pathogens, antimicrobial peptides and resistance (R) genes have been deployed. For example, introducing the *Xa21* gene in rice confers resistance to bacterial blight caused by *Xanthomonas oryzae*.

Tolerance to Abiotic Stresses

Abiotic stresses like drought, salinity, and temperature extremes are major challenges to sustainable crop production. Genetic modification provides tools to develop crops that can thrive under adverse environmental conditions.

Drought and Heat Tolerance: Genes such as *DREB* (Dehydration Responsive Element Binding) transcription factors regulate downstream stress-responsive genes, enhancing a plant's ability to withstand dehydration and high temperatures. This approach has been successfully tested in crops like wheat and rice.

Salinity Tolerance: Salt stress management involves the regulation of ion transporters and osmoprotectants. For example, the *NHX1* gene encodes a vacuolar Na^+/H^+ antiporter that helps sequester excess sodium ions into vacuoles, reducing their toxic effects and maintaining cellular ion homeostasis.

Enhanced Nutritional Content

Genetic modification also addresses nutritional deficiencies by biofortifying staple crops with essential nutrients.

Fortification of Staple Crops: Golden Rice is a well-known example, where genes from maize and bacteria were introduced to biosynthesize beta-carotene, a precursor to vitamin A, in rice endosperm. This innovation aims to combat vitamin A deficiency, a major cause of blindness and mortality in developing countries. Similarly, efforts are underway to enhance the iron, zinc, and folate content in crops like wheat and beans through genetic engineering.

Scientific Basis of Yield Enhancement through Genetic Modification

Role of Genetic Engineering in Yield Potential:

Genetic engineering enables the introduction of traits that have a direct or indirect influence on yield potential. By targeting critical physiological processes like photosynthesis, genetic modifications enhance a plant's capacity to convert sunlight into biomass efficiently. One area of focus is the Rubisco enzyme, a key player in carbon fixation during photosynthesis. Rubisco has inherent inefficiencies,

such as a tendency to fix oxygen instead of carbon dioxide, leading to photorespiration and energy loss. Engineering plants with improved Rubisco efficiency or introducing bypass pathways to reduce photorespiration can significantly boost photosynthetic productivity. Additionally, modifying light-harvesting complexes to optimize light use under variable environmental conditions is a promising strategy to increase yield potential.

Synergistic Effects of Gene Networks: Yield is a complex trait governed by the interplay of multiple genes. Genetic modification provides the tools to fine-tune these gene networks, achieving synergistic effects that maximize productivity. For instance, manipulating the source-sink relationship where the “source” refers to photosynthetic organs (leaves) and the “sink” refers to storage organs (seeds, fruits) is critical. By enhancing the transport and partitioning of carbohydrates from the source to the sink, genetic engineering can increase the size and weight of grains or fruits. For example, overexpression of *SWEET* genes, which encode sugar transporters, has been shown to improve seed filling and yield in crops like rice. Similarly, modifying hormone pathways to balance growth and resource allocation can lead to improved overall productivity.

Harnessing Epigenetics for Yield Improvement:

Epigenetic modifications regulate gene expression without altering the underlying DNA sequence, providing an additional layer of control over plant traits. DNA methylation, histone acetylation, and small RNA-mediated pathways can influence how

plants respond to environmental cues and stressors. By harnessing these epigenetic mechanisms, researchers have developed crops with enhanced resilience to abiotic and biotic stresses, which indirectly boosts yield. For example, stress-induced epigenetic changes can be stabilized and passed on to subsequent generations, resulting in crops better adapted to challenging environments. Additionally, epigenetic editing tools, such as CRISPR-dCas9 systems fused with epigenetic modulators, allow for precise regulation of target genes, offering novel opportunities to improve traits like flowering time, biomass accumulation, and stress tolerance.

These scientific advancements underline the multifaceted approaches employed in genetic modification to improve yield potential, offering sustainable solutions to meet the growing global demand for food.

Challenges in Genetic Modification for Yield Enhancement

Scientific and Technical Challenges

Despite the significant advancements in genetic modification, several scientific and technical hurdles remain.

Gene Silencing: Unintended suppression of target genes often occurs due to complex interactions within the genome. This phenomenon can negate the expected benefits of genetic modification and complicates the development of stable, high-performing GM crops.

Off-Target Effects: Precision tools like CRISPR/Cas9, while revolutionary, can sometimes edit unint-

ended regions of the genome. These off-target modifications may result in undesirable traits or reduced plant fitness, posing challenges for ensuring accuracy and safety.

Polygenic Traits: Yield traits are typically polygenic, involving multiple genes that interact in intricate ways. Modifying such traits is challenging, as it requires a comprehensive understanding of the genetic networks involved and the ability to coordinate changes across multiple loci.

Regulatory and Ethical Issues

The introduction of genetically modified crops is fraught with regulatory and ethical challenges.

Biosafety Concerns: There are apprehensions about the potential risks GM crops pose to non-target organisms and ecosystems, such as unintended effects on pollinators or the emergence of resistant pests.

Public Perception: Public resistance to GM crops often stems from misinformation and ethical debates about tampering with nature. This resistance hampers widespread adoption, despite evidence of safety and benefits.

Regulatory Hurdles: The approval process for GM crops is lengthy, expensive, and varies across countries. Strict regulations can delay the commercialization of beneficial technologies, particularly in regions with stringent biosafety protocols.

Socio-Economic Barriers

Socio-economic factors also play a critical role in the adoption and success of GM technologies.

Access to Technology: Low-income regions often lack the resources and infrastructure to adopt GM technologies, perpetuating disparities in agricultural productivity and food security.

Cost of Development: Developing genetically modified crops requires significant investment in research, development, and regulatory approvals. These costs can be prohibitive for small-scale enterprises and public sector institutions, limiting innovation.

Market Dynamics: Trade restrictions and labeling requirements for GM products in certain countries pose challenges for international trade. Farmers may be reluctant to adopt GM crops if export opportunities are constrained.

Addressing these challenges requires a multidisciplinary approach, including advances in genetic tools, transparent regulatory frameworks, effective communication strategies to engage the public, and initiatives to make GM technologies accessible and affordable for all.

Conclusion

Genetic modification holds immense potential for enhancing crop yields and addressing the pressing challenges of global food security. By enabling precise genetic improvements, GM technologies can optimize critical traits such as photosynthesis efficiency, pest resistance, drought tolerance and nutritional content, thereby contributing to more sustainable and resilient agricultural systems. However, the full potential of genetic modification is hindered by scientific, regulatory

and socio-economic challenges, including gene silencing, off-target effects, and public resistance. Overcoming these obstacles through continued research, transparent regulatory frameworks, and equitable access to technology is essential for realizing the benefits of GM crops. Ultimately, genetic modification, when integrated with other agricultural innovations, offers a promising path toward meeting the increasing global demand for food while ensuring environmental sustainability.

The Need of the Hour: Climate Smart Agriculture

Arham Tater, Prabhakar Prasad Barnwal and Subhajeet Sarkar

Abstract

Climate Smart Agriculture (CSA) is an innovative approach to sustainable farming that integrates climate change adaptation, mitigation, and food security. As the agricultural sector is highly dependent on natural climatic conditions, it therefore encounters more serious challenges due to prevailing erratic weather patterns. Under current scenario of soil degradation, water scarcity and a growing global population, CSA provide a key strategy to improve productivity, build resilience, and reduce greenhouse gas emissions. The principles of CSA broadly revolve around increasing farm productivity and profitability without posing a burden on the environment in the context of changing climate. It can be achieved by adopting agroforestry, crop diversification, shifting towards conservation agriculture practices and need based efficient application of farm input.

Introduction

Agriculture is at the intersection of two major global challenges: climate change and food security. Climate change, driven by human activities such as deforestation, agriculture, and the burning of fossil fuels, is causing shifts in weather patterns, rising temperatures, and increasing frequency of extreme events such as droughts and floods. These changes pose a significant threat to food production, particularly in vulnerable regions that are heavily dependent on rain-fed agriculture. To tackle these issues, the concept of Climate Smart Agriculture (CSA) has gained prominence. CSA aims to increase agricultural productivity in the face of climate change, enhance resilience to climate-related shocks, and reduce the carbon footprint of agricultural practices. By promoting sustainable practices, CSA ensures that the future of agriculture is both product-

ive and environmentally responsible.

Principles of Climate Smart Agriculture

Climate Smart Agriculture is built upon three core pillars:

Increasing Agricultural Productivity and Income

: CSA focuses on practices and technologies that optimize the use of natural resources, enhance yields, and improve farmers' livelihoods. This is critical for ensuring food security, especially as the global population continues to rise.

Enhancing Adaptation to Climate Change: CSA encourages farmers to adopt strategies that allow them to cope with and mitigate the impacts of climate change. These include improving water use efficiency, diversifying crops, and building soil health.

Mitigating Greenhouse Gas Emissions: CSA aims to reduce the environmental impact of agriculture by

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lowering greenhouse gas emissions. This is achieved through practices such as agroforestry, conservation tillage, and the use of cover crops, which sequester carbon in the soil and reduce emissions.

Key CSA Practices and Technologies

Agroforestry: This practice involves the integration of trees and shrubs into agricultural landscapes, providing benefits such as improved soil fertility, carbon sequestration, and biodiversity enhancement. Trees also help protect crops from wind and water erosion, while offering additional income sources through timber or fruit production.

Conservation Agriculture: Conservation tillage, crop rotation, and the use of cover crops are fundamental practices in conservation agriculture. These methods minimize soil disturbance, improve soil structure, and enhance water retention, all of which increase resilience to climate variability.

Precision Agriculture: Technologies such as remote sensing, GPS, and drones enable farmers to monitor crop health, soil conditions, and weather patterns in real-time. This helps optimize resource use, reducing waste and enhancing productivity, while also minimizing environmental impact.

Water Management Techniques: Given the increasing unpredictability of rainfall, efficient water management is a cornerstone of CSA. Techniques such as rainwater harvesting, drip irrigation, and the use of drought-resistant crops (like millets) can improve water use efficiency and increase resilience to water stress.

Diversification and Crop Selection: Climate-smart

farmers are encouraged to diversify their crops to reduce dependency on a single crop, thus mitigating the risk of crop failure due to unpredictable weather events. Additionally, selecting drought-tolerant or flood-resistant varieties can help maintain yields in adverse conditions.

Challenges to Implementing CSA

Despite its potential, the widespread adoption of CSA faces several challenges:

Limited Access to Resources: Smallholder farmers, particularly in developing countries, often lack access to the necessary financial resources, technology, and knowledge to implement CSA practices. Without access to credit or affordable inputs, many farmers remain locked into traditional, climate-vulnerable practices.

Knowledge Gaps and Training: The success of CSA hinges on farmers' ability to understand and apply new practices. There is often a lack of training and extension services to educate farmers about CSA techniques. Furthermore, information on the most effective climate-smart practices for specific regions may be scarce or inaccessible.

Policy and Institutional Barriers: In many countries, existing agricultural policies may not prioritize climate adaptation or sustainable practices. Lack of supportive policies, financial incentives, and market access for climate-smart products can hinder CSA adoption.

Climate Uncertainty: The unpredictability of climate change itself presents a major challenge. While CSA aims to improve resilience, the speed and

scale of climate change can still outpace efforts to adapt.

Conclusion

Climate Smart Agriculture is a transformative approach that holds significant promise for addressing the intertwined challenges of climate change and food security. By focusing on improving productivity, enhancing resilience, and reducing emissions, CSA provides a pathway to sustainable farming that benefits farmers, the environment, and society as a whole. However, achieving the widespread adoption of CSA requires overcoming financial, knowledge, and policy barriers, as well as fostering greater cooperation between governments, the private sector, and civil society. As the climate crisis continues to unfold, scaling CSA practices will be essential in ensuring that agriculture can adapt to future climate conditions while securing food for a growing global population. Ultimately, CSA offers a holistic framework that aligns agricultural development with environmental sustainability, enabling farmers to thrive in an increasingly unpredictable world.

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The Impact of Climate Change on Declining Apple Production in Himachal Pradesh

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Abstract

In terms of both production and land, Himachal Pradesh is the primary apple-producing region. In districts like Lahul, Spiti, and Kinnaur, however, apple agriculture is shifting towards higher elevations as a result of the effects of climate change. Crop improvement, soil conditions, and climate fluctuation are some of the reasons this change. Climate change is the most difficult to control of all the elements that lower production. Climate change is starting to influence agricultural productivity in high hill regions, which may ultimately affect the food security of the local population. These changes include erratic precipitation, rising temperatures, and fewer days with freezing temperatures.

Introduction

The northern Indian state of Himachal Pradesh is known as the “Apple State” because of its vast apple orchards. In Himachal Pradesh, apple cultivation accounts for about four-fifths of the state's total fruit production and nearly half of the entire land planted to fruit crops. This has a big effect on the state's economy and society, giving many individuals both inside and outside the state direct and indirect job opportunities. In terms of both production and acreage, the top producing districts are Shimla and Kullu. Nevertheless, the current situation in the area poses significant difficulties because of the effects of climate change, which is affecting apple output. Recessing snowfall in the Himalayas, retreating glaciers, and the northward migration of the temperate fruit belt are all signs of

global warming in Himachal Pradesh. These changes have caused the *rabi* season to shift and shorten, changed rainfall patterns, and negatively impacted apple yield. Apple growers are being forced to quickly adjust to these changing conditions by shifting their production methods from lower-lying regions to higher elevations due to rising temperatures and changing weather patterns. This essay explores the resulting paradigm shift toward higher-elevation places while critically examining the effects of climate change on Himachal Pradesh's declining apple crop.

Changing Climate Patterns: There have been noticeable changes in Himachal Pradesh's climate patterns since the onset of climate change. This area is currently seeing a significant increase in temperatures, changes in precipitation patterns, and

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an increased frequency of severe weather events, such as hailstorms and unexpected downpour. As a result, the delicate balance necessary for successful apple production in lower elevations has been upset, which presents serious problems for the farming methods used in these areas

Shifting Temperature Patterns: Apple cultivation in Himachal Pradesh has been directly impacted by the phenomenon of climate change, which has shown itself as noticeable changes in temperature patterns. Significantly, the area has experienced a noticeable change to milder winters, with less hours of chilling needed for the best bud formation and fruit set. On the other hand, summer temperatures have been higher, which could lead to hazards like heat stress, sunburn, and decreased apple tree photosynthetic efficiency. The region's apple orchards' ability to grow sustainably and produce fruit is severely hampered by these weather fluctuations.

Erratic Rainfall Patterns: The production of apples is significantly hampered by changes in rainfall patterns. The Indian summer monsoon is a major source of irrigation for Himachal Pradesh, although the distribution and timing of rainfall have grown more erratic. Inadequate pollination, a higher risk of disease, and fruit damage might result from premature rainfall during the flowering and fruiting periods, which will ultimately reduce apple production.

Altered Snowfall and Winter Conditions: Because snow provides vital services like soil moisture provision and insulation during the winter, it plays a

crucial role in the ecological dynamics of apple orchards. Snowfall is essential to maintaining ideal orchard conditions because it helps apple trees enter their dormant season and protects against damaging frost events. However, the onset of climate change has resulted in changes to snowfall patterns in the Himachal Pradesh region. The consequences of less snowfall or delayed melting include disrupting apple trees' natural development cycle, which increases their vulnerability to frost-related damage and reduces overall arboreal vigor.

Impact on Apple Production

The production of apples is a major contributor to the economy of Himachal Pradesh, and the industry faces substantial problems due to climate change. The region's economy as a whole is impacted by how climate change affects apple production. Reduced apple yields are one of the main effects of climate change. Reduced apple crop yield and quality can result from changes in temperature, precipitation patterns, and the prevalence of pests and diseases. This has a direct impact on apple growers' earnings and lowers their total profitability. The supply chain, which includes the apple processing and packaging sectors, is also impacted by lower yields, which lowers economic output and job possibilities. Additionally, Himachal Pradesh's apple sector depends on export sales to make money. Himachali apples' competitiveness in the global market may be weakened by the effects of climate change, such as reduced fruit quality and variations in yield. This may lead to lower export revenues and volumes,

which would further impact the local economy.

Table 1: Apple production in Himachal Pradesh - Production (000 Tonnes) (Source: NHB)

Year	Production	Share (%)
2020-2021	481.06	21.14
2019-2020	715.25	25.41
2018-2019	368.6	15.92
2017-2018	446.57	19.19
2016-2017	468.13	20.67
2015-2016	777.13	30.83
2014-2015	625.2	29.3
2013-2014	738.72	29.58

Shifting to Higher Regions: Apple growers in Himachal Pradesh are progressively moving their operations from lower elevations to higher elevations in an effort to counteract the negative impacts of climate change. Cooler temperatures, well distributed rainfall, and less pest and disease pressure are some of the more advantageous circumstances found in higher elevations. These areas provide apple trees a better chance of thriving and producing high-quality fruit. But moving to a higher altitude has its own set of difficulties. Farmers must invest in cutting-edge farming techniques appropriate for higher elevations, build infrastructure in isolated locations, and adjust to new terrain. In order to guarantee resource sustainability and reduce adverse effects on delicate mountain ecosystems, appropriate land management techniques are also necessary.

Strategies for mitigating the effect of climate change

Location-Specific climate adopting smart horticulture: Climate Smart Horticulture (CSH) is an essential tool for achieving food security and reducing emissions while enhancing ecosystem services. It helps farmers identify and address produ-

ction challenges and find suitable technologies to improve crop yields. While climate change is a global issue, its impacts vary by region. Understanding and analyzing these effects at the local level is critical for developing effective solutions through innovation. In India, the Department of Agriculture and Cooperation (DAC) promotes the National Horticulture Mission (NHM) across 380 districts in 18 states and three Union Territories. This mission focuses on increasing farm incomes, improving livelihood security, and generating employment opportunities.

Carbon sequestration Carbon: Sequestration is generally a process of capturing and storing atmospheric carbon dioxide. There are lot of anecdotal evidence from farmers engaging in practices designed to increase soil carbon in their fields which is termed regenerative Agriculture. The worldwide approach to mitigate climate change is to reduce the emission of greenhouse gases and transform atmospheric carbon into plant biomass and soil organic matter. Through Carbon sequestration, some of the mitigation efforts are taken up to reduce the impacts of climate change.

Modelling and climate analogues: Combating climate change requires tools such as modeling and climate analogs. These tools help farmers identify the crop traits and varieties that will be needed in specific locations. They also assist breeders and agronomists in adapting to climate change. Climate modeling generates future climatic variables, including maximum and minimum temperatures, the

length of the growing season, evapotranspiration, and the onset of the growing season, based on historical weather data. These models are a valuable resource for horticulture as they help describe the relationships between plant behavior and temperature.

Crop Models for Managing Horticulture:

Effective crop management can significantly minimize yield loss. There is an urgent need for a Decision Support System (DSS) to enhance agricultural management at both the farm and regional levels, promoting sustainable and climate-resilient crop production. Farmers require answers to many questions regarding crop production and marketing; therefore, crop models are extremely beneficial not only in addressing climate change issues but also in improving crop management practices.

GIS and remote sensing: Geographic Information Systems (GIS) and remote sensing are essential tools for mitigating climate change and helping farmers assess the health of their crops. These advanced technologies, including GPS, aid in monitoring climate variations, topography, soil, and land use. They can forecast crop production, assess damage, monitor progress, and identify pests and diseases. By integrating these tools, farmers and governments gain critical information for effective mitigation strategies and prompt action, ultimately supporting agricultural sustainability.

Breeding strategies: New cultivars can be developed to tolerate high temperatures, resist pests and

diseases, and maintain good yields under stress. These advancements will help mitigate climate change effects, as seen with successful low-chill varieties. Apple scab in the mid-hills and pest attacks in the low-hills indicate climate change influences on apple farming. This has led to a shift in land use toward coarse grains, seasonal vegetables, and other crops. To address these challenges, focusing on low-chilling cultivars, high-temperature tolerance, pest resistance, and high-tech horticulture, along with careful land management, will be crucial.

Developing Climate-Resilient apple genotypes:

Development of apple cultivars that are tolerant to high temperatures, drought tolerance and water-use efficiency, high tolerance to saline soils and irrigation water.

The efforts should also be made to check out strategy for Climate-Proofing through Genomics and Biotechnology.

Low chilling cultivar: Anna, Mayan, Tamma, Vered, Tropical Beauty, Parlin's Beauty, Schlomit, Michel, Neomi.

Drought tolerant (rootstocks): M. 7, M. 9 and M. 111

Winter hardiness: Antovnovka, McIntosh, Wealthy and Beacon.

Powdery mildew resistance: White Angle, Malus x robusta, David x robusta, David, M x zumi, Calocarpa.

Late blooming: Konig zuur, Gros bois, Rome beauty, Frost proof, Northern Spy, Spate bluhender.

Early maturity: Geneva Early, Quinte, Vista Bella.

Late maturing: Rome Beauty, Braeburn, Granny Smith.

Collar rot: Northern Spy, Malling Merton series

Apple rust

Homozygous resistance: Arkansas Black, McIntosh

Homozygous resistance: Delicious, Winesap, Wolf River

Fully susceptible: Jonathan and Rome Beauty

Government Initiatives and Support

The Himachal Pradesh government has taken several steps to facilitate the move to higher locations after realizing the difficulties experienced by apple growers. These consist of monetary aid, subsidies for the construction of infrastructure, the supply of better apple cultivars, and educational initiatives to improve farmers' knowledge of sustainable farming methods. To create apple types that are adaptable to shifting climate circumstances, the government is also funding research and development. By finding apple cultivars that are more resilient to heat, drought, and pests, this study seeks to lower the risks involved in moving production to higher elevations.

Conclusion

Climate change significantly impacts apple production in Himachal Pradesh, forcing farmers to shift cultivation to higher altitudes. While this change poses challenges, it also opens up opportunities for exploring resilient apple varieties and sustainable practices. Government support is essential to help ensure the long-term viability of apple farming. By working together, policymakers, researchers, and farmers can mitigate climate change

effects, safeguard growers' livelihoods, and promote the apple industry's future prosperity.

Selection for Improved Crop Quality Traits in Conventional Breeding

Punit Bhatt, Khamosh Gurjar, Prem Lata Nodal and Deepak Gupta

Abstract

Conventional breeding for improved crop quality traits plays a crucial role in enhancing the nutritional, sensory, and processing qualities of crops. This article explores the importance of quality traits such as nutritional content, flavor, texture, and storage capabilities in crops. It discusses the traditional breeding methods, including mass selection, pure line selection, pedigree selection, and backcross breeding, used to improve these traits. The challenges of genetic complexity, environmental influences, and balancing yield with quality are addressed. Success stories in biofortification and processing quality improvement are highlighted. In conventional plant breeding, the primary objective has traditionally been to enhance the yield and disease resistance of crops. However, over the years, breeding programs have increasingly focused on improving the quality of crops, considering their nutritional, sensory, and processing qualities. Quality traits such as flavor, texture, color, and nutritional content are crucial for the acceptance of agricultural products by consumers and for the economic viability of farming. With growing concerns about public health, the environment, and food security, breeding for improved crop quality has become more significant.

Importance of Crop Quality Traits

Crop quality traits can be broadly categorized into several categories, each of which plays a critical role in the overall value of a crop. These categories include:

Nutritional Quality: Nutritional quality refers to the concentration of essential nutrients such as vitamins, minerals, and antioxidants in crops. For example, the breeding of rice, maize, and wheat for higher levels of micronutrients like iron, zinc, and provitamin A (carotenoids) has gained attention in recent years, with the goal of addressing malnutrition, especially in developing countries.

Processing Quality: Processing quality is essential for crops used in food production, as it affects the ease and efficiency of processing, as well as the final product's appeal. For instance, tomato breeding has focused on traits such as fruit firmness, sugar content, and acidity levels to enhance the quality of processed tomato products like ketchup and sauces.

Sensory Quality: Sensory traits include characteristics like flavor, texture, aroma, and appearance, all of which influence consumer preferences. For instance, the sweet taste and crisp texture of certain carrot varieties have been prioritized in breeding programs to enhance consumer appeal.

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Storage and Shelf Life: Crop quality also extends to traits that influence the post-harvest life of a crop. Traits such as resistance to bruising, longer shelf life, and slower ripening are increasingly important in crops like apples, bananas, and potatoes, which are commonly stored and transported over long distances.

Conventional Breeding Methods for Improving Crop Quality Traits

The improvement of crop quality traits using conventional breeding methods typically involves the selection of superior plants based on their phenotypic traits, followed by crossbreeding and selection over several generations to stabilize desired traits. The most common methods include:

Mass Selection: Mass selection is one of the simplest and oldest methods used for improving quality traits. In mass selection, a population of plants is evaluated for desirable traits, and those with the highest expression of the traits are selected for the next generation. For instance, in wheat, farmers may select the plants with the highest protein content and replant their seeds, gradually increasing the protein concentration in the crop.

Pure Line Selection: Pure line selection is employed when a crop exhibits considerable variation within the population. By selecting and propagating individual plants with desirable quality traits, pure line selection aims to develop a uniform population with improved traits. For example, in tomatoes, pure line selection may be used to isolate varieties with consistent fruit size, color, and taste.

Pedigree Selection: Pedigree selection involves selecting plants from a particular family or lineage, ensuring that the desired quality traits are passed down through generations. This method is highly effective for enhancing traits like fruit size, color, or nutrient concentration in crops like apples, pears, and citrus fruits.

Backcross Breeding: Backcross breeding is particularly useful for introducing specific quality traits into a widely adapted variety without losing the overall productivity or resistance of the parent crop. For example, backcrossing can be used to transfer disease resistance from a wild species into a domesticated variety while preserving desirable quality traits such as flavor, texture, or color.

Challenges in Breeding for Crop Quality Traits

Breeding for quality traits in crops presents several challenges, which can complicate and lengthen the process. These challenges include:

Genetic Complexity: Many quality traits are controlled by multiple genes, often with interactions between genetic and environmental factors. This polygenic nature makes it difficult to predict the outcome of breeding programs aimed at improving quality traits. For example, improving the flavor of a fruit crop involves manipulating the levels of sugars, acids, and volatile compounds, each of which is controlled by different genes.

Environmental Influence: Quality traits are often influenced by environmental factors such as soil fertility, temperature, and water availability. As a result, the expression of quality traits may vary signi-

ificantly between different growing seasons or locations, making it challenging to select for stable, high-quality crops.

Trade-offs Between Yield and Quality: There is often a trade-off between improving yield and quality in conventional breeding. Some quality traits, such as higher sugar content or better flavor, may come at the expense of yield. For instance, certain breeding efforts to improve the sweetness of fruit may result in lower yields due to reduced plant vigor. Balancing yield and quality remains a central challenge in breeding programs.

Consumer Preferences and Market Demand: The selection of quality traits is also influenced by shifting consumer preferences and market demands. What is considered a high-quality trait in one region or country may not be valued in another. For example, while consumers in some countries prefer fruits with higher sugar content, others may prioritize lower sugar levels for health reasons.

Success Stories in Conventional Breeding for Quality Traits

Despite the challenges, there have been numerous successful breeding programs aimed at improving crop quality traits. Some notable examples include:

Golden Rice: Golden Rice is a well-known example of a crop bred for enhanced nutritional quality. Developed through conventional breeding, it has been genetically modified to produce higher levels of provitamin A (beta-carotene) in the grain, addressing vitamin A deficiency in many developing countries.

The success of Golden Rice demonstrates how traditional breeding methods can be adapted to address global health concerns.

High-Quality Tomatoes for Processing: In the tomato industry, traditional breeding has focused on improving processing traits such as fruit firmness, color, and acidity, making tomatoes more suitable for industrial uses like sauces and ketchup. These breeding efforts have led to varieties that perform better under processing conditions, leading to better quality products and higher market demand.

Biofortified Crops: Conventional breeding has also contributed to the development of biofortified crops, such as high-iron beans and zinc-rich wheat. These crops are bred to provide higher concentrations of micronutrients to combat malnutrition in populations that rely on staple foods for their daily diet.

Conclusion

Conventional breeding for improved crop quality traits remains a cornerstone of agricultural innovation, addressing both consumer preferences and global health needs. Despite challenges such as genetic complexity and environmental variability, significant progress has been made in developing crops with better nutritional content, sensory attributes, and processing qualities. Success stories like biofortified crops and high-quality tomatoes for processing demonstrate the potential of traditional breeding methods. The future of crop quality improvement will likely benefit from the integration of molecular tools with conventional techniques.

Transgenic Plants for Improved Nutritional Security

Khamosh Gurjar, Prem Lata Nodal, Punit Bhatt and Deepak Gupta

Abstract

India faces significant challenges related to food security and malnutrition, with a large portion of its population suffering from deficiencies in essential micronutrients such as vitamin A, iron, and zinc. These deficiencies lead to serious health issues, particularly among children and women. Transgenic plants, developed through genetic modification, have emerged as a promising solution to combat these micronutrient deficiencies by enhancing the nutritional profiles of staple crops. This article explores the role of transgenic plants in addressing malnutrition in India, highlighting key techniques such as recombinant DNA technology and CRISPR-Cas9, which have been employed to develop biofortified crops. Examples like Golden Rice, iron-enriched rice, and zinc-enhanced wheat are discussed, along with the potential benefits of transgenic crops in improving the nutritional quality of India's food supply. Additionally, the article covers the challenges and limitations of developing and adopting transgenic plants, including regulatory hurdles, environmental factors, and public acceptance. The future prospects for transgenic plants in India are also explored, emphasizing their role in sustainable agriculture and their integration with traditional breeding methods to create high-yielding, nutritionally enhanced crops.

The Need for Nutritionally Enhanced Crops in India

India's food security is challenged by a combination of factors, including population growth, climate change and declining agricultural productivity. A significant portion of the population relies heavily on staple foods like rice, wheat, and maize, which are often deficient in essential micronutrients. This reliance exacerbates malnutrition and its associated health issues, such as anemia, blindness, and developmental disorders, particularly in rural and economically disadvantaged areas. Conventional

breeding methods have been instrumental in improving crop yield and disease resistance. However, these methods often fall short when it comes to enhancing nutritional content due to the complex genetic architecture of nutrient traits. Genetic engineering offers a solution by enabling precise modifications to target nutritional deficiencies effectively and efficiently.

Conventional Breeding Methods for Nutritionally Enhanced Crops in India

Conventional breeding has been a cornerstone of agricultural improvement for decades,

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focusing on enhancing crop yields, disease resistance and stress tolerance. In the Indian context, where malnutrition and micronutrient deficiencies are prevalent, traditional breeding approaches have also been applied to develop nutritionally enhanced crops. While these methods are often slower compared to modern biotechnological approaches, they remain vital due to their acceptance, affordability, and sustainability.

Achievements in Conventional Breeding for Nutrition in India

High-Iron Pearl Millet: Conventional breeding has led to the development of iron-rich pearl millet varieties, addressing anemia in regions where millet is a staple food.

Protein-Enriched Wheat: Selective breeding has resulted in wheat varieties with higher protein content, catering to the nutritional needs of India's growing population.

Zinc-Enriched Rice: Conventional methods have produced rice varieties with enhanced zinc levels, essential for immune health and cognitive development.

Challenges and Limitations

While conventional breeding methods have contributed significantly to nutritional enhancement, they face several challenges:

Time-Intensive Process: Developing nutritionally enhanced crops through traditional breeding can take several years, delaying their impact.

Complex Traits: Nutritional traits are often controlled by multiple genes, making it difficult to achieve

significant improvements through conventional methods.

Environmental Interactions: The expression of nutritional traits can be influenced by environmental factors, complicating breeding efforts.

Techniques for Developing Transgenic Crops

Gene Cloning: Gene cloning is the initial and critical step in the development of transgenic crops. This process begins with identifying the specific genes responsible for desired traits, such as improved nutritional profiles. Modern genomic tools and bioinformatics are used to locate these genes in the source organism's genome. Once identified, the genes are isolated through enzymatic methods and amplified using Polymerase Chain Reaction (PCR). This ensures the availability of sufficient copies of the gene for further steps. The isolated gene is then prepared for insertion into the plant genome by adding promoter and terminator sequences, which control its expression. This precise step is crucial for ensuring that the gene functions optimally within the new host.

Recombinant DNA Technology: Recombinant DNA (rDNA) technology is central to creating transgenic crops. It involves inserting the cloned genes into a plant's genome using a vector, such as a plasmid or virus, designed to carry the gene of interest. The vector is engineered to include regulatory sequences that ensure proper gene expression in the target plant. The process of transformation follows, where the recombinant vector is introduced into the plant cells. Techniques such as Agrobacter-

ium-mediated transformation which uses a natural gene transfer mechanism of the bacterium or the gene gun method which physically introduces DNA into the cells are commonly employed. Once the gene integrates into the plant's genome, it enables the plant to express the desired traits, such as enhanced levels of vitamins, minerals, or essential amino acids. This technique is the foundation for producing transgenic plants like beta-carotene-rich rice and iron-fortified cereals.

CRISPR-Cas9: CRISPR-Cas9 is a groundbreaking genome-editing technology that allows precise and efficient modifications of a plant's DNA without introducing foreign genetic material. This method employs a guide RNA (gRNA) designed to recognize a specific DNA sequence in the plant genome. The Cas9 enzyme, guided by the RNA, creates a targeted double-strand break in the DNA. The plant's natural repair mechanisms are then harnessed to either knock out undesirable traits or introduce beneficial ones, such as increased nutrient content or resistance to environmental stresses. CRISPR-Cas9 stands out due to its high precision, reduced off-target effects, and faster turnaround time compared to traditional methods. Moreover, because it does not necessarily involve foreign DNA, CRISPR-edited crops often face fewer regulatory hurdles and are more acceptable to consumers. This technology has significant potential for creating nutritionally enhanced crops tailored to address specific deficiencies.

Examples of Transgenic Crops Developed Using Advanced Techniques

Golden Rice: Golden Rice is a notable example of a transgenic crop developed using recombinant DNA technology. It is biofortified with beta-carotene, a precursor to vitamin A, and was created to address vitamin A deficiency, which is a leading cause of preventable blindness and immune deficiencies, especially in developing countries like India. Genes from daffodil and a soil bacterium (*Pantoea ananatis*) were introduced into the rice genome, enabling it to produce beta-carotene in the rice endosperm. Golden Rice exemplifies how genetic engineering can be used to combat micronutrient deficiencies.

Iron-Rich Rice: Iron-deficiency anemia is a widespread problem in India. Genetic modification techniques, such as gene cloning and recombinant DNA technology, have been used to enhance the iron content in rice. The introduction of genes coding for iron transport and storage proteins, such as ferritin from legumes, has enabled the development of iron-rich rice varieties that can contribute to reducing anemia rates.

Zinc-Enriched Wheat: Zinc is an essential micronutrient for immune function and development, yet deficiencies are common in India. Transgenic approaches have been employed to develop zinc-enriched wheat. By introducing genes that enhance zinc uptake and storage, these wheat varieties provide a significant dietary source of zinc, aiding in alleviating deficiencies.

Lysine-Rich Corn: Corn is a staple food but is deficient in lysine, an essential amino acid. Using

CRISPR-Cas9, researchers have successfully edited the corn genome to increase lysine content. This biofortification not only improves the nutritional quality of corn-based diets but also supports better protein synthesis in populations relying heavily on maize as a primary food source.

Vitamin E-Enriched Soybean: Vitamin E is a powerful antioxidant beneficial for skin, vision, and immunity. By employing recombinant DNA techniques, genes responsible for tocopherol synthesis were enhanced in soybean, leading to higher Vitamin E levels. This development offers a nutritionally superior oil source for consumers.

Omega-3 Fatty Acid-Enriched Mustard: India's reliance on mustard oil makes it an ideal candidate for nutritional enhancement. Transgenic mustard varieties have been developed by introducing genes from algae that promote the synthesis of omega-3 fatty acids. This innovation supports cardiovascular health and provides a sustainable alternative to fish oil.

Protein-Enriched Potatoes: To combat protein malnutrition, particularly in rural India, genetic engineering techniques have been used to enhance protein levels in potatoes. For instance, the introduction of the AmA1 gene from amaranth has led to potatoes with a significantly higher protein content, addressing protein-energy malnutrition effectively.

Biofortified Millet: Millets, a staple crop in many arid regions of India, are naturally rich in nutrients but can be further enhanced through transgenic

methods. By modifying genes associated with calcium and iron storage, biofortified millet varieties have been developed to target deficiencies in these essential nutrients.

Future Prospects of Transgenic Plants for Nutritional Improvement

Biofortification of Staple Crops: Transgenic plants are being developed to enhance the nutritional quality of staple crops by increasing the levels of essential vitamins, minerals, and other nutrients. For example, Golden Rice, a transgenic variety of rice, has been engineered to produce provitamin A (beta-carotene) to combat vitamin A deficiency, which is prevalent in many developing countries. Similarly, efforts are underway to biofortify other crops like maize, wheat, and cassava with higher levels of micronutrients such as iron, zinc, and folate.

Enhanced Nutrient Availability and Absorption: Genetic modifications can increase not only the quantity of nutrients in crops but also improve their bioavailability and absorption by the human body. For instance, enhancing the iron content of rice or beans while improving the bioavailability of the iron could address iron deficiency anemia, a common health issue in low-income regions. Transgenic plants can also be designed to reduce anti-nutritional factors, such as phytates, that inhibit the absorption of minerals like zinc and iron.

Targeting Specific Nutritional Deficiencies: Genetic engineering allows for targeted nutritional improvement by focusing on specific deficiencies that are prevalent in different populations. For exam-

ple, genetically modified banana varieties are being developed with higher levels of provitamin A, iron, and other nutrients to address deficiencies in East Africa and other parts of the world. The use of CRISPR/Cas9 technology also allows for more precise modifications, enabling the development of crops with optimized nutrient profiles to suit specific regional dietary needs.

Sustainability in Agriculture: By increasing the nutritional content of crops without requiring additional land or extensive changes in farming practices, transgenic plants contribute to sustainable agriculture. Biofortified crops can help mitigate malnutrition without placing additional pressure on the environment or the food production system.

Combination with Other Breeding Techniques: Transgenic plants can be integrated with conventional breeding techniques to develop varieties that are both nutritionally enhanced and high-yielding. This combined approach can provide crops with better nutritional value, resistance to pests and diseases, and resilience to environmental stresses like drought or heat.

Conclusion

Transgenic plants offer promising solutions to address micronutrient deficiencies in India by enhancing the nutritional content of staple crops. Despite challenges such as regulatory concerns and public skepticism, they hold significant potential for improving food security and health outcomes. With continued research and integration into existing breeding practices, transgenic crops can contribute to

sustainable agricultural development in the country.

Genetic Engineering in Disease-Resistant Crop Development

Prem Lata Nodal, Punit Bhatt, Khamosh Gurjar and Deepak Gupta

Abstract

India faces significant challenges related to food security and malnutrition, with a large portion of its population suffering from deficiencies in essential micronutrients such as vitamin A, iron, and zinc. These deficiencies lead to serious health issues, particularly among children and women. Transgenic plants, developed through genetic modification, have emerged as a promising solution to combat these micronutrient deficiencies by enhancing the nutritional profiles of staple crops. This article explores the role of transgenic plants in addressing malnutrition in India, highlighting key techniques such as recombinant DNA technology and CRISPR-Cas9, which have been employed to develop biofortified crops. Examples like Golden Rice, iron-enriched rice, and zinc-enhanced wheat are discussed, along with the potential benefits of transgenic crops in improving the nutritional quality of India's food supply. Additionally, the article covers the challenges and limitations of developing and adopting transgenic plants, including regulatory hurdles, environmental factors, and public acceptance. The future prospects for transgenic plants in India are also explored, emphasizing their role in sustainable agriculture and their integration with traditional breeding methods to create high-yielding, nutritionally enhanced crops.

Techniques in Genetic Engineering for Disease Resistance

Gene Introduction: Gene introduction is one of the foundational techniques in genetic engineering for disease resistance. It involves incorporating specific genes into a plant's genome to enhance its defense mechanisms against pathogens. A key approach under this technique is Pathogen-Derived Resistance (PDR), where genes from the pathogens themselves are introduced into plants. These genes can help plants recognize and counteract the pathogen effectively. For instance, the introduction of viral

coat protein genes has proven successful in protecting crops such as papaya from the devastating Papaya Ringspot Virus (PRSV). Another important strategy involves using antimicrobial genes that encode proteins like chitinases, glucanases, and defensins. These proteins act by breaking down the cell walls of fungi and bacteria, thereby providing robust resistance to various fungal and bacterial pathogens.

CRISPR/Cas9 Genome Editing: The advent of CRISPR/Cas9 technology has revolutionized genetic engineering by enabling precise and targeted editing

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of plant genomes. This technology can be used to either knockout susceptibility genes, which are responsible for making plants vulnerable to specific diseases, or to enhance resistance genes that bolster the plant's immune system. A remarkable application of CRISPR/Cas9 is seen in the development of powdery mildew-resistant wheat. By modifying the MLO gene, scientists have successfully created wheat varieties that are less susceptible to this widespread fungal disease. The precision, efficiency, and adaptability of CRISPR/Cas9 make it a powerful tool in developing disease-resistant crops.

RNA Interference (RNAi): RNA Interference (RNAi) is a gene-silencing technology that targets specific genes involved in pathogen virulence. This technique works by introducing small RNA molecules that bind to the mRNA of target genes, preventing their translation into proteins. RNAi has been effectively utilized to protect crops against viral pathogens. For example, it has been applied to confer resistance in bananas against the Banana Bunchy Top Virus (BBTV). By silencing the genes critical for the virus's replication and spread, RNAi provides a highly specific and environmentally friendly method of disease control.

Marker-Assisted Genetic Engineering: Marker-assisted genetic engineering combines traditional breeding methods with molecular biology to enhance disease resistance in crops. Molecular markers linked to disease-resistant genes are identified and used to streamline the incorporation of these genes into elite crop varieties. This approach not only accelerates the

breeding process but also ensures that the desired traits are transferred with high precision. For example, markers associated with resistance to specific bacterial and fungal pathogens have been used to develop improved varieties of rice, wheat, and other staple crops. By integrating genetic markers with advanced engineering techniques, researchers can achieve more durable and effective resistance in crops.

Advantages of Genetic Engineering in Disease Resistance

Genetic engineering has revolutionized agriculture by offering innovative solutions for developing disease-resistant crops. The advantages of genetic engineering in disease resistance are numerous and transformative:

Enhanced Yield and Quality: By effectively reducing crop losses due to diseases, genetic engineering ensures higher productivity and better-quality produce, contributing to food security and economic growth.

Reduced Chemical Use: Disease-resistant crops minimize the need for fungicides and bactericides, lowering production costs and decreasing the environmental impact of chemical inputs.

Durable Resistance: Techniques like gene pyramiding allow the combination of multiple resistance genes, providing long-lasting protection against a wide range of pathogens.

Adaptability to Emerging Pathogens: Genetic engineering enables the rapid development of resistant crop varieties to combat new and evolving

pathogens, ensuring agricultural resilience.

Targeted and Precise Intervention: Genetic engineering facilitates precise targeting of genes associated with disease resistance, minimizing unintended effects on other plant traits and improving breeding efficiency.

Shorter Breeding Cycles: Compared to traditional breeding methods, genetic engineering significantly reduces the time needed to develop disease-resistant varieties, accelerating the delivery of improved crops to farmers.

Broader Range of Resistance: By transferring genes across species or utilizing novel genetic resources, genetic engineering provides resistance against pathogens that are challenging to control through conventional breeding.

Reduction in Post-Harvest Losses: Crops engineered for disease resistance are less likely to suffer from infections during storage and transport, reducing food waste and enhancing marketability.

Improved Environmental Sustainability: By decreasing reliance on chemical inputs, genetic engineering supports healthier ecosystems, mitigates soil and water pollution, and reduces the risk of pesticide resistance in pathogens.

Compatibility with Climate-Resilient Traits: Genetic engineering can integrate disease resistance with traits for drought, heat, or salinity tolerance, ensuring crop survival and performance under changing climatic conditions.

Enhanced Economic Returns for Farmers: Reduced crop losses, lower input costs and improved

crop quality lead to higher profitability for farmers, fostering better livelihoods.

Potential for Disease Control in Staple and Niche Crops: Genetic engineering extends its benefits to both major staple crops like rice and wheat and niche crops like bananas and chickpeas, vital for diverse agricultural systems worldwide.

Challenges and Future Directions in Genetic Engineering for Disease Resistance

Despite its potential, genetic engineering for disease resistance faces several challenges that require attention to fully realize its benefits. The future of this technology also lies in addressing these challenges and advancing research and development.

Challenges

Regulatory Hurdles: Genetically engineered crops are subject to stringent regulatory frameworks to ensure their safety for humans, animals, and the environment. The complex and time-consuming approval processes can delay commercialization and increase costs, limiting the availability of these crops to farmers.

Public Perception: A significant challenge is the widespread misinformation and skepticism surrounding genetically modified organisms (GMOs). Concerns about safety, ethics, and environmental impact reduce acceptance among consumers, policymakers, and even farmers, creating barriers to adoption.

Pathogen Evolution: Pathogens have the ability to evolve and adapt to resistance mechanisms introduced through genetic engineering. This phenomenon

can render resistance genes ineffective over time, necessitating ongoing research to stay ahead of evolving virulence.

Integration with Conventional Breeding: While genetic engineering offers precision and speed, integrating it with traditional breeding approaches is vital for optimizing disease resistance. Bridging this gap requires interdisciplinary expertise and resources to combine the best of both techniques.

High Costs and Accessibility: Developing genetically engineered crops is expensive, and smallholder farmers, especially in developing countries, may find it difficult to afford these advanced seeds. Ensuring equitable access is a critical challenge for widespread adoption.

Environmental and Ecological Concerns: There are concerns about potential unintended consequences, such as gene flow to wild relatives, impact on non-target organisms, and loss of biodiversity. Addressing these issues is crucial for the sustainable use of this technology.

Lack of Infrastructure in Developing Regions: The adoption of genetically engineered crops in many regions is hindered by limited access to research facilities, seed distribution networks, and farmer training programs.

Future Directions

Streamlining Regulatory Processes: Efforts are needed to harmonize and simplify regulatory frameworks while ensuring rigorous safety assessments. This will facilitate the faster and more affordable commercialization of genetically engineered

red crops.

Public Awareness and Education: Increasing awareness and transparency about the benefits and safety of genetic engineering through education campaigns and community engagement can improve public perception and acceptance of GMOs.

Gene Stacking and Durable Resistance: Developing crops with stacked resistance genes can delay the onset of pathogen adaptation and provide more robust, long-lasting protection against diseases.

Advances in Genome Editing Technologies: Technologies like CRISPR/Cas9 and base editing are evolving rapidly. These tools allow precise, targeted interventions, opening new possibilities for creating crops with enhanced resistance to a broad spectrum of pathogens.

Integration with Conventional and Marker-Assisted Breeding: Combining genetic engineering with marker-assisted selection and traditional breeding can enhance resistance, reduce costs, and make these innovations more accessible.

Focus on Minor and Orphan Crops: Future research should expand to include crops that are vital for local food security but are often overlooked in mainstream genetic engineering efforts.

Sustainability and Ecosystem-Friendly Approaches: Incorporating genetic engineering into sustainable agricultural practices can minimize ecological impact while maintaining high productivity.

Global Collaboration and Investment: Encouraging partnerships among governments, private

companies, and international organizations can drive innovation and ensure equitable access to genetic engineering advancements.

Personalized and Predictive Agriculture: Advances in data science and genomics could allow for the development of tailored genetic solutions for specific regions, climates, or pathogen threats, ensuring localized disease resistance.

Synthetic Biology and Beyond: Emerging trends like synthetic biology offer exciting possibilities to engineer entirely novel resistance pathways, further enhancing the resilience of crops against diseases.

Conclusion

Genetic engineering represents a transformative advancement in addressing crop diseases, improving food security, and reducing reliance on chemical inputs. By offering precise, efficient, and innovative solutions, it has the potential to overcome limitations of traditional breeding while fostering environmental sustainability. However, to unlock its full potential, challenges such as regulatory hurdles, public perception, and equitable access must be addressed. By leveraging emerging technologies like CRISPR/Cas9 and RNA interference, alongside the integration with conventional breeding methods, genetic engineering can revolutionize agriculture on a global scale, ensuring resilience against evolving pathogens and climate challenges.

Conservation Agriculture and its Importance in India: A Review

Prabhakar Prasad Barnwal, Kajal Singh and Arham Tater

Abstract

Conservation Agriculture (CA) is an innovative and sustainable farming approach that promotes soil health, water conservation, and biodiversity. As India faces the dual challenges of dwindling soil fertility and water scarcity, CA practices hold immense potential in enhancing agricultural productivity and ensuring long-term sustainability. This review article aims to explore the key principles, benefits, challenges, and future prospects of Conservation Agriculture in the Indian context.

Introduction

India, with its vast agricultural landscape and diverse agro-climatic zones, is heavily reliant on farming to sustain its economy and ensure food security. However, the country is grappling with numerous environmental challenges, including soil degradation, water scarcity, and the effects of climate change. In response to these challenges, Conservation Agriculture (CA) has emerged as a promising solution. CA is a set of agricultural practices aimed at enhancing and preserving the natural resource base while improving productivity and sustainability. It involves three primary principles:

- ✓ Minimal soil disturbance (through reduced or no-tillage),
- ✓ Permanent soil cover (using cover crops or mulching),
- ✓ Diverse crop rotations (to enhance biodiversity and soil health).

In the Indian context, CA offers a potential

pathway to address pressing issues such as land degradation, water depletion, and declining soil fertility.

Principles of Conservation Agriculture

The three core principles of Conservation Agriculture are crucial in mitigating the negative impacts of conventional farming practices.

Minimal Soil Disturbance (No-Till Farming):

Traditional farming methods involve plowing the soil, which disrupts soil structure and leads to erosion, compaction, and loss of organic matter. In contrast, no-till farming or reduced tillage leaves the soil structure intact, promoting better water infiltration, enhancing root growth, and preserving soil biodiversity (Jayaraman *et al.*, 2024).

Soil Cover (Cover Crops or Mulching):

Cover crops (such as legumes, grasses, or certain cereals) or mulching practices help protect the soil from wind and water erosion, enhance moisture retention, and add organic matter to improve soil fertility. These

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cover crops also fix nitrogen in the soil, which helps reduce the need for synthetic fertilizers (Zannopoulos *et al.*, 2024).

Crop Rotation and Diversification: Rotating different crops in the same field each season helps break pest and disease cycles, reduces the risk of soil nutrient depletion, and increases soil fertility. By diversifying crops, farmers can enhance biodiversity, reduce dependency on chemical inputs, and improve resilience to climate change (Ewing *et al.*, 2024).

Benefits of Conservation Agriculture in India

Improved Soil Health: One of the foremost benefits of CA is its positive impact on soil health. Traditional tillage practices often lead to soil erosion, compaction and depletion of essential nutrients. By reducing tillage and maintaining soil cover, CA helps restore soil organic matter, increases microbial activity, and promotes a more fertile soil ecosystem. This leads to enhanced water-holding capacity, better soil structure, and improved nutrient cycling (Dixit *et al.*, 2024).

Water Conservation: India is facing severe water scarcity, particularly in regions dependent on groundwater for irrigation. CA practices, such as reduced tillage and the use of cover crops, help improve water infiltration and retention. The reduced evaporation and enhanced soil moisture retention can significantly reduce the dependency on irrigation, thus conserving precious water resources. This is especially beneficial in drought-prone areas like Rajasthan, Maharashtra, and Tamil Nadu (Alharbi *et al.*, 2024).

Increased Agricultural Productivity: Several studies have shown that CA can lead to increased crop yields, even under challenging conditions. In regions where soil fertility is depleted, the adoption of CA can help restore productivity by enhancing nutrient availability. Furthermore, the improved water retention capacity allows crops to survive during periods of water scarcity, improving overall yield stability (Rathi *et al.*, 2024).

Mitigation of Climate Change: India's agriculture is highly vulnerable to climate change, with erratic rainfall patterns, increasing temperatures, and the frequency of extreme weather events. CA helps mitigate the impact of climate change by improving soil structure and water management, which enhances the resilience of crops. Additionally, reduced tillage leads to lower greenhouse gas emissions by maintaining soil carbon stocks (Prakash, 2024).

Reduced Input Costs: The adoption of CA practices reduces the need for expensive inputs like synthetic fertilizers and pesticides. For example, the use of cover crops can provide natural nitrogen fixation, reducing the need for chemical fertilizers. Furthermore, reduced tillage and mulching help suppress weeds, thus decreasing the need for herbicides (Ullah *et al.*, 2024).

Challenges to the Adoption of Conservation Agriculture in India

Despite its numerous advantages, the widespread adoption of CA in India faces several challenges:

Initial Investment and Knowledge Barriers: The

transition to CA requires an initial investment in specialized equipment (such as no-till drills) and a shift in farming practices. Many farmers, particularly smallholders, may be deterred by the high upfront costs and the lack of knowledge about CA principles. There is also a need for extensive training and extension services to educate farmers on how to effectively implement CA practices.

Resistance to Change: India's agricultural practices are deeply rooted in tradition, and many farmers are hesitant to move away from conventional methods. Changing the mindset of farmers and overcoming their resistance to adopting new technologies is a significant barrier to the widespread implementation of CA.

Fragmented Land Holdings: India's agricultural sector is characterized by small and fragmented landholdings, which makes it difficult to implement large-scale CA practices effectively. Coordinated efforts are required to promote CA among smallholder farmers and ensure that they have access to the necessary resources and support.

Infrastructure and Policy Support: The success of CA depends on a supportive policy environment, access to adequate infrastructure, and market linkages for sustainable farming practices. The government needs to provide incentives, subsidies, and institutional support to encourage farmers to adopt CA.

Future Prospects of Conservation Agriculture in India

While there are challenges to the adoption of

CA, the future prospects are promising. Government policies supporting sustainable agriculture, such as the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) and National Mission on Sustainable Agriculture (NMSA), are laying the groundwork for wider adoption of CA practices. Additionally, advancements in precision farming technologies, improved seed varieties, and agroecological research will further enhance the potential of CA in India. Farmers' associations, non-governmental organizations (NGOs), and agribusinesses are increasingly collaborating to disseminate knowledge about CA and demonstrate its benefits. Furthermore, integrating CA with organic farming and agroforestry systems could offer a holistic solution to the issues of soil health, water conservation, and climate resilience, leading to more sustainable agricultural practices in the country.

Conclusion

Conservation Agriculture presents a sustainable and effective approach to addressing the critical challenges faced by Indian agriculture. By improving soil health, conserving water, enhancing productivity and mitigating the impacts of climate change, CA can play a key role in ensuring long-term agricultural sustainability. However, overcoming the barriers to its adoption will require coordinated efforts from farmers, government, and the private sector. With continued research, awareness campaigns and policy support, Conservation Agriculture has the potential to transform Indian agriculture, making it more resilient, resource-efficient and climate-smart.

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Diseases and their Management Strategies for Citrus Fruits

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Abstract

India is the third largest producer of citrus in the world. It can be a world leader provided the productivity levels improve, which are much below the international figures. The reasons for very low productivity of citrus are mainly nutritional imbalances and lack of proper plant protection knowledge. Among the various biotic stresses, the losses caused by the diseases are very high. Furthermore, within the different groups the diseases those caused by fungi and viruses are the most serious, for example citrus canker, scab, anthracnose, powdery mildew citrus Tristeza and greening are some of them which are worth mentioning. Hence to achieve the high productivity, it is important to tackle the different diseases with appropriate disease management strategy.

Introduction

Citrus (*Citrus* spp.) is a group of fruits belong-ing to the Rutaceae family (the orange family) and includes 162 species. It is grown all around the world. Citrus and related genera are known to have developed in Southeast Asia, Australia, the islands that separate Asia and Australia, and central Africa. Citrus species that are grown most frequently are mandarin, sweet orange, acid lime, and lemon; other species, like seedless lime, pummelo, and grapefruit, are cultivated to a lesser extent. Citrus is an economically important genus that is well-known throughout the world for its distinctive flavor and attractive colors. Citrus trees gain aesthetic value from their evergreen foliage and blossoms as well as their exceptional aroma. In addition to being high in vitamin C, the fruits also contain vitamin P, which promotes the absorption of vitamin C and helps keep blood vessels healthy.

Citrus crops currently occupy 1.05 million hectares of land, yield 13.98 MT annually. Citrus fruit occupy about 13% of the total fruit production, among which Mandarin oranges contribute nearly 42% of the total citrus production. With 25-30% of global citrus fruit production, the China is the world's largest producer. Brazil, Japan, Spain, Italy, Mexico, India, Israel, Argentina and China are major producing countries. In India, Andhra Pradesh, Assam, Orissa, Maharashtra, Gujarat, Bihar, Punjab, Tamil Nadu, U.P. Hills, Himachal Pradesh, Sikkim, etc. are the major states. There are several diseases, like gummosis, citrus canker, scab, greening, citrus dieback, etc., which damage the foliage and reduce the yield and quality of fruits. Hence, it is necessary to be aware of diseases, their incidence, the nature of damage, and eco-friendly approaches to managing them. Below, we present some citrus diseases and their corresponding management strategies.

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Citrus canker (*Xanthomonas citri*): Canker is one of the most devastating diseases of citrus. It assumes serious proportions after the rainy season. The disease is severe on Kagzi limes, lemons, grapefruits, sour oranges, and citranges. Sweet oranges, baramasi lemons, and mandarins are less susceptible. *Xanthomonas citri* causes this disease, which is endemic to India and occurs in all growing areas. Pathogens of this disease get entry through stomata and wounds. Mostly, canker affects all parts of the plant. On both sides of the leaf, canker is characterized by round, water-soaked, yellowish spots that grow larger, become rough, corky, and brownish, and are encircled by a yellow halo. In comparison, canker is more common in regions with high rainfall than in regions with low rainfall. It can be controlled by pruning followed by burning affected twigs and branchlets during the months of May and June, and cut ends should be pasted with a Bordeaux mixture. Apply 2-3 sprays of streptomycin sulphate at 500 to 1000 ppm at intervals of 20-25 days.



Gummosis (*Phytophthora parasitica*): The disease is more common in heavy, ill-drained, and high waterlogged soils. Rough lemons and grapefruits are less susceptible. Lemon and sweet oranges are highly susceptible to gummosis, whereas sour oranges and mandarins are tolerant. The first indication of infection is the appearance of gum drops on the bark surface of the trunk. Infected bark and wood below it

become brown to dark brown. The bark develops vertical cracks. The infection spreads rapidly to the upper trunk and can also appear on branches. When gumming starts close to the soil, the disease spreads to the main roots, and there is girdling at the base of the trunk, as a result of which the tree starts declining. Prior to death, the tree usually blossoms heavily and dies before the fruit matures. The gummosis can be controlled by removing the diseased bark along with a 5-10 cm strip of healthy bark beyond the diseased portion, followed by disinfecting with mercuric chloride (0.1%) solutions. You can either spray 1.5 kg of copper oxychloride in 500 liters of water, or apply 2 g of Ridomil MZ per 100 ml to the infected area. Additionally, you can drench the soil at the base of the tree twice in February-March and again in July-August.



Scab (*Elsinoe fawcetti*): Scab becomes serious in many commercial cultivars during periods of high humidity and rainy seasons.



The disease attacks all the above-ground parts of the plant, including leaves, twigs, and fruits. On young leaves, lesions start as small, pale orange elevated spots, becoming sharply defined. In later stages, the lesions become rough, corky, and wart-like, with a color ranging from brown to dark brown. Affected leaves become distorted, wrinkled, stunted, and deformed. On the fruit, lesions consist of corky projections, which often break into scabs. For control

diseased leaves, twigs, and fruits should be pruned, collected, and destroyed. Spraying a Bordeaux mixture, or Blitox (0.3%), is quite effective.

Citrus greening: Greening is a serious disease of citrus. Fraser et al. first reported the disease from India. Leaves on the affected plant shows a chlorotic pattern. These may be completely yellow or yellow with green veins and small green dots. The chlorosis diffuses toward the leaf margins. The leaf blades may exhibit dwarfism and thickening. The leaves exhibit upright growth and may drop prematurely. Fruits from such trees are small and lopsided, and they break color first on the sides exposed to the sun. The disease is transmitted by *Citrus psylla*. The bud-wood used from the parent tree should be free from greening. *Citrus psylla* can be controlled by spreading 10% dimethoate granules on the soil around the base of the plant.



Anthracnose (*Colletotrichum* spp.): The disease appears in several forms, including dieback of twigs, leaf spotting, and rotting and dropping of fruits. In affected trees, brown, pimple-like, cloudy spots occur on the mature leaves. The twigs shrivel and assume a silvery gray appearance. Withertip occurs when the twig tips defoliate and dry out. The main symptoms of the disease are the shedding of leaves and the dieback disease of twigs. To minimize the infection, apply *Trichoderma viride* 50 g tree⁻¹ with FYM/compost as tree⁻¹ basin and irrigate the orchard



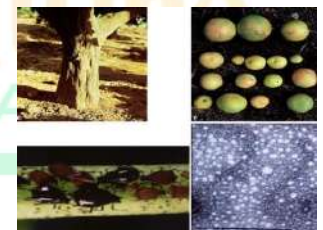
Spray copper oxychloride 0.3% is used. Prune the twigs 2 cm below the dried portion after harvest.

Stem and fruit rot (*Phomopsis citri*): *Phomopsis citri* causes the disease.



Symptoms are dark circular depressions with yellowish margins that appear on leaves, branches, and fruit. Later, the spot becomes raised, rough, and light brown, and yellow margins disappear. Sandpaper texture appears on the surface of fruit. Regular tree pruning can control it by improving air circulation and reducing humidity around the plant. Spraying with Bordeaux mixture (2:2:50) during July-August and September is recommended.

Tristeza virus disease (*Corium vialoris*): The symptoms of the disease are generally not appearing on the leaves of most *citrus* spp. The symptoms of tristeza resemble those of any root disease. The



blocking of food-conducting vessels leads to starvation of the roots, which results in defoliation, die-back of twigs, and stunting of the tree. Affected trees usually blossom heavily, and fruit size is reduced. "Honeycombing," which is made up of small holes in the wood and thorny growths on the inner bark surface of root stocks just below the bud union, is a specific sign of tristeza. Tristeza viruses are both vector and bud transmissible but not through seed. Main vectors are citrus aphids (*Aphids citricidus kirk*) and *Myzus persicae*. For control, use virus-free buds and tolerant rootstocks for propagate-

ion, like Jatti Khatti, sweet lime, Karna khatta, rangpur etc. Check insect vectors by spraying dimethoate (Rogor 30 EC) at 1250 ml in 500 liters of water at the time of the new flush in March.

Exocortis: Bark sealing and stunting of infected trees are the main symptoms caused by citrus exocortis viroid (CEV). Field symptoms of exocortis are characterized by epinasty of



leaves, browning of petiole and scaling of the bark. The bark becomes dead and dry. The disease also causes noticeable stunting on susceptible trees. The scaling of the bark interferes with the natural translocation of food materials to the roots which get starved and the infected portion does not receive proper nutrition. As a result, the infected trees show signs of general malnutrition and decline prematurely. The disease is transmitted by contaminated tools during budding or grafting and orchard operations. For control, Use certified viroid free budwood on tolerant root stock such as rough lemon for further multiplication of citrus trees. Tools should be frequently disinfected by dipping them in 1% solution of sodium hypochlorite during budding and other operations.

Powdery mildew (*Oidium tingitaninum*): Powdery mildew is a common disease in citrus growing areas.

Causes white patches on the upper surface of leaves and on twigs leading to leaf drop and die-back. Young



leaves are more prone to powdery mildew infection.

Moist conditions are favourable for the spread of disease. It is an air-borne disease. Sulphur fungicide is commonly used to control the disease. Carbendazim is systemic fungicide effective against powdery mildew in citrus.

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Agroforestry: Merging Trees and Crops for Sustainability

Laxman Navi, Atheek Ur Rehaman H. M. and Dayanandanaik S.

Abstract

Agroforestry, a sustainable land-use practice integrating trees with crops and livestock, offers significant ecological, economic and social benefits. It enhances soil fertility, sequesters carbon, conserves biodiversity and improves water management, addressing challenges such as land degradation, deforestation and climate change. By diversifying income streams, increasing food security and fostering climate resilience. Agroforestry supports sustainable livelihoods and aligns with several Sustainable Development Goals (SDGs), including poverty alleviation (SDG 1), zero hunger (SDG 2), climate action (SDG 13) and life on land (SDG 15). Despite challenges like knowledge gaps and policy barriers, agroforestry represents a transformative approach to building resilient and productive landscapes.

Introduction

Agroforestry is a land-use management practice that combines the cultivation of trees with agricultural crops or livestock on the same land. This synergistic integration leverages the ecological and economic benefits of diverse biological systems, aiming to achieve sustainability in agricultural production. By incorporating trees into agricultural landscapes, agroforestry systems provide ecological services such as soil fertility enhancement, carbon sequestration, biodiversity conservation and water resource management. Furthermore, they offer socio-economic advantages by diversifying farmers' income streams and increasing resilience to climatic and market fluctuations. The practice of agroforestry is not new; it has been utilized for centuries by indigenous communities worldwide. These tradition-

al systems often served as the foundation for sustainable livelihoods, ensuring food security while maintaining ecological balance. In recent years, agroforestry has gained renewed attention as a viable solution to address modern challenges, including land degradation, deforestation and the impacts of climate change. By blending traditional knowledge with scientific advancements, agroforestry offers a pathway to more resilient and productive landscapes. Agroforestry stands out as a holistic approach to land management. Unlike conventional monoculture farming systems that often degrade natural resources over time, agroforestry emphasizes the coexistence of multiple species, fostering symbiotic relationships. These relationships enhance nutrient cycling, pest control and ecosystem stability, creating a dynamic system capable of adapting to changing

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environmental conditions. Moreover, agroforestry aligns with the principles of regenerative agriculture, promoting practices that restore ecosystems and improve long-term agricultural sustainability.

The Principles of Agroforestry

Agroforestry is guided by principles that ensure both ecological integrity and economic viability:

Diversity and Complementarity: Agroforestry systems are designed to maximize the beneficial interactions between trees and crops. For example, trees can provide shade and wind protection for crops, while crops can benefit from improved soil conditions due to tree litter and root activity.

Resource Optimization: Integrating trees with crops, which optimizes the use of resources such as light, water and nutrients. This integration reduces competition and enhances overall productivity.

Sustainability: Agroforestry practices focus on maintaining long-term productivity and health of the land. Practices like alley cropping, silvipasture and windbreaks enhance soil health and reduce erosion.

Adaptability: Agroforestry systems are tailored to local environmental conditions, socio-economic contexts and cultural preferences, making them flexible and highly adaptable.

Types of Agroforestry Systems

Alley Cropping: In alley cropping, rows of trees or shrubs are planted alongside crops. The spacing is designed to allow sufficient light for crops while benefiting from the microclimate created by the trees. Common tree species include nitrogen-fixing

trees like *Gliricidia sepium* and *Leucaena leucocephala*.

Silvipasture: Silvipasture combines forestry and grazing animals in a mutually beneficial system. Trees provide shade and shelter for livestock, reducing heat stress and improving animal welfare. Meanwhile, livestock contribute to nutrient cycling through manure deposition.

Windbreaks and Shelterbelts: Rows of trees or shrubs planted along field boundaries protect crops from wind damage, reduce soil erosion and enhance microclimatic conditions. Windbreaks are particularly effective in arid and semi-arid regions.

Agrosilvicultural Systems: These systems integrate trees and crops, focusing on creating a balanced interaction. For example, coconut or oil palm plantations often incorporate understorey crops like cocoa or coffee.

Homegardens: Homegardens are small-scale agroforestry systems near households, combining fruit trees, vegetables, medicinal plants and small livestock. They are common in tropical regions and serve as a source of food security and supplementary income.

Environmental Benefits

Soil Conservation and Fertility: Agroforestry systems improve soil structure, reduce erosion and enhance fertility. Tree roots stabilize the soil and increase organic matter through litterfall and root decay. Nitrogen-fixing trees enrich the soil, reducing the need for chemical fertilizers.

Carbon Sequestration: Trees in agroforestry systems

ms act as carbon sinks, mitigating climate change by absorbing atmospheric CO₂. A study by Jose (2009) reported that agroforestry systems can sequester between 0.2 and 9.5 Mg C ha⁻¹ year⁻¹, depending on the system and tree species.

Biodiversity Conservation: Agroforestry systems create diverse habitats that support a wide range of flora and fauna. They serve as ecological corridors, connecting fragmented habitats and enhancing landscape connectivity.

Water Resource Management: Trees improve water infiltration and reduce surface runoff, enhancing groundwater recharge. They also reduce evapotranspiration, maintaining soil moisture levels and benefiting adjacent crops.

Economic and Social Benefits

Diversified Income Streams: Farmers can earn income from timber, fruits, nuts and other tree products in addition to their crops. This diversification reduces dependency on a single source of income and increases economic resilience.

Employment Opportunities: Agroforestry systems create jobs in planting, maintaining and harvesting tree-based products. They also support value-added industries like processing and marketing timber and non-timber forest products.

Food Security: By integrating fruit and nut trees, agroforestry systems enhance food availability and nutrition. Homegardens, for instance, provide households with a continuous supply of diverse food items.

Climate Resilience: Agroforestry increases resili-

ence to climate variability by creating microclimates, reducing vulnerability to droughts and improving water-use efficiency.

Challenges in Agroforestry Adoption

Despite its benefits, agroforestry faces several challenges:

Knowledge and Awareness: Many farmers lack awareness of agroforestry practices and their potential benefits.

Initial Investment: Establishing agroforestry systems requires upfront investment in tree planting and maintenance.

Policy and Institutional Barriers: Inadequate policies and lack of institutional support often hinder widespread adoption.

Market Access: Farmers may face challenges in accessing markets for tree-based products.

Land Tenure Issues: Unclear or insecure land tenure can discourage farmers from planting trees due to concerns about ownership rights.

Agroforestry and Sustainable Development Goals (SDGs)

Agroforestry contributes to several SDGs, including:

SDG 1: No Poverty: By diversifying income, agroforestry reduces poverty.

SDG 2: Zero Hunger: It enhances food security through increased production and nutritional diversity.

SDG 13: Climate Action: Agroforestry mitigates climate change through carbon sequestration and adaptation practices.

SDG 15: Life on Land: It promotes sustainable use

of terrestrial ecosystems and biodiversity conservation.

Conclusion

Agroforestry is a sustainable land-use approach that integrates trees with crops and livestock, offering ecological, economic and social benefits. It addresses challenges like climate change, deforestation and land degradation while supporting income diversification, food security and biodiversity. Aligning with key Sustainable Development Goals (SDGs), agroforestry is a transformative strategy for building resilient and productive landscapes.

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Agroclimatic Zoning and Crop Planning

Sujeet Deshmukh and Ranjeet Deshmukh

Agroclimatic zoning is a scientific method used to delineate regions with similar climatic and agricultural potential. This approach plays a pivotal role in optimizing agricultural productivity and ensuring sustainable land use by tailoring crop selection and farming practices to the specific climatic conditions of a region. Understanding the significance of agroclimatic zones in crop planning is crucial for improving food security, maximizing yields, and mitigating the impacts of climate variability.

Understanding Agroclimatic Zones

Agroclimatic zones are classified based on factors such as temperature, rainfall, humidity, soil type, and topography. These zones provide a framework to assess the suitability of crops and farming systems in a particular region. For instance, rice thrives in warm, humid conditions, while wheat prefers cooler climates. By identifying these zones, policymakers and farmers can align agricultural activities with the natural potential of the area, minimizing resource wastage and environmental degradation.

Globally, the classification of agroclimatic zones varies depending on the scale and purpose of the study. In India, the Planning Commission has

divided the country into 15 agroclimatic regions based on physiography, climate, and cropping patterns. Similarly, the Food and Agriculture Organization (FAO) employs agro-ecological zoning as a broader classification to guide international agricultural planning.

Significance in Crop Suitability

Scientific Crop Selection: Agroclimatic zoning helps in identifying crops that are best suited to the natural resources of a region. This ensures optimal use of land and water resources and reduces the risk of crop failure due to climatic incompatibility.

Adaptation to Climate Change: With changing climate patterns, agroclimatic zoning provides a dynamic tool to recommend adaptive measures, such as introducing drought-tolerant varieties in arid zones or shifting planting schedules.

Pest and Disease Management: The zoning approach helps predict the occurrence of pests and diseases, which are often climate specific. This allows for targeted management strategies, reducing yield losses.

Efficient Resource Use: By matching crops with suitable agroclimatic zones, water, fertilizers, and other inputs can be utilized more efficiently, leading to cost savings for farmers and reduced environment-

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al impact.

Role in Crop Planning

Crop planning involves deciding what crops to grow, when to grow them, and how to allocate resources effectively. Agroclimatic zoning serves as the foundation for informed crop planning by:

Optimizing Cropping Patterns: By analysing the climatic suitability, cropping patterns can be adjusted to maximize land productivity and ensure year-round food supply.

Promoting Crop Diversification: Agroclimatic assessments encourage diversification by recommending alternative crops suited to specific microclimates, reducing the risk of monoculture-related issues.

Improving Farmer Livelihoods: Proper crop planning increases productivity and profitability, directly benefiting farmers by aligning agricultural practices with market demands and environmental conditions.

Supporting Policy Formulation: Agroclimatic data aids in the development of region-specific agricultural policies, such as subsidies for drought-resistant crops in semi-arid zones or investment in irrigation infrastructure in water-scarce areas.

Challenges in Implementation

Despite its numerous benefits, the practical implementation of agroclimatic zoning and crop planning faces several challenges:

Data Availability: Accurate and high-resolution climatic, soil, and topographic data are essential but often unavailable or outdated in many regions.

Farmer Awareness: Disseminating knowledge about agroclimatic zoning to farmers and ensuring their participation in adopting recommended practices remains a significant hurdle.

Integration with Technology: The adoption of advanced tools like GIS, remote sensing, and climate models is vital for precise zoning but requires significant investment and expertise.

Climate Variability: The increasing unpredictability of weather patterns due to global warming complicates the process of defining stable agroclimatic zones.

Conclusion

Agro-climatic zoning is a cornerstone of sustainable agricultural development, offering a scientific basis for crop selection and planning. By leveraging the natural strengths of each agroclimatic zone, it is possible to enhance productivity, conserve resources, and build resilience against climate variability. The integration of modern technology, improved data collection, and farmer-centric policies will be key to overcoming existing challenges and fully realizing the potential of agroclimatic zoning in shaping the future of agriculture.

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The Role of Genomics in Modern Agriculture: A Revolution in Crop Improvement

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Abstract

In the past century, agriculture has evolved dramatically, driven by advancements in science and technology. One of the most exciting breakthroughs in recent decades has been the integration of genomics into crop breeding and farming practices. Genomics, the study of genes and their functions, has opened new possibilities for improving crop yields, resistance to diseases, and adaptability to changing climates. From precision farming to genetically modified crops, the role of genomics in modern agriculture is transforming the way we grow our food and ensuring food security for future generations.

What is Genomics and why does it Matter?

Genomics involves decoding the genetic material DNA of plants and animals to understand their genetic makeup. For plants, this means identifying specific genes that contribute to desirable traits like drought tolerance, disease resistance, and higher yields. By mapping these genes, scientists can harness the power of natural selection and breeding techniques to develop crops that are more efficient, resilient, and nutritious. In traditional agriculture, breeding has been based on selecting plants with desirable traits and crossbreeding them to pass those traits on to the next generation. While this approach has been successful for centuries, it has its limitations. Genomic tools, on the other hand, allow scientists to accelerate this process, making crop

improvement faster and more precise (Grover and Mohanty, 2015).

Genomics in Crop Improvement: The most significant application of genomics in agriculture is in crop improvement. Through genomic techniques like genetic mapping and genome-wide association studies (GWAS), researchers can identify genes responsible for key agricultural traits. These genes can then be targeted to develop new crop varieties that are better suited to meet the demands of modern agriculture. For example, in wheat, a staple crop that feeds billions worldwide, genomics is being used to enhance resistance to pests and diseases, improve drought tolerance, and increase nutritional content (Iqbal *et al.*, 2016). Through gene-editing technologies like CRISPR, scientists are now able to

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modify the DNA of wheat to introduce beneficial traits with unprecedented precision (Cao *et al.*, 2020). This has the potential to create varieties of wheat that are not only more resilient to climate change but also more nutritious and higher yielding.

Genomic Tools for Precision Farming: Another key area where genomics is making an impact is in precision farming. Precision farming refers to the use of advanced technologies, including genomics, to manage field variability and improve crop productivity. By analyzing the genetic makeup of crops in specific fields, farmers can make more informed decisions about how to treat their crops, optimizing water use, fertilizer application, and pest control. For instance, genomics can help identify specific genetic markers linked to traits like disease resistance. This allows farmers to choose the right crop varieties for their fields, ensuring that they are growing the best plants for their specific environment. As a result, farmers can reduce the need for chemical treatments, such as pesticides, and decrease the environmental impact of their farming practices (Zhang *et al.*, 2019).

Genomics and Climate Change: Building Resilient Crops: One of the greatest challenges facing agriculture today is climate change. Rising temperatures, unpredictable rainfall patterns, and extreme weather events are making it increasingly difficult to grow crops in many regions. Here, genomics offers a powerful tool for developing crops that are more resilient to these changing conditions. For example, drought-resistant crops have been a

major focus of genomic research. By identifying genes that help plants conserve water and thrive in dry conditions, scientists are working to breed crops that can survive in areas with limited water resources. Similarly, genetics is being used to develop crops that can withstand high temperatures or flooding, ensuring that we can continue to produce food in the face of a changing climate (Liu and Godwin, 2020).

Genomics in Pest and Disease Management: Another area where genomics plays a crucial role is in pest and disease management. By sequencing the genomes of pests and pathogens, scientists can better understand how these organisms interact with crops and how they evolve resistance to pesticides. This knowledge can lead to the development of new strategies for controlling pests and diseases, reducing the reliance on chemical pesticides and minimizing their impact on the environment. In some cases, genomics is being used to develop genetically modified crops that are resistant to specific pests. For example, *Bt* cotton, a genetically modified cotton variety, has been engineered to produce a toxin that kills certain insect pests. This has led to a reduction in pesticide use and increased crop yields, benefiting both farmers and the environment (Mann, 2018).

The Future of Genomics in Agriculture: The future of genomics in agriculture is bright, with new breakthroughs emerging every day. Advances in gene editing, synthetic biology, and artificial intelligence are opening even more possibilities for crop improvement and food production. As genomi-

cs continues to evolve, we can expect to see crops that are not only more resilient and productive but also more sustainable and nutritious. However, there are still challenges to overcome. The ethical implications of genetically modified organisms (GMOs), concerns about biodiversity, and the need for equitable access to genomic technologies are all important considerations that must be addressed as genomics becomes more integrated into agriculture.

Conclusion

In conclusion, genomics is revolutionizing modern agriculture by enabling scientists to create crops that are more resilient, nutritious, and adaptable to changing environmental conditions. From improving yields and reducing pesticide use to developing drought-resistant and disease-resistant crops, the potential benefits of genomics in agriculture are vast. As we continue to tackle the challenges of feeding a growing global population and combating climate change, genomics will undoubtedly play a critical role in shaping the future of farming and food security. By harnessing the power of genomics, we can build a more sustainable, efficient, and resilient agricultural system, ensuring that future generations have access to the food they need to thrive.

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Veld Grape: An Unattended Medicinal Valued Vegetable Crop

R. Sowbarnika, S. Suriya and T. Ilakiya

Abstract

The Veld Grape (*Cissus quadrangularis*) belongs to the Vitaceae family and is a perennial, succulent, or deciduous climbing plant. Additionally, Ayurveda and other traditional medical systems have long employed it. A variety of bioactive chemicals, such as iridoids, flavonoids, sterols, and stilbenes, are abundant in this plant. It is also used for a wide range of medical applications for reducing inflammation, oxidative stress, and diabetes. It has several uses in contemporary medicine, including bone health, inflammation, metabolic abnormalities, and gastroesophageal diseases, due to its potent herb and adaptable medicinal plant nature. This showed that veld grape may contain bioactive chemicals that need to be tested for their potential human health benefit through clinical, pathological, molecular, and toxicological research.

Introduction

For thousands of years, medicinal plants have been utilized to treat a wide range of illnesses all across the world. Modern medications are widely used for various purposes, with a significant number derived from medicinal plants. Our current understanding of how to formulate various medicinal medications has been enhanced by traditional wisdom. Throughout history, medicinal herbs have been used to make natural medications for thousands of years. The Veld grape (*Cissus quadrangularis*) is one such medicinal plant that has a wide range of applications. A natural herb found in sub-tropical areas, Veld grape is typically used as a remedy for a number of illnesses, including fever, piles, skin conditions, and malaria. The plant's powder and extracts are frequently used to accelerate bone and fracture healing and lessen pain and swelling.

The plant is known locally in India as “Hadjod,” which means it unites the bones because of its well-known property. This crop has many other names in different languages, including Pirandai (Tamil), Kandvali (Marathi), Harjora, Hadjod (Hindi), Vajravalli, Asthisamharaka (Sanskrit), Vedhari (Gujarati), and Nallaru (Telugu). In ancient Ayurvedic writings, Bava Prakasha and Chakra Dutta prescribed that the Veld grape was a good herb to use in products that resembled ice cream. Studies were examined and described the effects of adding veld grapes to ice cream on its physicochemical, nutritional, and sensory qualities.

Scientific classification

Kingdom : Plantae
Order : Vitales
Family : Vitaceae
Genus : Cissus

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Species : *quadrangularis*

Botanical Description

Appearance: A perennial, deciduous, or succulent climbing plant that can grow up to 1.5 meters angular-sectioned (4.9 feet) tall. It has quadrangular branches with internodes that are 8-10 centimeter (3-4 inches) long and 1.2-1.5 centimeter (0.5-0.6 inches) wide.



Leaves: Toothed trilobe leaves that are 2-5 centimeters (0.8-2.0 inches) wide and appear at the holes.

Flowers: Racemes of small white, yellowish, or greenish flowers that bloom throughout the year.

Fruits: Globular berries that are green when unripe and turns red when it ripe. The traits are edible, and the seeds can be used for cooking.

Roots: Tuberous and fleshy, which enables them to store water and other nutrients.

Tendrils: Simple, thin tendrils on the veld grape enables climbing.

Value-Added Products of Veld Grape

Here are some of the value-added products of veld grape (*Cissus quadrangularis*):

- ✓ Idly powder
- ✓ Dhal powder
- ✓ Soup mix
- ✓ Chutney
- ✓ Juice
- ✓ Paste
- ✓ Oil



Figure 1: (A) Veld grape stem, (B) Peeled stem, (C) Dehydrated veld grape, (D) Veld grapenutri powder



Figure 2: Veld grapenutri powder, Idly powder, Dhal powder and Soup mix

Nutritive value: The below table indicates the nutritive value of veld grape per 100 gram.

Table 1: Nutritive value of veld grape per 100g

Nutrients	Per 100 g	Nutrients	Per 100 g
Iron	7 mg	Fiber	74.36 g
Protien	6.44 g	Copper	5 mg
Fat	0.73 g	Cholesterol	0 mg
Carbohydrates	63.73 g	Vitamin E	696 mg
Calcium	39.5 mg	Vitamin C	327 mg
Potassium	67.5 mg	Magnesium	11.5 g
Lead	3.5 g	Candmium	39.5 mg
Sodium	22.5 g	Zinc	3.0 mg

Health Benefits

Bone health and heating: It enhances bone density and strengthens the bone. It helps in recovery of bone injuries and fractures. It also aids in the management of other bone-related problems.

Joint and Muscle Health: Reduces inflammation and pains in joints. Enhances recovery and reduces muscle soreness. Useful in inflammatory conditions and helps in managing arthritis.

Cardioprotective effects: Supports heart health by reducing cholesterol levels. Improves blood circulation and helps manage hypertension.

Antioxidant Activity: The plant is rich in antioxidants, which plays a crucial role in neutralizing harmful free radicals in the body, contributing to overall health and slow down the aging process.

Weight Management: Helps in reducing body fat and managing weight. It boosts body metabolism and supports healthy digestion.

Wound Healing: Exhibiting good healing activity.

Anti-ulcer Properties: The plant is traditionally used for the treatment of ulcers, indicating its anti-ulcer properties.

Anti-cancer Potential: Some studies suggest that *Cissus quadrangularis* may have anti-cancer properties, contributing to the exploration of natural remedies against cancer.

Conclusion

The effectiveness of medications derived from plants has been thoroughly examined, and they are widely regarded as safe for human consumption. The Hadjod (Veld grape) is a multipurpose medicinal plant that has many uses in both modern and ayurvedic medicine, especially for gastrointestinal problems, inflammation, metabolic abnormalities, and bone health. Scientific research is validating its traditional usage. Although it can be commercialized in the ayurvedic and medical fields, it is used as a traditional herb in many rural and home settings. The potential of the bioactive chemicals found in this plant should be further examined through clinical, pathological, molecular and toxicological investigations.

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The Dynamics of Innovation: Understanding Adoption in Agriculture

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Introduction

Innovation is the process of introducing new ideas, products, or practices that bring value to individuals or society. Its diffusion how innovations spread across populations depends on four key elements: the innovation itself, communication channels, time, and the social system. Understanding these elements is essential to promoting successful adoption, particularly in agriculture, where innovations can significantly enhance productivity and sustainability. The characteristics of innovations, the role of communication, time, and social systems, as well as the adopter categories and attributes that drive the adoption process in the agricultural sector. Practical examples, such as drought-resistant seeds and precision farming technologies, illustrate these concepts in action.

Innovation: Innovation is a process that involves introducing new ideas, products, or processes that bring value to individuals or society. The diffusion of innovation, or how innovations spread, depends on four key elements. Understanding these elements is crucial for ensuring the successful adoption of innovations.

Innovation: The innovation is the core idea, product, or practice being introduced. Its characteristics such

as relative advantage, compatibility, complexity, trialability, and observability play a pivotal role in its acceptance. The degree to which the innovation addresses a need, provides tangible benefits, and integrates into existing practices determines its appeal and effectiveness.

Communication Channels: Communication channels refer to the means through which information about the innovation is shared among potential adopters. These channels can be formal, such as advertisements and academic research, or informal, such as word-of-mouth and social media. Effective communication ensures that potential users are aware of the innovation, understand its benefits, and are motivated to adopt it.

Time: Time plays a critical role in the diffusion process. This element includes the time it takes for individuals to decide to adopt an innovation and the overall rate at which the innovation spreads through a population. Innovations typically pass through stages knowledge, persuasion, decision, implementation and confirmation before becoming widely accepted.

Social System: The social system is the network of individuals, groups, or organizations within which the innovation spreads. Factors such as cultural nor-

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ms, leadership influence, and peer networks shape how quickly and widely an innovation is adopted. Early adopters within a social system often influence the decisions of others, acting as catalysts for broader acceptance.

Adopter Categories

The adoption of innovations in agriculture, such as new crop varieties, farming techniques, or machinery, provides a clear and practical example of the adopter categories as described by Everett Rogers. Here's how these categories apply to farmers adopting a new agricultural innovation, such as drought-resistant seeds:

Innovators (2.5%): Innovators are the first to experiment with a new agricultural innovation. These are adventurous, risk-tolerant farmers who are willing to invest in untested methods or technologies.

Example: A farmer who immediately adopts a newly developed drought-resistant seed as soon as it is available, is often driven by curiosity and a desire to explore cutting-edge solutions.

Characteristics: Strong financial capacity to handle potential risks, Access to resources like agricultural research stations or pilot projects.

Early Adopters (13.5%): Early adopters are progressive and respected leaders in the farming community. They adopt innovations after observing the initial success of the innovators.

Example: A farmer who adopts the drought-resistant seed after hearing about its success in trial fields or from innovators in their area. These farmers often become role models for others.

Characteristics: Open-minded and well-connected within their community, often participate in farmer networks or extension programs.

Early Majority (34%): The early majority adopts innovations only after they see substantial evidence of benefits. They are cautious but pragmatic, waiting for feedback from the innovators and early adopters.

Example: Farmers who adopt the drought-resistant seed after witnessing consistent results over a few harvest seasons and after government subsidies or extension workers promote the innovation.

Characteristics: Risk-averse but willing to change when convinced, heavily influenced by peer recommendations and observable success.

Late Majority (34%): Late majority farmers adopt innovations only when they become mainstream and widely accepted. They often feel social or economic pressure to adapt.

Example: A farmer who plants the drought-resistant seed only after the majority of their neighbors have adopted it and when traditional seeds become difficult to source.

Characteristics: Skeptical of new ideas initially, Motivated by economic necessity or peer pressure.

Laggards (16%): Laggards are the last to adopt innovations. These farmers prefer traditional practices and may resist change until it becomes absolutely unavoidable.

Example: A farmer who adopts drought-resistant seeds only after facing repeated crop failures with traditional seeds and realizing there are no viable alternatives.

Characteristics: Strong attachment to traditional methods, Limited financial resources and access to information.

Insights for Agricultural Policy and Extension Services

Targeting Innovators and Early Adopters:

Agricultural innovations should be introduced through progressive farmers who can demonstrate the benefits to the wider community. For example, governments and NGOs can run pilot projects with innovators.

Building Evidence for the Early Majority:

Extension services should focus on providing training sessions, field demonstrations, and subsidies to address the cautious nature of the early majority.

Encouraging the Late Majority and Laggards:

These groups may require additional incentives, such as financial support or local success stories, to overcome skepticism and resource constraints.

Attributes of Innovation

The adoption of innovation is influenced by five key attributes that determine its acceptance and spread. These attributes, as defined by Everett Rogers in his Diffusion of Innovations theory, help explain why some innovations are adopted more quickly than others. Here's a detailed look at each attribute with examples from agriculture.

Relative Advantage: Relative advantage refers to the degree to which an innovation is perceived as better than the existing solution. The greater the benefits, the more likely farmers are to adopt it. Adoption of drip irrigation over traditional flood

irrigation. Drip irrigation provides significant advantages, such as water efficiency, reduced labor, and increased crop yield. Farmers who realize these benefits are more likely to adopt this technology.

Compatibility: Compatibility refers to how well an innovation fits with the values, needs, and practices of potential adopters. An innovation that aligns with the existing farming system is more likely to be accepted. Introduction of organic fertilizers in farming systems already focused on sustainable practices. Farmers using chemical-based farming methods may find this innovation incompatible, while organic farmers readily adopt it.

Complexity: Complexity is the degree to which an innovation is perceived as difficult to understand or use. Simpler innovations are more readily adopted than complex ones. Precision farming technologies like GPS-guided tractors can be perceived as complex, particularly by small-scale farmers with limited technical knowledge. These innovations may require training programs to reduce perceived complexity.

Trialability: Trialability refers to the extent to which an innovation can be tested or experimented with on a small scale before full adoption. Innovations that allow for trial runs reduce the risk for adopters. The introduction of drought-resistant seed varieties often allows farmers to test them on a small plot of land before committing to using them across their entire farm. This trialability encourages adoption.

Observability: Observability refers to the visibility of an innovation's results. When potential adopters

can see the benefits of an innovation firsthand, they are more likely to adopt it. The adoption of mechanized harvesters often spreads quickly in rural communities where farmers observe their neighbors reaping significant time and labor savings.

The Interplay of Attributes

The adoption of innovations often depends on how these attributes interact. For example: A farmer may adopt solar-powered irrigation pumps (high relative advantage) because they reduce electricity costs and align with sustainable practices (compatibility). However, adoption may be slower if the technology is too expensive (low trialability) or complicated to operate (high complexity).

Strategies for Promoting Agricultural Innovations

Demonstrate Relative Advantage: Highlight tangible benefits, such as increased yields or reduced costs, through real-world examples and testimonials.

Ensure Compatibility: Tailor innovations to fit the specific needs, practices, and cultural norms of local farmers.

Simplify Complexity: Provide training, user-friendly designs, and support services to make adoption easier.

Encourage Trialability: Allow small-scale experimentation with innovations, such as offering pilot projects or subsidized trials.

Enhance Observability: Use demonstration farms, field days, and peer networks to showcase visible results of the innovation.

Conclusion

The adoption of innovation in agriculture is shaped by its characteristics, such as relative advantage, compatibility, complexity, trialability, and observability. These attributes influence how quickly farmers embrace new ideas, products, or technologies. Additionally, the role of innovators, early adopters, and other categories of adopters highlights the importance of effective communication, trial opportunities, and visible benefits to encourage widespread adoption. By addressing these factors and tailoring strategies to specific adopter groups, agricultural policymakers and innovators can ensure successful diffusion, improving productivity and sustainability in farming systems worldwide.

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Multilayer Farming: Approaches for Better Utilization of Resources

Prince Mishra and Aditya Kumar Kashyap

Abstract

Multilayer farming, characterized by the simultaneous cultivation of multiple crops across vertical strata, has emerged as a pivotal innovation in sustainable agriculture. Amidst challenges such as urbanization, population growth, and declining arable land, this system optimizes resource utilization, enhances farm income, and fosters ecological resilience. This study critically examines the theoretical foundations, methodologies, and empirical outcomes of multilayer farming, offering insights into its potential to revolutionize contemporary agricultural practices.

Introduction

The escalating pressures on global agricultural systems, driven by increasing food demand and shrinking arable land, necessitate transformative approaches to land use. For sustainable production there are three key comprise nutritional security, ecological restoration and economic productivity. The approach ensures a regular income and employment throughout the year. Multilayer farming, also known as multitier cropping, the system accommodates crops of different heights, canopy patterns and rooting systems. Multilayer cropping systems are more amicable for horticultural crops as they include Vines, climbers, shrubs, annuals and shade loving or tolerant species. Its arrangement optimizes sunlight exposure, nutrient distribution, and water usage, resulting in enhanced productivity. One of the key advantages of multilayer farming is its potential to significantly increase overall yield per unit of land.

This strategy maximizes the efficient utilization of resources while simultaneously mitigating environmental degradation. Beyond its agronomic benefits, multilayer farming provides a robust framework for improving farmer livelihoods and promoting sustainable rural development.

Objectives

- ✓ To explore the principles and practices underpinning multilayer farming systems.
- ✓ To assess the ecological and economic impacts of multilayer cropping.
- ✓ To identify barriers and facilitators influencing the adoption of multilayer farming.
- ✓ To propose strategies for scaling up multilayer farming within diverse agro-ecological contexts.

Methodology

The research synthesizes data from peer-reviewed literature, case studies, and empirical field observations. Qualitative and quantitative methods

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were employed to evaluate the performance metrics of multilayer farming, including productivity indices, resource efficiency and socioeconomic outcomes. Data were analyzed to identify trends, challenges, and best practices across different geographical regions.

Basic principles of Multilayer Farming

Multilayer farming operates on foundational principles that align with sustainable agricultural paradigms:

Optimized spatial utilization: Strategic alignment of crop layers to maximize solar capture and minimize resource overlap.

Biodiversity synergy: Integration of species with complementary growth cycles and resource demands.

Circular resource management: Adoption of practices that recycle organic matter and minimize input dependency.

Resilience and adaptability: Enhancement of system robustness against climatic variability and market fluctuations.

Multilayer farming serves as an integrated model where total utilization of resources—water, manure and land—is achieved to maximize production. This approach requires less investment while yielding significantly higher benefits than traditional farming systems. Through optimized resource allocation, farmers can cultivate four to five crops using the same inputs typically required for a single crop, thus augmenting their income potential. Annually, this technique allows for harvesting multi-

ple crops from the same land area.

Fundamental principles include

Opportunities for crop diversification: Encouraging varied crop selection based on scientific, ecological, and economic criteria.

System productivity maximization: Achieving peak efficiency in resource usage.

Higher resource utilization: Optimizing inputs like water and solar energy.

Intensive input use: Facilitating multiple outputs from limited resources.

Sustainability: Ensuring long-term productivity and environmental conservation.

The system often integrates tall, perennial trees or shrubs as the overstory, paired with economic or forage crops as the understory. The spacing between trees is carefully designed to allow adequate light penetration, benefiting understory crops.

Benefits

Agronomic Advantages

Enhanced Productivity: Concurrent cultivation of multiple crops significantly increases yield per unit area.

Soil Health Preservation: Organic amendments and reduced chemical inputs promote long-term soil fertility.

Environmental Impact

Water Conservation: Reduced evaporation due to shaded soil contributes to improved water-use efficiency.

Climate Mitigation: Multilayer systems create

Table 1: Successful model of multi-cropping approach in horticulture

Cropping system/sequence	Place of report	Remarkable outcome of the system	Reference
Coconut + Cocoa + Banana + Moringa + Pineapple	AICRP, Aliyarnagar	This cropping system with 75 % NPK + organic recycling with vermicompost recorded highest nut yield of 182 per palm and highest net income (Rs. 3.80 lakhs per ha) and B:C ratio (2.71).	Nimbolkar <i>et al.</i> (2016)
(Aonla+ ber + cluster bean+ fennel), (Aonla + bael + cluster bean + Coriander), (Aonla + cluster bean + ajowain)	Arid regions of Rajasthan	These systems were reported as sustainable and remunerative under the arid ecosystem	Hare Krishan <i>et al.</i> (2013)
(Aonla + ber + karonda + cluster bean + brinjal), (Aonla + ber + karonda + mothbean <i>Vigna acontifolia</i> Jacq. Marechal) + indian mustard (<i>Brassica juncea</i> L. Czernj & Cosso)	Arid regions of Rajasthan	Plant height, number of branches/plant, fruits/plant and yield was found to be superior in these multispecies cropping systems as compared to sole cropping.	Arya <i>et al.</i> (2010)
Mango+ cowpea+ Indian mustard	Todapur Research Orchard of Horticulture Division, IARI, New Delhi	This system recorded significantly highest values of system productivity, gross returns, net returns and benefit: cost ratio during both the crop seasons.	Mirjha and Rana (2016)
Coconut + Black pepper + Banana + Elephant Foot Yam	East Coast Region of Tamil Nadu	This system considered as the most suitable intercropping system in coconut based on the feasibility, marketability, soil health and economic viability.	Thivruvarssan <i>et al.</i> (2014)

microclimates that buffer crops against extreme weather conditions.

Economic Implications

Income Diversification: Simultaneous harvests provide multiple revenue streams.

Cost Reduction: Economies of scale in resource usage lower overall cultivation costs.

Social Benefits

Employment Generation: Year-round cropping cycles sustain continuous labour demand.

Food Security: Increased output supports local and regional food systems.

Challenges in Adoption

Lack of access to training programs impedes the dissemination of essential knowledge on multilayer cropping techniques. Initial investments in structural modifications and crop diversification remain a significant deterrent for smallholder farmer-

rs. Reliance on organic inputs and precise irrigation systems poses logistical challenges in resource-scarce regions. Fragmented supply chains and inadequate market access undermine the economic potential of multilayer farming outputs.

Conclusion

Multilayer farming offers a transformative approach to address pressing agricultural challenges, effectively integrating ecological sustainability with economic resilience. As a paradigm of modern agricultural innovation, multilayer farming leverages the natural symbiosis between diverse crop species, facilitating enhanced productivity and resource efficiency. This system has demonstrated remarkable potential in mitigating the effects of climate change by creating microclimatic conditions and conserving critical resources like water and soil nutrients. Despite its evident advantages, the adoption of multi-

layer farming remains limited due to structural, financial, and educational barriers. Addressing these constraints requires concerted efforts from policy-makers, researchers and agricultural extension services to foster widespread awareness and implementation. Capacity-building programs tailored to local contexts can empower farmers with the necessary skills and knowledge to transition to multilayer farming practices. Furthermore, investments in infrastructure, market linkages, and resource accessibility will be pivotal in scaling this approach. The long-term implications of multilayer farming extend beyond agricultural productivity, offering pathways to enhanced rural livelihoods and sustainable food systems. By diversifying income streams and reducing dependency on single crops, this system provides economic stability to farmers, particularly smallholders and those in marginalized communities. Additionally, its alignment with global sustainable development goals underscores its relevance in contemporary agricultural discourse. As the global population continues to grow and pressures on natural resources intensify, multilayer farming stands as a beacon of innovation. Its capacity to harmonize ecological health with economic viability positions it as a cornerstone for the future of sustainable agriculture. Expanding its adoption and refining its methodologies through research and innovation will ensure that multilayer farming continues to address the evolving challenges of the 21st century, paving the way for resilient and inclusive agricultural landscapes.

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Management of Yellow Vain Mosaic Virus (YVMV) of Okra and its Vector: A Success Story

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Okra (*Abelmoschous esculentus* (L.) Moench) also called bhendi or lady's finger, belongs to family malvaceae and is an important vegetable grown throughout the world mainly for its pods. Okra crop extensively cultivated in summer and *kharif* seasons in India. The cultivation of okra faces serious problems due to virus diseases viz., yellow vein mosaic virus (YVMV) and leaf curl which account for more losses as compared to the diseases caused by fungi, bacteria and nematodes. Among these, the former is the most serious and common disease in Panchmahal district of Gujarat. Yellow vein mosaic transmitted by white fly- *Bemisia tabaci* Genn. The symptoms of the disease start with yellowing of veins and clearing of veinlets followed by complete chlorosis of veins, vein swelling, slight downward curling of leaf margins, twisting of petioles, dwarfening and finally complete yellowing of leaf lamina resulting into retardation of growth. If infection is severe, plants become stunted and pods turn yellow, deformed, fibrous and are rendered unmarketable. This disease has become major constraint in okra cultivation affecting the crop at any growth stage and it causing significant losses in yield and fruit quality. The vector of yellow vein mosaic virus is *Bemisia tabaci* Genn. Taking into account the above considerations, frontline demonstrations

(recommended technology) were carried out during *Kharif* season 2014-15 in a systematic manner in the farmer field of Sh. Vinjaybhai Bhailalbhai Patel, Village-Vavadi Bujrag, Taluka- Godhra, Dist- Panchmahal, Gujarat with an objective to reduce yellow vein mosaic virus of okra and its vector for enhancing productivity of okra.

Methodology

The field experiments were carried out to demonstrate the recommended technology for the management of yellow vein mosaic virus of okra and its vector under FLD activity of ICAR- Krishi Vigyan Kendra-Panchmahal (Gujarat) at farmer's field. The recommended technology was adopted from AAU, Anand (Gujarat). Implementation of management of yellow vein mosaic virus of okra package by treated the seeds with imidacloprid 70 WS @ 7.5 g kg⁻¹ and subsequently application of three sprays of 5 g of acephate 50% and imidacloprid 1.8% in 10 liters of water at 40, 55 and 70 days after sowing while the prevailing farmers practice i.e. un-recommended pesticides were treated as control for comparison. Experimental trials were conducted by following all standard and recommended packages of practices such as tillage, spacing, irrigation and disease control for cultivation of the crop. Observations on the infestation of whiteflies and incidence of

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okra yellow vein mosaic virus disease were made by standard procedures. At the time of harvest, yield was recorded both in the recommended practices and farmer's practice fields and the cost: benefit ratios were worked out.

In the present study, technology gap, extension gap and technology index were calculated. Technology gap = Potential yield – Demonstration yield;

Extension gap= Demonstration yield – Yield under existing practice;

Technology index = $\frac{\text{Potential yield} - \text{Demonstration yield}}{\text{Potential yield}} \times 100$.

Result and Discussion

A comparison of frontline demonstrations due to recommended technology and farmers practice were analyzed and presented in Table 1. Of the two practices, recommended practice was found to be more effective in managing yellow vein mosaic virus of okra and its vector over farmers practice. From the present investigation, it can be concluded that the recommended practices revealed lower mean whiteflies population ($1.06 \text{ leaf}^{-1} \text{ plant}^{-1}$) and disease incidence of YVMV (13.06 %). The farmer practices showed higher infestation of whiteflies ($4.52 \text{ leaf}^{-1} \text{ plant}^{-1}$) and more disease incidence (23.10 %). In the present study, recommended practice was found to be effective in bringing down the vector population. Higher mean yield of 66.25 q ha^{-1} in were recorded in the recommended practice which is almost 36.60 % higher than farmers practice (48.50 q ha^{-1}) resulting in higher B:C ratio of 2.17 demonstrated

fields as compared to 1.70 for the farmers practices. Yield enhancement in okra crop in efficacy of Integrated Disease Management (IDM) modules for okra yellow vein mosaic virus been documented by Khajuria *et al.* (2015) who obtained significantly highest yield and gave satisfactory management of okra yellow vein mosaic virus.

The technology gap show gap in the demonstration yield over potential yield and it was 23.75 q ha^{-1} . The frontline demonstrations were laid down under the keen supervision of KVK specialist at the farmer's field. The observed technological gap might be attributed to dissimilarities in soil fertility, salinity, erratic rainfall and vagaries of weather conditions in the region. Hence, to narrow down the gap between the yields of different varieties, location specific recommendation appeared to essential. These findings were similar to the findings of Khajuria *et al.* (2016a). Technology index show the feasibility of recommended practices at the farmer's field. The lower the value of technology index more is the feasibility. Result of study depicted in Table 1 revealed that the technology index value was 19.72 %.

The economics of okra production under front line demonstrations were estimated as presented in Table 2. Economic analysis of the yield performance revealed that front line demonstrations recommended practices recorded higher gross returns (Rs $66,250 \text{ ha}^{-1}$) and net return (Rs $35,750 \text{ ha}^{-1}$) with higher benefit cost ratio (2.17) as compared to farmers practices (1.70). Further, additional cost

Table 1: Yield attributes, technology gap, extension gap and technology index of demonstration

Variables	Whiteflies/ leaf ^a	Disease incidence (%) ^b	Yield (q ha ⁻¹)	Yield increase (%) (q ha ⁻¹)	Technology gap (q ha ⁻¹)	Extension gap (q ha ⁻¹)	Technology index (%)
Farmer's practice	4.53 (1.44)	23.10 (21.02)	48.50	36.60	23.75	17.75	19.72
Recommended practice	1.06 (2.35)	13.06 (28.71)	66.25				
S.E $\pm$	(0.03)	(0.80)	1.07				
CV	(3.71)	(9.19)	5.26				
LSD (P = 0.05)	(0.08)*	(2.70)*	3.50*				

a Figures in parenthesis are transformed values of $\sqrt{x+1}$

b Figures in parenthesis are transformed angular values;

* Significant at 5%

Table 2: Economics of frontline demonstrations

Variables	Cost of cultivation (Rs ha ⁻¹)	Gross return (Rs ha ⁻¹)	Net return (Rs ha ⁻¹)	Benefit cost ratio
Farmer's practice	28,500	48,500	20,000	1.70
Recommended practice	30,500	66,250	35,750	2.17
Additional in recommended practice	2,000	17,750	15,750	8.88*

of Rs 2,000 ha⁻¹ in demonstration acquired on additional net return of Rs 15,750 ha⁻¹ with an incremental benefit cost ratio 8.88 suggesting its higher profitability and economic viability of the demonstration. Similar results were also reported by Khajuria *et al.* (2016b).

1.8% in 10 liters of water at 40, 55 and 70 days after sowing) was feasible, economically viable and effective technology for management of okra YVMV and its vector. The demonstration convinced most of the farmers to use recommended technology on account of its obvious advantages and effective management of okra YVMV and its vector. These innovative practices will help in solving the farmer's problem, decision-making and ability to modify their farming practices.

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Conclusion

Outcome of the frontline demonstrations clearly brought out that the adoption of recommended practice (treated the seeds with imidacloprid 70 WS @ 7.5 g kg⁻¹ and subsequently application of three sprays of 5 g of acephate 50% and imidacloprid

virus in semi arid region of middle Gujarat.

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Present Scenario of Agricultural Biotechnology in India

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Abstract

Agricultural biotechnology in India is revolutionizing farming through innovations like GM crops, tissue culture, biofertilizers, and genome editing. These advancements enhance productivity, sustainability, and food security while addressing climate resilience and malnutrition. Despite challenges in regulation, public perception, and accessibility, biotechnology promises a sustainable and transformative future for Indian agriculture.

Introduction

In recent years, agriculture and industry, two key sectors of the Indian economy, have been introduced to a completely new range of technologies. Among these, advancements in biotechnology hold particular significance. This cutting-edge technology is especially crucial for a developing country like India, where agriculture faces challenges such as stagnant productivity and various biotic and abiotic stresses, necessitating a push for higher growth. Similarly, the industrial sector anticipates transformations in production processes through the development of novel molecules and enzymes. These advancements take on greater importance within the framework of an intellectual property rights (IPR) system, which employs more robust measures for protection. The integration of biotechnology in agriculture is transforming traditional practices, contributing to sustainable and resilient farming

systems. (Ministry of Science & Technology, Government of India. (n.d.).

Achievements in Agricultural Biotechnology

Genetically Modified (GM) Crops: The GM crops in India began with *Bt* cotton, a genetically engineered variety designed to resist bollworms. Approved in 2002, *Bt* cotton has revolutionized India's cotton industry by increasing yields, reducing pesticide usage, and improving farmer incomes. Today, over 90% of India's cotton cultivation relies on *Bt* cotton, making the country the world's largest producer of cotton (Choudhary and Gaur, 2015; James, 2017).

Tissue Culture and Micropropagation: Tissue culture techniques have been widely adopted for the large-scale production of disease-free and high-yielding plant varieties. Crops like banana, sugarcane, potato, and ornamental plants have benefited significantly from this technology. Tissue culture not

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only ensures uniformity and quality but also supports the conservation of endangered plant species. (Indian Council of Agricultural Research ICAR (n.d.).

Biofertilizers and Biopesticides: The shift toward sustainable agriculture has increased the adoption of biofertilizers and biopesticides. These biological solutions enhance soil fertility and control pests without harming the environment. Products like Rhizobium, Azotobacter, and Trichoderma have gained popularity among farmers, contributing to eco-friendly farming practices (Wani and Sreedevi, 2005).

Marker-Assisted Breeding: Marker-assisted selection (MAS) has become a powerful tool in crop improvement programs. By identifying and selecting specific genes linked to desirable traits, scientists have developed crops with improved resistance to diseases, pests, and environmental stresses. For instance, drought-resistant rice and disease-resistant wheat varieties have been developed using MAS. (National Biotechnology Development Strategy (2021-25)).

Role of Institutions and Policies

India's advancements in agricultural biotechnology are supported by a robust institutional and policy framework. The Department of Biotechnology (DBT), under the Ministry of Science and Technology, spearheads research and development activities. Other key organizations include the Indian Council of Agricultural Research (ICAR) and state agricultural universities, which focus on technology dissemination and capacity building. The regulatory

landscape for GM crops is overseen by the Genetic Engineering Appraisal Committee (GEAC), ensuring biosafety and compliance with global standards. The National Biotechnology Development Strategy outlines a roadmap for fostering innovation, addressing regulatory challenges, and promoting public-private partnerships.

Challenges in Agricultural Biotechnology

Regulatory Hurdles: The approval process for GM crops in India is lengthy and often influenced by public and political resistance. For instance, *Bt* brinjal, despite being approved by GEAC in 2009, faced a moratorium due to opposition from various stakeholders. Similarly, GM mustard's commercial release has been delayed for years.

Public Perception and Awareness: The acceptance of biotechnology among farmers and consumers remains a challenge. Misinformation about GM crops and concerns regarding health and environmental risks have led to skepticism. Efforts to educate the public and dispel myths are crucial for wider adoption.

Access and Affordability: Smallholder farmers, who constitute the majority of India's agricultural workforce, often lack access to biotechnological innovations due to high costs and limited infrastructure. Bridging this gap is essential to ensure equitable benefits.

Intellectual Property Rights (IPR): The IPR regime poses challenges for technology dissemination. Strong patent protections can restrict the availability of seeds and technologies to farmers,

necessitating a balance between innovation incentives and accessibility.

Climate Change Impacts: Climate change exacerbates challenges such as water scarcity, soil degradation and pest outbreaks. While biotechnology offers solutions, its adoption needs to be scaled up rapidly to mitigate these impacts effectively (Climate Adapt, 2023).

Emerging Trends in Agricultural Biotechnology

Techniques like CRISPR-Cas9 are revolutionizing crop improvement by enabling precise gene editing. Genome editing holds promise for developing crops with enhanced traits such as improved yield, nutritional quality, and stress tolerance (Sharma and Aggarwal, 2019). Synthetic biology is being explored to create artificial biological systems for agriculture. For example, researchers are working on engineering microbes that can fix atmospheric nitrogen, reducing the need for chemical fertilizers. Understanding and manipulating plant microbiomes can enhance soil health and plant productivity. Microbial consortia are being developed to boost crop resilience and nutrient uptake. The integration of biotechnology with digital tools like sensors, drones, and AI is transforming precision agriculture. These technologies enable real-time monitoring of crop health and optimize resource usage (World Economic Forum, 2021)

Impact on Food Security and Sustainability

Agricultural biotechnology has a direct impact on India's food security by increasing crop yields, reducing post-harvest losses, and improving

nutritional quality. Biofortified crops, such as iron-rich rice and vitamin A-enriched sweet potatoes, address malnutrition effectively. Sustainability is another critical area where biotechnology contributes. By reducing the dependency on chemical inputs, biotechnology minimizes environmental pollution and conserves natural resources. Drought-tolerant and saline-resistant crops are helping farmers adapt to changing climatic conditions (Qaim and Kouser, 2013).

Future Prospects

The future of agricultural biotechnology in India looks promising, with several opportunities for growth: Collaborative efforts between government agencies, research institutions and private companies can accelerate the development and dissemination of biotechnological innovations. Investments in training programs for scientists, extension workers, and farmers are essential to build a skilled workforce capable of leveraging biotechnology effectively. Partnerships with international organizations and participation in global research initiatives can facilitate knowledge exchange and access to advanced technologies. Streamlining regulatory processes and fostering a conducive environment for innovation will be key to overcoming existing bottlenecks.

Conclusion

Agricultural biotechnology in India is at a crossroads, offering immense potential to transform the agricultural landscape. While the country has made significant strides, challenges such as regulat-

ory hurdles, public perception, and access disparities need to be addressed. By fostering innovation, enhancing awareness, and promoting equitable access, India can harness the full potential of biotechnology to achieve food security, sustainability, and economic growth. As the global demand for food rises, agricultural biotechnology will undoubtedly play a central role in shaping the future of Indian agriculture.

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Eco-Friendly Packaging Solutions for the E-Commerce Industry: Assessing Environmental Impact and Exploring Sustainable Alternatives

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Abstract

The rapid expansion of the e-commerce industry has brought convenience and accessibility to consumers worldwide. However, this growth has also intensified the demand for packaging materials, contributing significantly to environmental pollution. The current reliance on single-use plastics, non-biodegradable materials, and excessive packaging has a substantial ecological impact, particularly through resource depletion, waste generation, and carbon emissions. This paper examines the environmental consequences of conventional e-commerce packaging and highlights viable eco-friendly alternatives. These alternatives offer solutions that maintain product safety while minimizing environmental harm, aiming for a sustainable balance between functionality and ecological responsibility.

Introduction

The global shift towards online shopping has transformed the retail landscape, with e-commerce becoming an indispensable part of daily life. As the volume of online orders rises, so does the demand for packaging. This demand leads to a parallel increase in packaging waste, much of which ends up in landfills, oceans, and other ecosystems, posing a threat to environmental health. The traditional materials used in e-commerce packaging, like plastic and polystyrene, are not only resource-intensive but are also slow to decompose, contributing to long-term pollution. Given these concerns, there is a growing need to adopt eco-friendly packaging solutions that reduce waste and limit environmental

damage.

Environmental Impact of Conventional E-commerce Packaging

Plastic Pollution: Most e-commerce packages use plastics, such as polyethylene mailers, bubble wrap, and plastic adhesives. These materials derive from non-renewable fossil fuels and contribute to greenhouse gas emissions during production. Once discarded, they can take hundreds of years to break down, littering land and water and creating hazards for wildlife. According to the Environmental Protection Agency (EPA), plastics are among the top contributors to global pollution, with only a small percentage being recycled effectively. Resource Depletion Packaging materials like cardboard and

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paper-based fillers come from natural resources, particularly trees, whose harvesting can lead to deforestation and loss of biodiversity. The production of plastic and other synthetic materials is also energy-intensive, further increasing their carbon footprint. For example, it is estimated that producing one ton of cardboard requires 17 trees and 7,000 gallons of water.

Generation and Landfill Accumulation: The use of single-use materials in packaging means that much of it ends up in landfills, often because of contamination or the inability to recycle certain materials. These landfills generate methane, a potent greenhouse gas, and contribute to soil and water contamination. With the exponential growth of e-commerce, the waste generated is projected to increase, worsening landfill and pollution issues globally.

Carbon Emissions from Transport: The weight and volume of packaging significantly influence transportation costs and associated carbon emissions. Heavier packaging materials require more fuel for transportation, leading to higher emissions. The cumulative impact of these emissions is considerable, especially in a high-frequency delivery model like e-commerce.

Alternatives to Traditional E-commerce Packaging: In response to the environmental impact of conventional materials, several sustainable alternatives have emerged. These options focus on reducing waste, lowering emissions, and enhancing recyclability, all while maintaining product protect-

ion.

Biodegradable and Compostable Materials: Biodegradable packaging materials, such as mushroom-based foam, cornstarch plastics, and plant fibers, decompose faster than traditional plastics, leaving minimal ecological footprints. Compostable materials, including polylactic acid (PLA) made from corn starch, can be broken down in compost environments, providing nutrients to the soil rather than accumulating as waste.

Recyclable and Packaging: Using recycled cardboard, paper fillers, and other recyclable materials is another sustainable approach. Circular packaging models, where customers can return packaging for reuse, have gained traction and offer a promising way to minimize waste and reduce production demand.

Edible Packaging for Foli Goods: For food products, edible packaging, such as seaweed-based or starch-based films, provides an innovative zero-waste solution. These packaging materials, which are safe for consumption or composting, help reduce single-use plastics and encourage waste-free practices.

Water-Soluble Packaging: Water-soaking materials, like polyvinyl alcohol (PVA), dissolve in water, leaving no environmental residue. These materials are ideal for lightweight products that do not require extensive protection, such as small non-fragile items. However, careful handling is required to prevent accidental degradation during transport.

Corrugated Cardboard and Paper-Based Cushi-

oning: Corrugated cardboard with innovative design features can offer cushioning without additional materials, reducing the need for plastic or foam inserts. This type of packaging is recyclable, renewable, and, when properly designed, provides effective protection. Brands like Amazon have adopted this strategy in their “Frustration-Free Packaging,” which minimizes unnecessary layers and plastic.

Air Pillows Made from Recycled Paper: Replitic bubble wrap with air pillows made from recycled paper provides a biodegradable alternative without compromising on protective qualities. These paper-based materials are recyclable and decompose faster than plastics, addressing the long-standing issue of plastic waste in cushioning products.

Benefits and Challenges of Adopting Sustainable Packaging in E-commerce

Benefits

Environmental Conservation: Sustainable packaging reduces plastic waste, cuts emissions, and conserves natural resources.

Positive Brand Image: Consumers increasingly favor brands with environmental commitments, enhancing loyalty and market share.

Cost Savings over Time: Though initially expensive, eco-friendly packaging solutions can save costs in the long run by reducing material use and promoting reusable packaging.

Challenges

Cost Constraints

- ✓ Sustainable materials often have higher produ-

ction costs compared to conventional options, making them less accessible for small businesses.

- ✓ Cost-efficiency in large-scale adoption remains a significant barrier.

Infrastructure Limitations

- ✓ Lack of proper composting or recycling infrastructure can undermine the effectiveness of biodegradable or recyclable packaging.
- ✓ Developing regions face challenges in managing innovative packaging waste.

Consumer Behavior and Awareness

- ✓ Many consumers are unaware of how to properly dispose of sustainable packaging. Mismanagement leads to contamination in recycling or composting streams.
- ✓ Clear labeling and education are necessary to optimize end-of-life disposal.

Scalability Issues: Limited availability of sustainable raw materials and production capabilities hinders widespread adoption of eco-friendly packaging.

Compliance and Regulations: Inconsistent regulations regarding sustainable packaging across countries create hurdles for global e-commerce businesses.

Future Outlook and Conclusion

The future of eco-friendly packaging in the e-commerce industry is promising, with innovations continuously emerging to address the challenges of waste and environmental degradation. As more companies adopt sustainable alternatives, the industry will likely witness a shift towards materials

that balance protection with environmental responsibility. For long-term success, brands must commit to educating consumers on eco-friendly disposal practices, reducing material use and investing in research to optimize packaging solutions. Eco-friendly packaging is no longer a luxury; it is an essential part of a sustainable future. E-commerce companies have the power and responsibility to drive this change, benefitting not only the environment but also enhancing brand reputation and meeting consumer expectations for greener choices.

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The Art and Science of Saffron Cultivation

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Abstract

Saffron, often dubbed “red gold,” is not merely a spice but a testament to human perseverance and agricultural finesse. This article delves into the intricate world of saffron farming, exploring its taxonomy, global distribution and the meticulous production technology that has evolved over millennia. We unravel the complexities of cultivating *Crocus sativus*, examining the plant's unique characteristics and the painstaking process of harvesting its prized stigmas. Beyond its culinary allure, saffron's medicinal properties and diverse applications in daily life are scrutinized, shedding light on the active compounds that make this spice a treasure trove of potential health benefits. By intertwining historical context with cutting-edge research, this comprehensive exploration aims to provide readers with a nuanced understanding of saffron's journey from field to kitchen and laboratory.

Introduction

In entire global agriculture, few threads shine as brightly as saffron. This illustrious spice, derived from the flower of *Crocus sativus*, has captivated human imagination and palates for over three millennia. Its story is one of patience, precision and passion, woven through the annals of history from ancient Persia to modern-day kitchens and laboratories worldwide. Saffron's allure extends far beyond its distinctive flavor and color. It's a spice that has sparked wars, adorned the robes of royalty



and continues to be one of the most valuable agricultural products by weight. The journey of saffron from a humble crocus flower to the golden threads that grace our dishes is a testament to the intricate dance between nature and human ingenuity. This article aims to unfurl the complex world of saffron farming, offering a comprehensive look at the botanical marvel that is *Crocus sativus*, the painstaking process of its cultivation and the myriad ways in which this “red gold” enriches our lives. From the sun-drenched fields of Iran to the misty valleys of Kashmir, we'll explore how geography, climate and human expertise combine to produce one

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of the world's most sought-after spices.

As we delve into the scientific intricacies of saffron's taxonomy and the artisanal craft of its production, we'll also uncover the hidden potential locked within its delicate threads. From ancient medicinal uses to cutting-edge pharmaceutical research, saffron continues to surprise and delight, offering a bounty of possibilities for health and wellness. Join us on this journey through the golden fields of saffron, where tradition meets innovation and where each crimson stigma tells a story of dedication, craftsmanship and the enduring appeal of one of nature's most extraordinary gifts.

Taxonomy, Description and Distribution

Botanical Classification

Saffron, scientifically known as *Crocus sativus* L., belongs to the family Iridaceae. This perennial herb is a member of the genus *Crocus*, which encompasses about 90 species (Koul and Farooq, 2017). What sets *Crocus sativus* apart is its triploid nature, rendering it sterile and dependent on human intervention for propagation. This unique characteristic has played a crucial role in shaping the history and cultivation practices of saffron.

Morphological Features: The saffron plant is a small perennial herb, typically growing to a height of 20-30 cm. Its most distinctive feature is the flower, which boasts a vibrant purple hue. Each flower contains three stigmas, the coveted part of the plant from which the saffron



spice is derived. These stigmas are a deep crimson color and can reach up to 30-35 mm in length. The plant develops from a corm, a bulb-like structure that serves as its primary means of reproduction. These corms are covered with a fibrous, brown tissue and can produce up to ten flowers each. The leaves of the saffron plant are grass-like, narrow and can grow up to 40 cm long (Gresta *et al.*, 2008).

Global Distribution: While *Crocus sativus* is believed to have originated in Greece and Asia Minor, its cultivation has spread across various parts of the world. Today, saffron is primarily grown in a belt extending from the Mediterranean to Iran and Kashmir. Iran leads global production, accounting for more than 90% of the world's saffron output. Other significant producers include Spain, Greece, Morocco and India, particularly in the Kashmir region (Cardone *et al.*, 2020). The plant thrives in areas with hot, dry summers and cool winters. It requires well-drained soils and is often cultivated at altitudes ranging from 600 to 1700 meters above sea level. This specific climatic requirement has limited large-scale saffron production to particular geographical regions, contributing to its rarity and high value.

Area and Production

Global Production Landscape: The global saffron market is characterized by its limited production areas and high market value. As of 2020, the global saffron market was valued at approximately \$500 million, with projections suggesting growth to reach \$750 million by 2025 (Grand View Research, 2021).

Iran dominates the global saffron production landscape, producing over 300 tons annually, which accounts for more than 90% of the world's supply. The Iranian provinces of Khorasan Razavi, South Khorasan and Fars are the primary cultivation areas, with the city of Torbat Heydariyeh often referred to as the “capital of saffron” (Koocheki *et al.*, 2019).

Spain, the second-largest producer, cultivates saffron primarily in the La Mancha region, producing about 1.5 tons annually. Greek saffron, known for its high quality, is mainly produced in the Kozani region, with an annual output of around 7 tons. India's saffron production is centered in Jammu and Kashmir, yielding approximately 15 tons per year (Kumar *et al.*, 2020).

Yield and Economic Impact: Saffron's economic significance is disproportionate to its production volume due to its high market value. The yield of saffron is measured in kilograms ha⁻¹, with average yields ranging from 3 to 6 kg ha⁻¹ in traditional cultivation systems. However, with improved cultivation techniques, yields of up to 15 kg ha⁻¹ have been reported in some regions (Gresta *et al.*, 2008). The economic impact of saffron farming extends beyond direct sales. In many producing regions, saffron cultivation supports rural economies, providing employment and attracting tourism. For instance, in Kashmir, saffron farming is not just an economic activity but a cultural heritage, supporting thousands of families and forming an integral part of the region's identity (Husaini *et al.*,



2010).

Detailed Production Technology

Soil Preparation and Planting: Successful saffron cultivation begins with meticulous soil preparation. The ideal soil for saffron is well-drained, clay-loam with a pH between 6.0 and 8.0. Before planting, the soil is deeply plowed to a depth of 30-40 cm and enriched with organic matter. This preparation is crucial as the corms will remain in the soil for several years (Molina *et al.*, 2005). Planting typically occurs in late summer or early autumn. Corms are planted in rows, with spacing varying depending on the cultivation system. Traditional methods often use a spacing of 10-15 cm between corms and 20-25 cm between rows. More intensive systems may plant corms closer together to maximize yield per area (Gresta *et al.*, 2008).

Irrigation and Fertilization: While saffron is relatively drought-tolerant, strategic irrigation can significantly enhance yield and quality. The critical periods for irrigation are during sprouting in autumn and during the vegetative growth phase in spring. Drip irrigation systems are increasingly being adopted in modern saffron farms for their efficiency and precision (Koocheki *et al.*, 2019). Fertilization practices vary depending on soil conditions and cultivation intensity. Generally, saffron benefits from moderate applications of nitrogen, phosphorus and potassium. Organic fertilizers, such as well-rotted manure, are often preferred as they improve soil structure and water retention capacity (Mollafilabi *et al.*, 2014).

Pest and Disease Management: Saffron is susceptible to various pests and diseases, necessitating vigilant management practices. Common pests include rodents, which feed on corms and thrips, which can damage flowers. Diseases such as corm rot, caused by *Fusarium* species, can be particularly devastating. Integrated Pest Management (IPM) strategies are increasingly being adopted in saffron cultivation. These include crop rotation, use of disease-resistant corm varieties and biological control methods. Chemical interventions are used judiciously to minimize environmental impact and preserve the spice's purity (Husaini *et al.*, 2010).

Harvesting and Post-Harvest Handling: The harvesting of saffron is undoubtedly the most labor-intensive and crucial phase of production. Flowers typically bloom for only 15-20 days in the autumn and each flower is open for just one day. Harvesting must occur in the early morning before the flowers fully open to preserve the stigmas' quality. The flowers are hand-picked, a process that requires great skill and care. The stigmas are then separated from the rest of the flower, a delicate process known as "saffron peeling" or "saffron plucking." This step is traditionally done by hand, though some mechanical methods have been developed for larger operations (Cardone *et al.*, 2020). After separation, the stigmas undergo a drying process to reduce their moisture content from about 80% to 10-12%. This is typically done using gentle heat, either through sun-drying in traditional methods or controlled dehydration in modern facilities. The drying process is critical in

developing saffron's characteristic flavor and aroma compounds (Ahrazem *et al.*, 2015).

Corm Management and Reproduction: As saffron is sterile and reproduces vegetatively, proper corm management is essential for sustaining production. Corms multiply underground, producing smaller corms known as cormels. After 3-5 years, depending on the cultivation system, the corms are typically uprooted, separated and replanted to maintain productivity (Gresta *et al.*, 2008). During the dormant period in summer, corms are carefully inspected for size and health. Larger corms (>10 g) are preferred for replanting as they tend to produce more flowers. This selection process is crucial for maintaining and improving the quality and yield of saffron over successive seasons (Koocheki *et al.*, 2019).

Medicinal Uses and Daily Life Applications

Traditional Medicinal Applications: Saffron's use in traditional medicine spans cultures and millennia. In ancient Persia, it was used as a mood enhancer and to treat various ailments including menstrual disorders, liver disease and pain. In traditional Chinese medicine, saffron has been employed to improve circulation, reduce inflammation and as an aphrodisiac (Hosseinzadeh and Nassiri-Asl, 2013). In Ayurvedic medicine, saffron is known as "Kesar" and is valued for its ability to balance the three doshas (vata, pitta and kapha). It's used in formulations to treat respiratory issues, improve digestion and enhance skin health. European folk medicine has utilized saffron for its purported anti-

spasmodic and sedative properties (Mousavi and Bathaie, 2011).

Modern Pharmacological Research

Contemporary scientific research has begun to validate many of saffron's traditional uses while uncovering new potential applications. Studies have shown promising results in several areas:

Mental Health: Saffron extracts have demonstrated antidepressant effects comparable to some pharmaceutical antidepressants in clinical trials. It's also being investigated for its potential in managing anxiety disorders and improving cognitive function in neurodegenerative diseases (Lopresti and Drummond, 2014).

Eye Health: Research suggests that saffron may have protective effects against age-related macular degeneration and may improve visual acuity in early-stage retinitis pigmentosa (Bisti *et al.*, 2014).

Cardiovascular Health: Saffron's antioxidant properties may contribute to improved heart health by reducing cholesterol levels and protecting against oxidative stress (Christodoulou *et al.*, 2015).

Cancer Research: Preliminary studies indicate that certain compounds in saffron may have anti-tumor properties, showing potential in inhibiting the growth of various cancer cell lines (Samarghandian and Borji, 2014).

Culinary Uses and Daily Life Applications

In the culinary world, saffron is prized for its unique flavor profile, described as subtly earthy with hints of honey and its ability to impart a golden-yellow hue to dishes. It's a key ingredient in iconic

dishes such as Spanish paella, Italian risotto Milanese and Indian biryani. Beyond its use in main courses, saffron finds its way into various everyday applications:

Beverages: Saffron-infused teas, milk and even cocktails are gaining popularity for their distinctive flavor and purported health benefits.

Desserts: From traditional Middle Eastern sweets to modern ice creams and chocolates, saffron adds a luxurious touch to confections.

Aromatherapy: Saffron essential oil is used in aromatherapy for its calming and mood-enhancing properties.

Cosmetics: The spice is incorporated into skincare products for its antioxidant properties and in perfumes for its unique scent profile.

Dyes: Historically used to dye textiles, saffron continues to be used in natural dye processes, particularly for special or ceremonial garments.

Active Chemicals and Their Properties

The unique properties of saffron are attributed to its complex chemical composition. The main bioactive compounds responsible for saffron's color, flavor and medicinal properties can be categorized into three groups:

Crocins: Crocins are water-soluble carotenoids that give saffron its characteristic golden-yellow color. The primary crocin in saffron is crocin-1, also known as α -crocin. These compounds are powerful antioxidants and have been associated with various



health benefits, including:

- ✓ Neuroprotective effects, potentially beneficial in cognitive disorders (Finley and Gao, 2017).
- ✓ Anti-inflammatory properties, which may help in managing chronic inflammatory conditions (Poma *et al.*, 2012).
- ✓ Potential anti-cancer activities, showing promise in inhibiting the growth of certain cancer cell lines (Samarghandian and Borji, 2014).

Picrocrocin: Picrocrocin is the main compound responsible for saffron's bitter taste. Upon degradation, it produces safranal, which contributes to the spice's aroma. Research on picrocrocin has revealed:

- ✓ Potential anti-depressant effects, contributing to saffron's mood-enhancing properties (Lopresti and Drummond, 2014)
- ✓ Possible anti-convulsant activities, suggesting applications in managing epilepsy (Hossein-zadeh and Sadeghnia, 2007)

Safranal: Safranal is the principal component of saffron's volatile oil and is largely responsible for its distinctive aroma. This compound has shown several promising properties in scientific studies:

- ✓ Antioxidant effects, potentially protecting cells from oxidative stress (Assimopoulou *et al.*, 2005)
- ✓ Anticancer potential, with studies indicating possible pro-apoptotic effects on cancer cells (Samarghandian *et al.*, 2014)
- ✓ Anxiolytic and hypnotic effects, suggesting potential applications in managing anxiety and sleep disorders (Hossein-zadeh and Noraei, 2009)

Other Compounds

In addition to these primary bioactive compounds, saffron contains various other substances that contribute to its overall effects:

Flavonoids: These compounds contribute to saffron's antioxidant properties and may have cardioprotective effects.

Vitamins: Saffron contains small amounts of vitamins A and C, contributing to its nutritional value.

Minerals: Trace amounts of calcium, iron, magnesium and potassium are present in saffron.

The synergistic action of these compounds is believed to be responsible for saffron's wide range of potential health benefits and its unique sensory properties.

Conclusion

The journey through the golden fields of saffron cultivation reveals a spice that is as complex in its growth requirements as it is in its chemical composition. From its meticulous cultivation process to its myriad applications in cuisine, medicine and daily life, saffron stands as a testament to the intricate relationship between humans and plants. The production of saffron, with its labor-intensive harvesting and processing, underscores the value of traditional agricultural knowledge and the importance of preserving such practices in our modern world. At the same time, ongoing scientific research into saffron's bioactive compounds opens new avenues for its application in modern medicine and wellness practices. The potential of saffron in

addressing contemporary health challenges, from mental health disorders to age-related diseases, highlights the importance of bridging traditional knowledge with cutting-edge scientific inquiry. The global saffron industry, while still rooted in traditional producing regions, is witnessing a gradual expansion to new areas, driven by increasing demand and the spice's high economic value. This expansion brings with it both opportunities and challenges. On one hand, it offers economic prospects for rural communities and diversification of agricultural practices. On the other, it necessitates careful management to maintain the quality standards and authenticity that have made saffron so prized throughout history. As we look to the future, the sustainability of saffron production emerges as a critical concern. Climate change poses significant challenges to traditional growing regions, potentially altering suitable cultivation areas and impacting yield and quality. Adaptation strategies, including the development of more resilient cultivars and innovative farming techniques, will be crucial in ensuring the continued availability of this precious spice. Moreover, the high value of saffron makes it a target for adulteration and fraud, underscoring the need for stringent quality control measures and traceability systems. The development and implementation of advanced analytical techniques for authenticating saffron will be essential in protecting both producers and consumers. In conclusion, saffron stands as more than just a spice; it is a cultural heritage, an economic lifeline for many communities

and a subject of fascinating scientific inquiry. Its journey from the field to our plates and medicine cabinets is a remarkable tale of human ingenuity, patience and the enduring allure of nature's gifts. As we continue to unravel the secrets held within its delicate threads, saffron promises to remain a golden treasure, bridging past and future, tradition and innovation, in the ever-evolving tapestry of global agriculture and human health.

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Automating Farms with Arduino

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Abstract

Arduino is a microprocessor which is based on open-source platform. Arduino makes it possible to create intelligent and automated farming systems by combining a wide range of sensors, including light, temperature, humidity, and soil moisture sensors. With real-time data and accurate control over important environmental elements, these systems enable farmers to maximize resource use, boost crop yields, and improve farm productivity. For farmers of all skill levels, Arduino's open-source nature and simplicity of programming encourage creativity and accessibility. Even while issues like data security and cost-effectiveness still exist, these constraints are being continuously addressed via research and development. This evaluation demonstrates Arduino's enormous potential to promote effective and sustainable farming methods, which will ultimately strengthen and safeguard the world's food supply.

Introduction

Agriculture, the backbone of human society, has changed significantly over time. In the modern era, technology has emerged as a catalyst that directs farming methods toward greater efficiency and output. Precision agriculture signifies a significant paradigm shift by emphasizing data-driven decision-making, resource efficiency, and sustainability to create a more intelligent and flexible agricultural ecosystem. Precision agriculture employs a number of technical advancements, but sensors stand out as being very crucial tools in this ground-breaking process. Due to their ability to measure and monitor a wide range of environmental characteristics, these sensors are crucial for giving real-time information regarding crop conditions. The Smart Agriculture

System is an innovative initiative that skillfully integrates a variety of sensors to create an automated and intelligent farming infrastructure (Mini *et al.*, 2023). The Smart Agriculture System's main goal is to address the challenges posed by conventional farming practices and move agriculture toward a more sophisticated and flexible framework. Conventional methods usually apply resources, such as water and fertilizer, widely and uniformly without considering the needs of each crop. In addition to causing wasteful resource consumption, this may also have adverse environmental implications. In contrast, the Smart Agriculture System incorporates several strategically positioned sensors into the agricultural environment. These sensors serve as the system's eyes and ears, gathering data on crucial

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elements influencing crop growth on a constant basis. Among the crucial components are a thermal sensor, a gas sensor, a photodiode for ambient light detection, and a soil moisture sensor. Important information from each sensor contributes to a comprehensive understanding of the agricultural ecology. Using the power of sensors, automation, and precision agricultural principles, this system seeks to revolutionize farming techniques, promoting sustainability, resource efficiency, and increased crop yields in the rapidly evolving field of contemporary agriculture. By facilitating informed decision-making in response to changing climate patterns, giving farmers relevant information, enhancing precision agriculture for higher yields, and leveraging technological advancements, the system's incorporation of temperature sensors promotes climate resilience. The ultimate objective is to promote a resilient, technologically sophisticated and ecologically sensitive agricultural landscape in order to contribute to global food security (Rahman *et al.*, 2018).

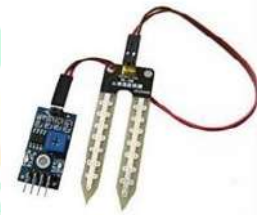
Arduino UNO: Among the Arduino family's most popular microcontroller boards is the Arduino Uno R3. 2011 saw the release of the Arduino board's third and most recent version. This board's primary benefit is that its microcontroller may be swapped out in the event that something goes wrong. This board's primary characteristics are its dual-inline-package (DIP) design, detachability, and ATmega328 CPU. One type of microcontroller board based on the ATmega328P is the Arduino Uno R3. Six analog

inputs, fourteen digital input/output pins (six of which can be used as PWM outputs), a reset button, a USB connector, a power jack, an ICSP header, and a ceramic resonator running at 16 MHz are all included (Mohankumar and Gowtham, 2024).



Fig. 1: Arduino UNO R3 board

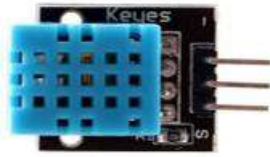
Soil Moisture Sensor: A soil moisture sensor's function is to measure the amount of water in the soil and report the moisture content at the output. The sensor can be used in either mode because it has both analog and digital output. Two probes make up the soil moisture sensor. These probes are used to test the volumetric content of water. Current is allowed to pass through the soil with the help of the probes, and the resistance value that is acquired is then used to calculate the moisture value. On the other hand, dry earth conducts electricity poorly. As a result, when there is less water present, electrical conductivity will be extremely low, suggesting that there is greater resistance (Raj and Ananthi, 2019).



Temperature and Humidity Sensor: This digital sensor is used to track and collect data regarding the green house's current humidity and temperature. It

operates between 3 and 5 volts with a maximum current of 2.5 milliamperes.

The humidity percentage is set between 20 and 80



percent, and the temperature range is maintained between 0 and 50 degrees. The internal thermistor uses a negative temperature coefficient and a humidity sensor to determine the amount of moisture in the air (Srivastava *et al.*, 2018).

Light Sensor: This makes it possible to add control over the greenhouse conditions; the GL5528 measures the environment's light intensity. 5V is the input voltage that powers it. The light sensor's output voltage varies with light intensity; as light intensity rises, the voltage measured at the output is extremely high, and as light intensity falls, the output voltage falls.

Few studies using Arduino for automation: Using an Arduino Uno and DHT11 sensor, the system suggested by Hammami (2019) gathers temperature and humidity data and sends it to the ThinkSpeak web service, which is accessed through the Application Programmable Interface (API) through a mobile Wi-Fi router-provided internet connection. However, it lacks a notification system in case of an anomaly.

Taru and Karwankar (2017) designed the water quality detection systems that use web-based panel monitors constructed using LabView apps, an Arduino UNO coupled to a DS18S20 sensor to measure water temperature, pH sensors to evaluate water acidity, and turbidity sensors to measure water

clarity. Suma *et al.* (2017) by offering an IOT-based smart agriculture system that includes remote control monitoring for sensing of the moisture, temperature, intruder, security, and the leaf wetness using the GPS module.

Conclusion

To sum up, this article thoroughly investigates Arduino's expanding contribution to the transformation of contemporary agriculture. Arduino makes it possible to create intelligent and automated farming systems by combining a wide range of sensors, including light, temperature, humidity, and soil moisture sensors. With real-time data and accurate control over important environmental elements, these systems enable farmers to maximize resource use, boost crop yields, and improve farm productivity.

Furthermore, farmers of all skill levels can use Arduino because of its open-source nature and simplicity of programming. The democratization of technology encourages creativity and makes it possible to create solutions that are specifically suited to the demands and difficulties faced by farmers. Even if there are still issues with cost-effectiveness, dependability, and data security, these constraints are being continuously addressed by research and development. This evaluation demonstrates Arduino's enormous potential to promote effective and sustainable farming methods, which will ultimately strengthen and safeguard the world's food supply.

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Parthenocarpy in Vegetable Crops

Pankaj Kumar Ray and Pallavi Bharti

Introduction

Parthenocarpy is the process of fruit development without fertilization, or the natural or artificial inducement of fruit production without pollination and fertilization (Parthenos, virgin; karpos, fruit). Noll was the first to use the term “parthenocarpy” (1902). Seedlessness is a desirable quality in edible fruits with hard seeds, such as pineapples, oranges, grapefruits, and bananas. In fruit crops that might be difficult to pollinate or fertilize, it is also a beneficial trait. Parthenocarpy increases fruit output in dioecious plants since staminate trees do not need to be planted to provide pollen. It increases final profitability, improves processing quality, and extends shelf life by reducing the amount of ethylene that seeds emit. The development of novel cultivars that can yield fruits without pollination or artificial stimuli is a potential approach. Numerous methods, including as the use of plant growth regulators, distant hybridization, mutation, irradiation pollen, chromosomal number alternation, gene transfer, gene silencing, and genome editing tools, can be used to naturally or intentionally generate parthenocarpy.

Parthenocarpic Vegetable Crop Benefits

- ✓ Pollination and fertilization are negatively impacted by environmental stresses such as high

or low temperatures; nevertheless, parthenocarpic vegetables continue to grow and bear fruit even in the absence of these processes, leading to stability in their development and yield.

- ✓ Fruits without seeds, like parthenocarpic cucumbers, watermelons and pickled cucumbers, are preferred by consumers.
- ✓ Parthenocarpy is the cause of new plants like the seedless watermelon, parthenocarpic cucumber, and seedless tomato.
- ✓ In certain situations, parthenocarpic vegetables with no seeds may taste and feel better. By eliminating bitter or undesirable seed components, the vegetable's overall palatability and satisfaction of ingestion can be enhanced.
- ✓ The processing sector is more profitable because seedless fruits don't need their seeds removed during processing. For example, a tomato without seeds.
- ✓ Preserve GM crops: if a transgene is attached to seedlessness, it will prevent someone from unjustly stealing it by simply crossing the transgenic plant with another commercial variety.
- ✓ Parthenocarpic fruits, like parthenocarpic cucumbers, produce early.

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- ✓ Vertical fruit harvesting: Growing parthenocarpic cucumbers in greenhouses where fruit sets continually on the plant yields additional advantages. This will reduce the time and cost of pollen vibrators and manual pollination, both of which are required for greenhouse vegetable production.

Types of Parthenocarpy

Natural or Genetic Parthenocarpy: Genetic parthenocarpy is known as facultative when it occurs only under unfavorable conditions for pollination and fertilization and mandatory when it occurs without external influence. Natural parthenocarpy is caused by an excess of endogenous hormones in the ovary when pollination and fertilization are not present, while facultative parthenocarpy is the term used to describe fruit whose parthenocarpic growth occurs only when pollination and fertilization are not present. Genetic parthenocarpy can address low pollen viability and poor pollen discharge. These issues usually occur in open and greenhouse settings with variable temperatures and little light.

Artificial Parthenocarpy

Some fruits need the same stimulation procedures as fertilization and pollination to develop. A range of crops and methods can be used to create parthenocarpic fruits. These include:

Plant growth regulator use: Parthenocarpy can be initiated efficiently by applying exogenous plant growth regulators to the stigma or carpels of vegetables. Auxins, cytokinins, and gibberellins are plant growth regulators that result in parthenocarpy.

Wide/Distant Hybridization: Wide hybridization allows a genome to be transferred from one species to another, increasing the genotypes and phenotypes of progeny by removing the so-called species hindrance to gene transfer. Traditional breeding involves two basic steps: (1) establishing a breeding population that segregates for the parthenocarpy phenotype of one parental genotype, and (2) choosing offspring from a segregating population that exhibits both parthenocarpy and the desirable characteristics of the non-parthenocarpic parent.

Mutation: Mutant breeding can lessen the lack of natural genetic variety in the gene pool, which is one of the primary disadvantages of traditional breeding. Even though some mutations can now be targeted and produced, historically, genetic variation has arisen from random mutations. Chemicals or radiation therapy can cause mutations when wild populations' genetic diversity is reduced. A range of radiation treatments, including as helium-accelerated ions in tomatoes, soft-X-ray in watermelon, and gamma radiation in *Citrullus lanatus*, have been used to successfully create parthenocarpic mutants.

Use of irradiated pollen: Pollens treated with moderate X-rays or γ -rays are used for pollination in order to produce seedless fruits. Bottle gourd pollen softened by X-ray radiation has been used to make seedless watermelon (*Citrullus lanatus*) cultivars.

Alternation in chromosome number: Using triploid plants to produce fruit with only the residual integuments and no seeds, Kihara's group invented this method in the 1940s, mostly for watermelon.

Haploids that result from chromosomal elimination in wide crossings are of special interest to breeders. Parthenogenesis is the process by which haploids develop as a result of interspecific hybridization.

Gene transfer: Transgenic fruits, such as tomatoes, typically resemble seeded fruits in both size and shape. Transgenic parthenocarpic plants have also been shown to have higher overall yields, better flavor (high soluble solids, high brix), and lower processing costs when compared to non-transgenic plants. Even though the transgenic strategy might provide a realistic means of producing parthenocarpic cultivars with additional advantages, its commercial viability has been called into doubt because of consumer concerns and the difficulties in producing transgenic plants.

Gene silencing: One very successful molecular reverse genetic technique that prevents some genes from working is gene silencing (GS). Gene expression interference (RNAi) and antisense RNA technologies have been used to generate vegetable parthenocarpy.

Tools for genome editing: Using genome editing technologies like CRISPR/Cas9, ZFNs, and TALENs to induce parthenocarpy is a relatively new and advanced method. The only genome editing method that has been used more extensively is CRISPR/Cas9, which allows for the rapid generation of new parthenocarpic vegetable cultivars.

Conclusion

Parthenocarpy is necessary to improve the yield, quality, and processing properties of vegetable

crops. When cultivating cross-pollinated vegetable crops in greenhouses, this trait is especially beneficial. Many methods have been created and made available to construct genetic parthenocarpy in transgenic plants as a result of multiple approaches providing a conceptual framework. Thus, genetically modified parthenocarpy will soon improve the quality and yield of many horticultural agriculture plants. The application of biotechnological methods will also improve the efficiency and identification of parthenocarpic genes in crops for the good of humanity. Advanced breeding techniques like MAS can improve the accuracy and speed of generation, even though genome editing methods like CRISPR/Cas9 are a relatively recent trend for rapidly producing parthenocarpic vegetables. In order to meet the demands of our society and improve our knowledge of fruit agriculture, new technologies could be required to boost fruit quality and output.

Flowering Climbers to Transform Your Garden

Ayesha Syed, P. T. Srinivas, M. Raja Naik and N. Vinod Kumar

Gardens would be incomplete without flowering climbers, which give a splash of color, texture and frequent scent to vertical areas. These adaptable plants may grow on fences, trellises, walls, and pergolas to form living tapestries that soften buildings and enhance outdoor areas natural beauty. Flowering climbers complement a range of garden designs, from formal landscapes to cottage gardens, with blooms that range from delicate pastels to vibrant, bright colors. Climbing plants are also incredibly diverse: some, like clematis and honeysuckle, are known for their vibrant flowers, while others, like jasmine and passionflower, are prized for their scent. There are options for every climate and season, whether it's the hardy wisteria blooming in spring, the bougainvillea bringing heat-loving color, or the winter-blooming climbing roses that add charm year-round. Flowering climbers provide height, privacy, and lushness, and they can attract beneficial wildlife such as bees, butterflies, and birds. Incorporating flowering climbers into a garden is a simple way to add vertical interest and year-round beauty, creating a multi-layered landscape that is both functional and visually captivating.

Flame vine

Scientific name: *Pyrostegia venusta*

Common names: Flame vine, orange trumpet vine,

Firecracker vine

Family: Bigoniaceae

Growth habit: Vigorous, ever-green climber and tendrils

Height: Can reach up to 20-30 feet (6-9 meters) in height with proper support

Blooming time: Primarily in winter and early spring.

Temperature: Thrives in tropical and subtropical climates and can tolerate mild frost but may need protection in colder regions.

Uses in Landscaping

- ✓ Works well as a screen on fences or trellises for privacy.
- ✓ Its vibrant flowers make it an ideal choice for creating a focal point in gardens.
- ✓ Attracts pollinators, adding life and movement to the garden.
- ✓ The Flame Vine is a beautiful addition to gardens in warmer climates, where it can be appreciated for its stunning floral display and ability to cover large areas with ease.



Bougainvillea

Scientific Name: *Bougainvillea* spp.

Common Names: Bougainvillea, Paper Flower

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Family: Nyctaginaceae

Growth Habit: Woody, thorny vine or shrub, climbing up to 20-30 feet (6-9 meters) with support, though it can be pruned as a bush or hedge.

Flowers and bracts

- ✓ The “flowers” that give bougainvillea its color are actually papery bracts in shades of pink, purple, red, orange, white, and yellow.
- ✓ Small, tubular white or cream-colored flowers are located at the center of the bracts.
- ✓ Can bloom almost year-round in warm climates, but most profuse in spring and summer.

Temperature: Ideal for warm, frost-free regions. While some varieties are hardy to mild frost, severe cold can damage or kill the plant.

Uses in Landscaping

- ✓ Perfect for covering trellises, fences, walls, and pergolas with colorful cascades of blooms.
- ✓ Can be grown in containers with proper pruning and makes an eye-catching addition to patios and terraces.
- ✓ Dwarf or bush varieties can serve as low hedges, and their thorny stems provide security as a natural barrier.

Bougainvillea's vibrant colors, low maintenance, and adaptability to warm climates make it a favorite in gardens worldwide. With the right care, it can produce breathtaking displays that transform outdoor spaces into colorful oases.



Trumpet vine

Scientific Name: *Campsis radicans*

Common Names: Trumpet Vine, Trumpet Creeper, Cow-Itch Vine

Family: Bignoniaceae

Growth Habit: Fast-growing, woody, deciduous vine that can reach up to 30-40 feet (9-12 meters) with support.

Bloom time: Mid to late summer, with flowers lasting into early fall.

Temperature: Trumpet vine tolerates cold winters and hot summers, making it versatile in many climates.

Uses in Landscaping

- ✓ Excellent for quickly covering fences, walls, pergolas, and trellises with lush foliage and showy blooms.
- ✓ Creates a dense screen or barrier when grown along fences.

Special considerations: Trumpet vine can spread aggressively through underground runners and self-seeding. It is considered invasive in some areas. Root barriers or regular pruning can help contain it. While trumpet vine is generally safe for wildlife, its sap can cause skin irritation in humans, so gloves are recommended when handling.



Rangoon creeper

Scientific name: *Combretum indicum*

Common names: Rangoon Creeper, Chinese Honeysuckle, Burma Creeper

Family: Combreteceae

Growth: A vigorous, woody, perennial climber that can reach 20-30 feet (6-9 meters) in length.

Bloom time: In warm, tropical regions, the vine can bloom almost continuously from late spring until early fall. The warmer temperatures and humidity encourage frequent, lush flowering. In slightly cooler, subtropical areas, the flowering season may be shorter, typically from mid-summer to early fall, as the plant responds to warmer months.



Uses in landscaping

- ✓ With its bright colors, fragrance, and versatile climbing ability, *Combretum indicum* is a favorite choice for adding visual interest, fragrance, and natural charm to many landscape designs.
- ✓ The Rangoon Creeper's climbing habit makes it perfect for covering trellises, arches, and pergolas.
- ✓ Rangoon Creeper is often planted near entryways or garden gates, where its sweet scent can welcome visitors.

- ✓ In landscapes with slopes, it can be used as a cascading ground cover to prevent soil erosion while adding greenery and flowers to otherwise difficult-to-manage spaces.

Morning glory

Scientific name: *Ipomea sps*

Common names: Morning glory, Moonflower, Bindweed

Family: Convolvaceae

Growth habit: Morning glories are twining vines that grow rapidly, often reaching heights of 10-15 feet (3-4.5 meters) or more. They are annual in colder climates but can be perennial in tropical or subtropical regions.

Blooming time: Blooms primarily from summer through fall (late spring to early fall in warmer climates). Flowers open in the morning with sunlight and close by afternoon or evening.



Landscape uses

- ✓ Morning glories are ideal for vertical spaces, creating vibrant, living walls.
- ✓ They can also work as ground cover in areas where they can spread freely.
- ✓ These work well for morning glories when allowed to trail or climb a small support.
- ✓ Morning glories attract pollinators such as bees, butterflies, and hummingbirds due to their bright colors and tubular shape.

Allamanda

Scientific name: *Allamanda cathartica*

Common names: Golden trumpet, Yellow bell, Buttercup Flower

Family: Apocyanaceae



Growth habit: *Allamanda* is a fast-growing, evergreen shrub or climbing vine. It can be trained to grow as a bush or allowed to sprawl and climb on structures like trellises, fences, or walls.

Blooming time: It typically blooms throughout the warmer months, from spring to fall. In tropical climates, *Allamanda* may bloom year-round.

Landscape uses

Hedges and Borders: Ideal for creating bright, natural boundaries.

Climbing Vine: Works well on trellises, fences, and walls to create vibrant screens.

Containers and Pots: Suitable for large pots in patios and balconies.

Garden Accent: Adds a tropical look to gardens and landscapes, especially in warm regions.

Transgenic Breeding in Vegetables

D. G. Kachot, Y. A. Viradiya, D. K. Patel and U. B. Jadav

Abstract

In India, the rising consumption of vegetables and fruits, driven by increased income and health awareness, is met with challenges in vegetable production due to pests and diseases. Transgenic vegetables, developed through genetic modifications, offer solutions by improving traits like pest resistance and drought tolerance. Genetic engineering enhances crop yields, quality, and resilience. Gene transfer technologies, such as the *Agrobacterium*-mediated method and direct techniques like electroporation and biolistics, enable the development of genetically modified crops. These methods are crucial for improving agricultural productivity and addressing challenges in crop protection and enhancement.

Introduction

India is experiencing a huge growth in the consumption of vegetables and fruits, which is a reflection of the nation's growing wealth, diversity, and overall health consciousness. Approximately 204.96 million metric tons of vegetables are produced annually in India over an area of 11.11 million hectares (APEDA, 2024). Additionally, vegetables are linked to better gastrointestinal health, clear vision, and a lower risk of heart disease, stroke, diabetes, and various types of cancer (Desai *et al.*, 2020). The production of vegetables is subject to several biotic stressors brought on by weeds, pests, and diseases, necessitating large quantities of plant protection chemicals ha^{-1} . Strong antioxidants, multiple phytochemicals appear to lower the risk of

chronic disease by preventing damage from free radicals, altering the metabolic activation and detoxification of carcinogens, or even affecting mechanisms that change the trajectory of tumor cells. In the twenty-first century, transgenic vegetable crops may play a significant role in sustainable vegetable production (Desai *et al.*, 2020). Approximately 190 million hectares of GM crops are grown by 22 million farmers across 29 countries (ISAAA, 2024). The United States grows more than half of the genetically modified crop, with Brazil, Argentina, Canada, and India following closely after (ISAAA, 2024). According to Raji *et al.* (2013), transgenic plants are created by altering their genomes by adding beneficial genes and removing harmful ones. A foreign gene from a different species or even king-

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dom may be introduced into a plant. The nptII bacterial antibiotic resistance gene was inserted into tobacco to create the first transgenic plant (Framond *et al.*, 1983). Since then, with rapid advances in plant molecular biology and genetic engineering technology, a diverse range of transgenic plants with important agronomic traits such as pest resistance and drought tolerance have been developed, ranging from dicots to monocots that can be genetically modified. The primary goal of creating transgenic plants is to create crops with superior quality, high yield, and perfect features. According to Lai *et al.* (2012), the plants can serve as a factory for the manufacturing of medicinal proteins in addition to being advantageous to the agricultural industry. The development of novel functional genomics methods for gene identification and characterization holds great promise for improving conventional plant breeding and creating genetically modified plants for specific purposes. The development of these technologies, as well as some key advances in transgenic crop production and commercialization (Estrella *et al.*, 2005). Transgenic crops, also known as genetically modified crops (GMOs), allow plant breeders to incorporate useful genes into elite cultivars which were previously unavailable, greatly increasing their value and providing unique opportunities to address significant issues in contemporary agriculture, such as plants with improved agronomic traits, resistance to biotic and abiotic stresses, tolerance to herbicides, and improved nutritional quality.

What is Transgenic breeding?

Genetic improvement of crop plants, domestic animals and microbes through biotechnology. A plant in which a foreign gene has been transferred through technologies of genetic engineering is called a Transgenic plant and the gene so transferred is called as Transgene. The term “transgenic” refers to organisms that contain genes from a different species, while “breeding” traditionally involves the controlled mating of organisms to enhance specific traits. However, in the context of transgenic breeding, the process goes beyond conventional breeding by incorporating genetic modification (GM) or transformation techniques to introduce traits that cannot typically be achieved through traditional methods. Transgenic organisms are created by inserting foreign genetic material into their DNA, often from entirely different species, using techniques like gene cloning, viral vectors, or microinjection. The introduced gene, called a transgene, becomes part of the host organism's genome and can be expressed, resulting in new traits such as enhanced disease resistance, modified nutritional content, or faster growth.

Key Features of Transgenic Breeding

Incorporation of Foreign Genes (Transgenes)

In transgenic breeding, the main goal is to introduce new genes from a different species into the host organism. These genes can come from plants, animals, bacteria, fungi, or even viruses. The introduced gene may provide resistance to pests, diseases, or environmental stress, improve growth

rate or reproductive efficiency, modify the nutritional content of the organism (*e.g.*, golden rice with increased vitamin A) or introduce novel traits like bioluminescence or the ability to produce specific proteins.

Genetic Engineering Techniques

The process typically involves several steps, including:

Gene Isolation: Identifying and isolating the gene of interest from the donor organism.

Gene Cloning: The gene is inserted into a vector (usually a plasmid) that can carry the gene into the host organism's cells.

Transformation: The recombinant DNA (vector with the transgene) is introduced into the target organism's cells. Transformation done using methods such as:

- ✓ *Agrobacterium*-mediated transformation (common in plants).
- ✓ Gene gun or biolistics (used in plants).
- ✓ Electroporation, lipofection, or microinjection (used in animals and other systems).

Selection: The transformed cells are selected for using markers (*e.g.*, antibiotic resistance).

Breeding /Selection of Progeny: Once the transgenic organism is created, it is bred to stabilize the transgene in future generations and to ensure that the new trait is inherited.

Transgenic Breeding in Agriculture

In plants, transgenic breeding is commonly used to create genetically modified (GM) crops with desirable traits. Some of the well-known examples

include:

Golden rice: Genetically engineered to produce higher levels of provitamin A (beta-carotene), addressing vitamin A deficiencies in developing countries.

Bt cotton and Bt corn: These crops have been genetically modified to express the *Bacillus thuringiensis* toxin, which provides resistance to certain insect pests of lepidoptera order.

Herbicide-tolerant crops: For example, Roundup Ready soybeans and cotton are engineered to tolerate herbicides, making weed control easier without harming the crop.

Virus-resistant crops: Some crops have been engineered to resist viral infections that would otherwise reduce crop yields.

Transgenic Breeding in Animals

Transgenic animals are created for various purposes, such as:

Research models: Transgenic mice and other animals are often created to study gene function, disease mechanisms, or therapeutic interventions.

Pharmaceutical production: Transgenic animals can be engineered to produce valuable proteins or hormones in their milk, blood, or other tissues (*e.g.*, bioreactors). An example is the production of human proteins like antithrombin in the milk of transgenic goats.

Livestock improvement: In some cases, transgenic breeding is used to introduce genes that increase growth rates, improve disease resistance, or enhance the nutritional value of animal products. However,

this is less common than in plants due to ethical concerns.

Why Make Transgenic Crops?

- ✓ Conventional plant breeding involves exchange of genes between two plants to produce a hybrid having desired trait by techniques such as cross pollination and grafting.
- ✓ This crossbreeding however is limited to exchanges between the same or closely related species.
- ✓ Therefore, it requires a long time to achieve the desired results and sometimes a related species having the characteristics of interest may not be found.
- ✓ Genetic engineering enables transfer of genes more easily across taxonomic boundaries.
- ✓ The useful genes can be introduced not just from within species or closely related plants but even from a wide range of organisms.
- ✓ This gives a wider range of trait to choose from with the transfer being undertaken in a more controlled and predictable way.
- ✓ Transgenic crop plants can therefore incorporate the desired traits more quickly and more reliably than through conventional methods.

Procedure for production of Transgenic crop

Selection of the Gene of Interest

The first step in the process is the selection of the gene that you want to insert into the vector. This gene can be from any organism (*e.g.*, human, bacteria, plants, etc.), and it is typically selected based on the research or application requirements.

Sequence Information: The complete nucleotide sequence of the gene is required.

Gene Preparation: The gene might be already available, or it could need to be isolated using techniques like PCR (Polymerase Chain Reaction).

Choosing the Appropriate Vector

A vector must be chosen based on the following criteria:

Type of Expression: Whether you want to express the gene in bacterial, yeast, mammalian, or plant cells.

Size of the Gene: The vector must have the capacity to accommodate the gene's size.

Selection Markers: Most vectors contain antibiotic resistance genes or other markers to help identify cells that have successfully taken up the vector.

Promoter/Regulatory Elements: For expression in the host, vectors often include promoters, enhancers, or other regulatory elements needed for transcription and translation of the inserted gene.

Common types of vectors include

Plasmids: Small, circular DNA molecules, widely used for cloning in bacteria (*e.g.*, pUC19, pGEM).

Bacteriophages: Viruses that infect bacteria, often used in phage display or large DNA insertions (*e.g.*, Lambda phage).

Cosmids: Hybrid vectors that combine features of plasmids and phages, used for cloning larger DNA fragments.

Bacterial Artificial Chromosomes (BACs): Used for very large DNA fragments.

Viral Vectors: Used in gene therapy and viral

expression systems (e.g., adenoviral vectors).

Gene Isolation

The gene of interest needs to be isolated from its source organism. This can be done using methods like:

Restriction Enzyme Digestion: If the gene is part of a larger DNA sequence, it can be cleaved out using specific restriction enzymes that cut DNA at defined sequences.

Polymerase Chain Reaction (PCR): A method for amplifying the gene of interest using primers that flank the desired gene sequence.

Digestion of Vector and Gene

Restriction Enzyme Digestion: Both the gene of interest and the vector are cut with specific restriction enzymes that create compatible ends for ligation.

Sticky ends: Overhanging sequences at the cut sites that facilitate the binding of the gene to the vector.

Blunt ends: No overhangs, requiring additional steps like blunt-end ligation.

Considerations: The restriction enzymes chosen must create compatible overhangs between the vector and the gene to allow efficient ligation. If using blunt ends, ligase may require more effort to join the gene to the vector.

Ligation

The process of joining the gene of interest into the vector is called ligation. This is typically performed by an enzyme called DNA ligase, which covalently bonds the sugar-phosphate backbone of the vector and the gene. The vector and the gene fragment are mixed with DNA ligase and ATP (to

drive the ligation reaction). The ligase seals the nicks in the DNA, joining the gene to the vector.

Transformation or Transfection

After ligation, the recombinant vector (with the inserted gene) is introduced into a host cell. This step is called transformation (for bacteria or yeast) or transfection (for mammalian or plant cells).

Methods of transformation include

Chemical Transformation: Treating bacterial cells (often *E. coli*) with chemicals like calcium chloride, making them competent to take up foreign DNA.

Electroporation: Using an electric field to create temporary pores in the cell membrane, allowing the DNA to enter.

Viral Infection: In mammalian cells, viral vectors can be used for gene delivery.

Selection of Transformed Cells

After transformation, not all cells will have successfully taken up the recombinant vector. Therefore, a selection process is required to identify the cells that have received the gene of interest.

Antibiotic Selection: Most vectors contain a selectable marker gene, such as antibiotic resistance. Cells that have taken up the vector will be resistant to a specific antibiotic, while non-transformed cells will not survive.

Blue/White Screening: In some vectors, an additional system is used where the inserted gene disrupts a lacZ gene. Colonies are then screened by their colour (blue or white) after a substrate like X-gal is added.

Verification of Insertion

Once transformed cells are selected, it is necessary to verify that the gene has been correctly inserted into the vector.

Restriction Enzyme Mapping: The recombinant plasmid can be digested with restriction enzymes, and the resulting pattern can be compared to the expected pattern based on the vector and inserted gene.

PCR: Primers specific to the vector and the gene can be used to amplify the region of interest.

Sequencing: To confirm the exact sequence of the inserted gene and ensure there are no mutations or errors in the insertion.

Expression of the Gene

If the goal is to express the gene (produce the corresponding protein), the transformed cells are grown under conditions that induce the expression system within the vector. This may involve:

Induction with Specific Chemicals: For example, IPTG is often used to induce gene expression in bacterial systems.

Harvesting and Purification: Once the protein is expressed, it may need to be purified using techniques like affinity chromatography

Common Methods used for Gene transfer

Indirect gene transfer: *Agrobacterium* mediated

Direct gene transfer: Microprojectile/Particle bombardment, Electroporation, Microinjection, Chemical mediated

Indirect methods of gene transfer

***Agrobacterium* mediated gene transfer:** *Agrobacterium*, the nature's genetic engineer, has been

used as a vector to create transgenic plants. *Agrobacterium*-mediated gene transfer in plants is a highly efficient transformation process which is governed by various factors including genotype of the host plant, explant, vector, plasmid, bacterial strain, composition of culture medium, tissue damage, and temperature of co-cultivation. *Agrobacterium* is the only cellular organism on Earth that is naturally capable of transferring genetic material between the kingdoms of life, from prokaryotes to eukaryotes. Thirty years ago, the concept of using *Agrobacterium tumefaciens*, a Gram-negative soil bacterium, as a vector to create transgenic plants was viewed as a prospect and a wish. Today, it has advanced from a dream to a reality for a large number of agronomically and horticulturally important species; and it has become the most essential tool for plant genetic engineering for the introduction of foreign genes into plant cells to raise transgenics. *Agrobacterium*-mediated plant transformation in cereals, legumes, and other crop plants has boosted agricultural biotechnology and has led to improved yield and quality of crops to meet the requirements of increasing world population.

Plant Viruses vector: Plant viral vectors delivered by *Agrobacterium* are the basis of several manufacturing processes that are currently in use for producing a wide range of proteins for multiple applications, including vaccine antigens, antibodies, protein nanoparticles such as virus-like particles (VLPs), and other protein and protein-RNA scaffolds. Viral vectors delivered by *agrobacterium* T-

DNA transfer (magnification) have also become important tools in research. In recent years, essential advances have been made both in the development of second-generation vectors designed using the 'deconstructed virus' approach, as well as in the development of upstream manufacturing processes that are robust and fully scalable. The strategy relies on *Agrobacterium* as a vector to deliver DNA copies of one or more viral RNA/DNA replicons; the bacteria are delivered into leaves by vacuum infiltration, and the viral machinery takes over from the point of T-DNA transfer to the plant cell nucleus, driving massive RNA and protein production and, if required, cell-to-cell spread of the replicons. Among the most often used viral backbones are those of the RNA viruses Tobacco mosaic virus (TMV), Potato virus X (PVX) and Cowpea mosaic virus (CPMV), and the DNA gemini virus Bean yellow dwarf virus. Prototypes of industrial processes that provide for high yield, rapid scale up and fast manufacturing cycles have been designed, and several GMP-compliant and GMP-certified manufacturing facilities are in place.

Direct methods of gene transfer

Electroporation: This method involves suspension of plant protoplasts in a suitable ionic solution containing linearized recombinant plasmid DNA. This mixture is then exposed to low voltage-long pulses or high voltage short pulses for the desired number of cycles. The electrical pulses are thought to induce transient pores in the plasma lemma through which the DNA molecules are incorporated.

Treated protoplasts are then cultured to obtain cell colonies and plants. This method is called electroporation (*i.e.* introduction of DNA into plant cells by making minute pores in the plant cell membrane).

Microinjection: Microinjection is a direct physical method involving the mechanical insertion of the desirable DNA into a target cell. The target cell may be the one identified from intact cells, protoplasts, callus, embryos, meristems, etc. Microinjection is used for the transfer of cellular organelles and for the manipulation of chromosomes. The technique of microinjection involves the transfer of the gene through a micropipette (0.5-10.0 μm tip) into the cytoplasm/nucleus of a plant cell or protoplast. While the gene transfer is done, the recipient cells are kept immobilized in agarose embedding, and held by a suction holding pipette. As the process of microinjection is complete, the transformed cell is cultured and grown to develop into a transgenic plant. In fact, transgenic tobacco and Brassica napus have been developed by this approach. The major limitations of microinjection are that it is slow, expensive, and has to be performed by trained and skilled personnel.

Particle Bombardment Gun Method (Biolistics):

Particle bombardment is the most effective method for gene transfer, and creation of transgenic plants. This method is versatile due to the fact that it can be successfully used for the DNA transfer in mammalian cells and microorganisms. The micro projectile bombardment method was initially named

as biolistics by its inventor Sanford (1987). Biolistics is a combination of biological and ballistic. In this method, 1-2 μm gold or tungsten particles coated with DNA are shot into the plant cells using a helium pressure particle gun device. Important crop plants like, wheat, rice and maize have now been transformed by this method.

Chemical Gene Transfer Method: Polyethylene glycol (PEG)-mediated transfer: DNA molecules can be forced to enter into the host genome only in those cells which do not possess cell walls. The naked plant protoplasts are mixed with molecules of linearized plasmid DNA containing the foreign gene. The two are mixed in a transformation medium rich in Mg^{2+} ions in place of Ca^{2+} ions, following which 20% polyethylene glycol (PEG) solution is added. After the treatment, the PEG concentration is reduced and Ca^{2+} concentration is enhanced. It promotes the frequency of transformation. The chemical method involving transformation in presence of polyethylene glycol is convenient and simple but there are, however, some disadvantages like many cells are so sensitive that the chemical method cannot be applied whereas some cells die during the treatment. This method is not perfect because many treated cells do not contain any transfer DNA. Sometimes the foreign DNA is degraded in the cytoplasm before reaching the nucleus.

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CRISPR and Genetic Engineering in Insect Pest Management

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Abstract

Phytophagous insects cause significant damage to global crop yields, threatening food security and contributing to societal issues such as hunger and poverty. Traditional pest control methods, including plant breeding and agrochemicals, have proven insufficient and environmentally harmful, necessitating innovative solutions. Genetic engineering, particularly CRISPR/Cas9-based genome editing, offers a promising approach to enhance pest resistance in crops and insects. This review explores the application of CRISPR/Cas9 for insect pest control, highlighting its role in developing genetically modified insects and plants with improved pest resistance. The CRISPR/Cas system enables precise gene manipulation, facilitating the development of gene drive systems for population control and the engineering of insect-resistant crops. Despite significant advances, challenges such as off-target effects, delivery mechanisms, and editing efficiency persist. However, the integration of CRISPR with techniques like Sterile Insect Techniques (SIT) and transcription regulation provides new opportunities for overcoming these obstacles. The evolution of CRISPR technology holds promise for sustainable, effective pest management solutions, contributing to enhanced crop yields and food security. Future research focusing on the ecological impacts and efficiency of these technologies will be crucial in realizing their full potential in agriculture.

Introduction

Annually, phytophagous insects cause damage to about one-fifth of the world's total crop yield. This biotic stress significantly affects food security by reducing crop production quality and quantity. The loss in yield due to insect infestations leads to serious societal issues like hunger and poverty.

The combined effects of emerging or resurging insect pests and the rapidly growing human population require immediate innovation and the implementation of integrated agricultural practices. According to the FAO, plant diseases and pests are responsible for an annual 20-40% reduction in global crop yields (FAOSTAT, 2017). Researchers have

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predicted that climate change and shifting weather patterns will likely cause a sharp decline in crop yields, with the risk posed by phytophagous pests increasing, making them an even more serious threat to crops. Although plant breeding has been used for thousands of years to develop insect-resistant crop varieties, it is a labour-intensive and time-consuming process, with unpredictable results. The lack of available genetic resistance in the gene pool has further limited breeding efforts. In response, toxic and expensive agrochemicals have become the primary solution for crop protection. However, the negative environmental impacts of these chemicals have created a demand for the development of genetically stable, pest-resistant plant varieties.

Genetic engineering plays a pivotal role in conferring resistance against insects. This tool is being exploited to introduce specific DNA sequences or genes into crop plants through *Agrobacterium*-mediated transformation or particle bombardment for insect control (Juturu *et al.* 2015). *Bacillus thuringiensis* (Bt) is a gram-positive soil bacterium that forms parasporal crystals that contain insecticidal proteins ICPs. ICPs are endotoxins that are highly toxic to certain classes of insects. They kill the insects by acting on the epithelium tissue of the midgut of the larvae of Lepidopteran, Coleopteran and Dipteran insects (Paul and Das, 2020).

CRISPR/Cas-Mediated Genome Editing in Insects: Since the development of the CRISPR/Cas9 gene-editing system for mammalian cells in 2012 (Zong *et al* 2017). Biotechnology and molecular

biology have undergone significant advancements. The discovery of the homology-dependent cleavage recombination mechanism expanded the potential of CRISPR/Cas9 for genome editing, making it a promising tool. The increasing use of gene-editing techniques as a site-specific approach to modifying genomes offers numerous opportunities, particularly in improving important agronomic traits such as resistance to biotic stresses (Jinek, 2012). This review explores the novel possibilities presented by the CRISPR/Cas9 system and highlights its growing role in insect pest control, which contributes to better crop yields and food security. A combination of gene-editing tools and insect manipulation techniques has already been applied to species such as *Drosophila melanogaster*, various tephritids, and mosquitoes, providing valuable insights into insect biology. Recently, CRISPR/Cas9 has been used to develop new pest control strategies, proving to be an efficient method for pest management. Advances in genome editing have opened the door to innovative pest control solutions through the creation of genetically modified insects. CRISPR/Cas technology continues to evolve, offering significant benefits for precise gene manipulation and customization. The CRISPR/Cas components, including sgRNA and Cas9 protein, can be delivered to the target organism as plasmid DNA, RNA, or as a ribonucleoprotein (RNP) complex.

Molecular Genetic Manipulation of Insects: To achieve effective population replacement for insect pest control, a gene drive system capable of biasing

inheritance in its favour is essential. This requires the introduction of a selfish genetic element that autonomously spreads with super-Mendelian inheritance (greater than a 50% likelihood) within the target population, ultimately leading to the replacement of the local population with a specific genotype. This introduced construct could potentially disrupt or introduce a desired gene that lacks disease transmission capability or exhibits reduced virulence and damaging characteristics. Several gene drive approaches are currently under investigation, including HEGs (homing endo-nuclease genes) (Windbichler *et al.*, 1999). Medea (maternal effect dominant embryonic arrest), and CRISPR-Cas (clustered regularly interspaced short palindromic repeats-CRISPR-associated proteins) systems. While the concept of using gene drives to manage insect pests is not new, achieving this goal remains challenging, hampered by scientific and technical obstacles. Recent advancements in the CRISPR-Cas system, a precise site-specific gene editing technology, offer promising solutions to overcome some of these challenges. Therefore, we primarily focus on the application of CRISPR-Cas technology in gene drive systems.

Performance of CRISPR-Cas-Mediated Gene Drive Populations: The CRISPR-Cas-mediated gene drive in insects was first reported in *Drosophila melanogaster* in March 2015. Subsequent experiments successfully applied this system to *Anopheles gambiae*, *Anopheles stephensi*, *Aedes aegypti*, *Drosophila suzukii*, *Ceratitis capitata*, and *Plutella*

xylostella. Cas9 was utilized to integrate trait or cargo genes, with Gantz pioneering the mutagenic chain reaction (MCR) in *D. melanogaster*. The MCR achieved transmission efficiencies averaging 97%, significantly exceeding Mendelian inheritance expectations for a recessive X-linked yellow locus. Oberhofer *et al.* developed the ClvR (Cleave and Rescue) system in *D. melanogaster*, a toxin-antidote gene drive on an autosomal chromosome targeting an essential X-linked gene. It imposes fitness costs on wild-type offspring, favoring ClvR-bearing chromosomes through gene conversion and maternally transmitted Cas9 activity. ClvRtko effectively deactivated over 99% of the targeted genes with minimal functional resistance mutations. Another ClvR-based strategy developed by Oberhofer *et al.* involves placing two distinct ClvR elements that target different essential genes at the same genomic locus but on different homologous chromosomes.

Ideal Traits for Gene Drives in Pest Control: CRISPR-Cas-mediated gene drive systems offer substantial potential for pest control by replacing harmful wild-type alleles with gene drive alleles. This approach allows the engineered individuals to replace the target populations rapidly, even with a low initial frequency. Successful implementation of this strategy as a population replacement tool for pest management requires the selection of key phenotype-related genes for targeting or insertion (Ying *et al.*, 2023). Potential applications include reducing fertility, limiting development, altering food consumption, impacting mating competitive-

ness, skewing sex ratios, curtailing migration, decreasing longevity, reducing stress resistance, modifying behaviour, affecting immune function, and lowering disease transmission all aimed at diminishing fitness traits or species pest potential.

Genetic engineering of Cry genes for insect resistance:

Transgenic plants producing ICP have made a tremendous impact on the successful development of insect resistance. The *B. thuringiensis* (*Bt*) produces the ICPs which are synthesized during the process of sporulation. *Bt* toxins, ICPs, d-endotoxins or crystalline proteins can be solubilized and activated by proteinases in the midgut region of an insect. The toxin binds to a specific receptor, creating a pore in the epithelial cells of the insect gut and finally kills the insect pest. Resistance to insect pests was shown mainly when *Bt* toxin-producing ICP genes under the control of tissue-specific or constitutive promoters and introduced in different crop species, including maize, sweet potato, cotton and tomato (Chang *et al.*, 2017). The first-generation *Bt* cotton (Bollgard I - BG I) expressing Cry1Ac was commercialized and released in 2002 in India. Second-generation pyramided trait (Bollgard II) expressing Cry1Ac and Cry2Ab2 (MON15985 event) was approved in 2006, which currently occupies 95% of the cotton growing area in India. Introduction of *Bt* cotton controlled the major bollworms, including *Helicoverpa armigera*, *Earias vittella* and *Pectinophora gossypiella* in cotton growing regions and it ultimately improved the crop yields and also farmer's income. Then, widestrike

cotton containing Cry1Ac + Cry1F by Dow agro Sciences was introduced in USA in the year 2004. Both BG II and wide-strike cotton expressing multiple toxins have higher potential in controlling the broad range of caterpillar insects than BG I. Apart from cotton, four insect-resistant *Bt* brinjal varieties were approved and commercialized in Bangladesh in the year 2014 (Koch *et al.*, 2015). Transgenic soybean expressing Cry1Ac+Cry1Ab was approved for commercial use in Latin America (Koch *et al.*, 2015). The transgenic cotton expressing cry1Ac gene under the regulation of a strong constitutive Figwort Mosaic Virus (FMV) promoter showed elevated expression of Cry1Ac toxin that was lethal to lepidopteran insects, especially *H. armigera*.

The CRISPR/Cas9 System in Pest Management: Challenges and Future Prospects:

In the past decade, the CRISPR/Cas9 system has emerged as an elegant and affordable genetic technique, and it is expected to be extensively applied in pest control applications for crop improvement shortly. Even after the rapid progression in the field of CRISPR/Cas9-based genome editing methods, researchers are facing challenges such as off-target effects, efficient delivery methods and genome editing efficiency. Despite these challenges, the CRISPR/Cas9 system has the potential to revolutionize the field of agriculture. Now, there is a need to focus on the improvement of the CRISPR/Cas9- based pest management technologies such as combining the SIT with the CRISPR/Cas9 system, which has great pest control capabilities as it targets the reproductive

fitness of them. Similarly, the utilization of the CRISPR/Cas9 system for transcription regulation could be a promising technique, but the genetically modified organism in such cases will not be “transgene-free” as it will carry a transgene for dead Cas9 (dCas9) and gRNA expression cassette. Recently, one more novel approach has been explored which involves the transportation of the injected RNP complex which is assisted by the ovary-targeting peptide ligand or BAPC in nymphs and adult flies. Using this method, the CRISPR components can be directly injected near the ovary of an adult female fly, thus making it more convenient when it is compared to the micro-injections in the eggs or embryos. This approach has much scope, and this similar concept can be applied to other insect orders for pest management

Conclusion

The CRISPR/Cas9 gene-editing system has revolutionized the field of pest management, offering innovative approaches to control insect pests that significantly impact global crop yields. With the ongoing challenges posed by phytophagous insects and the growing demands of global food security, the need for efficient, sustainable pest control strategies is more critical than ever. The CRISPR/Cas9 system, with its precise and versatile genome-editing capabilities, presents a promising solution by enabling the development of genetically modified insects and plants with enhanced resistance to pests. The application of CRISPR/Cas9 in gene drive systems offers an exciting avenue for population

control, potentially reducing the spread of harmful pests and diseases in agricultural environments. While substantial progress has been made, challenges such as off-target effects, efficient delivery mechanisms, and genome editing efficiency remain. However, advancements in technology, such as the integration of CRISPR with sterile insect techniques (SIT), transcription regulation and improved delivery methods, show great potential for overcoming these obstacles. As the technology evolves, CRISPR-based pest management will likely play an increasingly pivotal role in the future of agriculture, contributing to more sustainable, effective, and environmentally friendly solutions for pest control. The continued development of CRISPR-based technologies, coupled with careful consideration of ecological impacts, will help ensure that they contribute to global food security and crop protection in the years to come.

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Recent Advances in Cauliflower Breeding

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Introduction

The cauliflower genome size is 584.60 Mb, contained 47,772 genes and 56.65% of the genome is composed of repetitive sequences (Sun *et al.*, 2019). The curd is the edible part of cauliflower, which is made of pre-floral apical meristematic tissues. It is a dome of tissues made up of a mass of proliferated floral meristems at harvest. Curd colour of cauliflower orange (due to β -carotene), purple (anthocyanin) and green (chlorophyll). It is an ideal candidate crop for biofortification of β -carotene. Cauliflower contains a group of substances known as glucosinolates which are responsible for the pungent aroma and bitterness. The flowers have four sepals, four petals and six stamens. The sepals are green and erect. The petals are arranged perpendicular to each other, forming a cross. The androecium is tetradynamous *i.e.* there are two short and four long stamens. The two functional nectaries are present which are situated between the bases of ovary and short stamens and the other two inactive nectaries at the bases of pairs of long stamens. Honey bees are the usual pollinating agents, though bumble bees may also be responsible for pollination. Stigma of cauliflower is receptive even 5 days (protogynous)

before and 4 days after anthesis. The ideal temperature for pollination has been found to be 12 to 18 °C. Protects heart health, lowers cholesterol, establishes immune system, prevents bone loss, good source of calcium, reduces cancer risk, Protects skin from UV rays, aids in digestion. Nutrition quality of cauliflower 2.6 g protein, 30 mg B carotene, 33 mg calcium, 4 Kcal energy, 57 mg phosphorus, 1.2 mg iron and 56 mg vitamin C.

Physiological Disorders: Buttoning, Riceyness, Blindness, Leafiness, Browning, Hollow Stem

Important Diseases: Club Root, Downy Mildew, Black Rot, White Rust, Alternaria, Leaf Spot, Damping off

Gene Action

Curd Weight: Additive and dominance gene action (Swarup, 2006).

Curd Depth: Pronounced additive gene action (Chand, 1980).

Curd Diameter: Predominance of dominance Gene action (Lal, 1978).

Curd Size Index: Partial dominance and epistatic effects (Kale *et al.*, 1979).

Curd Solidarity: Dominance and epistatic effects (Chatterjee *et al.*, 2018)

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Table 1: Different types of cauliflower (Swarup and Chatterjee, 1972)

Type	Country of origin	Period of first Cultivation	Characters
Italians or originals	Mediterranean	16 th century	Plants short, white to yellowish curds
Cornish	England	Early 19 th Century	Plants are long stalked, yellowish curds, highly flavored
Northerns	England	19 th Century	Leaves are very wavy and serrated, curds are good and well protected
Roscoff	France	19 th Century	Plants are short, curds are white or creamy with hemispherical shape
Angers	France	19 th Century	Leaves are very wavy, solid curds
Erfurt and snowball	Germany and Netherlands	18 th Century	Dwarf plants, solid whitish curds and well protected
Indian cauliflower	India	Late 19 th Century	Plants short and long stalked, yellow to creamy curds and highly flavored

Table 2: Classification of cauliflower grown in India on the basis of maturity period and temperature requirement (Singh *et al.*, 2018)

Maturity Group	Common name	Period of availability	Curd initiation temp. (°C)	Cultivars
I-A (Early)	Kunwari	Aug. - Oct.	20-27	Punjab Kunwari, Pusa Early Synthetic, Pusa Meghna, Pusa Ashwini, Barsati
I-B (Early)	Katki	Oct.- Nov.	20-25	Pusa Deepali, Pusa Subhra, Pant Gobhi-3, VRCF-86
II (Mid early)	Aghani	Nov. - Dec.	16-20	Improved Japanese, Pant Gobhi-2, Pant Gobhi-4, Pusa Hybrid-2
III (Mid late)	Poosi	Dec.- Jan.	12-16	Pusa Synthetic, Pusa Himjyoti, Hissar-1, Ooty-1, Pusa Subhra
IV (Late)	Maghi	Jan.- March	10-16	Pusa Snowball-1, Pusa Snowball-2, Pusa Snowball Kt-25

Curd Architecture: Polygenic and additive gene action (Chatterjee *et al.*, 2018)

Curd Compactness: Additive gene action (Co.1 and Co.2) (Singh *et al.*, 1978)

Curd angle: Additive and dominance gene action (Chand, 1980)

Ways to Genetic Improvement

Identification of homozygous male-sterile plants in dominant male sterile lines using MAS. Development of homozygous lines through tissue culture. QTL identification to develop markers for marker assisted selection. Maintaining the CMS lines in vitro to ensure greater uniformity in F1 hybrids. Development of gene transfer techniques to introduce agronomically important traits. Utilization of embryo rescue or somatic hybridization. Techniq-

ues to overcome natural reproductive barriers in the development of inter-specific hybrids.

Conventional Breeding Methods: Sporophytic Self Incompatibility, Self-Incompatibility, Cytoplasmic Male Sterility, Male Sterility.

Constraints in Exploiting S.I. in Cauliflower:

Continuous inbreeding may lead to complete loss of inbred lines. Pseudo incompatibility may lead to self seed instead of hybrid seed. High temperature and relative humidity may weaken S- allele action. Synchronization of flowering among the S.I. lines is difficult. Maintenance of S-allele lines is a difficult and costly affair (hybrid seeds will be expensive).

Cytoplasmic Male Sterility In Cauliflower: The most significant source of sterile cytoplasm employed in cauliflower is the ogura cytoplasm of

the radish species *Raphanus*. CMS was transferred from Ogura to cauliflower via hybrids. Nevertheless, issues with temperature sensitivity and protoplast fusion to overcome chlorosis in hybrid plants. Several cauliflower groups have demonstrated CMS male sterility, particularly Ogura, which is being investigated for F₁ hybrid creation at the Indian Agricultural Research Institute (IARI), New Delhi. It is also being investigated as a potential new source to aid F₁ hybrid breeding: the transfer of sterile Anand cytoplasm from *Brassica rapa*, which was initially obtained from the wild species, *B. tournefortii*, via *B. napus*, into cauliflower. Ogura cytoplasm causing male sterility in Japanese radish was discovered long back in 1968.

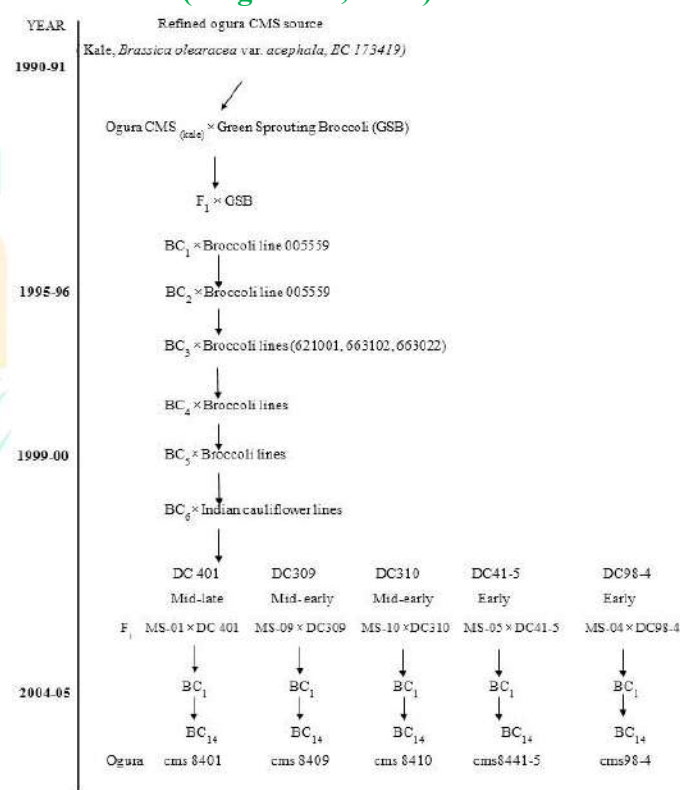
Table 3: Contribution of scientists for introgression CMS line into various cole crops

Pearson (1972)	Crossed cabbage with <i>Brassica nigra</i> and developed male sterile lines (lack of nectarines, floral abnormalities)
Dickson (1975)	Transferred it from broccoli to cauliflower
Bonnet (1975)	Introduced this male sterility in European cauliflowers by making a series of crosses
Bannerot (1977)	Reported successful introduction of cabbage nucleus into the cytoplasm of the male sterile Japanese radish by means of repeated back crosses
Chiang and Crete (1987)	Introduced male sterility from <i>Brassica napus</i> into cabbage and later from cabbage to cauliflower
Krauze (1987)	Transferred it from broccoli to cauliflower, cabbage and kale
Earle and Dickson (1995)	Cold-tolerant CMS broccoli, cauliflower and cabbage lines
Lin <i>et al.</i> (1997)	Developed CMS line of broccoli by crossing with male sterile cauliflower line

Later it was introduced by transferring to *Brassica oleracea* genome through repeated backcrossing with broccoli. Transgenic cauliflower hybrids are being created using the transgenes

Barnase, *Bar*, and *Barstar*. The transgene for male sterility *Bacillus amyloliquifaciens* also contains *barnase*, a ribonuclease that breaks down the tapetum layer in pollen to create stable, male sterile plants. The herbicide resistance gene, *bar*, is connected to the male sterility *ms* gene. By expressing the gene encoding for *barstar*, the restorer line for the *barnase* sterile lines may be produced.

Introgression of Ogura CMS Line in Indian Cauliflower (Singh *et al.*, 2022)



Advanced Breeding Methods

Plant tissue culture

Microspore Culture: Bhatia *et al.* (2019) used microspore embryogenesis in cauliflower (*Brassica oleracea* var. *botrytis* L.) using cultivars of different maturity group for development of plants with different ploidy level and their use in breeding programme.

Embryo Rescue: Sharma *et al.* (2017) introgressed Black rot resistance in Cauliflower by developing interspecific hybrid between *Brassica carinata* variety NPC-9 and cauliflower variety Pusa sharad and therefore employing in vitro embryo rescue technique.

Somatic Hybridization: Wang *et al.* (2016) developed a number of hybrid progenies from asymmetric somatic hybrids between cauliflower “Korso” and black mustard “G1/1”.

Molecular Breeding

Marker Assisted Selection: Zhao *et al.* (2020) used marker assisted selection on two DH population including 122 and 79 lines for identification QTLs associated with curd architecture of cauliflower. A total of 20 QTLs were detected with the minimum likelihood of odd (LOD) values ranging from 2.61 to 8.38.

Marker Assisted Backcrossing: Singh *et al.* (2020) (IARI) started breeding work using MABC for introgression of “Or” gene in early maturity group (DC 98-1, DC-41-5, CC-14) and mid early maturity group (DC 309, CC-35, DC18-19) of tropical cauliflower breeding lines and in BC₂F₂ generation he identified few breeding line which carry sufficient quantity of β - carotene (10-12 ppm).

Marker Assisted Pyramiding: Shah *et al.* (2021) have under gone breeding work through marker-assisted backcross breeding method which is used to pyramid a black rot-resistant gene (Xca1bo) and a downy mildew-resistant gene (Ppa3) from donors BR-161 and BR-2 respectively into the background

of Pusa Meghna cauliflower cultivar.

Achievements

Important released varieties of cauliflower

Cultivars		
Cultivars	Maturity group	Remarks
Pusa Shubhra	Early	Black rot and Alternaria blight resistance
Pusa Meghna	Extra early	Suitable for Delhi NCR region
Pusa Sharad	Mid early	Semi dome shaped and very compact curd, high yielding variety
Pusa Betakesari-1	Mid late	First ever indigenously bred bio-fortified beta carotene rich cultivar, compact curd with self blanching habit
Pusa Synthetic	Mid early	Variety with good general combining ability
Dania Kalimpong	Late	Suitable for eastern region, less sensitive to environmental fluctuations
Pusa Snowball K-1	Mid early	Tolerant to black rot
Hybrids		
Cultivars	Maturity group	Remarks
Pusa Kartik Shankar	Early	Resistant to Downy mildew
Pusa Snowball Cauliflower Hybrid -1	Early	CMS based hybrid with self blanching habit, Tolerant to black rot
Pusa Hybrid-3	Mid-early	Suitable for north Indian plain condition, Resistance to downy mildew and moderately resistance to black rot
Pusa Hybrid-301	Mid-late	First CMS based F ₁ hybrid developed for mid-late maturity group of Indian cauliflower
Pusa Purple Cauliflower-1	Late	First purple cauliflower cultivar developed by indian public sector, average anthocyanin concentration-43.7 mg/ 100 g
Pusa Snowball Hybrid-2	Late	First DH based F ₁ hybrid among all the vegetable crops in india
Pusa Snowball K-53	Late	Lawyana Old × 13-85, Doubled haploid based hybrid

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Mastering the Art of Bonsai: A Journey into Miniature Tree Cultivation

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Abstract

This piece delves into the age-old craft of bonsai, a discipline that blends gardening with imagination, perseverance, and reverence for the natural world. Originating in China and honed in Japan, bonsai is the art of growing small trees that capture the spirit of the outdoors. More than just visually appealing, bonsai represents a way of life centered on minimalism, equilibrium, and unity, encouraging a state of awareness and a profound bond with the surroundings. The piece goes into the background, core beliefs, and methods of bonsai, offering novice's advice on choosing appropriate tree types, learning crucial tools, and starting with basic skills like trimming, bending, and transplanting. It also discusses the classic styles of bonsai design and the continuous maintenance required to keep a bonsai healthy.

Introduction

In Japanese, 'bonsai' translates to 'tree in a pot', with 'bon' referring to a type of tray-like pot and 'sai' signifying a plant. The term 'bonsai' is the Japanese way of saying 'penzai', which is the Chinese term for the same art form.

Bonsai is the craft of cultivating trees in small containers. These tiny trees are shaped and grown to look like mature trees that have weathered the passage of time. It's important to note that bonsai trees are not genetically altered to be small; rather, they are shaped through methods such as pruning, root reduction, potting, defoliation, and grafting. These techniques result in small trees that accurately reflect the appearance and aesthetic of fully grown, large trees (Sasi and Sreeramya, 1996). Bonsai is a



favored pastime across the globe due to its diverse elements, including horticulture, meditation and mindfulness. It combines creativity, relaxation and artistic expression into a single activity, which benefits both physical and mental health and overall well-being (Hermann and Edwards, 2021).

Brief History of Bonsai

Bonsai, the technique of cultivating small trees in containers, began in China over a thousand years ago as "penjing," which entailed building complete miniature landscapes. When this method migrated to Japan, it evolved into what we now call bonsai, which focuses on growing individual trees to capture the spirit of nature. In Japan, bonsai became inextricably linked with Zen Buddhism, and it was viewed as a type of meditation and spiritual practice that emphasized simplicity, harmony, and reverence for nature. Over the ages, the Japanese polished

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bonsai into a separate artistic tradition, with varied styles and techniques that represent various natural shapes. Bonsai gained appeal across the world in the nineteenth and twentieth centuries, particularly in Europe and the United States, and became an international symbol of patience, beauty and the balance between nature and human innovation. Bonsai is now widely practiced across the world, valued both as a form of creative expression and as a means of cultivating mindfulness and a deeper connection to nature.

Bonsai sizes

Mini Bonsai	Up to 2 inches
Mame	Up to 6 inches
Small	6 to 12 inches
Medium	12 to 24 inches
Large	24 to 42 inches

Propagation of plants

- ✓ Plants grown from seeds and seedlings
- ✓ Nursery Plant
- ✓ Air Layering
- ✓ Cuttings
- ✓ Grafting on Root Stock

Styles of bonsai

Formal Upright style: This is a traditional style where the trunk is perfectly vertical. The branches are arranged alternately from left to right to mimic the natural aging process. The lower third of the branches are pruned away, and the rest are bent downward.

Informal upright style: This style is all about capturing the raw beauty of nature. The trunk is gently curved, showcasing the ruggedness of the outdoors. It's easy to achieve with the use of wire

and/or cords, making it suitable for both conifers and broadleaf trees.

Broom style: In the broom style, the trunk is straight and upright and does not continue to the top of the tree. It branches out in all directions at about $\frac{1}{3}$ rd the height of the tree. The branch and leaves form a ball-shaped crown (Hodge *et al.*, 1972).

Forest style: The forest style looks quite similar to the multi-trunk style. The difference is that this would involve a cluster of several trees, not one tree with several trunks. The most developed trees are planted in the middle of the large and shallow pot. On the sides are planted a few smaller trees to contribute to one single crown. The trees are planted, not in a direct line, but in a Zigzag pattern, so the forest would appear more natural and real.

Literati style: This species is found growing in nature when there is a large group of them together in one area. Other trees, and the competition is so fierce that the only way for the tree to survive is by growing above all other plants and trees around it. The bole grows upward in a zigzag manner without branching of any kind, since the sun only hits the top of the tree. Some of the branches are “Jinned” to make sure it looks even tougher with no bark.

Windswept style: The branches and trunk grow to one in the windswept form. Tree was bent into one side, as if the wind was blowing it continuously in one direction. The branches grow outward in all directions from the trunk but will all eventually be bent to one side.

Plants suitable for bonsai

Although it was known decades ago that certain types of plants were needed to create bonsai, any naturally occurring perennial woody stemmed tree or shrub species can be used to create a bonsai. You can utilize anything from broadleaved evergreens to pines and conifers, as well as deciduous trees. Ficus species, Juniper Bonsai (juniperus), Bougainvillea species, Duranta species, Jasminum species, Murraya species, Hamelia patens, *Hibiscus rosa sinensis*, Juniper chinensis, Neem, Pine, Pomegranate, Poinsettia, Mini Kumquat, Sapota, Schefflera, Bottle Brush, and Cypress are some of the plants that make good bonsai. Most commonly used plants for bonsai are:



Juniper: Tolerates heavy pruning and is ideal for learning wiring techniques.

Ficus: One of the most common indoor bonsai tree types and best if you're not consistent with watering. Japanese red maple: Affordable tree that will tolerate the pruning mistakes of novice bonsai artists, but you'll need to remember to water it.

Chinese elm: Great for learning pruning techniques; thrives indoors or outdoors.

Planting Media

Media consists of

Loam soil: 2 parts; Leaf mould: 1 parts; Coarse sand little

Media can be covered with moss and one or two pebbles can be placed to give a natural look.

Pruning: Pruning is done for the structural, and

usually, it entails the removal of the primary branches. Shoot and Branch Pruning is most important practice in shaping a bonsai. Leaf Pruning encourages the growth of smaller leaves and also branch ramification. To encourage more branching De-budding and pinching is done to create a more compact shape. Small Twig Pruning is thinning out the crown by removing small branches to allow more light and air. For undergoing some radical or structural change to its shape. Regular and timely pruning should be done.

Selection of a pot

Never go larger than twice your plant. Normally, a suitable pot should not exceed about 1/3 of the total height of your tree as it maintains balance while providing ample space for the roots to grow.

Rectangular: Ideal for tall upright trees;

Round: Appropriate for more rounded or informal types;

Oval: Suitable for trees with flowing, relaxed shapes;

- ✓ Shallow pots are used mainly in case of small rooting structures whereas deeper ones serve better in case of bigger rooted organisms.
- ✓ Clay is traditional and helps in moisture control. As it's also porous, air can get through and reach the roots.
- ✓ Glazed ceramic give people different colors and designs however they could retain too much of water hence should be watered carefully.
- ✓ Lightweight as well as affordable option available. It does not dry out quickly like clay or

ceramic hence become useful to beginners.

- ✓ Choose a color that complements the tree and enhances its overall appearance. Neutral colors such as beige, gray or brown are always classic choices. Colors which may clash or overwhelm other elements of the tree should be avoided.
- ✓ Make sure there are enough drainage holes on the pot. Proper drainage will avert root rot among other problems.

Fertilizer: The bonsai pots are artificial surroundings. Constant supply of fertilizer is what you need to do for your bonsai to be healthy and to grow. Every 15 days, apply to your bonsai a balanced fertilizer with NPK ratio of 19:19:19 (NPK 20:20:20 is also good). The figures show how much of each N, P or K element is contained (in percentages) in that particular fertilizer. To prevent chlorosis (yellowing of leaves), these three elements plus some trace elements like zinc, iron, manganese, boron and copper play important roles during photosynthesis.

Repotting: Repotting involves three steps. The initial step is to eliminate the old soil. Two methods for repotting a plant are:

- ✓ Replacing the pot with fresh soil and trimming the plant's roots.
- ✓ The next step is to decide on the angle at which the plant should be placed and then transfer it to a new pot ideal new pot to showcase the beauty of the tree.

Easy Steps for bonsai growing

Tree selection: Opt for a tree that thrives in the climate. The trunk should be wider at the base and

narrower at its peak. There should be many living branches on the tree along with multiple small branches.

Modeling the tree: The next step is to create a tree and provide its description. At the front of the tree, determine where the first branch will grow either left or right up-to one third of the height of the tree. The subsequent branches must be higher, on different sides. All unnecessary branches are removed.

Pruning: Shaping technique which is so significant to promote growth and retention in this way. Prune in order form triangular shape out of wood material.

Cable: Can bend to form branches when simple aluminum wires or copper wires are used for wrapping purposes around it. This temporary call occurs until it reaches its new position then removes this call too. Get rid off before it gets into contact with skin thus causing diseases. Rope must be made at an angle of forty-five degrees and lie closely against the branch neither too tight nor too loose.

Pot: When you finish wiring your tree; it is time to plant your specimen within bonsai pot that has enough holes for drainage; mix river sand, red soil as well as vermicompost or fertilizer in equal amounts (1:1:1). Most importantly keep soil moist; have proper drainage systems as well as enough ventilation.

Mosturization: These trees are grown in pots that are small in size; the soil tends to dry up quickly. That is why watering should be done only when the soil in the pot is dry.

Location: It is recommended that you choose an area

with sufficient sunlight and good air circulation since bonsai requires about five hours of sun light on a daily basis.

Fertilization: Given that the trees are found potted tightly in containers thus having insufficient nutrients as well as ‘space’, they must be frequently fertilized with either organic or mineral substances or you can make use of liquid fertilizers (apply once every two weeks) which also need to be carefully timed during their growing season.

Pest and Disease: When insects are discovered on or in the soil, treatment should begin immediately. Keep the bonsai on an elevated shelf in a sunny and airy location and spray with a general purpose insecticide at regular intervals. Common pests include ants, aphids, earthworms, red spiders, mealy bugs, and more. Insecticides such as rotenone and pyrethrum mixed with vegetable oil, as well as pesticides such as Rogor and Mathron, are available.

Benefits of Growing a Bonsai: Beyond their beauty, Bonsai trees offer profound benefits. Cultivating Bonsai fosters relaxation, a Zen-like mindset, and mental reprieve through simple tasks like pruning and watering. This hobby cultivates patience and a deeper appreciation for aesthetics, turning the tree into a living work of art. As your Bonsai matures, it brings admiration, a sense of accomplishment, and the joy of nurturing something that can thrive for over a century.

OECD Seed Certification in India

Jasmin R. Busa and Yagnesh A. Viradiya

History

Seed certification in the US and Canada began in the early 1900s, with federal experiment stations and state land grant institutions releasing new varieties. Before this, most field crops were imported, and new types were often lost, polluted, or of low quality. Organizations were established between 1900 and 1920 to provide college-bred seeds. These groups served as extension service providers or experiment stations for land-grant universities in the 1920s, 1930s, and 1940s. Seed certification was a well-established system for producing and disseminating premium seed for enhanced varieties, often resulting from university or government agency breeding programs. The OECD council authorized the Indian membership to participate in the six OECD seed programs starting in October 2008.

- ✓ Cereals
- ✓ Maize
- ✓ Sorghum
- ✓ Grasses and legumes
- ✓ Crucifers and other oil or fibre species
- ✓ Vegetables

Objectives of OECD Seed Certification

- ✓ Plans Encourage the Use of Quality-Guaranteed

Seeds.

- ✓ Promote the use of “quality-guaranteed” seed in nations that are involved.
- ✓ Approve certifications and labeling for foreign trade.
- ✓ Import/Export Plans for Seeds.
- ✓ Enable the import and export of seeds using labels that are recognized worldwide.
- ✓ Establish standards for seed propagation overseas.
- ✓ Assign control tasks to the private sector in exchange for certification.

Advantages of the Schemes

- ✓ Promotes worldwide trade through the use of OECD trademarks.
- ✓ Creates structures for seed production with nations or businesses.
- ✓ Supports global regulations for seed certification.
- ✓ Inspire cooperation between public and private sectors.
- ✓ Enables consistent information sharing with national certifying bodies.

Guidelines and Policies for the OECD Seed Program

- ✓ It relates to cultivars meeting official lists, agronomic value, uniformity, stability and differ-

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entiation requirements.

- ✓ Through the processes of planting, processing, and labeling, guarantees varietal identification and purity.
- ✓ Promotes global trade by eliminating technical trade restrictions and recognizing “quality guaranteed” seed.

Notification of National Designated Authority

(NDA): India has appointed the Joint Secretary of the Department of Agriculture and Co-operation and Farmers Welfare as the National Designated Authority (NDA) for the OECD Seed Scheme. Taking into account their administrative and technical capabilities, the NDA has selected nine State Seed Certification Agencies, including KSSOCA to manage the Seed Certification procedure across India.

KSSOCA's responsibilities include

- ✓ Listing varieties that are listed by the OECD in the National Official Catalogue.
- ✓ Making maintenance responsibilities known.
- ✓ Speaking with the maintainer/breeder.
- ✓ Giving a formal consent in writing for seed multiplication outside of the nation of registration.
- ✓ Keeping genuine standard crop cultivar seed on hand.
- ✓ Upholding official descriptions of multiplied varieties that are based on physical characteristics of seeds and plants.
- ✓ The Seed Scheme's Category Designation Acknowledges. Three types of seeds are available:

Pre-Basic, Basic and Certified.

Fee structure of OECD Seed Certification in India

Operation details	Registration Charges (Rs.)	Annual Renewal Charges (Rs.)
Seed Producer	2000	2000
Seed Processing Unit	5000	3000

✓ Grass and legume Seed

✓ Cereal Seed

✓ Maize Seed

✓ Sorghum Seed

Operational details	Charges (INR)
Registration charges for grower	125
Field inspection charges/acre	
Varieties:	500
Hybrids:	750
Processing charges	40 Qtls
Seed Testing Charges per Sample	400 or actual
Charges for Pre control and Post control test per sample	1000 or actual
Charges for Tag per label.	10
Charges for Varietal purity per sample	2000 or actual

Crucifer and other Oil or Fibre species seeds

Operational details	Charges (INR)
Registration charges for grower	125
Field inspection charges/acre	
Varieties:	500
Hybrids:	750
Processing charges	40 Qtls
For Cotton: Ginning and processing	75 qtl. ⁻¹ of kapas
Seed Testing Charges per Sample	400 or actual
Charges for Pre control and Post control test per sample	1000 or actual
Charges for Tag per label.	10
Charges for Varietal purity per sample	2000 or actual

Vegetables Seed

Operational details	Charges (INR)
Registration charges for grower	125
Field inspection charges/acre	
Pod crops: (Pea, Cowpea, Beans)	500
Leafy vegetables (Lettuce, Spinach, Fenugreek, Coriander)	750
Fruit vegetable (Brinjal, Tomato, Capsicum, Chillies) Varieties	2000 acre ⁻¹
Okra	1000 acre ⁻¹
Cole crops (Cauliflower, Cabbage, Knol Khol, Broccoli)	4000 acre ⁻¹
Tuber crops (Garlic, Turnip, Carrot)	1000 acre ⁻¹
Root crops (Radish, Turnip, Carrot)	2000 acre ⁻¹
Bulb crops (Garlic, Onion)	4000 acre ⁻¹
Cucurbits (Cucumber and all gourds)	2000 acre ⁻¹

Post-harvest supervision charges for 8 hours	1000 for 8 hrs.
Seed Testing Charges per Sample	400 for sample or actual
Charges for Pre control and Post control test per sample	1000 sample ⁻¹
Charges for Tag per label.	10 tag ⁻¹
Charges for Varietal purity per sample	2000 for sample or actual

List of OECD Seed Certification forms

Description	Form Number
Application form for Registration/Renewal of seed Producing Agency.	Form-I
Application form for Seed Production.	Form-II
Seed Plot Inspection Report.	Form-III
Profile of Seed Produced.	Form-IV
Seed Sample Slip	Form-V
Seed Sample Forwarding	Form-VI
ISTA Seed Analysis Report (Orange/Blue Certificate)	Form-VII
Certificate Issued for Varietal Certification of Seed moving in International Trade.	Form-VIII
Application form for Registration/Renewal of Seed Processing Unit.	Form-IX A

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Seed Dressing

Jasmin R. Busa and Yagnesh A. Viradiya

Introduction

In pest control, there is the process of treating seeds with insect pesticides through seed dressing. This essentially deters both underground and above-ground pests as well as soil-borne fungal illnesses. Another approach to consider is the use of systemic insecticides as a seed treatment which would safeguard the planted seeds from being affected by the roots of other plants and soil and would deter pests such as thrips, aphids and various beetles from coming near the seed including beetles. The application of thiamethoxam and imidacloprid can be used repeatedly as it is effective against early pests. It goes to say that imidacloprid and thiamethoxam can indeed keep away a number of pests at bay. However, thiamethoxam and imidacloprid, two available insecticides manufactured, were not tested and used against certain insect vectors in Ethiopia. Judging by these thoughts, this study aims to test the effectiveness of a number of seed-treatment insecticides regarding the MLN caused viruses and what other pests target these viruses in the early growing season.

Seed dressing: Applying a thin coating of active substance to the seed's surface is known as seed dressing. The applicant may consist of any organic

or inorganic substances, as well as fertilizers, insecticides, and certain growth enhancers.

- ✓ The most popular technique for applying small amounts of active ingredients to seeds is seed dressing.
- ✓ The rotary coater is the most often used coating equipment, despite the fact that there are many other kinds of coating equipment.
- ✓ Seeds are atomized by applying liquids onto a rotating disk that rotate within a metal cylinder, after which the newly treated seeds are released.
- ✓ This technique may be used to apply a variety of active compounds, including chemical plant protectants.

Types of seed dressing

Insecticides: To produce pellets with a consistent size and shape, seeds are coated uniformly. This facilitates weed control and precise planting.

Fungicides: prevents fungal diseases including rots, smuts, and seedling blights, which speeds up the establishment of seeds.

Bactericides: Assist in countering bacterial diseases afflicting seeds or seedling.

Mycorrhizae: Assist in enhancing the interaction of plants with soil fungi.

Plant growth regulators: Affect the growth and

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Table 1: Some recommendation of seed treatment for different crops

Name of Crop	Pest/Disease	Seed Treatment	Remarks
Sugarcane	wilt and root rot	✓ 0.1% carbendazim 2 grams per kilogram of seed ✓ Seed of <i>Trichoderma</i> spp. 4-6 gm kg ⁻¹	Polythene bags or metal seed dressers/earthen pots are used for seed dressing.
Rice	insects and pests, such as rice root rot Bacterial sheath blight	✓ <i>Trichoderma</i> 5-10 grams per kilogram of seed (before to transplanting) ✓ 3 gm kg ⁻¹ of chlorpyrifos seed. <i>Pseudomonas fluorescens</i> 10 gm kg ⁻¹ 0.5% W.P.	Polythene bags or metal seed dressers/earthen pots are used for seed dressing.
Pigeon pea	Wilt, Blight and Root rot	✓ <i>Trichoderma</i> spp. 4 grams per kilogram of seed	Polythene bags or metal seed dressers/earthen pots are used for seed dressing.
Tomato	Soil borne infection of fungal disease Early blight Damping off Wilt	✓ <i>T. viride</i> at a rate of 2 gram/100 gm seed. ✓ For soaking soil, use 75 WS at 1.5 to 2.0 gram liter ⁻¹ . ✓ <i>Cladosporium</i> and <i>Pseudomonas fluorescens</i> at 10 g kg ⁻¹ as seed dressers	Polythene bags or metal seed dressers/earthen pots are used for seed dressing.
Chillies	Anthrachnose spp. Damping off	Carbendazim at 1 g/100 gm seed and <i>Trichoderma viride</i> at 4 g kg ⁻¹ are used as seed treatments.	Polythene bags or metal seed dressers/earthen pots are used for seed dressing.
Brinjal	Bacterial wilt	<i>Pseudomonas fluorescens</i> at 10 g kg ⁻¹ .	Polythene bags or metal seed dressers/earthen pots are used for seed dressing.
Wheat	Termite Bunt/ False smut/loose smut/ covered smut	Apply any of the following pesticides to the seed before planting. ✓ 4 ml kg ⁻¹ of chlorpyrifos seed ✓ Thiram 75% WP ✓ 75% WP carboxin ✓ For every kilogram of seed, tebuconazole 2 DS at 1.5 to 1.87 gm ✓ 1.15 percent WP at 4 grams kg ⁻¹ of <i>T. viride</i> .	Polythene bags or metal seed dressers/earthen pots are used for seed dressing.

development of plants.

Film coating: To cut down on dust and facilitate the movement of seeds through processing and planting machinery, a smooth surface is produced.

Chemical used in seed dressing

Both liquid and dry forms of seed dressing control agents are available for purchase. According to the suppliers' rules, combinations of various chemicals can be used to treat seeds; these should not be confused with agents used to prevent food from being banned during storage. Tetramethyl thiram

disulfide and N-trichloromethyl-thio-4-cyclohexene-1, 2-dicarboximide are the most widely used broad-spectrum fungicides for seed dressing because of their low toxicity. Up until the plant reaches maturity, several systemic fungicides, such as metalaxyl, provide protection against fungal infections. N-methylcarbamate, imidacloprid, and thiamethoxam are insecticides used for seed dressing that combat bean stem maggots and thrips. There are also “do it yourself” seed treatment preparations that contain both insecticides and fungicides. By buying cheap

packets of seed dressing pesticides, farmers that grow their own bean seed can also benefit from this method. To ensure that treated seeds are not eaten, seed dressing products must be clearly marked with warnings and colored to be easily recognized.

Important of seed dressing

Protects against disease and pests: The use of seed dressing prevents the seed from pathogens that it encounters in soil or from other seeds. This is effective in preventing insects above and below the ground from attacking seeds.

Promotes germination: With the combination of soil and fertilizer when applied into its surface this changes porousness of the seed coat hence leading to faster germination of the chick peas inside the seed.

Improves crop health: The sowing aids in altering the resistance of the seed coating which in turn, amplifies the sprouting of the seeds.

Increases yield: Accro makes it possible for a greater maize yield of the single-planned cast as well as other varieties of maize planted by Seed dressing.

Reduces negative impact of weather conditions

: Regardless of the existence of unfavorable climatic conditions, Sowing provides for the protection of growing plants and seeds for a specified period before planting.

Environmentally friendly: Sowing is on the safer side as it uses a lesser concentration of chemicals in comparison that would be required to treat the ground.

Supplies micronutrients: For a healthy plant micro-nutrient that are vital for the plant's well-being are

provided by seed treatments.

Helps with water retention: Polymeric materials can be placed with the seeds in the instance, that the seeds are placed in the dry environment to aid moisture intake.

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Silkworm Disease Diagnosis: Molecular Innovations in Sericulture

Madhaiyan Sakthivel, Senthilkumar S., Marimuthu Elangovan and Karan Sathish

Abstract

Silkworm diseases significantly impact the sericulture industry, threatening silk quality and production. Traditional diagnostic methods are often time-intensive and lack precision. The advent of molecular diagnostics, such as Polymerase Chain Reaction (PCR), Loop-Mediated Isothermal Amplification (LAMP), and immunodiagnostic assays, has revolutionized pathogen detection in silkworms. These methods enable early, sensitive, and specific identification of pathogens like bacteria, viruses, fungi, and microsporidians. Tools like quantitative PCR and nucleic acid lateral flow strips enhance diagnostic accuracy and field applicability, while ELISA and Western blot assays provide robust protein-based detection. Advancing molecular tools will improve disease management, boost economic sustainability, and ensure high-quality silk production for global markets.

Introduction

Sericulture, the practice of rearing silkworms for the production of raw silk, is an essential agro-based industry, particularly in countries like India and China. The Silk is a proteinaceous fibre produced by the larva/caterpillar of the silkworm, utilised for its elasticity, thermal insulation, skin affinity and tensile strength properties. It is regarded as 'Queen of Textiles' due to its lustrous insect natural fibre. The mulberry silkworm, *Bombyx mori* L. (Lepidoptera: Bombycidae), and non-mulberry silkworms (*Antheraea* sp. and *Samia* sp.) of the Saturniidae family are the economic insects that are employed for commercial production of silk. The domesticated silkworm *B. mori* generates over >70%

of the total silk produced in India. Silkworms are affected by number of diseases caused by bacteria, viruses, fungi, and parasites, which directly affect the silk production. Traditional methods for disease identification (e.g., microscopy, culturing) are time-consuming and often lack sensitivity and specificity. The development of molecular techniques for pathogen identification has revolutionised the field of sericulture over the last decade. Molecular diagnostics can be used to rapidly and accurately identify the causative agents of silkworm diseases, which allows for the implementation of effective disease control measures.

Detection of Silkworm pathogens using Molecular technologies

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The advent of molecular diagnostics has brought about a transformative shift in the field of sericulture, allowing for precise and efficient disease management. These tools leverage advancements in molecular biology to identify previously difficult or impossible to detect pathogens using traditional methods. Various molecular techniques used for pathogen identification in silkworms are discussed below.

Polymerase Chain Reaction (PCR): A Cornerstone Technique

PCR, a versatile enzyme-driven technique, amplifies short DNA segments in vitro using a thermostable DNA polymerase, primers, and nucleotides. The target DNA is exponentially amplified by repeated heating and cooling cycles in a thermocycler, resulting in rounds of target DNA denaturation, primer hybridisation, and primer extension (Fig. 1). PCR has been extensively used to detect various pathogens such as viruses, bacteria, fungi and microsporidia pathogens in silkworms. For example, a PCR assay targeting the SSU-RNA gene identified the microsporidian pathogen of the Muga silkworm (*Antheraea assamensis*), caused by *Nosema bombycis*. Different variants of PCR for the diagnosis of silkworm pathogens are mentioned below.

Conventional PCR: It is widely used for detecting pathogens like *N. bombycis* (causing pebrine) and nucleopolyhedrovirus (causing grasserie).

Multiplex PCR: Multiplex PCR (M-PCR) enables the simultaneous detection of several target sequen-

ces by incorporating multiple sets of primers, thus enabling the detection of multiple target genes in a single step. For example, simultaneous detection of *N. bombycis*, nucleopolyhedrovirus (NPV), and densovirus (DNVs) is possible with a single tube reaction.

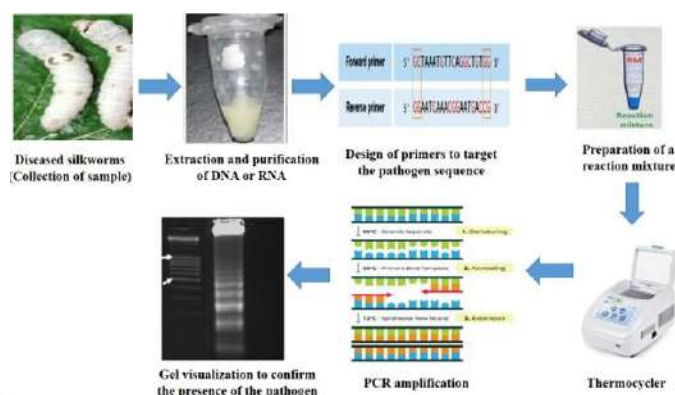


Fig. 1: Steps involved in polymerase chain reaction

Reverse Transcription PCR (RT-PCR): A method specially designed for detection of RNA viruses in silkworms. In RT-PCR, viral RNA is converted to cDNA using reverse transcriptase, which is then amplified by PCR with specific primers, and detected via methods like gel electrophoresis or fluorescence. This has been proven effective for detecting RNA-based pathogens like Infectious flacherie virus (IFV), caused by flacherie disease in silkworms.

Quantitative PCR: Quantitative PCR (qPCR) detects DNA or RNA sequences in real-time for absolute or relative quantification. Absolute quantitation determines exact gene copy numbers using a standard curve from reference DNA, useful for precise pathogen quantification or tissue-specific studies. Relative quantitation compares target gene expression to a reference (housekeeping) gene within

the same experiment, commonly used to study changes in gene expression in silkworms under different conditions. For example, qPCR has been used to measure the abundance of *N. bombycis* in infected silkworms, offering a sensitivity 100 times greater than conventional PCR.

Loop-Mediated Isothermal Amplification (LAMP): A Game-Changer

LAMP is a rapid and sensitive method for the amplification of DNA or RNA that can be performed at a constant temperature, typically around 65–68°C. It has emerged as a field-friendly alternative to PCR. This method amplifies DNA at a constant temperature, eliminating the need for sophisticated thermocyclers. A major advantage of LAMP over PCR is its simplicity and rapid results make it ideal for use in resource-limited settings, such as sericulture farms. LAMP-Lateral Flow Dipstick (LFD) assay enables rapid, sensitive detection of *B. mori* bidensovirus (BmBDV), with a limit of detection (LOD) is 5 fg, 400 copies of the BmBDV genome and an upper limit is 50 fg, 4000 copies of the BmBDV genome. This method is mainly used for field diagnostics with silkworm faeces.

Immunodiagnosics-based Detection techniques

Immunodiagnostic techniques utilize antigen-antibody interactions for the detection of silkworm pathogens. Several immunoassays have been developed to detect diseases of silkworms caused by viruses and microsporidians, such as traditional precipitin (ring and immunodiffusion) and immunofluorescence (fluorescent antibody), enzyme

-linked immunosorbent and dipstick assays.

Enzyme-linked immunosorbent assay (ELISA):

The labelled immunoassay can detect and measure molecules like antibodies, antigens, proteins, glycoproteins and hormones, and is exceedingly sensitive. Antibodies and antigens are complexed to detect these products and provide a quantifiable result. For example, Polyclonal antibodies against *B. mori* Nucleopolyhedrovirus (BmNPV) polyhedron protein and virions were used to develop F(ab)₂-ELISA, capable of detecting ng levels of BmNPV infection within 6 hours.

Western blot: Immunoblotting is used to detect specific proteins in a sample of tissue homogenate or extract. Denatured proteins are separated by SDS-PAGE and transferred onto a nitrocellulose membrane. The membrane is treated with enzyme-conjugated antibodies specific to the target protein. A chromogenic substrate produces colored bands where the antibodies bind the protein. SDS-PAGE was used to resolve the protein profiles of silkworm tissues infected with *N. bombycis* or *Nosema* spore extracts, and western blotting was used to determine the protein's immunological affinities.

Lateral flow assay: Lateral flow assay (LFA) kits are widely used in sericulture to rapidly detect and quantify various analytes, including viruses, bacteria and proteins. These kits are simple, rapid and portable, making them indispensable for large-scale sericulture operations (Fig. 2).

Nucleic acid lateral flow strip: He *et al.* (2019) developed a PCR-based detection technique combi-

ned with a nucleic acid lateral flow strip (NALFS), integrating molecular and immunological methods. NALFS is accurate, fast, cost-effective, and stable, making it suitable for detecting various microorganisms. In detecting silkworm eggs infected with *N. bombycis*, this method showed high sensitivity (1 pg or 100 spores), which is 100 times more sensitive than conventional PCR.

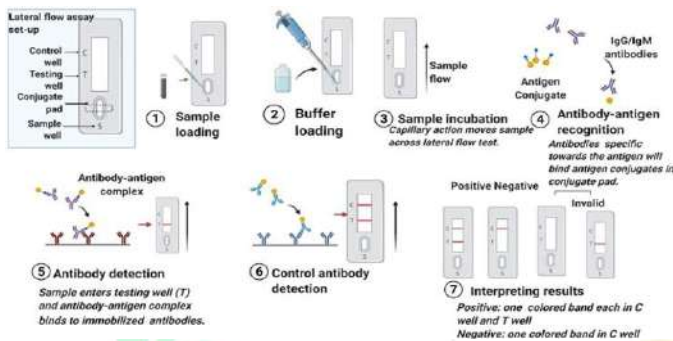


Fig. 2: Process of a lateral flow assay

Impact of Molecular Diagnostics on the Sericulture Industry

The integration of these molecular tools has revolutionized disease management in the sericulture industry. The following impacts highlight their significance:

Enhanced Disease Management: Molecular tools allow for the early detection of pathogens, enabling timely interventions and reducing the economic losses caused by widespread infections.

Improved Silk Quality: By minimizing disease-related damages, these diagnostics contribute to the production of higher-quality silk, meeting global market demands.

Economic Benefits: Reduced crop losses lead to increased profitability for sericulturists, promoting sustainability and growth in the industry.

Field Accessibility: Innovations like LAMP and lateral flow assays have empowered farmers to conduct on-site diagnostics, bridging the gap between laboratory capabilities and field requirements.

Future Directions

Future directions aim to address these limitations by focusing on the development of faster, more accurate, and cost-effective diagnostic tools. High-throughput technologies, such as next-generation sequencing (NGS), offer the potential to detect a wide range of pathogens simultaneously and in greater detail. Furthermore, integrating biosensors and microfluidic platforms could lead to portable, user-friendly diagnostic systems suitable for field conditions. Artificial intelligence (AI) and machine learning (ML) could be leveraged to analyze large datasets, improving the accuracy and efficiency of diagnosis. By advancing these technologies, molecular diagnostics could become more effective in early detection, monitoring, and managing silkworm diseases, benefiting the global sericulture industries.

Conclusion

Molecular diagnostic technologies have significantly transformed the field of sericulture by enabling precise, rapid, and efficient detection of silkworm pathogens. Techniques like PCR, LAMP, and immunodiagnostics have improved disease management, silk quality and economic sustainability while empowering farmers with accessible diagnostic tools. However, challenges such as the

need for comprehensive pathogen identification and cost-effective solutions remain. The future of the seri-industry demands precise rapid and economical pathogen detection strategies to combat crop losses and improve quality silk production.

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Priyangu (*Callicarpa macrophylla* Vahl.): Botany and Pharmacology Properties

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Introduction

In this era of modern medicine and scientific research, traditionally used medicines in various indigenous systems of medicine are increasingly being researched. They are rightfully gaining their deserved place in the armamentarium of the modern physician. Medicinal plants play a key role in human health care. About 80% of the world population relies on the use of traditional medicine which is predominantly based on plant materials (WHO, 1993). As per World Health Organisation (WHO) estimates, almost 80% of the population of developing countries relies on traditional medicines, mostly plant drugs, for their primary health care needs. In India's rural and tribal regions, over 7,500 plants are thought to be employed in traditional medical practices. Of these, the general public is either unaware of or has limited knowledge of the true medical benefits of approximately 4,000 plants. Approximately 1,200 plants are used in traditional medical systems like Ayurveda, Siddha, Amchi, Unani, and Tibetan. Priyangu (*Callicarpa macrophylla* Vahl.) is a shrub. It belongs to family

Verbenaceae. It is an important known medicinal plant of the lower warm valleys of the Himalaya. In addition to the Ayurveda system, *C. macrophylla* is widely used in many traditional medical systems, such as the Sidha, homeopathy, and Unani systems (Sharma *et al.*, 2008). *C. macrophylla* is globally distributed across India, China, Bhutan, Myanmar, South East Asia, and Nepal. In India, it is distributed in Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh, Bihar, Sikkim, West Bengal, Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur, Mizoram, Tripura, and Andhra Pradesh, up to an altitude of 1800 meters (Shi *et al.*, 2013). It is cultivated in drained sandy, loamy and clayey soils with acidic and alkaline nature. The hardy zone preferred is majorly cultivated at altitudes of Himalayas. It is also found near swampy areas, waste lands, and roadsides. Plant propagation is by seed on February. Despite their wide use in Chinese medicine. In addition to the traditional and medicinal uses for the treatment of different diseases and disorder such as a tumor, polydipsia, diarrhea, diabetes, dysentery, fever, as a blood purifier, anti-

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pyretic, analgesic, anti-ulcer, gastric stimulants etc.

Taxonomic position

Kingdom: Plantae
Division: Angiospermae
Order: Lamiales
Family: Verbanaceae
Class: Dicotyledons
Genus: <i>Callicarpa</i>
Species: <i>Macrophylla</i>

Table 1: Vernacular name of *Callicarpa Macrophylla* in different regions

Vernacular Names	Region/Language
Mathara, Barmala, Dhalahuja, Aplotan	Bengali
Bonmala, Tong loti	Assamese
Daiya, Daya, Priyamgu, Bastara	Hindi
Chinpompil, Cimpompil, Nalal	Malayalam
Mondol-Panamana	Manipuri
Huakhkar	Mizoram
Gandhaphali, Kanta, Phalin, Phalini, Priyangu	Sanskrit
Nalalu, Kattu-K-Kumil	Tamil
Guenlo	Nepal
Latapriyangu	Gujarati
Ayamsar	Konkani
Darus, Denthar, Patthar Man	Punjabi
Sungru Muuk	Lepcha

Botanical description: The plant is an erect undershrub, 1.5-2.5 m tall. Leaves are elliptic-oblong to lanceolate or ovate to ovate-lanceolate, 12-25 × 5-11 cm, acute or acuminate at apex, acute or cuneate at base, glabrescent, crenate-dentate; densely stellate-tomentose beneath; petiole 4-12 mm long; Inflorescence axillary, solitary or often corymbose-cyme; Flowers purplish; Calyx 5, 4-toothed, bell-shaped, persistent gamosepalous, covering almost half of the fruit sometimes attached; corolla lilac or purple, about 3 cm long; lobes 4, ovate, subacute. Fruits globose, drupes or berries, white to yellowish-brown with or without fruit stalk, fresh being succulent, 1-3 mm in dia. Intact fruits are smooth and

brownish in colour and exhibit centrally located bilocular carpel and 4 nutlets each embedded with a yellowish white seed, in a transversely cut surface of a fruit; Flowering & fruiting: June-Dec. Fruits taste at first somewhat sweet, later bitterish; odour fragrant specially after slight bruising the fruit (Mehta *et al.*, 2010). The inflorescence is densely stellate-hairy; primary peduncles equal to or a little longer than the petioles, 1-2.5 cm long. Flowers on short, slender pedicels and pedicel gland-dotted.

Phytochemistry: Priyangu leaves contains α -amyrenol, α -amyrin, ursolic acid, 2 α , 3 α , 19 α -trihydroxy-12-dien-28- ursolic acid, betulinic acid, β -sitosterol, daucosterol 18; flavanoids such as luteolin, apigenin, luteolin-7-O-glucuronide, apigenin -7 -O -glucuronide, β -sitosterol- β -D-glucoside, 2 α -hydroxy ursolic acid, crategolic acid, docosanoic acid, tricosanoic acid, tetracosanoic acid, ethyl tricosanoate, 3,7,3'-trimethoxy-4',5'- dihydroxyflavone. The bark contain betulinic acid. The roots and aerial part contain essential oil, (diterpene) calliterpenone, calliterpenone monoacetate 21; & Seeds contains calliterpenone, calliterpenone-17-acetate, oleanolic acid.

Pharmacological Properties

Leaves: The ethanolic and aqueous extracts of leaves at the dose of 200 mg kg⁻¹ and 400 mg kg⁻¹ showed dose dependent anti-inflammatory action when evaluated by carrageenan induced rat paw edema method using diclofenac sodium as standard drug (Yadav *et al.*, 2011). Ethanolic extracts of leaves at the concentration of 200 and 400 μ g disc⁻¹ showed

significant anti-fungal activity against *Gibberella fujikoro*, *Cryptococcus neoformans*, *Candida albicans*, *Myrothecium verrucaria*, *Aspergillus niger*, *Neurospora crassa* and *Rhizopus oligosporus* fungal strains when evaluated using disk diffusion method using fluconazole as standard drug while aqueous extract showed no antifungal activity (Yadav *et al.*, 2011).

Stem: Ethanolic extract of stem at concentration of 200 $\mu\text{l disc}^{-1}$ and 400 $\mu\text{l disc}^{-1}$ exhibited in-vitro antibacterial activity against various gram positive bacterial strains like *Streptococcus pyogenes*, *Bacillus cereus*, *Micrococcus luteus*, *Staphylococcus epidermidis*, *Clostridium sporogens*, *Streptococcus faecalis*, *Staphylococcus aureus* and *Bacillus subtilis* and gram negative bacterial strains like *Agrobacterium tumefaciens*, *Klebsiella pneumonia*, *Salmonella typhimurium*, *Pseudomonas aeruginosa*, *Serratia marcescens*, *Enterobacteria aerogens*, *Proteus vulgaris* and *Escherichia coli* when compared with the standard drug ciprofloxacin. Aqueous extract was found inactive against all the bacterial strains.

Flower: The alcohol extract of flowers, at the dose of 100 and 200 mg kg^{-1} , was found to exhibit significant dose dependent antidiabetic activity along with reduction in hyperlipidemia in dexamethasone induced insulin resistance and streptozotocin induced diabetes in rats (Patel, 2011).

Medicinal Properties: The plant is reported to be useful to stop internal and external bleeding and to treat burns. According to the tribal people of Sikkim,

India, the plant is bitter in taste and useful in blood dysentery, sweating, burning sensation and fever due to its cold potency. This is the best medicine for bleeding disorders and it reduces the bad smell from body (Panda, 2007). Fruits have cold, heavy, and dry physical characteristics, cold potency, and a sweet, bitter, and astringent flavor. Fruit has blood-purifying properties and reduces essential pitta and vata. The physical characteristics of inflorescence are dry, cold in potency, and after digestion, they have a sharp, bitter, and astringent taste. Inflorescence has several functions, such as reducing pitta and vata, acting as a refrigerant, anti-diarrheal, diuretic, jointer, wound healer, and blood purifier. Roots are useful in the treatment of pneumonia, stomach disorders and rheumatic pain. The Bark is used in the treatment of rheumatism and gonorrhea. The aromatic oil from the roots is reported to be useful to treat disordered stomach. Leaves are used for the treatment of stomach disorder. In the Apatani of Ziro valley in Arunachal Pradesh, leaves are used for treatment of headache. Fever, vomiting, blood disorders, vertigo, neurological system, and rheumatic diseases are among the conditions for which fruits are used in medicine, whereas fever, blood pitta diseases, amoebic dysentery, hyperhydrosis, and burning sensation in the body are all treated with inflorescence.



Conclusion

Priyangu (*Callicarpa macrophylla*) is an important medicinal plant used in a wide range of medical treatments. In traditional medicine, *Callicarpa macrophylla* (Verbenaceae) is frequently used to treat a variety of conditions pertaining to the respiratory, skeletal, digestive, endocrine, circulatory, and infectious systems. It offers the most recent data on the pharmacology, toxicity, phytochemistry, botany, and traditional use of *Callicarpa macrophylla*. There have been no known significant negative consequences from the plant's lengthy history of use. The comprehensive data in this review supports its traditional, pharmacological, and phytochemical applications. Future research of this kind will yield intriguing phytochemical sources with enormous promise for the pharmaceutical sector.

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Nutritional Composition and Medicinal Potential of Indian Mushrooms

Ashok Kumar Koshariya, Shrikrishna Balaso Narale and Manish Sardiwal

Introduction

Mushrooms have been a food supplement in various cultures and they are cultivated and eaten for delicacy. In most countries, there is a well-established consumer acceptance for wild edible mushrooms, probably due to their unique flavour and texture but also by their chemical, nutritional components. These are traditionally used in many Asian countries as food and medicine (Sanmee *et al.*, 2003). Human tendency is to taste the different foods all around available whole through the year and he is continuously in search of new dishes. As the mushrooms is gaining popularity in the present days, in context to the medicinal and also pharmaceutical industries, utilization of mushrooms. A mushroom is a macro fungus with a distinctive fruiting body and large enough to be seen with the naked eye and to be picked by hand. Mushrooms belong to the family Agaricaceae. The types of mushrooms differ in colors, shapes, surfaces, and activities. They are produced over the ground of soil or on their food sources, such as decaying wood in a moist and cold environment (Ogidi *et al.*, 2020). Edible mushrooms are rich in proteins, dietary fiber, vitamins, minerals,

and other bioactive components (alkaloids, lactones, polysaccharides, polyphenolic compounds, sesquiterpenes, sterols, and terpenoids). Several bioactive ingredients can be extracted from edible mushrooms and incorporated into health-promoting supplements. It has been suggested that several human diseases can be treated with extracts from edible mushrooms, as these extracts have biological effects including anticancer, antidiabetic, antiviral, antioxidant, hepatoprotective, immunopotentiating and hypocholesterolemic influences. For thousands of years, several of them have been utilized in traditional medicine. Among these are nutraceuticals, which are natural foods that may help preserve good health and strengthening the human body's immune system), whereas others are able to create powerful nutraceuticals (compounds with nutritional and medicinal properties that are taken as medications in the form of tablets or capsules but not as food). Due to a number of nutraceuticals and medicinal mushrooms that have been found to be beneficial to the development of human health as food, medicine, minerals, and drugs, among other things, mushrooms are a boon for advancement in the fields of food,

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medicine, and unemployment in developing nations with rich biodiversity, such as India (Wani *et al.*, 2010).

Nutritional potential of mushroom

Since the beginning of time, humans have been searching for wild mushrooms. Because of their chemical makeup, which is appealing from a nutritional standpoint, higher fungi's fruiting bodies have been eaten as food for thousands of years (Mattila *et al.*, 2001). Mushrooms were eaten in the early stages of civilization mostly because of their distinct flavors and palatability. Since extensive research on the chemical makeup of mushrooms has shown that they can be used as a diet to fight diseases, their current application is quite different from their historic purpose. Protein is an important constituent of mushrooms. Protein content of mushrooms depends on the composition of the substratum, size of pileus, harvest time and species of mushrooms. Pushpa and Purushothama (2010) have analyzed the nutrition of five mushroom species and found 21.60, 41.06, 27.83, 26.25, 18.31% protein in *C. indica*, *A. bisporus*, *P. florida*, *Russula delica* and *Lyophyllum decastes*, respectively. In mushrooms, the fat content is very low as compared to proteins and carbohydrates. The fats present in mushroom fruiting bodies are dominated by unsaturated fatty acids. Mushrooms are one of the best sources of vitamins especially vitamin B.

Medicinal potential of mushroom

As old as the traditional usage of mushrooms is medical mycology. Since the Neolithic and Paleo-

lithic periods, they have been employed in medicine. Scientists only looked into the fundamental active ingredients of mushrooms that promote health in 1960, despite the fact that they have been used as medicine in China since 100 A.D. In the medical field, mushrooms have been used to cure a variety of illnesses, from common and simple ones like skin conditions to complex and pandemic diseases like AIDS. People throughout Asia are aware that mushrooms constitute a significant biosource of new secondary metabolites from the 20th century.



The medicinal qualities of mushrooms are used through-out India, especially in the alternative medical systems. Mushrooms possess medicinal properties because of the presence of different types of secondary metabolites. These secondary metabolites are bioactive, low molecular weight compounds which are produced in response to stress

that help in its survival by signalling and defense but are generally not required by the fungi for their normal growth and reproduction. The most important secondary metabolite in medicinal mushrooms are polysaccharides, which belong to 1,3- β -glucans family, having antitumor activities which are achieved by enhancing and blocking cellular immunity pathway. These polysaccharides exhibit antitumor and immunostimulating properties and generally, glucans with high molecular weight seem to be more effective as compared to low molecular weight. According to a number of studies, these secondary metabolites interfere with various transduction pathways to modify distinct cellular responses in addition to stimulating the immune system. Through the up-regulation of cell cycle regulatory protein, *Pleurotus ostreatus*, an edible fungus, can inhibit the growth of breast and colon cancer cells. Through the inhibition of the PI3k/AKT signaling pathway, the extract of *Pleurotus pulmonaris* inhibits the development of liver cancer. Extracted proteoglycans from *Ganoderma lucidum* have a protective effect against liver injury. The mushrooms with medicinal values are often termed as ‘mushroom nutraceuticals’. This mushroom nutraceutical is consumed in the form of capsules or tablets as dietary supplements which is derived from the extract or dried biomass of mycelium or the fruiting body of a mushroom that has potential therapeutic applications. It has been reported that with regular intake of these nutraceuticals, there may be enhancement in the immune response of the hum-

an body which helps in increasing resistance to disease and at times improving the condition of the disease state.

Table 1: Medicinal properties of different bioactive compounds from mushroom extracts

Disease/ bioactivity	Bioactive mushroom extract	Mushroom species
Anti-cancer	Methanol extract Polysaccharides extract	<i>Ganoderma tsugae</i>
Anti-diabetic	Vanadium	<i>Grifola frondosa</i>
Cardiovascular disease	Crude extract	<i>Agaricus bisporus</i>
Immune-function	Lectine	<i>Pleurotus ostreatus</i>
Rheumatoid arthritis	Polysaccharides extract	<i>Grifola frondosa</i>
Neurodegenerative	Aqueous extract	<i>Ganoderma lucidum</i>
DNA damage	Water extract	<i>Agaricus blazei</i>

Breast cancer is the major cause of death of women worldwide. It has been found that the reproductive hormone, estrogen, is present in the breast of postmenopausal women and influences breast cancer by affecting cell proliferation and DNA damage as well as the promotion of cancer growth. Aromatase expression occurs in breast tumours which plays a major role in tumour proliferation; this aromatase converts androgen hormone to estrogen. Blocking aromatase with an alternative drug helps to reduce the serum estradiol levels in healthy females. It occurs mainly in women who had early menopause, late or fewer pregnancies by affecting the reproductive hormone. Triterpenes and ganoderic acid extracted from medicinal mushroom, *Ganoderma lucidum*, suppresses the growth of MDA MB breast cancer cell lines by inhibiting cell proliferation and colony formation. Extracts from edible mushrooms,

Agaricus bisporus and *Pleurotus ostreatus*, affect the growth of breast and colon cancer cells by suppressing the proliferation of different breast cancer cell lines. The bioactive compound, clitocine, isolated from *Leucopaxillus giganteus*, is responsible for changing the morphology of cells and induces cell death in human cervical cancer cell lines (HeLa cells).

Conclusion

India is home to a broad variety of mushrooms that may have both nutritional and therapeutic benefits due to its diverse habitats and ecological circumstances. Numerous bioactive compounds, including antibacterial, antifungal, antiviral, antiparasitic, antioxidant, antiinflammatory, antiproliferative, anticancer, antitumor, cytotoxic, anti-HIV, hypocholesterolemic, antidiabetic, anticoagulant, and hepatoprotective, have been identified in a variety of mushrooms. Tribals have utilized these mushrooms as ethnomedicines to cure a variety of illnesses. We are unaware of the nutritional and health benefits of many mushrooms, which are currently underreported. If found, some of them might be rich in nutrients and useful sources of bioactive substances with a wide range of medicinal uses.

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Therapeutic Uses of Flowers

Mansi Mishra, P. Helen Kumary and Shubhangee Ankushrao Waske

Introduction

Flowers have been a vital part of society from the beginning of time. Because of their beauty, they are used as ornaments in a variety of settings, including pots, gardens, landscaping, and containers filled with cut flowers. Particularly cultivated for their eye-catching look, unique foliage, and subtle scent, decorative. Any area is made more charming and unique by the presence of plants. Beyond their aesthetic value, flowers have long served as emotional symbols, appearing in religious ceremonies, celebrations, and professions of love and grief. They also have positive effects on mental and emotional health (Coyago-Cruz *et al.*, 2023). The traditional primary health care system in India is embodied in a 'people's health culture'. This culture is based on very effective and sound, region-specific health practices involving 8,000 species of plants across the country where flowers play a prominent role among them. For several centuries medical practitioners have long been acknowledged the therapeutic properties of certain flowers. Flowers are matchless ornaments to the nature Queen. They are not only a source of beauty and delicacy but also

fountain heads of health and joy. The kingdom of flowers is very vast as we can categorize them in general into four main classes depending upon the purpose for which they are grown, i.e. ornamental, commercial, medicinal and vegetable or edible flowers. Flower therapy uses essential oils, flower waters, flower juice, flower petals (fresh and dried), and aroma to heal mind and body. Modern medications include flower extracts due to the therapeutic qualities of flowers. The importance of flowers is assessed in terms of possible health benefits, primarily the impact of color, flavor, and odor components on antioxidant activity, reactive oxygen radical scavenging action, and cancer prevention. Historically apart from medicinal usage, flowers also used for edible purposes too, for example in ancient Rome, various species of Roses were used in cooking of different kinds of puree and omelets; in medieval France *Calendula officinalis* in preparation of salads; saffron (*Crocus sativus*) as flavoring agent; *Viola odorata* for coloring of sugar, syrups and various potions; *Borago officinalis* and Roses as aromatic enhancers of pastry and dandelion (*Taraxacum officinale*) flowers for preparation of

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drinks and salads in Europe. The majority of people in today's concrete jungle are afflicted with several lifestyle ailments. Fast and accurate diagnosis, disease prevention before it affects, less expensive treatment with little or no side effects, a permanent cure, and avoiding unneeded procedures are all urgent needs for today's society. Flowers have a significant role in the Unani System of Medicine; they are used to treat illnesses, maintain health, and enhance beauty over time. They are also used to make a variety of cosmetic products that are thought to be essential in daily life and to create a warm, inviting, and fresh atmosphere that promotes mental relaxation at any time of day.

Use of Flowers for Therapeutic and Nutritional Purposes throughout History

The use of flowers in food and medicine dates back thousands of years. These usage were first documented in Mesopotamian and Egyptian cultures around 4000 BC. Chamomile (*Chamomilla recutita* L.), whose dried flowers have been used since ancient times to treat menstrual irregularities, sleeplessness, ulcers, hemorrhoids, and other diseases, is a prime example of the historic use of a flower for medicinal purposes. Similarly, numerous cultures have utilized cannabis (*Cannabis sativa* L.), which is well-known for its calming and anticonvulsant qualities, as a medicinal substance. Despite being listed in both the British and later American pharmacopoeia, this plant was removed in the 20th century due to worries about misuse and intoxication. Similarly, flowers of the Asteraceae family

(*Achillea millefolium* L., *Arnica montana* L., *Bellis perennis* L., *Calendula officinalis* L., *Chamaemelum nobile* L., *Helichrysum stoechas* L. and *Taraxacum officinale* L.) have been traditionally used in folk medicine for various therapeutic purposes (Garcia-Oliveira *et al.*, 2021). Around 180 plant species belonging to 97 families have been reported as producing edible flowers. The use of flowers in gastronomy is documented in various cultures, such as Roman, Greek, Chinese, Indian, and Central European, where they are used to enhance both the presentation and nutritional value of food. In ancient Rome, several roses were often used in omelettes and purées. In mediaeval France, marigolds were a common ingredient in salads. The stigmas of the saffron flower are one of the most commonly used colouring and flavouring agents in cooking.



Table 1: Details of flowers used in various systems of Indian Medicine

Botanical name	Flower description	Chemical constituents	Medicinal uses
<i>Abutilon indicum</i>	Flowers yellow and Solitary	Luteolin, chrysoeriol, luteolin	Disorders of Nervous system, pain due to vata, internal injury of chest, Piles, ulcers, cough, skin diseases, leucorrhoea, jaundice, aphrodisiac
<i>Adhatoda zeylanica</i>	Flowers large, white with red or yellow spot at throat.	Luteolin, quercetin, kaempferol, alpfa-amyryn and alpfasitostero	Bronchial asthma, haemorrhage, wasting diseases, fever, delirium, skin diseasepiles, vomiting
<i>Anthocephalous cadamba</i>	Flowers are rounded Crown, bears drooping branches and yellow flowers in globose heads.	Triterpenes, triterpenoid glycoside, flavonoid	It induces lactation
<i>Cassia alata</i>	Flowers large, yellow	Triterpenoid glycoside, flavonoid, Saponins, Tannins	Strong decoctions good for eczema, herpes and a lotion for ringworm, extracts used internally in cases of bronchitis
<i>Chrysanthemum indicum</i>	These dramatic flowers come in a wide range of colors, including red, orange, yellow, pink, white, and purple	Azulene and alpfa-3 carene, sesquiterpene ketodiol, indiculmenone	Juice or infusion of flowers is employed in vertigo, fever, headache, ophthalmia, xerophthalmia, hypertension, furunculosis and phlegm.
<i>Crocus sativus</i>	Flowers solitary or clustered, narrowly sessile, stamens 3 eared, basifixed blue, scented, appearing with leaves, throat of perianth bearded, anthers yellow.	Safranul, isophorene, glucoside, corcin, crocetin, picrocrocine lycopene	Dried stigmas are useful in bronchitis, anaemia, asthma, leucorrhoea, coughs, sexual debility, nephropathy and skin diseases
<i>Eriodendron pentandra</i>	Flowers rose or dark red with large flowers.	-	Menorrhagia, fever, urinary disorders, diarrhea, diseases of pitta, dysentery, gout, haemorrhage
<i>Hibiscus mutabilis</i>	Flowers white/pink.	Quercimeritrin, meatrin and cyanin	Respiratory disorders, Expectorant, Antidote to poisons and Anodyne. Recommended for persistent coughs, Menorrhagia
<i>Jasminium sambac</i>	Flowers white, solitary or in cymes, fragrant.	Triterpenes, sesquiterpenes, linallol, cis-caryophyllene, indole, cis-3-hexenyl benzoate and methyl anthranilate	Useful in foetid smell in ear and nose, eye diseases, vomiting in hypertension

Similarly, violet petals were used to make sweets and colour sugar, while dandelion flowers were used in drinks and salads. Additionally, some of the vegetables that are frequently eaten in the Mediterranean diet are flowers, including broccoli, cauliflower, artichokes, and capers. Globally, countries like Brazil, the United States, France, Italy, Portugal, China, and Japan value and consume edible flowers like pansy, marigold, borage, nasturtium, mini rose, torenia, mini daisy, cosmos, clitoria, craving, begonia, sunflower, snapdragon, and squash

blossom (Barros *et al.*, 2021).

Conclusion

Flowers either directly or indirectly play a significant influence in our daily lives. The sexually reproductive organs of plants are their flowers. Since ancient times, they have been an essential component of human life for a variety of uses, including decoration, ornamentation, and medicine (fresh, distillates, decoction and powdered form), nutrients/foods (fresh garnishes, dried, in cocktails, canned sugar), in food preparations, essential oils, cosmetic

care products, religious ceremonies, and for praying to gods. As a result, the current article on medicinal flowers not only acknowledges this knowledge but also contributes to its preservation by offering pharmacological leads for the advancement of human society.

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Effect of Climate Change on Agriculture

Priyanka Jattan, Karanpreet Singh and Banafshaa Baig

Introduction

Climate has a significant impact on agricultural output. Concern over agriculture's essential role in human welfare has been voiced by numerous groups and others on how agricultural productivity may be impacted by climate change. Over the past ten years, a significant amount of study on climate change and agriculture has been spurred by interest in this topic. Climate change is anticipated to affect input supply, hydrologic balances, animal and agricultural productivity, and other components of agricultural systems. Climate change is caused by the release of 'greenhouse' gases into the atmosphere. These gases accumulate in the atmosphere, which result global warming. The changes in global climate related parameters such as temperature, precipitation, soil moisture and sea level. However, the reliability of the predictions on climate change is uncertain. There are no hard facts about what will definitely be the result of increases in the concentration of greenhouse gases within the atmosphere and no firm timescales are known. Agriculture is one sector, which is important to consider in terms of climate change. Natural resources, especially those of soil, water, plants, and

animal diversity, vegetation cover, renewable energy sources, climate, and ecosystem services are fundamental for the structure and function of agricultural farming systems. With the established increase in atmospheric concentrations of GHGs (Houghton *et al.*, 2001) together with changes in precipitation patterns and increasing temperature the natural resource components of an agricultural farming systems would be altered positively or negatively and, in turn, affect farm productivity throughout the world (Cline, 2007), including in Australia and New South Wales.

Implications of climate change

There is also a broad scientific consensus that, as the Earth warms, precipitation patterns shift and extreme events, such as droughts, floods, and forest fires, become more frequent. These implications of climate change are now well understood; the IPCC Fourth Assessment Report. Increased frequency of heat stress, droughts, and floods negatively impacts livestock and crop yields beyond the effects of mean climate change, according to Rosenzweig *et al.* (2007). This raises the possibility of surprises, with larger and earlier impacts than those predicted by changes in mean

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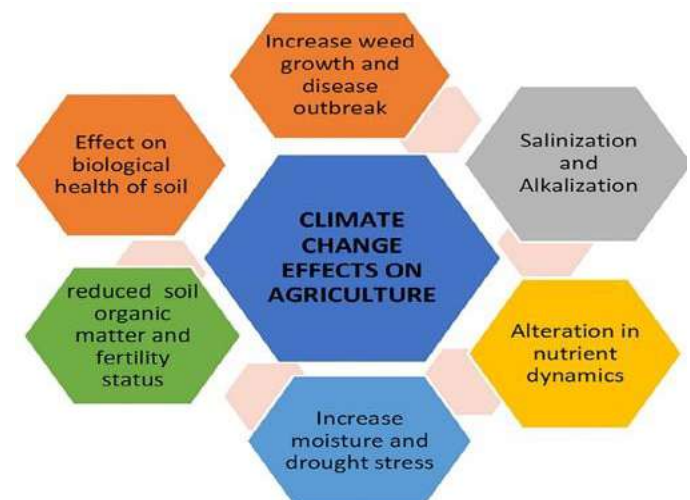
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variables alone. Therefore, it is extremely concerning that, given the current state of the climate, catastrophic events and climate variability may harm the main elements of agricultural farming systems.

Impact of climate change in Agriculture

Agriculture is an economic activity that produces food, fiber, and other necessities for human survival and is heavily reliant on weather and environment. Since agriculture is the foundation of any nation, economic activity is anticipated to be susceptible to variations in the climate. According to Van Vuuren *et al.* (2009), it involves natural processes that frequently call for specific ratios of nutrients, temperatures, precipitation, and other factors. Less than 2% of GDP is derived from agriculture in industrialized or high-income nations, and 2.9% globally. Climate change can affect agriculture in many ways such as variations in rainfall, average temperatures, and climate extremes with an important impact on soil erosion (i.e., floods and drought): changes in diseases and pests, changes in carbon dioxide, changes in food quality that is nutrition, changes in growing season, and changes in sea level. Crop yield shows a strong correlation with temperature change and with the duration of warm or cold waves and differs on the basis of plant maturity stages during extreme weather events. Changes in rainfall patterns will result in a shortage of water, drought-related issues for crops, and adjustments to irrigation planning. They also make rainfall less predictable, which affects farmers' planning. Changes in temperature and moisture content can

indirectly affect how quickly fertilizers and minerals are absorbed, which affects crop production. Climate change is a major concern in every sector such as livestock, which also affects CC in the quality and quantity of feed. Conversely, many reports showed that present agricultural activities are an important source of GHGs that make worse climate interruption. Mostly developing countries produced GHG from agriculture field and a large number of farm animals and inadequate fertilizer management, improper use of agrochemicals and mismanagement of the land. Impact of CCs becomes more severe in developing countries because they are mostly depending on the agriculture field. In the agricultural field, the major potential to mitigate and adapt CC is vital. Climate change also has considerable indirect effect on agricultural land use in India due to availability of irrigation water, frequency and intensity of inter- and intra-seasonal droughts and floods, soil organic matter transformations, soil erosion, changes in pest profiles, decline in arable areas due to submergence of coastal land, and availability of energy.



Effects on crops

- ✓ Reduction in yield in the rainfed areas due to increased crop water demand and changes in rainfall pattern during monsoon season.
- ✓ Declined quality of fruits, vegetables, tea, coffee, aromatic, and medicinal plants.
- ✓ Alteration of agricultural pests and diseases because of more pathogen and vector development, rapid pathogen transmission and increased host susceptibility.
- ✓ In contrast to all of the aforementioned negative effects, projections indicate that future atmospheric temperature rise will result in fewer cold waves and frost events. This would reduce the likelihood of yield loss from frost damage in northern India for crops like vegetables and mustard.

Effect on water

- ✓ Greater evapo-transpiration and warmer temperatures lead to increased irrigation requirements. In certain locations, this can also cause the groundwater table to drop.
- ✓ In the near term, melting Himalayan glaciers may boost the amount of water available in the Ganges, Bhramaputra, and their tributaries, but over time, there would be a significant decline in water availability.

Effect on Soil

- ✓ Reduced organic matter content, which is already rather low in Indian soil, in terms of both quantity and quality.
- ✓ Crop residues have a higher C:N ratio when CO₂

concentration is higher, which may slow down their rate of breakdown and nutrient availability.

- ✓ Change in rainfall volume and frequency and wind intensity may alter the severity, frequency and extent of soil erosion.

Effect on Livestock

- ✓ Climate change has pronounced effect on feed production and nutrition of livestock. Increased temperature results in enhanced lignification of plant tissues and reduced digestibility. Increased water scarcity would also decrease food and fodder production.
- ✓ Global warming would increase water, shelter, and energy requirement of livestock for meeting projected milk demand.
- ✓ Climate change is likely to aggravate the heat stress in dairy animals, adversely affecting their reproductive performance.

Effect on Fishery

- ✓ Increasing sea and river water temperature is likely to affect fish breeding, migration, and harvest.
- ✓ Coral bleaching is likely to increase due to higher sea surface temperature.
- ✓ Impact of increased temperature and tropical cyclonic activity would affect the capture, production and marketing costs of the marine fish.

Effect on crop physiology

- ✓ Temperature increase up to a certain level will enable plants to produce more energy but beyond these limits the photosynthesis of the leaves

decreases sharply and is irreversibly lost.

- ✓ Drought decreases the turgor pressure of plants which ultimately limits cell growth. Deficiency of water also influences the activity of photosynthetic enzymes and reduces the efficiency of metabolic processes and consequently dysfunctions the photosynthetic apparatus (Zargar *et al.*, 2017).
- ✓ Increase in concentration of CO₂ due to changing climatic conditions results in declined plant respiration and increased temperature. Crop respiration increases with increase in temperature up to the range of 15-40°C and then decline.
- ✓ In periods of high temperature, there is a very severe damage to the chlorophyll, as heat stress changes the structural arrangement of the thylakoids, thus affecting its functionality, and also reducing the chlorophyll content of the plant. The above adverse effects on the plant reduces the ability of the plant to photosynthesize because by reducing the chlorophyll content, the photosynthetic pigments are reduced, thereby leading to physiological impairment and reduced growth of the plant.

Various government initiatives taken to tackle the impact of climate change on Indian agriculture

Pradhan Mantra Fasal Bima Yojana (PMFBY):

It was Launched by The government of India in April 2016 to Financial support will be provided to farmers in distress due to loss and damage of crops caused by unexpected calamities.

Pradhan Mantra Krishi Sinchayee Yojana

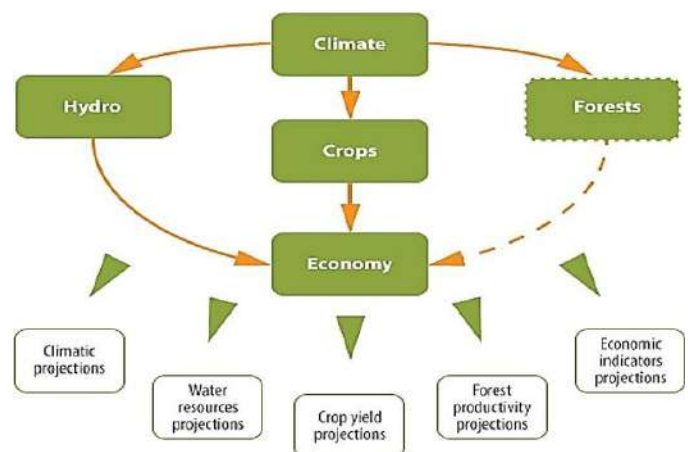
(PMKSY) - micro irrigation: It aims to provide protective irrigation to all farms in the country, to produce “per drop more crop”.



National Mission on Sustainable Agriculture

(NMSA): It is a Mission launched under the National Action Plan on Climate Change (NAPCC) in 2008. The Mission aims to evolve and implement strategies to make Indian agriculture resilient to climate change.

National Seed Corporation (NSC): Established in 1963 and acts as a nodal agency for seed multiplication, in order to make the seeds climate adapted, the seeds are tested for its's genotypes and its resistances against drought and heat.



Conclusion

Climate change effects on agriculture are likely to be ubiquitous, both in terms of direct and indirect impacts. Maintaining plant health across the planet, in turn, is a key requirement for climate change mitigation, as well as the conservation of biodiversity and the provision of ecosystem services under global change. Changes in climate Because of the regular changes in the earth's climate, it has led to significant changes in the pattern of the weather. It has detrimental effects on the environment, human health, the global water system, etc. Acknowledging the inventive and imaginative approaches to climate change adaptation and mitigation is essential.

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Processing and By-products of Sugarcane

Ram Bharai and Ajay Baldaniya

Abstract

Sugarcane is a key commercial crop in India. During 2022-2023, it was cultivated on 5,883 thousand hectares, yielding 494,228 thousand tonnes of sugarcane across India. The processing of sugarcane produces four primary byproducts: bagasse, filter cake, molasses, and cane tops. At harvesting and processing of sugarcane, approximately 120 kg of sugar, 38 kg of molasses, 36 kg of filter mud, 250 kg of bagasse, 60 kg of straw, and 100 kg of tops can be obtained for each ton of sugarcane harvested. Here are the details on the processing of sugarcane and its byproducts.

Introduction

Sugarcane (*Saccharum officinarum*) is an important cash crop belonging to the family Gramineae, cultivated in tropical and sub-tropical regions of the world. About 200 countries are cultivating it, amongst which Brazil is the largest producer, contributing around 25% of the world's total production. The global annual production of sugarcane is 1794 million tonnes, occupies area of 25.4 million hectares. Approximately 70% of the global sugar production is derived from sugarcane. India is the second largest global producer of sugarcane next to Brazil and the world's leading sugar consumer. Sugarcane is a rich source of sucrose (~10 %) and accounts for approximately 80 % of the global sugar production. India is one of the leading sugarcane (and sugar) producing countries in the world. Indian sugar industry has witnessed trem-

endous growth in the past 60 years without any impediments. As a result, the area under sugarcane cultivation and sugar production have been continuously increasing over the last six decades. India currently ranks second in cultivation area (5.11 million ha) and sugarcane production (303.83 million tonnes) next to Brazil. Sugarcane is a long-duration cash crop categorized under exhaustive crop (Paul *et al.* 2005). It requires larger amounts of macro- as well as micro-plant nutrients. More than 45 million sugarcane growers in India, and about 65 % of the rural population depend on this agro-based industry. These industries are struggling for energy with high cost of production. It needs lower cost input and use of by-products as a fertilizer (Dotaniya *et al.*, 2014). The sugar industry is the second largest agricultural industry in the country after the textile industry. Its importance in day-to-day life adds its

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value. In this respect, it has the lot of importance in Indian agriculture. Maharashtra sugar industry is one of the most notable and large-scale sugar manufacturing sectors in the country. In India, between the sixth and fourth centuries BC, the Persians, followed by the Greeks, discovered the famous “reeds that produce honey without bees”. They adopted and then spread sugar and sugarcane agriculture. The main products of the sugar and ethanol sector are sugar, which supplies the food market, anhydrous ethanol, used as an additional fuel for gasoline, and hydrous ethanol, which serves flex vehicles, as well as a small market for non-energy uses.

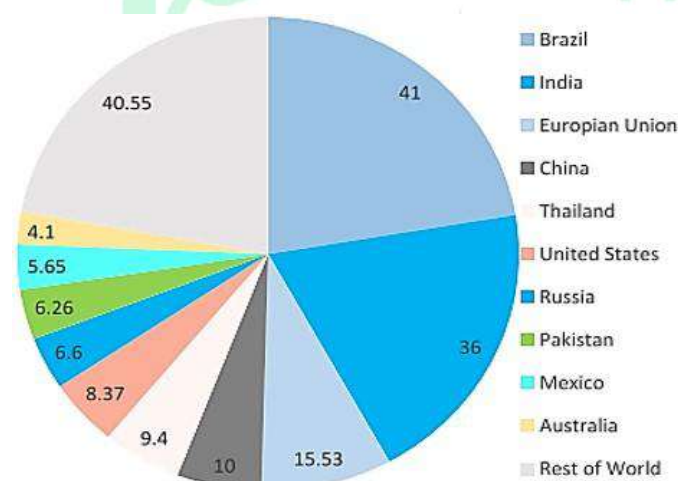


Fig. 1: Global production of sugar amounting to 183.46 million metric tons for the year 2023-24 (USDA, 2024)

Processing of sugarcane

Sugarcane-processing industries are producing different byproducts that have different storage and disposing-of issues. Their utilization in the agricultural ecosystem is also under consideration, and the release of these byproducts at different processing periods is shown in Figure 2.

They are being produced at milling, purification, and fermentation stages for the production of sugarcane juice, sugar, and alcohol, respectively. Organic natured byproducts have different nutrient pools, and chemical and physical properties to influence the soil properties. After transportation to the production facility, the sugarcane is typically washed and directed to the broth preparation and extraction system, which consists of four to seven milling units. The broth is extracted, separating sugars from the fiber (bagasse), which is then sent to the energy plant of the production unit. To enhance extraction yields, the chopped and shredded cane undergoes multiple washes with hot water to extract additional sugars. Finally, the cane passes through a drying roller for producing bagasse for use in the boilers. The sugarcane juice obtained in the mill or diffuser can then be utilized to produce either sugar or ethanol. In order to make sugar, the Broth goes through a number of treatment procedures that include chemical reactions (aided by the addition of different substances) and physical techniques (including sifting, heating, and flashing). In order to enhance sucrose recovery and guarantee a high-quality end product, these procedures seek to remove non-sugars, colloids, turbidity and colour while encouraging sedimentation. Following the chemical treatment, the broth is heated to sterilize by eliminating microorganisms, completing reactions with the alkalizing agent, coagulating and flocculating insoluble impurities, and removing gases. The broth is then transferred to a decanter or

clarifier, where the flocculated impurities, known as sludge, are separated. The clarified broth flows out from the top of the trays, which are now largely free of impurities. In the decanters, only the physical separation of the broth from the sludge occurs. The removed sludge is combined with bagasse and filtered to recover any remaining sucrose, while the residual filter cake is used as fertilizer in sugarcane fields.



Ethanol production

The initial stages of ethanol production closely resemble those of sugar production. After treatment, the cane juice is evaporated to adjust its sugar concentration and is then mixed with molasses to create the wort. This wort is transferred to fermentation units, where it is combined with yeasts (*Saccharomyces cerevisiae*) and fermented for about 6 to 10 hours, resulting in a fermented mixture known as wine, with an alcohol concentration of 7% to 10%. Following fermentation, the yeasts are recovered and prepared for reuse, while the wine is sent to distillation columns. This process offers economic benefits by allowing the reuse of yeasts in

fermentation. Distillation serves as a physical method for separating components in a mixture based on their relative volatility.

Various By-product of sugarcane

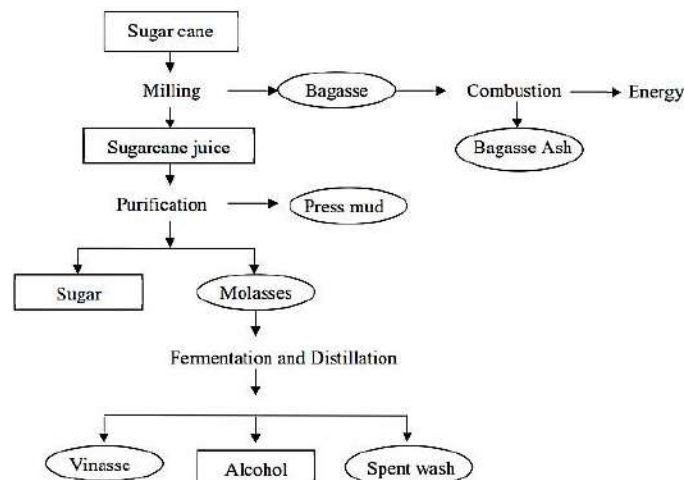


Fig. 2: Flowchart of sugar and ethanol production process along with byproducts

Sugarcane bagasse is a cellulosic agro-industrial byproduct released after crushing and extracting juice from the canes. It is pulpy residue and is fibrous in nature. In summer seasons, in local markets, we can see bagasse heaps at sugarcane juice corner. It is used as a bio-fuels or in industrial level; it is used as a binding material. In general, bagasse contains major portion as cellulose, hemicellulose, and lignin are 47-52, 25-28 and 20-21 %, respectively. Apart from this 0.8-3% other compounds and ashes are pre-dominantly found (Rocha *et al.*, 2011). It contains sugar, which is responsible for fast bio-degradable within 3 months. The application of bagasse in agricultural crop production system can be reduced the application rate of fertilizers. It produced organic acids, which mobilized the insoluble P from soil to soil solution in labile form. During application, it is suggested that

these bagasse properly chopped; and applied one month prior to seed sowing in the field for proper decomposition.

Molasses: It is produced during sugar production from raw juice. It is a viscous liquid which can be separated by massecuite. It contains higher microbial activities used for the production of alcohol and/or ethanol, or fuel for ethanol. An average of 1 t sugarcane produces 23 L of molasses. Molasses is one of the most economically important byproducts of sugar industries. This has many industrial uses, viz., generation of alcohol, preparation of animal feeds, and food stuffs. Molasses containing large fractions of fermentable sugars which is diluted (three times) with good water and allowed to ferment in the presence of yeast culture (*Saccharomyces cerevisiae*) either by batch or continuous process of fermentation. The fermentable sugars are recovered by the action of yeast as an alcohol (rectified spirit)/ethanol, leaving unfermented lower order sugars (such as dioses, trioses, tetroses, pentoses, etc.), water soluble amino acids, lignins, and other organic fractions, etc., in spentwash. The organic constituents present in higher concentration undergo reduction generating unpleasant odour.

Vinasse: Vinasse is the final by-product from the distillation of fermentation wine used to produce ethanol. It has a brown color that darkens with oxidation when exposed to air. This by-product is a significant and concerning liquid effluent in the agro-energy industry. For every liter of ethanol produced, approximately 10 to 15 liters of vinasse are generat-

ed. The challenge associated with this volume of vinasse stems from the toxicity of ethanol to the yeasts employed, which necessitates lowering the alcohol content during the final stage of fermentation.

Conclusion

Sugarcane crop is an important cash crop grown for the preparation of sugar and related products. The sugar industry is an agro-based industry that discharges different waste products during sugar and alcohol formation. The byproduct of sugarcane juice extraction is bagasse. Being a by-product, it has almost no production or transportation costs, making it highly valued primarily for replacing wood and fossil fuels in the production of steam and electricity, enabling the producing units to become energy self-sufficient and, in certain cases, for the commercialization of excess electricity. Additionally, bagasse is utilized to make furfural and cellulosic ethanol. Lubricating oils, wood resins, and vegetable oils are refined using furfural as a solvent. Furfuryl alcohol is utilized as a raw material for furanic polymers, anticorrosives, urea polymers, modified formaldehyde, perfumes, and resin and dye solvents.

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Value Addition of Vegetables

Ram Bharai and Karishma D. Wakulkar

Introduction

A balanced daily diet must include vegetables as a key ingredient. They are known as protective foods due to their high mineral, vitamin, and phytonutrient content. Nowadays, most people agree that vegetables are important for tackling the problem of food and nutritional security. Dietary vegetables are strongly associated with improved gastrointestinal health, improved vision, and a decreased risk of heart disease, stroke, diabetes, and various types of cancer. India is the second-largest producer of fruits and vegetables in the world, after China. Furthermore, because many commodities are perishable, they suffer large postharvest losses. Approximately one-third of the product is typically squandered during various handling procedures between harvest and consumption. Thus, processing and value addition are essential components of the horticulture business because they help to reduce post-harvest losses and waste, manage gluts, assure nutritional security, use marketable excess and ensure that producers and processors receive fair returns. As a result, more value added, ready-to-use vegetable products, as well as vegetable in consumer packs, are being used (Datta *et al.*, 2015). In addition to allowing for regular ingestion throughout the year

in place of fresh vegetables, processed vegetable forms may enhance overall consumption. The majority of veggies are naturally low in calories and fat. Numerous nutrients, such as potassium, dietary fiber, folic acid, vitamin A, and vitamin C, are found in vegetables. Potassium-rich diets may support the maintenance of normal blood pressure. Sweet potatoes, white potatoes, kidney beans, tomato products (paste, sauce, and juice), beet greens, soybeans, lima beans, spinach, and kidney beans are examples of vegetables that are high in potassium. Vegetable dietary fiber lowers blood cholesterol and may lessen the risk of heart disease when consumed as part of a balanced diet. Fiber is necessary for healthy intestinal function. It lessens the discomfort of constipation illness. Value addition is a process of increasing the economic value and consumer appeal of an agricultural commodity. It is a production/marketing strategy driven by customer needs and preferences. “Value-added” is used to characterize food products converted from raw materials through processes that give the resulting product an “incremental value” in the market place either through higher price or expanded market. Examples of value-added products are preserves, tomato purees, ketchup, pickles and dehydrated products.

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Table 1: Major vegetables producing states of India

State	Major Vegetables
Maharashtra	Onion, tomato, capsicum beans, brinjal
Karnataka	Tomato, gherkin, chili, onion
Himachal Pradesh	Cole crops, mushroom, pea
Andhra Pradesh	Chili, brinjal, tomato, okra, onion, tapioca
Gujarat	Potato, brinjal, okra, tomato, onion
Tamil Nadu	Tapioca, onion, tomato, cabbage, brinjal
Uttar Pradesh	Potato, brinjal, cabbage, cauliflower, pea, tomato
West Bengal	Brinjal, tomato, okra
Bihar	Potato, brinjal, onion, cauliflower
Madhya Pradesh	Onion, beans, potato, tomato, brinjal, cauliflower

Reason for increasing demand for value addition of vegetables in India

- ✓ Less price of fresh produce as prices in India is fixed based on demand and supply. In peak season, when there is a glut in market prices drop down drastically and farmers didn't even get the production cost incurred.
- ✓ A yearly increase in vegetable production as a result of growing hybrid types and increased productivity. Therefore, it is possible to process the excess output.
- ✓ Introduction of the corporate sector in vegetable marketing as well as in processing industry.
- ✓ Processing industries employ the labour with minimum wages and also the overall production cost must be lower. Such requirements can be easily accomplished in India as compared to European and American countries.
- ✓ Processable varieties introduced or developed indigenously which are specifically used for processing in a way to increase the recovery of final products.

- ✓ Government is also promoting the farmers/rural youth to establish their own processing industry by providing financial support to promote establish the small scale industries.
- ✓ The countrymen's eating habits have drastically changed as a result of their attraction to junk food like pizza, burgers, pasta, noodles, and so forth. Since eating habits cannot be altered, goods made with extrusion processes can incorporate vegetables in the form of powder, flakes, or paste to increase vegetable consumption. Researchers use powdered versions of leafy vegetables, such as spinach, moringa, curry leaf, fenugreek, etc., to make a variety of extruded goods.

Different value added products from vegetables

Potato flour chips: For potato chips, fresh potatoes with a high dry matter content are preferred; these chips can also be made into potato flour. The browning interaction between sugars and other ingredients, primarily amino acids, produces the chip's colour. High-sugared potato chips turn brown or black when fried and the same thing happens to boiled and peeled potatoes. The production of chips is determined by the specific gravity/dry weight of the potatoes. (Garayo and Moreira, 2002).

Dehydrated Products (Potato flour, Granules and Flakes): A high dry matter content results in a high production of the final product while requiring less energy to remove the relatively low moisture content of the raw materials. The preserved potatoes are high in sugar and protein and low in moisture when compared to fresh potatoes. To avoid browning,

potato flour is usually made from fresh potatoes (Pedreschi, 2009).

Tomato ketchup/sauce: The ingredients for tomato sauce and ketchup include strained tomato juice or pulp, spices, salt, sugar, vinegar (with or without onion) and garlic paste. They are semisolid processed tomato products. Sauces can be sieved and have a smoother consistency. At least 12% tomato solids and 25% total solids are present in the sauce.

Dehydrated/frozen pea: Due to their improved flavor, extended shelf life, and ease of handling and transportation, dehydrated peas are growing in popularity. The drying process should successfully maintain the produce's color, texture, flavor, taste, and nutritional value, much like it does with fresh peas. For drying peas, fluidized bed drying is becoming more and more popular. Small, dark-green peas with seeds are best for freezing. Fresh peas are frozen at 18°C using polythene sheets that are impermeable to water vapor and resistant to low temperatures. Tender, large-sized pods with delicious, assertive seeds are chosen for canning. Cultivars with wrinkled and smooth seeds are suitable for canning. However, due to their skin's propensity to turn bronze in the course of processing or storage, cultivars grown from freezing are not suitable for canning (Burrier, 2000).

Cabbage: Some nations in Europe and the USA enjoy enormous popularity with sauerkraut. It denotes acidic kale. It is a pure, healthy product with a distinct flavour that is made by fully fermenting shreds of cabbage in the presence of 2 % to 3 % salt.

1.5 % lactic acid and 0.5- 2.5 % salt can be found in good sauerkraut. Sauerkraut should only be made with fully matured cabbage because using green cabbage could result in poor colour and texture (Satora *et al.*, 2021).

Carrot Powder: Carrots may be preserved quite effectively by dehydration and powder production. The two main pretreatments used to prepare carrot powder are blanching and boiling. More beta-carotene and total dietary fibre in carrot powder made by boiling the carrots. Washing, cutting into 22 cm pieces, cooking for 10 minutes, mashing, allowing to cool at room temperature, drying for 18 hours at 50 °C and then grinding into powder.



Dehydrated leafy vegetables: It has the tremendous potential to be utilized all year round, even in the off-season, for the preparation of many types of mixed vegetables following rehydration. It has the potential to develop into a significant product since it is affordable, simple to prepare and packed with nutrients that are vital to good health. Currently, India exports a sizable number of value-added goods made from vegetables and spices, generating a sizable sum of foreign cash.

Future perspectives

Post-harvest management and value addition in vegetables presents promising prospects for enhancing food security, economic growth, and sustainability in agriculture. Processing techniques like freezing, drying and fermentation can transform perishable vegetables into products with significantly extended shelf lives. Value addition encourages innovation and entrepreneurship. It opens doors for the creation of new products, innovative packaging solutions, and the development of healthier and more convenient food options. Small and medium enterprises (SMEs) can find new avenues for growth and employment through these ventures. Investment in research and development for improved post-harvest technologies, better infrastructure for storage and handling, and innovative processing holds key to unlocking full potential of value addition in vegetable crops. Effective upscaling of technology will contribute to economic development, and self-reliance and meet growing demands for nutritious and high-quality vegetable produce. Apart from traditional vegetable processing such as drying, canning, freezing, juice extraction and concentration etc. vegetable sector has huge potential to fuel the growth of food processing in India. Some potential future areas that require utmost importance are the nutraceutical, ready-to eat and fresh-cut vegetable industry

Conclusion

India is the world's second largest producer of fruits and vegetables. Today, the importance of

vegetables in solving the problem of food and nutritional security is widely acknowledged. In vegetable production, over one-third of the crop is often lost due to various handling procedures from harvest to consumption. Since most vegetables have a limited shelf life and must be sold immediately, they must also be processed into a range of value-added products. In order to reduce post-harvest losses and waste, manage gluts, ensure nutritional security, use marketable surplus, and make sure producers and processors receive fair compensation, processing and value addition are therefore essential components of the horticulture sector.

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Enzyme Applications in the Food Industry

Shrikrishna Balaso Narale, Banafshaa Baig and Abhishek Belli M.

Introduction

Enzymes are natural catalysts that facilitate the majority of chemical reactions in biological systems by enhancing the rate of reactions. Enzymes have been used to enhance the shelf-life of foods and beverages since ancient times. Since the beginning of time, natural enzymes have been utilized to produce goods like leather, indigo, and linen as well as culinary items like cheese, sourdough, beer, wine, and vinegar. All of these procedures depended on either enzymes generated by microorganisms that grew on their own or enzymes found in extra preparations like papaya fruit or the rumen of calves. As a result, no pure or thoroughly studied version of the enzymes was utilized. Enzymes may now be produced as purified, well-characterized preparations even on a large scale because to the development of fermentation techniques in the latter half of the 20th century, which were particularly designed to produce enzymes using specialized production strains. Still, their demand is constantly increasing in the food industry. The role of enzymes as catalysts was recognized in the 19th and early twentieth centuries. Initially, the role of yeast extract

in the conversion of glucose to ethanol was discovered by Eduard Buchner in 1897. Later on, it was found that the enzyme present in yeast extract was responsible for the conversion. Firstly, James B. Sumner isolated and crystallized the pure enzyme, urease, and won the Nobel Prize (1946) for the same (Hua *et al.*, 2018). In the food industry, enzymes are utilized to increase production and also improve texture as well as aroma, color, and flavor. Also, the enzymes are utilized to provide raw materials such as dough in the baking for the production of standard bakery products of high quality. In the beverage industry, enzymes have been used to produce high-quality beer and wines by improving the brewing process (Kuddus, 2018). Along with this, the food business also produces high-quality, nutrient-dense feed and uses enzymes in the processing and meat for cattle. The global industrial enzyme market is projected to reach USD 6.95 billion in 2022 and develop at a compound yearly growth rate of 6.4% between 2023 and 2050. The demand for enzymes in the sector is predicted to rise more as the consumption of juice and baked goods rises.

Application of enzymes in different food sector

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Baking Industry

Enzymes Used: Amylase, Protease, Glucose Oxidase

Applications

Dough Development: Amylase breaks down starches into sugars, providing fermentable sugars for yeast, which improves the dough's rise and texture.

Shelf Life Extension: Enzymes help retain moisture in baked goods, prolonging freshness and reducing staleness.

Texture Improvement: Protease enhances the extensibility and elasticity of the dough, resulting in softer bread and improved crumb structure.

Brewing Industry

Enzymes Used: Alpha-Amylase, Beta-Amylase, Glucanase

Applications

Mashing Process: Alpha and beta-amylases convert starches in malted grains into fermentable sugars, crucial for alcohol production during fermentation.

Clarity Enhancement: Glucanase breaks down glucans that can cause haze in beer, improving clarity and stability.

Flavor Development: Enzymatic reactions contribute to the development of complex flavors in beer.

Dairy Processing

Enzymes Used: Rennet, Lactase, Lipase

Applications

Cheese Production: Rennet coagulates/pilk, facilitating the separation of curds and whey, essential for cheese making.

Lactose Hydrolysis: Lactase is used to convert lactose into glucose and galactose, creating lactose-free dairy products for lactose-intolerant consumers.

Flavor and Texture Enhancement: Lipase improves the flavor profile of certain cheeses by breaking down fats into free fatty acids, enhancing aroma and taste.

Dairy production	Brewing	Baking	Wine and fruit juice	Meat
Rennet	β -Glucanase	Maltogenic amylase	Pectinase	Protease
Lactase	α -Amylase	Glucose oxidase	β -Glucanase	Papain
Protease	Protease	Pentosenase		
Catalases	Amyloglucosidase			
				

Meat Production

Enzymes Used: Papain, Bromelain, Ficin

Applications

Tenderization: Proteolytic enzymes like papain and bromelain break down muscle fibers and connective tissues, improving the tenderness of meats.

Flavor Enhancement: Enzymes are used in marinades to enhance the flavor profile of meats through the development of flavor compounds during marination.

Fermented Products: Enzymes contribute to the fermentation process in products like sausages, improving flavor and texture.

Beverage Industry

Enzymes Used: Pectinase, Cellulase, Glucosidase

Applications

Wine Production: Pectinase aids in the clarification of wine by breaking down pectin, resulting in clearer, higher-quality products.

Fruit Juices: Enzymes help in the extraction and clarification of juices, enhancing yield and quality.

Fermentation: Enzymes facilitate the fermentation process in beverages, improving taste and alcohol content.

Techniques employed for enzyme purification

Enzyme purification represents a crucial step in the industrial application of enzymes. The enzyme mixture obtained after microbial fermentation to produce a specific enzyme often contains impurities and solvents that can impact enzyme kinetics, compromising the quality and final yield of the enzyme. Purified enzymes, however, exhibit increased stability and higher specificity towards their substrate. One of the simplest methods for enzyme purification, applicable under various conditions, is precipitation. This involves the addition of an organic solvent or salt, leading to the precipitation of the enzyme, a technique commonly referred to as salting out. The resulting precipitate can be collected through centrifugation or filtration (Larsson and Mosbach, 1979). Another widely used technique for enzyme purification is chromatography. This method involves the separation of a protein mixture through a column containing a polar stationary phase and a non-polar mobile phase to achieve homogeneity. Various chromatography techniques can be employed based on the size, charge, and affinity of the enzyme. The choice of column type is tailored to the specific requirements of the purification process (Rodriguez *et al.*, 2020). In the food industry, electrophoresis is another technique

employed by industries for enzyme extraction. This method involves the separation of proteins based on their charge and size through an electric field.

Benefits of Enzyme use in Food Industry

- ✓ The application of enzymes in the food industry offers numerous advantages that contribute to improved product quality, enhanced processing efficiency, and better sustainability practices.
- ✓ Enzymes improve the texture of food products. For example, in baking, enzymes like amylase and protease help create a softer crumb structure and improve dough elasticity.
- ✓ Enzymatic reactions can develop complex flavors in food. In cheese production, enzymes like lipase break down fats into free fatty acids, enhancing the aroma and taste of the cheese.
- ✓ Enzymes can enhance the bioavailability of nutrients, making them more accessible for absorption. For instance, lactase helps lactose-intolerant individuals digest dairy products, improving their nutritional intake.
- ✓ Enzymes can inhibit microbial growth and enzymatic reactions that lead to spoilage. For example, pectinase can prevent browning in cut fruits, extending their shelf life.
- ✓ Enzymes help retain moisture in baked goods, reducing staleness and prolonging freshness. This is particularly beneficial for bread and pastries.
- ✓ Enzymes accelerate biochemical reactions, reducing the time required for food processing. For instance, in brewing, amylases speed up

Table 1: Enzyme commonly used in food industry

Enzyme Name	Type	Application	Food Products
Amylase	Carbohydrase	Breaks down starch into sugars	Baked goods, brewing
Protease	Proteolytic	Tenderizes meat and improves dough texture	Meat products, baking
Lactase	Glycosidehydrolase	Converts lactose into glucose and galactose	Dairy products (lactose-free milk)
Lipase	Lipolytic	Breaks down fats and improves flavor	Cheese, dairy products, flavored oils
Pectinase	Pectinase	Breaks down pectin, aiding juice extraction	Fruit juices, jellies
Cellulase	Cellulase	Breaks down cellulose, improving texture	Fruit and processing
Glucose Oxidase	Oxidoreductase	Enhances dough strength and shelf life	Baked goods
Invertase	Glycosidehydrolase	Converts sucrose into glucose and fructose	Confectionery, chocolate
Rennet	Proteolytic	Coagulates milk for cheese production	Cheese production
Phytase	Phytase	Breaks down phytic acid, improving nutrient bioavailability	Animal feed, some food products
Chymosin	Proteolytic	Coagulates milk for cheese production	Cheese production

starch conversion to sugars, allowing for quicker fermentation.

Conclusion

Enzymes are currently employed in a wide range of industrial processes and products, and new uses are being introduced on a regular basis. Thanks to developments in contemporary biotechnology, enzymes may now be created for applications that were unthinkable just ten years ago. Common to the majority of applications, the introduction of enzymes as efficient catalysts operating in moderate conditions leads to notable resource savings, including water and energy, which benefit the environment as well as the sector in question. Enzymes are invaluable tools in the food industry, facilitating improvements in quality, efficiency, and safety across various sectors. Their ability to enhance product attributes while promoting clean labeling aligns with current consumer trends toward natural and sustainable food products. As the food industry continues to innovate, enzymes will likely play an increasingly prominent role, supporting the development of high-quality, safe, and sustainable food options.

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The Rising Threat of Antibiotic Resistance: A Call for Global Action

Ibrahim

Abstract

Antibiotic resistance is a growing global concern, resulting from the ability of bacteria to survive and thrive despite antibiotic treatments. This issue has escalated due to the overuse and misuse of antibiotics in human medicine, veterinary practices, and agriculture. Resistant bacteria pose significant risks to human and animal health, food security, and economic stability, leading to longer illnesses, increased medical costs, and higher mortality rates. Preventative measures, such as improving hygiene, animal welfare, and biosecurity, can reduce the need for antibiotics. Global initiatives like the One Health approach emphasize the interconnectedness of human, animal, and environmental health in combating antibiotic resistance. Collective action and innovative strategies are vital to address this challenge and protect public health and ecosystems for future generations.

Introduction

Antibiotic resistance is a critical global challenge, posing a serious threat to human health, food security, and sustainable development. It arises when bacteria develop the ability to withstand the effects of antibiotics designed to destroy them. This phenomenon is exacerbated by the misuse and overuse of antibiotics in humans, animals, and agriculture, which accelerates resistance development and reduces the efficacy of treatments. From its origins with Alexander Fleming's discovery of penicillin to its misuse in healthcare and farming, antibiotic resistance has evolved into a pressing issue, necessitating immediate and collaborative efforts across sectors to mitigate its impact.

Antibiotic Resistance: Antibiotic resistance refers to the ability of bacteria to survive and thrive even after being exposed to antibiotics that were designed

to kill them. This phenomenon occurs when bacteria encounter low doses of antibiotics, allowing them to survive and develop resistance. Over time, this resistance can be passed on from one bacterial generation to the next and even between different species of bacteria.

The Origins of Antibiotic Resistance

In 1928, Alexander Fleming discovered penicillin, marking the advent of antibiotics. These life-saving drugs drastically reduced deaths from bacterial infections in humans and animals. However, widespread use and large-scale production of antibiotics began in the 1930s and 1940s, leading to misuse. Antibiotics were not only used to treat diseases but also for growth promotion in livestock and as preventive measures, even for infections caused by viruses or parasites. This overuse has contributed to bacteria becoming resistant, rendering

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many antibiotics less effective.

How Antibiotic Resistance Impacts Us: Antibiotic resistance is a major threat to global health, food security, and development. It can affect anyone, regardless of age or location. Diseases like pneumonia, tuberculosis, gonorrhea and salmonellosis are becoming increasingly difficult to treat as bacteria evolve resistance. This results in prolonged illnesses, extended hospital stays, higher medical costs, and increased mortality. A 2019 study published in *The Lancet* estimated that 1.27 million people globally died due to bacterial resistance. Without significant changes, this number could rise to 10 million deaths annually by 2050.

Current Challenges and Consequences: Despite global awareness, antibiotics continue to be overused in humans, animals, and agriculture, accelerating resistance. In the agricultural sector, the extensive use of antibiotics in animal farming contributes significantly to this problem. Antibiotic-resistant bacteria can transfer to humans through food products and direct contact, creating a two-way transmission pathway. Moreover, antibiotic residues in food pose additional health risks. Failure to observe withdrawal periods after administering antibiotics in animals can lead to harmful residues in meat or milk, affecting human consumers and damaging the reputation of producers.

Preventing Antibiotic Resistance

Hygiene and Animal Welfare: Maintaining hygienic and comfortable living conditions for animals significantly reduces disease risk. Proper ventilation,

clean bedding, and regular disinfection can prevent infections and reduce the need for antibiotics.

Biosecurity Measures: Biosecurity involves minimizing exposure to pathogenic bacteria. Steps include wearing clean clothes and shoes before entering animal areas, disinfecting equipment, and isolating sick animals. Avoiding unnecessary visitors and maintaining cleanliness in barns are also essential.

Vaccination and Preventive Healthcare: Vaccinating animals against common diseases helps build immunity and lowers the chances of infection. Veterinarians can advise on region-specific vaccination programs to ensure effective prevention.

Responsible Use of Antibiotics

When antibiotics are necessary, they should be used responsibly:

- ✓ Always follow veterinary prescriptions and avoid self-administration.
- ✓ Respect withdrawal periods to ensure no antibiotic residues remain in animal products.
- ✓ Properly dispose of expired antibiotics and products with residues to prevent environmental contamination.
- ✓ Understand the financial implications of improper antibiotic use, which can lead to rejected milk or meat and financial losses.

Global Initiatives to Combat Antibiotic Resistance

International organizations, including the World Health Organization (WHO), the Food and Agriculture Organization (FAO), and the World

Organisation for Animal Health (WOAH), have been working together to address antibiotic resistance. These efforts have been bolstered by the United Nations Environment Programme (UNEP) under the One Health approach.

The One Health Approach: One Health emphasizes the interconnectedness of human, animal, plant, and environmental health. This approach fosters collaboration among sectors to address antibiotic resistance comprehensively. By sharing data and resources, countries can identify hotspots of resistance and implement targeted interventions. Farmers play a crucial role in maintaining a balance between health, food safety, and environmental sustainability.

Conclusion

Antibiotic resistance demands urgent, responsible action from all stakeholders, including governments, healthcare providers, farmers, and the public. Adopting preventive measures like improved hygiene, biosecurity and vaccination can significantly reduce reliance on antibiotics. Furthermore, global initiatives such as the One Health approach highlight the importance of integrating efforts across human, animal, and environmental health sectors. Together, these strategies can combat antibiotic resistance, safeguard public health, and ensure sustainable food systems. By prioritizing responsible antibiotic use and innovative solutions, we can confront this growing threat and protect future generations.

Microplastics in Agricultural Soils: Emerging Contaminants and their Impacts

Anjaly Yadav, Anand Kumar Diwakar, Anamika Tomar, Thodusu Mamatha and Rajendra Kumar

Abstract

Microplastics (MPs), defined as plastic particles smaller than 5 mm, are emerging as significant contaminants in various environmental compartments, including soil, water, air, and food. Due to their persistence, bioaccumulation, and toxicity, MPs threaten ecosystem health, agricultural productivity, and human well-being. This article explores the impact of MPs on soil ecosystems and their potential entry into the food chain through crops. MPs, such as polyethylene (PE), polypropylene (PP), and polystyrene (PS), are prevalent in the environment and affect soil's physical, chemical, and biological properties. Studies have demonstrated that MPs can disrupt plant growth, alter microbial communities, and lead to oxidative stress, resulting in reduced germination, seedling mortality, and soil fertility. Additionally, MPs serve as carriers for toxic substances, amplifying their environmental risks. This article also highlights the current efforts in India, including the Food Safety and Standards Authority of India's initiative to detect MPs in food and government regulations aimed at plastic waste management and reduction. It advocates for developing cost-effective biological methods for MP degradation and emphasizes the need for further research on bioremediation strategies. The findings underscore the urgent need for comprehensive action to mitigate MP contamination and its adverse effects on ecosystems and human health.

Introduction

Microplastics (MPs) are small pieces of plastic that are less than 5 millimetres in size. Due to MPs persistent and bioaccumulation properties it's hard to remove from nature. MPs are considered to be ubiquitous and widespread emerging contaminants. Recognising microplastic pollution as an emerging threat that requires immediate attention,

the project “Micro-and Nano-Plastics as Emerging Food Contaminants: Establishing Validated Methodologies and Understanding the Prevalence in Different Food Matrices” was started in March this year to develop and validate analytical methods for detecting micro and nano-plastics in various food products, as well as assess their prevalence and exposure levels in India. The major plastic particles

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in the form of microplastics released into the environment are made up of polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinylchloride (PVC) and polyethylene terephthalate (PET). PE, which is widely used in packaging, containers, automotive, household daily products. The MPs are transboundary and ubiquitous pollutants that affect various environmental compartments, including air, water, soil, food, and beverages. MPs can alter the soil's physical, chemical and biological properties like soil structure, porosity and water holding capacity, nutrient availability and microbial populations. Microplastics in soils can eventually make their way into the human diet through contaminated crops, posing potential health risks, including inflammation and hormonal disruption. Microplastics act as carriers for toxic substances, including pesticides and heavy metals, which can bind to their surfaces. These pollutants may leach into the soil and groundwater and causing plant and human health risks. Earthworms, fungi, and bacteria play a crucial role in maintaining soil health, which are affected by MPs contamination and MPs can interfere with the functioning of these organisms, disrupting nutrient cycles and soil fertility. This may lead to reduced crop yields and increased vulnerability to drought. The MPs load in the environment is increasing and it is present in a variety of sizes and polymer types. Their persistent nature and toxicity have raised concerns about their effective management and mitigation from the environment. Anthropogenic activities are the major

contributor of MPs in beach sediments. MPs are widely distributed along beaches and pose a serious threat to the marine food chain including human health. The presence of MPs in the atmosphere depends on their size and density. Larger particles deposit more rapidly and settle on the soil surface, while smaller particles in the inhalable range are present in the environment (Dris *et al.*, 2017). In the environment, the MPs can be categorized into primary or secondary. The primary MPs are deliberately created in microscopic size (e.g., microbeads), while secondary MPs arise from the breakdown of larger plastic particles. The degradation of plastics, i.e., thermal degradation, photodegradation, thermos oxidative degradation, biodegradation and hydrolysis in the environment results in the generation of secondary MPs. The primary MPs are released into the environment during industrial activities and domestic applications, viz., cosmetics and personal care products, synthetic clothing, insect repellents, drilling fluids, and air blasting media. The secondary MPs are small plastic fragments originating from macroplastic debris breakdown in aquatic and terrestrial environments. It is also important to measure and keep track of how much microplastic reaches the environment and how it influences its biota. The abundance of microplastics varies greatly, even within one area. Being low denser, microplastics are easily transported by the currents and amenable to accumulate in regions of less favourable hydrodynamic circumstances and may be responsible for the unequal dispersion pattern. Developing

methods for precisely quantifying microplastics in marine ecosystems and those consumed by marine organisms is becoming more and more crucial. In comparison to developed nations, recycling rates of plastic trash are substantially lower in developing nations. Plastic pollution has been deemed as a serious issue by the United Nations Environment Programme (UNEP), and the use of microplastics as additives in consumer and industrial products has been a topic of discussion for the past few years. According to the many comprehensive studies, the Open Ocean, shorelines, deep sea, and polar zone are all being affected by the ubiquitous occurrences of microplastics. Microorganisms ranging from bacteria to algae like *Bacillus*, *Pseudomonas*, *Aspergillus*, *Cyanobacteria* etc shown the capabilities to degrade microplastic present in the environment and help in the biodegradation of MPs particles.

Impact on Soil Ecosystem

The impact of microplastics on soil and rhizosphere environment are shown in figure 1. Microplastics not only impact soil quality but may also enter the food chain, Sridharan *et al.* (2023) reported that the impacts of virgin polypropylene (PP), polyvinyl chloride (PVC), and polylactic acid (PLA) MPs (0%, 0.05%, 0.1%, and 0.5% w/w dry soil) on the germination of an agricultural herb, coriander (*Coriandrum sativum* L.), under outdoor (field pots) and indoor (greenhouse) conditions. They observed that all three polymeric MPs in the soil delayed the germination (60-100% inhibition up to day 7) and impacted the seedling length within the

30-day exposure. The inhibitory effect was higher in the field than in the greenhouse. PVC showed the highest inhibition of germination under both conditions, followed by PP and PLA. PLA impaired the root length of the seedlings more than PP and PVC. At 0.5% (w/w), all polymers showed significantly elevated levels of reactive oxygen species in the root tips than control, suggesting MP-induced oxidative stress as a potential mechanism behind the impaired germination and seedling growth. These results clearly indicated a potential decline in crop survival and productivity caused by virgin MPs. The findings proposed that the soil MPs could be a global threat to the plants and ecosystem succession and the presence of microplastics in agricultural soils poses risks to crop growth and quality. According to Miri *et al.* (2022) the current knowledge of biotechnological, aerobic and aerobic biodegradation approaches emphasizes the microbial culture's potential towards MPs removal. It provides recent biotechnological advances such as bio-stimulation, bioaugmentation and enzymatic biodegradation that can be applied for MPs removal by biodegradation and bioaccumulation. To address complex issues regarding the bioremediation of MP pollution, it is necessary to apply multi-disciplinary research strategies such as assessing MPs, screening and characterization of efficient microbes (bacteria and fungi) using innovative assessment tools (genomics), and evaluation of in situ toxicity. For some recalcitrant MPs (e.g., polyolefins), microbial activities can be employed to use plastic waste as

feedstock for biotransformation or biodegradation following chemical depolymerization methods (e.g., glycolysis).

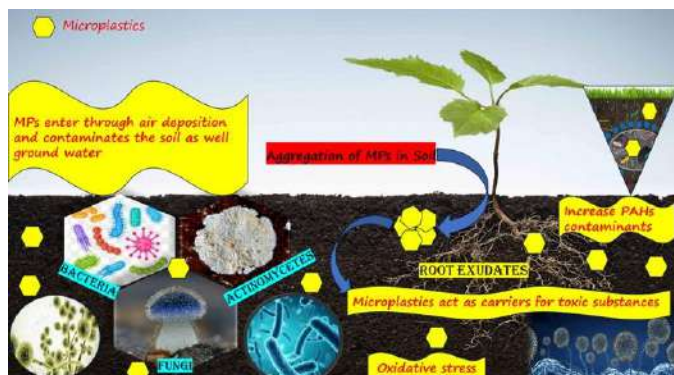


Figure 1: Impact of microplastics on soil and rhizosphere environment

Sample Processing/ Laboratory analysis

Soil Sampling

The top soil (0-30 cm) samples were collected and samples were transferred to the laboratory for analysis.

Extraction of MPs from soil sample: The soil sample were homogenized, sieved and dried at 40°C. 100 g of dried soil sample was washed with 96% ethanol to remove organic matter. After washing the soil, 200 ml of saturated $ZnCl_2$ is added to density separate the MPs particles, stirred for 5 mins and allowed to settle for 24 hrs. Then, the supernatant was filtered. The extraction procedure was repeated 3 times to extract the maximum particles. Finally, the filters were dried at room temperature and stored in a glass petri dish for further analysis (Chen *et al.*, 2019).

Screening or Identification of MPs: Visualization of MPs is achieved through optical microscopy and fluorescence microscopy.

Chemical characterization: The chemical charact-

erization of the polymer was performed using attenuated total reflection-Fourier transform infrared spectroscopy (ATR-FTIR).

Control: To prevent contamination, all solutions and water were vacuum filtered, working surfaces were adequately cleaned with ethanol, and all glassware was triple rinsed with distilled water. The laboratory blank was processed during the whole analysis process for quality control and quality assurance, which indicates the contamination of MPs particles from the containers during the processing or aerial contamination, which is negligible.

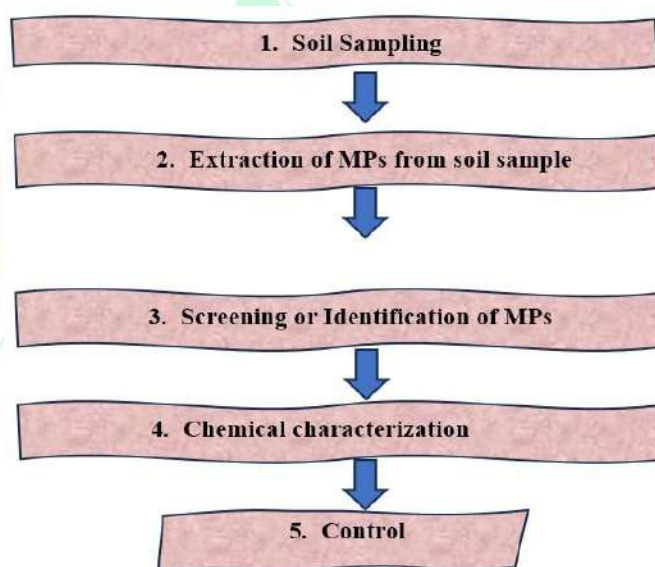


Figure 2: Flow chart of laboratory analysis

Impact of MPs on soil and Plants

- ✓ The MPs may accumulate, persist, affect the biodiversity, and alter the physiochemical and biological properties of soil.
- ✓ MPs can alter the soil structure, water retention capacity and microbial community.
- ✓ Inhibited germination, seedling mortality, reduced plant biomass and pre-mature flowering
- ✓ Reduction in rhizosphere PGPR communities.

- ✓ Cause a reduction in the growth of earthworms
- ✓ Increased oxidative stress
- ✓ Their physicochemical properties, distribution, accumulation, bioavailability and adverse effects play an important role in mitigating MPs contamination.
- ✓ Entry of MPs into the food chain via plant roots and soil organisms.

Microplastic control actions in India

- ✓ The first international research workshop organized by National Oceanic and Atmospheric Administration (NOAA, 2008) on “The occurrence, effects, and fate of microplastic marine debris”.
- ✓ The Plastic Waste Management (Amendment) Rules 2018 introduced Extended Producer Responsibility (EPR) to improve waste management and recycling.
- ✓ According to the Central Pollution Control Board report (2021) about 160000 metric tonnes per day (TPD) of trash are generated in India. Out of which, 95.4% of waste is properly collected, 50 % is treated, 18% undergo landfill and about 32 % remains untreated or unaccounted. From 1990 (0.9 MT) to 2018 (18.45 MT) India's plastic use increased by 20 times (Indian Plastic Industry Report, 2019), and over the past five years, the amount has nearly doubled per person.
- ✓ In 2021, the “Zero Pollution Action Plan” provided further impetus by setting a 30% reduction target for MPs releases by 2030.
- ✓ In 2022, the government banned certain single-

use plastic items, such as plates, cups and polystyrene.

- ✓ New FSSAI Initiative Aims to Develop Detection Methods and Assess Prevalence of Microplastics in Indian Food. The Food Safety and Standards Authority of India (FSSAI) launched an innovative project to tackle the growing concern of microplastic contamination in food on August 18, 2024, in New Delhi.

Swachhata Sagar: The Ministry of Earth Sciences has prepared a framework for a clean ocean mission as part of the Swachhata Action Plan.

Conclusion

Considering the harmful impacts of microplastics, it is recommended to develop proper solid waste management. Eco-friendly, efficient and cost-effective waste management of plastics is needed. So, it is always preferred to develop a less expensive and less resource intensive biological method that degrades or naturally recycles them. To the best of our knowledge, the feasibility of applying different types of species for bioremediation purposes (e.g., biosorption) that have potential for MPs retention is not yet explored. The ‘microplastic cycle’ is occurring in the environment, indicating the movement and exchange of MPs between the different environments. There are many pathways through which MPs travel between the environmental compartments, including atmospheric, aquatic, terrestrial, and human systems. As it is evident that the MPs are highly prevalent, it is important to scientifically study the toxic impacts that MPs exert on the eco-

system.

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Beyond Boundaries: How GIS helps in Studying the Watersheds

Sugavaneshwaran K. and Abithaa P.

Introduction

In planning, analysing, and implementing watershed management strategies by integrating spatial and non-spatial data, Geographic Information Systems play a transformative role in the management of water resources in an environmentally conserving manner. This paper explores the scientific applications of GIS in watershed management; its utility is highlighted both in hydrological modelling and in soil conservation and assessing water quality.

Understanding Watersheds and their Management: A watershed, sometimes referred to as a drainage basin, is an area of land that precipitation collects and drains into a common outlet, like a river, lake, or ocean. Watershed management involves optimizing the use of land and water resources with minimum environmental impacts. It deals with runoff control, reducing soil erosion, agricultural practices management and water resources conservation.

Role of GIS in Watershed Management

GIS acts as an indispensable tool in watershed management through the provision of:

Data Integration and Visualization: GIS integrates diverse datasets, which include satellite imagery, topographic maps and field observations, to enable the comprehensive visualization of watershed characteristics.

characteristics.

Spatial Analysis: It allows for the identification of critical zones of soil erosion, water logging, or pollution, enabling interventions at these specific locations.

Modelling and Simulation: Hydrological models like the Soil and Water Assessment Tool (SWAT) can be integrated with GIS to simulate water flow, sediment transport, and nutrient cycling within a watershed.

Decision Support Systems: GIS-based decision support systems assist policymakers in evaluating different management scenarios and choosing the best options.

Methods	Utility
Watershed Delineation	Defines the boundaries of a watershed and its drainage network. Using the tools Digital Elevation Models (DEMs) and hydrological analysis tools in GIS software (e.g., ArcGIS, QGIS).
Land Use and Land Cover (LULC) Analysis	To Understand the distribution of different land cover types and their impact on watershed dynamics using Satellite imagery (e.g., Landsat, Sentinel-2) and classification algorithms (e.g., supervised or unsupervised classification in GIS).
Soil and Terrain Analysis	Evaluating the soil properties and terrain characteristics to assess their influence on water movement and erosion with the help of Soil maps, DEMs, and GIS analysis tools.
Hydrological Modelling	Simulating the water flow, runoff, and sediment transport within the watershed. Models like SWAT (Soil and Water Assessment Tool) or HEC-HMS are integrated with GIS.
Rainfall-Runoff Modelling	Estimate runoff generation based on rainfall events using SCS-CN (Soil Cons. Service Curve Number) method integrated with GIS.

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Applications of GIS in Watershed Management

Hydrological Modelling: Hydrological modelling is the mainstay of watershed management. GIS supports:

- ✓ Runoff Estimation
- ✓ Flood Risk Assessment
- ✓ Groundwater Recharge Mapping

Soil and Land Use Management: Soil erosion and land degradation are critical issues in watershed management. GIS helps:

- ✓ Erosion Risk Assessment
- ✓ Land Use Planning

Water Quality Monitoring: Water quality monitoring is an essential requirement for maintaining healthy ecosystems and for human consumption. GIS supports:

- ✓ Pollution Source Identification
- ✓ Water Quality Mapping
- ✓ Nutrient Load Analysis

Climate Change Impact Assessment: Climate change is a major driving force for watershed dynamics. GIS helps in:

- ✓ Vulnerability Mapping
- ✓ Scenario Analysis

Benefits and Challenges of Applying GIS in Watershed Management

Benefits	Challenges
Accuracy and Precision	Availability and Quality of Data
Time and Cost Efficiency	Technical Competency
Scenario Planning	High Initial Investments

Prospects for the Future

GIS, coupled with leading-edge technologies such as remote sensing, artificial intelligence, and big data analytics, promises to bring about the next wave in watershed management. Newer applications

that include real-time monitoring, predictive modelling and automatic decision-making systems would lead the way to more resilient and sustainable water resource management.

Conclusion

GIS has revolutionized watershed management by enabling comprehensive analysis, efficient planning, and informed decision-making. Despite certain challenges, its benefits far outweigh the limitations, making it an indispensable tool for sustainable water resource management. As technology advances, GIS applications in watershed management are poised to become even more impactful, addressing complex environmental challenges and ensuring water security for future generations.

Woven with Technology: The Role of Remote Sensing in Sericulture Innovation

Sugavaneshwaran K. and Abithaa P.

Introduction

Sericulture, or the production of silk from the breeding of silkworms (*Bombyx mori*), has existed for thousands of years; in countries such as China, India, and Japan, it has been around for ages. Traditionally, sericulture was determined based on manual monitoring of health, mulberry leaf quality, and environmental conditions; however, with growing demand for higher-quality silk and greater efficiency and sustainability in the production process, sericulture is slowly adapting modern technologies. One of the developments is the application of remote sensing, which monitors and manages various aspects of sericulture through satellite, drone, and ground-based sensors in a more precise and effective manner. The integration of remote sensing in sericulture helps to optimize mulberry crop management, monitor environmental variables affecting silkworms, and mitigate issues related to pest infestation, diseases, and climate change. These technologies can analyse multispectral and hyperspectral data, providing deeper insights into the health of both mulberry plants and silkworms, as well as offering methods to enhance productivity and sustainability. The paper discusses the technical applications of remote sensing technology in sericulture, relating to precision agric-

ulture, monitoring crop condition, silkworm health, and practicing sustainability.

Remote Sensing in Mulberry Crop Management

Mulberry is the primary food for silkworms and determines the productivity and quality of silk. The health and growth of mulberry crops directly influence the health of silkworms, which then affects the yield of silk. In the past, farmers would have to rely on the naked eye and manual sampling to monitor the health of mulberry crops, which is labour-intensive and often not accurate. Remote sensing provides a more efficient way to monitor large-scale mulberry plantations, thus allowing precision agriculture techniques that ensure optimal growth conditions.

Multispectral and Hyperspectral Imagery: These remote sensing techniques can provide insights into the chlorophyll content and overall health of mulberry leaves. Healthy vegetation reflects light in a specific pattern across different wavelengths. Using spectral indices such as the Normalized Difference Vegetation Index (NDVI), which is derived from the ratio of near-infrared and red reflectance, farmers can assess the chlorophyll content in mulberry leaves. High NDVI values indicate healthy vegetation, while lower values signal stress, disease, or nutrient deficiencies.

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Hyperspectral imagery, which captures hundreds of narrow bands of light, provides even more detailed spectral information, allowing for early detection of diseases like powdery mildew or leaf spot based on unique spectral signatures.

Vegetation Indices and Canopy Density: Remote sensing allows the measurement of canopy density and leaf area index (LAI) from a distance. The Leaf Area Index (LAI), a key parameter in plant growth, indicates the amount of leaf material per unit area and provides insights into the productivity and health of mulberry plantations. Using satellite data, drones, and LiDAR technology, farmers can estimate the LAI across large areas and identify regions that may require more attention in terms of irrigation, fertilization, or pest control.

Precision Agriculture and Resource Optimization

The principles of precision agriculture are being adopted in sericulture to optimize input usage and ensure that resources like water, fertilizers, and pesticides are used efficiently. Remote sensing technologies enable farmers to manage their mulberry plantations with higher accuracy, reducing waste and environmental impact.

Soil Moisture and Irrigation Management: The Normalized Difference Water Index (NDWI), derived from remote sensing data, helps monitor soil moisture levels in mulberry plantations. This index, which uses infrared and shortwave infrared bands, can detect water stress in the soil and assess irrigation requirements. In regions where water scarcity is a concern, remote sensing can help farmers adopt effi-

cient irrigation systems, such as drip irrigation or smart irrigation, that deliver water precisely where it is needed, improving crop yield and conserving water.

Nutrient Management: Remote sensing also assists in managing the nutrient status of mulberry crops. Using spectral data, it is possible to detect deficiencies in essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K). By monitoring the absorption and reflectance properties of the leaves, remote sensing systems can identify areas of nutrient stress, which can then be addressed with targeted fertilization. This reduces the overuse of fertilizers, minimizing soil degradation and environmental pollution.

Variable Rate Application (VRA): The data collected through remote sensing can be integrated with Geographic Information System (GIS) technologies to create variable rate prescriptions for applying fertilizers and pesticides. These prescriptions help farmers apply the correct number of inputs based on the specific needs of different areas within the plantation, minimizing excess usage and improving the overall efficiency of the farm.

Monitoring Silkworm Health and Environmental Conditions

Silkworms are sensitive to various environmental variables, including temperature, humidity, and air quality. These factors significantly influence their growth, feeding behaviour, and silk production. Remote sensing technologies offer ways to monitor these parameters in real-time, optimizing the condi-

ons for silkworm rearing.

Thermal Infrared Sensing: Silkworms are sensitive to temperature variations, with optimal rearing conditions falling between 25°C to 28°C. Thermal infrared imagery can be used to monitor the temperature inside silkworm rearing houses. Fluctuations in temperature can cause stress, reduce feed intake, and ultimately decrease silk production. Remote sensing technologies equipped with thermal sensors provide continuous monitoring of temperature, enabling adjustments to be made in ventilation or heating systems to maintain optimal conditions.

Humidity Monitoring and Control: Humidity is another critical factor in silkworm rearing. Excessive moisture can lead to the development of diseases like fungal infections, while low humidity can cause dehydration in silkworms. Remote sensing tools such as hyperspectral sensors can be used to monitor atmospheric conditions within rearing houses and predict areas with suboptimal humidity levels. This data helps farmers adjust environmental controls to maintain favourable conditions for silkworm development.

Behavioural Monitoring through Image Processing: The growth and behaviour of silkworms can be monitored using high-resolution imagery captured by drones or stationary cameras. Using image processing techniques and computer vision algorithms, researchers and farmers can track the feeding habits, movement, and development of silkworms. This data provides valuable insights into

silkworm health and welfare, helping to identify issues like overcrowding, malnutrition, or disease early.

Early Detection of Pest Infestations and Diseases

Pest and disease management is a critical aspect of sericulture, as infestations can devastate mulberry crops and silkworm populations. Remote sensing can play a pivotal role in the early detection of pests and diseases, reducing the need for extensive pesticide use and minimizing crop losses.

Spectral Signatures of Pests and Diseases: Remote sensing technologies can detect changes in plant reflectance caused by pest damage or diseases. For example, the presence of leaf-eating pests or the spread of fungal infections can alter the spectral reflectance of mulberry leaves. By using high-resolution multispectral or hyperspectral sensors, these changes can be identified early, often before visual symptoms are noticeable. For example, the infestation of root-knot nematodes or damage caused by leafhoppers can be detected through subtle shifts in the spectral signatures of the affected leaves.

Aerial Surveillance and Pest Mapping: Drones equipped with multispectral and thermal cameras can be used to monitor mulberry plantations and identify areas affected by pests or diseases. Using georeferenced data, farmers can create pest maps, which help them focus control efforts on specific areas rather than applying pesticides indiscriminately across the entire plantation. This leads to reduced pesticide use, lower production costs, and a healthier ecosystem.

Climate Change Adaptation and Sustainability

Climate change poses significant challenges to sericulture, particularly in regions where temperature and precipitation patterns are becoming more erratic. Remote sensing technologies offer critical tools for adapting to these changes and ensuring the long-term sustainability of sericulture.

Monitoring Climate Variables: Remote sensing satellites can track long-term changes in key climate variables such as temperature, precipitation, and humidity. By analyzing this data, farmers can predict potential risks to their mulberry crops and silkworms, such as heat stress or drought. Early warnings allow for better preparation, including adjusting irrigation systems, modifying rearing house environments, or selecting more resilient mulberry varieties.

Sustainable Land Use and Forest Management:

The sustainable management of mulberry plantations and surrounding ecosystems is essential for maintaining the long-term viability of sericulture. Remote sensing can be used to monitor deforestation, land degradation, and soil erosion, helping to implement sustainable land management practices. Additionally, using satellite data to monitor carbon sequestration in mulberry forests can help farmers earn carbon credits, making sericulture a more environmentally friendly and economically viable practice.

Conclusion

Remote sensing technologies are transforming sericulture by improving the management of

mulberry crops, monitoring silkworm health, and optimizing environmental conditions for silk production. Through the use of multispectral, hyperspectral, and thermal sensors, sericulture practitioners can make more informed decisions, resulting in improved productivity, reduced environmental impact, and enhanced sustainability. As the industry continues to embrace these advanced technologies, the future of sericulture looks promising, with higher quality silk production and greater resilience to environmental challenges.

Robotic Automation and AI in Agronomy

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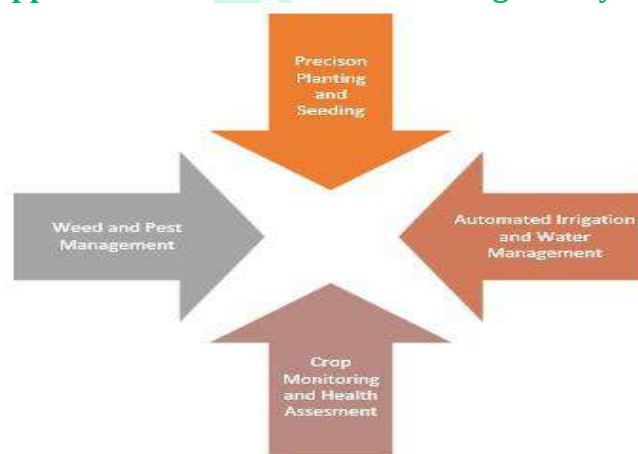
Abstract

Robotic automation and artificial intelligence (AI) are transforming agronomy by enhancing precision, efficiency, and sustainability in agricultural practices. These technologies enable tasks such as planting, monitoring, irrigation, and harvesting to be performed with unparalleled accuracy and minimal human intervention. AI-powered systems analyze vast datasets, offering insights into soil health, crop conditions, and pest management, while robotic machinery executes labor-intensive operations with speed and consistency. This synergy reduces resource consumption, mitigates environmental impacts, and addresses labor shortages, paving the way for a more resilient agricultural future.

Introduction

The integration of robotic automation and artificial intelligence (AI) in agronomy is revolutionizing modern agriculture. These technologies offer innovative solutions to traditional challenges such as labor shortages, inefficiencies, and the growing demand for sustainable practices. By automating repetitive tasks and leveraging data-driven insights, robotics and AI enhance productivity, optimize resource use, and ensure precision in agricultural operations. This article delves into the applications, benefits, and challenges associated with robotic automation and AI in agronomy.

Applications of Robotics and AI in Agronomy



Precision Planting and Seeding: Robotic systems equipped with GPS and AI algorithms ensure accurate seed placement and optimal spacing. This precision minimizes seed wastage and maximizes

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crop yield potential (Shamshiri *et al.*, 2018).

Automated Irrigation and Water Management:

AI-powered irrigation systems monitor soil moisture and weather conditions to deliver the right amount of water at the right time. Robotic irrigation units further enhance efficiency by targeting specific areas, reducing water wastage (Khanal *et al.*, 2020).

Crop Monitoring and Health Assessment: Drones and ground robots equipped with sensors and AI analyze crop health in real-time. These systems detect nutrient deficiencies, pest infestations, and diseases early, allowing for timely interventions (Sharma *et al.*, 2022).

Weed and Pest Management: AI-driven robots identify and remove weeds or apply targeted herbicides, reducing the use of chemicals. Similarly, robotic pest control systems deploy biological agents or precision pesticides to manage infestations (Slaughter *et al.*, 2008).

Harvesting and Post-Harvest Automation: Robots equipped with machine vision and AI algorithms perform harvesting tasks with precision, reducing crop damage. Post-harvest robots sort, grade, and package produce efficiently, ensuring quality and consistency (Bac *et al.*, 2014).

Benefits of Robotic Automation and AI in Agronomy

Increased Efficiency and Productivity: Automating labor-intensive tasks reduces human error and accelerates operations, enabling farmers to manage larger fields with fewer resources (Shamshiri *et al.*, 2018).

Resource Optimization: AI systems analyze data to optimize the use of inputs such as water, fertilizers, and pesticides, minimizing waste and environmental impact (Khanal *et al.*, 2020).

Enhanced Decision-Making: Data-driven insights provided by AI enhance decision-making in crop management, soil health, and pest control, leading to better outcomes (Sharma *et al.*, 2022).

Labor Shortage Mitigation: Robotic systems address labor shortages by performing tasks traditionally reliant on manual labor, ensuring continuity in agricultural operations (Bac *et al.*, 2014).

Challenges in Implementing Robotics and AI in Agronomy

High Initial Investment: The cost of acquiring and maintaining advanced robotic and AI systems can be prohibitive for small and medium-scale farmers (Shamshiri *et al.*, 2018).

Technical Expertise: Successful implementation requires technical knowledge and training, which can be a barrier in regions with limited access to education and resources (Khanal *et al.*, 2020).

Data Privacy and Security: The extensive use of data in AI systems raises concerns about privacy and security, necessitating robust regulations and safeguards (Sharma *et al.*, 2022).

Dependence on Infrastructure: Robotic and AI systems require reliable internet connectivity and power supply, which may not be available in remote agricultural regions (Slaughter *et al.*, 2008).

Future Prospects

Integration with IoT and Big Data: The combination of AI, robotics, and Internet of Things (IoT) devices will enable real-time monitoring and seamless communication between systems, further enhancing precision and efficiency.

Sustainable Agriculture: By optimizing resource use and reducing waste, robotic automation and AI contribute to sustainable agricultural practices that address climate change and resource scarcity.

Accessibility and Scalability: Ongoing advancements in technology are expected to reduce costs and improve accessibility, enabling broader adoption across diverse agricultural landscapes.

Conclusion

Robotic automation and AI are transforming agronomy by enhancing efficiency, precision, and sustainability. While challenges such as high costs and technical expertise remain, the benefits far outweigh the barriers. As technology continues to evolve, these innovations will play a pivotal role in shaping the future of agriculture, ensuring global food security and environmental sustainability.

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Understanding Soil Properties and How they Interact with Growing Crop

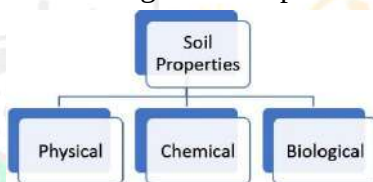
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Abstract

Soil serves as the foundation for agricultural productivity, influencing crop growth through its physical, chemical, and biological properties. This article explores the intricate relationship between soil characteristics and plant development, providing insights into how soil texture, structure, water-holding capacity, nutrient availability, pH, and microbial activity interact with crop physiology. Key processes such as nutrient cycling, root-soil interactions, and moisture retention are examined to highlight their role in crop yield and resilience. Emphasis is placed on sustainable management practices that enhance soil health, optimize resource use, and mitigate environmental impacts. By understanding and harnessing these interactions, farmers and agronomists can develop strategies to improve crop performance and ensure sustainable agricultural systems.

Introduction to Soil Properties

Soil is the cornerstone of agricultural productivity, serving as the medium that supports plant growth by providing essential nutrients, water, and a stable rooting environment. Understanding soil properties is fundamental to optimizing crop performance and ensuring sustainable agricultural practices (Brady, 1984). The interaction between soil characteristics and crops determines plant health, yield, and resilience to environmental stresses.



Physical Properties of Soil

Soil Texture and Its Impact on Root Growth: Soil texture, defined by the proportion of sand, silt, and clay, plays a critical role in determining soil behavior. Sandy soils, with larger particles, allow for easy root penetration but have poor water retention. In contrast, clayey soils retain water but may impede root growth due to compaction (White, 2005).

Soil Structure and Aeration: The arrangement of soil particles into aggregates, known as soil structure, influences aeration and water movement. Well-structured soils promote healthy root respiration and

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water infiltration, essential for crop growth (Brady, 1984).

Water-Holding Capacity and Drainage: The ability of soil to retain and supply water to plants is vital. Loamy soils, a balanced mix of sand, silt, and clay, offer optimal water-holding capacity and drainage, supporting consistent plant growth (Marschner, 2011).

Chemical Properties of Soil

Soil pH and Nutrient Availability: Soil pH affects the availability of nutrients to plants. Most crops thrive in a pH range of 6.0 to 7.5. Extreme pH levels can lead to nutrient deficiencies or toxicities, impacting crop health (White, 2021).

Essential Nutrients and their Roles in Crop Growth: Macro- and micronutrients, such as nitrogen (N), phosphorus (P), potassium (K), and iron (Fe), are crucial for plant development. Each nutrient has specific roles, from photosynthesis to cell division, that directly influence crop productivity (Marschner, 2011).

Salinity and Its Effects on Crops: High soil salinity can hinder water uptake by plants, leading to physiological drought. Managing salinity through irrigation techniques and salt-tolerant crop varieties is essential in affected regions (FAO, 2021).

Biological Properties of Soil

Soil Microbiome and Its Role in Plant Health: The diverse community of microorganisms in the soil contributes to nutrient cycling, organic matter decomposition, and disease suppression. Beneficial microbes, such as rhizobia, enhance nitrogen fixat-

ion, while mycorrhizal fungi improve phosphorus uptake (Brady, 1984).

Organic Matter and Nutrient Cycling: Organic matter is a reservoir of nutrients and improves soil structure, water retention, and microbial activity. Decomposing organic matter releases nutrients in forms accessible to plants (Marschner, 2011).

Symbiotic Relationships: Mycorrhizae and Nitrogen-Fixing Bacteria: Symbiotic relationships between plants and soil organisms, such as mycorrhizae and nitrogen-fixing bacteria, enhance nutrient acquisition and overall plant health (White, 2005).

Soil-Water-Plant Interactions

Water Uptake and Its Impact on Plant Physiology: Water is essential for photosynthesis, nutrient transport, and cell turgidity. Soil properties influence water availability and uptake, directly affecting crop growth (Marschner, 2011).

Moisture Stress and Crop Productivity: Insufficient or excess soil moisture can cause stress in plants, reducing growth and yield. Understanding soil-water interactions helps mitigate these challenges through effective irrigation management (FAO, 2021).

Soil Fertility and Crop Performance

Soil Testing and Fertility Assessment: Regular soil testing provides insights into nutrient levels and deficiencies, guiding fertilizer application to maintain soil fertility (Lal, 2020).

Role of Fertilizers and Amendments: Fertilizers replenish essential nutrients, while soil amendments, such as lime or gypsum, correct pH imbalances and

improve soil structure (White, 2005).

Balancing Nutrient Inputs and Outputs: Sustainable nutrient management involves balancing inputs (fertilizers, organic matter) with outputs (crop uptake, leaching) to prevent soil degradation (Brady, 1984).

Impact of Soil Degradation on Crops

Erosion, Compaction, and Organic Matter Loss: Soil degradation, caused by erosion, compaction, and organic matter depletion, reduces fertility and productivity. Practices such as contour farming and organic amendments can mitigate these effects (Lal, 2020).

Strategies to Mitigate Soil Degradation: Adopting conservation tillage, cover cropping, and crop rotation helps restore soil health and sustain agricultural systems (FAO, 2021).

Sustainable Soil Management Practices

Conservation Tillage and Cover Cropping: Minimal tillage preserves soil structure and reduces erosion. Cover crops protect soil from erosion, enhance organic matter, and suppress weeds (Brady, 1984).

Crop Rotation and Diversification: Rotating crops and diversifying planting systems reduce pest pressures, improve nutrient cycling, and enhance soil fertility (White, 2005).

Integrated Nutrient Management: Combining organic and inorganic fertilizers optimizes nutrient use efficiency, minimizes environmental impact, and sustains soil health (Marschner, 2011).

Technological Advancements in Understanding

Soil-Crop Interactions

Precision Agriculture and Soil Mapping: Precision agriculture technologies, such as GPS-guided equipment and soil sensors, provide data for tailored soil and crop management (Lal, 2020).

Remote Sensing and Soil Monitoring Tools: Remote sensing tools monitor soil moisture, nutrient levels, and crop health, enabling informed decision-making for improved productivity (FAO, 2021).

Conclusion and Future Directions

Understanding soil properties and their interaction with growing crops is fundamental to achieving sustainable agricultural productivity. Future advancements in soil science and technology will further enhance our ability to manage soil resources effectively, ensuring global food security and environmental sustainability.

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Rooftop Floriculture: Creating a Lush Floral Oasis in Small Spaces

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Introduction to Rooftop Floriculture

Urban areas around the world are increasingly becoming more congested, with limited availability of green spaces. Rooftops, once merely functional, are now being reimagined as areas for recreation, relaxation, and gardening. Rooftop floriculture growing flowers and ornamental plants on building rooftops offers a practical solution to this urban green space crisis. It involves cultivating flowers, shrubs, and even small trees in containers or raised beds on rooftops. This gardening practice not only helps beautify the urban landscape but also provides several environmental, social, and economic benefits. In cities where parks and gardens are scarce, rooftop floriculture can significantly contribute to the urban ecosystem by improving air quality, providing habitats for pollinators, and mitigating the heat island effect. Additionally, rooftop gardens offer private, tranquil retreats that allow individuals to reconnect with nature.

Benefits of Rooftop Floriculture: Rooftop floriculture brings numerous benefits, both tangible and intangible. These benefits go beyond the aesthetic appeal and can have a profound impact on the environment and well-being of individuals living in urban areas.

Environmental Benefits

Reduction in Urban Heat Island Effect: Cities

often experience higher temperatures than surrounding rural areas due to the concentration of buildings and limited greenery. This is called the urban heat island effect. Rooftop gardens, with their plants and greenery, can help cool down the surrounding environment by absorbing heat and providing shade. Green roofs can reduce the need for air conditioning, thereby saving energy and reducing carbon footprints.

Air Quality Improvement: Plants naturally absorb carbon dioxide and release oxygen. Rooftop gardens help purify the air by filtering pollutants and dust, improving air quality in densely populated areas. Certain plants, such as flowering shrubs and trees, are particularly effective at trapping airborne pollutants.

Stormwater Management: Rooftop gardens also contribute to stormwater management by absorbing rainwater, reducing runoff, and preventing water from overwhelming city drainage systems. Green roofs retain and slow down the flow of rainwater, which helps prevent flooding and erosion.

Biodiversity Conservation: Urban areas often lack natural habitats for wildlife. Rooftop floriculture can provide crucial habitats for pollinators like bees, butterflies, and birds. By introducing a diverse range of plants on rooftops, gardeners can create microhabitats that support these important species.

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Economic Benefits

Energy Cost Reduction: Rooftop gardens can significantly reduce the need for heating and cooling in buildings. During the summer, they cool down the building and reduce the need for air conditioning, and in the winter, they provide insulation, which reduces heating costs.

Increased Property Value: Well-designed rooftop gardens can enhance the aesthetic appeal of a building, making it more attractive to potential buyers or renters. The addition of a lush floral oasis can increase the resale value or rental price of a property.

Local Food Production: In addition to growing flowers, rooftop gardens can be used to grow fruits and vegetables, creating a small urban farm. This local food production reduces transportation costs, encourages self-sufficiency, and supports the growing trend of urban farming.

Psychological and Social Benefits

Mental Health Improvement: Studies have shown that exposure to nature, even in small urban settings, can have a positive impact on mental health. Rooftop gardens provide a peaceful retreat, offering individuals a space to relax, unwind, and connect with nature amidst the hustle and bustle of city life.

Community Engagement: Rooftop floriculture can foster community spirit, particularly in shared or communal rooftop gardens. Gardening as a group can help build stronger social connections among residents and create a sense of pride in maintaining a shared space.

Recreational Space: A well-designed rooftop garden serves as a recreational space where individuals can entertain guests, hold events, or simply enjoy personal downtime. The addition of a floral oasis makes these spaces not only functional but also aesthetically pleasing and enjoyable.

Planning Your Rooftop Floriculture Garden

Before embarking on the journey of rooftop floriculture, careful planning is essential to ensure that your garden is both beautiful and functional. Proper planning involves evaluating the space, considering the structural integrity of the roof, selecting appropriate plants, and creating a suitable design.

Assessing the Roof Structure: The first step in creating a rooftop garden is to assess the structural integrity of your roof. Not all roofs are suitable for gardening, and the weight of plants, containers, and soil can put significant pressure on the roof's structure. It's important to consult with a structural engineer or roofing professional to ensure that your roof can bear the weight of your garden. Additionally, consider factors such as drainage, sunlight, and wind exposure, as these elements will significantly impact the success of your garden.

Choosing the Right Containers: Since most rooftop gardens rely on containers or raised beds, selecting the right type of container is critical. Containers should be lightweight yet durable, capable of retaining moisture while allowing for good drainage. Popular options include:

✓ **Plastic Containers:** Lightweight and durable,

they are available in various shapes and sizes and are easy to move.

- ✓ **Fabric Pots:** These breathable pots allow for excellent drainage and prevent the roots from becoming root-bound.
- ✓ **Raised Beds:** Wooden or metal raised beds are ideal for larger plantings, offering ample space for flower growth.
- ✓ **Modular Planters:** These interlocking planters allow for flexibility in design and can be rearranged or expanded as needed.

Sunlight and Exposure: The amount of sunlight your rooftop receives will determine the types of plants you can grow. Most flowering plants require at least 6-8 hours of direct sunlight each day. If your rooftop garden faces a shaded area or gets less sunlight, you may need to choose shade-tolerant plants that thrive under lower light conditions. Consider using shading structures or green trellises to create micro-environments for more delicate plants if the rooftop receives too much direct sun.

Wind Protection: Rooftops are often exposed to strong winds, which can dry out plants and even damage them. Installing windbreaks such as tall shrubs, fences, or mesh barriers can provide much-needed protection for your garden. Additionally, grouping plants together can help shield each other from harsh winds.

Irrigation System: Watering is one of the most important aspects of rooftop floriculture. Rooftop gardens are often subject to drying out quickly due to sun exposure and wind. Installing an efficient irriga-

tion system is essential for maintaining plant health. Drip irrigation systems are ideal for rooftop gardens, as they provide targeted watering and conserve water. For smaller spaces, self-watering containers or using a hose with a sprinkler attachment can help ensure that plants are watered consistently.

Selecting Plants for Your Rooftop Floriculture Garden

Selecting the right plants is key to ensuring a successful rooftop garden. It's important to choose plants that are well-suited to the local climate, the amount of sunlight available, and the growing conditions on your rooftop. For rooftop floriculture, the following categories of plants are often ideal:

Annual Flowers: Annuals bloom brightly and are perfect for creating a colorful display on rooftops. Popular annual flowers for rooftop gardens include:

- ✓ **Petunias:** Known for their vibrant colors, petunias thrive in containers and can withstand the heat of summer.
- ✓ **Geraniums:** These hardy flowers are well-suited for rooftop gardens, with a wide range of colors and sizes.
- ✓ **Marigolds:** Marigolds are easy to grow, low-maintenance, and resistant to pests, making them a great choice for beginners.

Perennials: Perennials are flowers that return year after year, making them a sustainable choice for rooftop gardens. Some excellent perennial options include:

- ✓ **Lavender:** Lavender not only adds a fragrant touch to your rooftop but also attracts pollinators

like bees.

- ✓ **Daylilies:** Known for their resilience and long blooming period, daylilies are perfect for rooftop gardens.
- ✓ **Coneflower (Echinacea):** These sturdy plants bloom throughout the summer and attract pollinators, adding both beauty and biodiversity to your rooftop.

Succulents and Cacti: For rooftop floriculture in dry climates, succulents and cacti are excellent choices. These drought-tolerant plants require minimal water and are perfect for low-maintenance gardening.

- ✓ **Aloe Vera:** Aloe Vera is a hardy succulent that thrives in sunny conditions and can be used in a variety of garden designs.
- ✓ **Sedum:** Known for its ability to thrive in poor soil conditions, sedum is a popular choice for green roofs and rooftop floriculture.

Vines and Climbers: Climbing plants are perfect for adding vertical interest to your rooftop garden. These plants can be grown on trellises, fences, or other structures, providing a lush and green cover.

- ✓ **Clematis:** Known for its vibrant blooms, clematis is an excellent climber for rooftop gardens. It can be trained up trellises or fences, creating a cascading floral display.
- ✓ **Morning Glory:** These fast-growing vines are perfect for adding color and height to your rooftop garden, with vibrant blooms that open early in the day.
- ✓ **Sweet Peas:** Sweet peas are not only beautiful

but also fragrant, making them ideal for creating an aromatic, vertical floral display on your rooftop.

Herbs and Edible Flowers: Incorporating herbs and edible flowers into your rooftop garden can add both beauty and practicality. Edible flowers, such as pansies, nasturtiums, and marigolds, can be used in culinary applications, while herbs like basil, mint, and rosemary can be harvested for cooking.

- ✓ **Nasturtiums:** With their peppery flavor, nasturtiums are both edible and ornamental, making them an excellent addition to rooftop gardens.
- ✓ **Basil:** Basil is perfect for sunny rooftop gardens. It's easy to grow and can be used fresh in a variety of dishes.
- ✓ **Chives:** Chives add both a mild onion flavor and delicate purple flowers, making them a great choice for rooftop gardens that combine beauty and utility.

Designing Your Rooftop Floriculture Garden

The design of your rooftop garden will determine how effectively it functions as a floral oasis. Good design involves considering the layout, colors, textures, and focal points, as well as accessibility and practicality. Here are some tips to help you create a cohesive and beautiful rooftop garden:

Layout and Zoning: The first step in designing your rooftop garden is planning the layout. Think about the space as a whole and consider creating different zones or areas within your garden. You may want to

designate specific areas for flowers, herbs, and relaxation.

- ✓ **Central Focal Point:** Consider placing a focal point in the center of your rooftop garden, such as a decorative sculpture, a small water feature, or a statement plant like a large tree or flowering shrub.
- ✓ **Raised Beds:** Raised beds are great for creating a tiered effect, which allows for better visibility and accessibility. They also provide excellent drainage, which is crucial for rooftop gardening.
- ✓ **Container Grouping:** Grouping similar plants in containers can help create a harmonious look. Mix tall, medium, and low plants to create visual interest and layers.

Addressing Leakage Problems: Leakage is a common concern when creating a rooftop garden, as excess water can seep through and damage the building structure. To avoid this, it is essential to use proper waterproofing methods:

- ✓ **Waterproof Membranes:** Install a high-quality waterproof membrane across the rooftop before adding soil or containers.
- ✓ **Drainage Systems:** Ensure the garden has an effective drainage system to prevent water pooling. Use lightweight, well-draining soil mixtures and incorporate drainage layers like gravel or geotextiles.
- ✓ **Regular Inspections:** Periodically inspect the rooftop for any signs of water leakage or cracks in the waterproofing layer. Address issues promptly to maintain the structural integrity of

the building.

Color and Texture: When selecting plants for your rooftop garden, consider the color palette and texture of the foliage and flowers. A well-planned color scheme can create a soothing or dramatic atmosphere.

- ✓ **Vibrant Blooms:** If you prefer a vibrant, lively garden, choose plants with bright, bold colors like red, orange, and yellow.
- ✓ **Soothing Tones:** For a more tranquil atmosphere, select pastel-colored flowers or plants with white, pink, or purple blooms.
- ✓ **Texture Contrast:** Mix plants with different textures, such as the soft, smooth leaves of succulents alongside the rougher foliage of lavender or sage. This adds depth and visual intrigue to your garden.

Accessibility and Comfort: Since your rooftop garden will likely be a place for relaxation and enjoyment, it's important to make it comfortable and accessible. Consider adding comfortable seating like outdoor chairs, benches, or lounge chairs. Creating shaded areas using umbrellas or pergolas will allow you to enjoy the space during warmer months. If possible, include walkways made of permeable materials like gravel, stone, or decking to allow easy movement around the garden. Ensure that the pathways are wide enough to accommodate watering cans or a hose, and that they are sturdy enough to support your gardening activities.

Maintenance of Rooftop Floriculture Gardens

Maintaining a rooftop garden requires a bit

more effort than traditional gardening due to the challenging conditions of sun exposure, wind, and limited soil volume. Here are some maintenance tips to help your rooftop floriculture garden thrive:

Watering: Watering is critical in rooftop gardens, especially since the heat and wind tend to dry out plants quickly. Make sure that your irrigation system, whether it's a drip irrigation system, soaker hoses, or self-watering containers, is working properly.

✓ **Watering Frequency:** Plants in containers typically need more frequent watering than those in the ground. Check the moisture levels in your containers regularly, especially during the hotter months.

✓ **Mulching:** Apply a layer of organic mulch to your plants to help retain moisture and regulate soil temperature. Mulching also reduces water evaporation, which is particularly important in a rooftop garden where water retention can be a challenge.

Fertilization: Plants in containers tend to exhaust the nutrients in the soil more quickly than those in the ground. To keep your flowers healthy and vibrant, fertilize them regularly. Use a balanced, slow-release fertilizer to ensure your plants receive the nutrients they need throughout the growing season. For organic gardeners, compost and organic fertilizers such as fish emulsion or worm castings can provide an eco-friendly nutrient boost.

Pruning and Deadheading: Regular pruning and deadheading are essential for keeping your rooftop garden looking tidy and encouraging continued

blooming. Remove dead or damaged flowers, stems, and leaves to prevent disease and promote new growth. Prune back plants that are growing too tall or spreading too much to maintain a well-maintained and balanced look.

✓ **Deadheading:** Removing spent flowers will encourage many plants to produce more blooms, extending the flowering season.

✓ **Pruning:** Trim back any overgrown vines or shrubs to ensure they don't become unruly or damage other plants.

Pest and Disease Control: While rooftop gardens can offer some protection from pests (due to their elevated nature), they are still susceptible to common garden pests such as aphids, spider mites, and whiteflies. Regularly inspect your plants for signs of pests or disease.

✓ **Natural Pest Control:** Encourage beneficial insects like ladybugs, predatory mites, and bees to inhabit your rooftop garden. These insects can help control pest populations naturally.

✓ **Organic Treatments:** If you encounter pest issues, consider using organic treatments such as neem oil or insecticidal soap to combat infestations without harming the environment.

Conclusion

Rooftop floriculture is an exciting and creative way to bring the beauty of nature into urban environments, making the most of small, unused spaces. By carefully selecting plants, planning the layout, and ensuring proper maintenance, you can transform your rooftop into a lush floral oasis that

adds beauty, sustainability, and personal enjoyment to your living space. Whether you're looking to reduce your carbon footprint, enhance your property's value, or simply create a serene retreat in the city, rooftop floriculture offers an abundance of possibilities. With the right tools, knowledge, and a bit of creativity, you can cultivate a rooftop garden that flourishes year-round, providing a peaceful escape and a sense of connection to nature even in the heart of the city.

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Beyond the Bouquet: Exploring the Healing Power of Flowers through Aromatherapy

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Abstract

Flowers have been cherished for their beauty and fragrance for centuries, but their therapeutic potential often remains overlooked. This article delves into the healing power of flowers through the lens of aromatherapy, a holistic practice utilizing natural plant extracts to promote physical and emotional well-being. By exploring the history, scientific principles, and diverse applications of floral aromatherapy, we highlight how specific flower essences contribute to stress reduction, improved sleep, and enhanced mood. This comprehensive exploration emphasizes the integration of flower-based aromatherapy into daily routines, offering insights into its benefits and guiding readers toward informed usage. With a focus on evidence-based practices and practical implementation, this article underscores the profound impact of flowers beyond their ornamental value.

Introduction

Flowers have always held a special place in human culture, celebrated for their aesthetic and symbolic significance. Beyond their ornamental allure, flowers have also been revered for their therapeutic properties. Aromatherapy, a holistic healing method that uses natural plant extracts, prominently features flower essences to enhance physical and emotional health. This article investigates the transformative potential of flowers in aromatherapy, their scientific underpinnings, and practical applications for modern wellness.

Historical Perspective on Aromatherapy

The use of flowers in healing dates back to ancient civilizations. Egyptians employed floral oils in their embalming practices and spiritual rituals, while the Greeks utilized rose and lavender extracts for therapeutic purposes. Indian Ayurveda and Traditional Chinese Medicine have long integrated floral remedies for emotional balance and physical ailments. The rediscovery of aromatherapy in the 20th century by René-Maurice Gattefossé reaffirmed the profound healing properties of floral essences.

Scientific Basis of Aromatherapy

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Aromatherapy works through the olfactory system, which directly connects the sense of smell to the brain's limbic system. This system governs emotions, memories, and stress responses. Volatile compounds in floral essential oils, such as linalool (lavender) and geraniol (rose), interact with receptors to produce calming or uplifting effects. Scientific studies have shown that inhalation of floral scents can lower cortisol levels, regulate heart rate, and improve overall mood.

Healing Properties of Popular Flowers in Aromatherapy

Lavender (*Lavandula angustifolia*): Known for its calming effects, lavender essential oil is widely used to alleviate anxiety, improve sleep, and reduce headaches.

Rose (*Rosa damascena*): The “queen of flowers,” rose oil is celebrated for its antidepressant and aphrodisiac properties, often used to uplift mood and foster emotional healing.

Chamomile (*Matricaria chamomilla*): Chamomile oil, extracted from daisy-like flowers, is effective in reducing stress, easing muscle tension, and promoting restful sleep.

Jasmine (*Jasminum grandiflorum*): Jasmine's exotic fragrance has stimulating and confidence-boosting properties, making it ideal for combating fatigue and apathy.

Ylang-Ylang (*Cananga odorata*): With its sweet floral aroma, ylang-ylang oil is renowned for its ability to reduce blood pressure and evoke a sense of tranquility.

Therapeutic Effects of Floral Aromatherapy

Stress and Anxiety Reduction: Aromatherapy using floral scents such as lavender and jasmine has been shown to lower stress hormones like cortisol, promoting a sense of calm. These oils can be diffused at home or applied topically with carrier oils during massages to relieve anxiety and tension.

Sleep Enhancement: Sleep disorders are increasingly common, and floral oils like chamomile and lavender are widely used to combat insomnia. Diffusers and pillow sprays infused with these essences create a calming bedtime environment.

Emotional Well-being: Essential oils like rose and ylang-ylang uplift mood and combat depressive symptoms by stimulating serotonin and dopamine production. Regular use helps stabilize emotions and enhance positivity.

Pain Relief and Muscle Relaxation: Chamomile and lavender are often used in massage therapy to alleviate muscle pain, joint discomfort, and headaches. Their anti-inflammatory properties make them effective in reducing swelling and tension.

Skin and Hair Care: Flower oils, such as rose and jasmine, are popular ingredients in skincare routines due to their moisturizing, anti-aging, and anti-microbial benefits. They are often used in creams, serums, and bath oils.

Applications of Floral Aromatherapy

Stress Reduction: Incorporating floral scents into daily routines, such as through diffusers or massage oils, can significantly lower stress levels.

Improved Sleep Quality: Essential oils like lavender

er and chamomile are commonly used in sleep sprays, bath salts, and bedtime rituals to promote relaxation.

Emotional Balance: Floral scents have a profound impact on emotions, helping individuals navigate grief, depression, or anxiety.

Skin Care: Many floral oils possess antimicrobial and anti-inflammatory properties, making them ideal for skincare routines.

Enhanced Focus and Productivity: Jasmine and rosemary oils are known for their ability to enhance concentration and cognitive performance.

Challenges and Considerations

While floral aromatherapy offers numerous benefits, it is crucial to use essential oils responsibly. Misuse, such as applying undiluted oils directly to the skin, can cause irritation or allergic reactions. Pregnant individuals, children, and those with specific health conditions should consult professionals before use.

Emerging Trends in Floral Aromatherapy

Advances in extraction techniques and growing consumer interest in natural remedies have spurred innovation in aromatherapy. Researchers are now exploring the potential of lesser-known flowers and sustainable cultivation practices to meet rising demand.

Conclusion

Flowers are far more than nature's ornaments; they are powerful allies in promoting holistic well-being. Through aromatherapy, their essence transcends aesthetics, offering profound physical and

emotional benefits. By understanding the science and practical applications of floral aromatherapy, individuals can unlock a deeper connection with nature and enhance their quality of life. Embracing these practices responsibly and knowledgeably allows us to harness the healing power of flowers to their fullest potential.

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Success Story of Hybrids (Pusa HQPM 5 Improved) in Hazaribag District of Jharkhand

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Introduction

Maize (*Zea mays* L.) is the most versatile food crop being grown on 194 mha area in more than 166 countries across the globe, including tropical, subtropical and temperate regions, from sea level to 3000 m above mean sea level. It is cultivated in nearly 205 m ha with a production of 1210 m tonnes and productivity of 5878 kg ha⁻¹ all over the world, having wider diversity of soil, climate, biodiversity and management practices. India produced 33.62 million tonnes in an area of 10.04 million hectares in 2021-22, whereas in *kharif* 2022-23, maize production was 23.10 million tonnes (1st advance estimates) in an area of 9.68 million hectares. Maize is one of the most important cereal crops of the world and contributes to food security in most of the developing countries. In India, maize is emerging as third most important crop after rice and wheat. Its importance lies in the fact that it is not only used for human food and animal feed but at the same time it is also widely used for corn starch industry, corn oil production, baby corns *etc.* Production of maize in India has increased at a CAGR (Compound Annual Growth Rate) of 5.5 per cent from 14 Mn MT in 2004-05 to 23 Mn MT in 2013-14. However, productivity of

maize in Jharkhand (2.02 t ha⁻¹) are below the national average of 2.6 t ha⁻¹.

Maize is the second most important crop in Jharkhand next to rice and is mostly grown under rainfed hilly upland conditions during *kharif* season. The region has enough potential to raise the productivity of maize by adopting the high yielding hybrid varieties and scientific way of cultivation technologies. The overall positive trend has been observed in this crop in the state. The area under crop increased from 211.11 thousand hectare (2006-07) to 249.33 thousand hectares (2012-13), which increased further to 294 thousand hectares in 2017-18. The productivity analysis has shown a significant growth in the state from 1384 to 2025 Kg ha⁻¹ during 1999-2000 to 2017-18. However, the productivity of maize in the state is below the national average due to non-availability of quality seeds as well as seeds of improved hybrid varieties on time. Mostly the farmers are either using the hybrid seeds of the local private companies or growing the land races.

Jharkhand as the 14th most populous state in India is home to 33 million people, out of which 13 million people are poor. More than 70 per cent of people in this state live in rural areas, and around 37

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per cent of the state's population are classified as living below the poverty line (BPL). There is a general agreement that the health status of the tribal population (26.3%) in Jharkhand is very poor and deficient in fulfilling their adequate nutritional requirement. Many underprivileged remote areas of Jharkhand are more at risk of severe under-nourishment especially among the children and women. Tribal population of Jharkhand constitutes around 26.3% of the total population. Thus, a sizable tribal population exist which is economically deprived. Many steps have resulted in ensuring the food security in the state. However, food security also considers quality aspects to ensure adequate nutrition and a healthy diet to protect people from diseases. The challenge, therefore, is to deliver nutritious, safe and affordable food to reduce the impact of nutritional-insecurity. Since, a significant portion of dietary requirement for energy is being met from maize in these rural and tribal areas and mostly traditional cultivars are consumed in these regions. The quality of protein and level of vitamin A found in normal maize is not sufficient enough to meet the daily diet requirement of the human body or other mono-gastric animals. Biofortified maize with enhanced lysine, tryptophan and pro-vitamin A possesses enormous potential to alleviate malnutrition. The composition of maize protein has an in-built drawback of being deficient in two essential amino acids, viz., lysine and tryptophan. These two amino acids (lysine and tryptophan) are not synthesized by our body. The level of vitamin A

found in normal maize is also not sufficient enough to meet the daily diet requirement of the human body. Therefore, populations depending on maize as their staple food generally show the protein deficiency disorders like Marasmus and Kwashiorkor. Keeping in view, Quality protein maize (QPM) have been developed by incorporating opaque-2 mutant gene + modifiers in different parental lines. QPM looks and taste like normal maize, but it contains nearly twice the quality of lysine and tryptophan along with balanced amino acid profile.

Maize cultivars with improved protein quality and pro-vitamin A have been developed whose dissemination and promoting the farmers to adopt these biofortified varieties may lead to alleviation of hidden hunger by improving the diets and health. Adoption of these multi-nutrient rich maize would help in achieving nutritional security in a more holistic way. It will also help in training the rural youths regarding the hybrid seed production technology and other entrepreneurship skills. The promotion of the high yielding biofortified maize hybrids in Jharkhand will not only help in achieving sustainable nutritional security but will also improve their standard of living due to income from the surplus production as well as less expenditure on health issues. This project will also help in the creation of entrepreneurship among the rural youths leading to creation of job opportunity among them through the trainings on hybrid seed production and value addition. Thus, to improve the nutritional security as well as maize productivity of the Jharkha-

nd, the high yielding biofortified short to medium duration maize single cross hybrids can contribute significantly. In the recent past, public sector researchers have bred several productive bio-fortified single cross maize hybrids (Table 1). These have enhanced micronutrient content (lysine, tryptophan, and pro-vitamin A, either alone or in combination). However, these biofortified hybrids are yet to deliver on their promise in Indian farmers' fields. The main constraint in QPM taking off is non-availability of seeds for cultivation and that has to do with the absence of an active seed production programme. Success of these efforts will be met when they reach the masses of rural and tribal India where maize is mostly consumed as food. With consumption and creation of demand more and more farmer will be motivated for cultivation of these bio-fortified hybrids. The timely availability of quality seeds and technical advice for the seed production and hybrid cultivation to seed grower and farmer may play an important role in this regard. This will not only create a value chain in terms of seed production and cultivation but also the creation of entrepreneurship in terms of value-added products from these biofortified hybrids. Thus, popularization and promotion of the elite, potential and high yielding QPM/QPM+proVit.A enriched hybrids will open a new window for ensuring the sustainable nutritional security in the rural and tribal areas of the Jharkhand. The promotion of hybrid seed production in the state would bring awareness among farmers about hybrids. It will also ensure the availability of

quality seeds of public bred hybrids to the reach of farmers.

Materials and methods: Keeping in view the above facts, the demonstration of QPM hybrids viz. "Pusa HQPM-1 improved & Pusa HQPM-5 improved" were conducted on farmers' field across a substantial number of villages in Hazaribag district during the *Kharif* 2022, *Kharif* 2023 and *Kharif* 2024 through the financial support of NABARD, Ranchi. In *Kharif* 2022, the QPM hybrid demonstrations took place in 60 different villages, showcasing the potential yield of these improved maize varieties. The initiative was expanded even further in *Kharif* 2023 and 2024, covering a total of 210 and 200 villages respectively in the district. All these demonstrations were conducted in coordination with the Farmer Producer organizations of the Hazaribag district promoted by NABARD. Before conducting the demonstration, five innovative farmers of each FPO were trained in terms of the scientific package of practices for maize cultivation viz. spacing, water management at critical stages, weed management, plant protection from insect as well as diseases and postharvest management so as to achieve higher productivity and profitability. These trainees acted as the master trainer among the farmers of the concerned FPOs. Furthermore, to ensure that farmers had a first-hand experience of the QPM hybrids and their yield potential, field days were organized in all 240 villages where the demonstrations were conducted. During these field days, farmers were given the opportunity to observe the QPM hybrids up close.

Blocks	No. of Villages		Kharif 2024	Pusa HQPM-5 improved			Hybrid available in local market		
	Kharif 2022	Kharif 2023		Kharif 2022	Kharif 2023	Kharif 2024	Kharif 2022	Kharif 2023	Kharif 2024
				GY (GCY)	GY (GCY)	GY (GCY)	GY (GCY)	GY (GCY)	GY (GCY)
Barhi		25	25	56.1 (219)	54.1 (226)	55.5 (221)	46.8 (204)	44.6 (201)	53.1 (215)
Hazaribag		15		57.8 (235)	54.5 (222)		45.5 (206)	42.5 (196)	
Churchu	10	25	10	56.4 (226)	52.2 (214)	55.0 (215)	49.4 (214)	45.2 (205)	56.4 (230)
Dadi (Belsagra)	15	20	20	57.9 (233)	52.6 (219)	54.9 (217)	50.2 (218)	44.3 (201)	52.6 (206)
Ichak		15	15	58.7 (234)	53.4 (225)	51.8 (230)	48.6 (210)	42.6 (194)	49.3 (218)
Vishnugarh	10	20	10	57.2 (231)	51.9 (209)	50.6 (217)	47.7 (212)	43.7 (195)	44.7 (209)
Tatijhariya		10	15	59.2 (235)	55.5 (230)	57.9 (236)	49.2 (220)	46.8 (199)	52.1 (214)
Barkagaon	10	15	10	-	58.2 (236)	59.1 (228)	-	47.1 (206)	53.5 (211)
Katkam Sandi /Gidhaur/Barkatha/Chauparan	5	5	55	-	55.3 (224)	56.7 (231)	-	46.5 (205)	54.6 (234)
Keredari		10	15	-	61.4 (238)	60.8 (238)	-	51.2 (215)	57.2 (221)
Gidhi (Dadi Block)	10	50	25	58.5 (233)	59.4 (235)	57.9 (233)	52.1 (235)	49.4 (211)	56.4 (203)
Average yield				57.7 (231)	55.3 (225)	56.50 (227.1)	48.7 (215)	45.8 (209)	53.79 (216.2)

Crop cutting was performed in a meticulous manner, with a focus on a 4-square meter area and five replications on each demonstration plot. This meticulous approach allowed for an accurate assessment of the yield potential of the QPM maize hybrids. Green cobs were also harvested in the similar manner during the grain filling stage of the crop. The QPM hybrids were demonstrated alongside the maize hybrids available in the local market and the indigenous land races. This comparative aspect of the demonstration provides an important context, as it underscores the significant superiority of the demonstrated QPM hybrids in terms of yield when compared to both traditional varieties and the hybrids readily accessible in the local market.

Results and discussion: The results demonstrate the consistent performance of Pusa HQPM-5 improved across all blocks and years. The average grain yield (GY) and green cob yield (GCY) for this variety

were stable, with an average GY of 57.7 q ha⁻¹ (231 GCY) in *Kharif* 2022, 55.3 q ha⁻¹ (225 GCY) in *Kharif* 2023, and 56.5 q ha⁻¹ (227.1 GCY) in *Kharif* 2024. This highlights its reliability as a high-yielding variety. In comparison, the hybrids available in the local market underperformed, with average GY values of 48.7 q ha⁻¹ (215 GCY) in *Kharif* 2022, 45.8 q ha⁻¹ (209 GCY) in *Kharif* 2023, and 53.79 q ha⁻¹ (216.2 GCY) in *Kharif* 2024. On average, Pusa HQPM-5 improved showed a yield advantage of 9 q ha⁻¹ in GY and 12 GCY over local hybrids. Block-wise analysis revealed that Tatijhariya performed exceptionally well, achieving the highest yields in 2022 and 2024, with 59.2 q ha⁻¹ (235 GCY) and 57.9 q ha⁻¹ (236 GCY), respectively. Keredari recorded the highest yields in 2023, with 61.4 q ha⁻¹ (238 GCY). Gidhi (Dadi Block) demonstrated consistent high yields across all years, maintaining GY above q ha⁻¹ and GCY above 230. These findings underscore the adaptability and high productivity of Pusa HQP

M-5 improved across diverse agro-climatic conditions. The variety consistently outperformed local market hybrids, making it a superior choice for farmers. The minor year-on-year variations in yield indicate its resilience to environmental changes and effective management practices. Overall, Pusa HQPM-5 improved has shown significant potential for enhancing maize productivity in Jharkhand, making it a strong candidate for widespread adoption.



Figure 1: Field View of Pusa HQPM-5 Improved

Salinity Stress in Plants: Effects and Adaptation Mechanisms

Jyoti Nishad and Chongtham Nirmala

Introduction

Soil salinity is one of the serious abiotic stresses that restrict the crop growth as well as production throughout the world. Soil salinization of cultivated land has emerged as significant threats to worldwide agricultural sustainability and food security (Phour and Sindhu, 2023). Rising surface temperatures, changes in precipitation patterns and prolonged droughts have increased surface evaporation and increased soil salt accumulation. Sea-level rise due to glacial snow melt and thermal expansion of ocean and sea water intrusion will exacerbate coastal salinization. To counteract the adverse effect of salinity stress, plants have evolved a myriad of mechanisms to alter physiological and developmental responses. Upon exposure to salt stress, a set of stress-induced genes are activated to orchestrate salt tolerance responses in plants. The identification and characterization of key salt-stress-tolerance genes and further understanding the regulatory mechanisms of rice salt stress responses have important implications for improving salt tolerance in crops and global food security. This article provides a synopsis of salt stress responses and adaptation in plants.

Adverse Effects of Salinity Stress

The increasing area of salt affected soils has become a major global problem that limits sustainab-

le development, agricultural productivity and ultimately threatening food security. It has been reported that soil salinity affects around 80 mha cultivated land (Zhang *et al.*, 2012). Saline soils and sodic soils contribute 23% and 37% of the total world's cultivated land. Plant physiological physiognomies are extensively susceptible to the highly saline rhizosphere. High salt level affects seed germination, plant life, and crop productivity. One of the initial effects of salt stress is the reduction of growth rate. The first phase of the growth response results from the effect of salt outside the plant. The salt in the soil solution reduces leaf growth and to a lesser extent root growth. The second phase of the growth response results from the toxic effect of salt inside the plant. Salinity stress is dominated by sodium (Na^+) and chloride (Cl^-) ions affect plant growth and development by creating ionic, osmotic and oxidative stresses. Higher amount Na^+ in saline medium inhibits uptake and transport of Ca^{2+} and might induce Ca^{2+} deficiency in plants because of higher $\text{Na}^+/\text{Ca}^{2+}$ ratios (Lynch *et al.*, 1989). According to FAO (2022), 70% more food is required for 2.3 billion people in the world by 2050. So, it is necessary to improve food production in future especially crop yield under salt stress.

Plant Adaptation Mechanisms under Salinity

Osmoprotectants: Osmoprotectants or osmolytes

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are small organic molecules that help plants to survive under extreme osmotic stress. Osmotic adaptation is important in regulating cellular turgor to maintain plant metabolic activity, growth, and ultimately productivity. Crop synthesizes compatible osmolytes such as prolines, polyamines, soluble sugars and proteins, betaine, myoinositol, mannitol and trehalose and glycine to provide osmotic balance at the cellular level. Under salt stress, these important osmolytes reduce osmotic potential, stabilize proteins, and ultimately preserve cellular structure, thus ensuring plant osmotic adaptation (Hasanuzzaman, 2022). It has been found that these compounds are non-toxic as they can accumulate to high intracellular concentrations without disrupting the hydration shell of proteins and membranes.

Role of Transporters in Maintaining Ion Homeostasis: Transporters play important role in maintaining homeostasis by sequestering Na^+ ion. Salt stress is usually associated with excessive amounts of NaCl . Several key mechanisms, such as Na^+ efflux from uptake, vacuolar Na^+ sequestration, xylem Na^+ loading and recovery from shoots, and K^+ retention in the cytosol, confer ion homeostasis in plants under saline conditions. In the salt overly sensitive (SOS) pathway, the Ca^{2+} -binding protein SOS3 directly interacts to activate the serine/threonine protein kinase SOS2. SOS3 recruits SOS2 to the plasma membrane, where the SOS2-SOS3 complex phosphorylates SOS1 (Kumar *et al.*, 2022). SOS1 is a plasma membrane Na^+/H^+ antiporter that extrude Na^+ from cells.

Intracellular Compartmentalization: Intracellular compartmentalization is an adaptive response mechanism which is involved in salinity stress tolerance. Sodium chloride is one of the most commonly released salts. Limiting excessive transport of Na^+ to shoots is one of the key factors in mitigating salt damage to plants. Plants deliver toxic ions to older leaves and leaf sheaths to rescue young growing meristematic tissues. Continued salt transport to transpiring leaves over a long period of time eventually leads to very high Na^+ and Cl^- concentrations and leaves die.

Antioxidant System: Oxygen is one of the essential biomolecules involved in cellular metabolism, mitochondrial respiration, and oxidative phosphorylation for energy production in plants. However, oxygen is converted to reactive oxygen species (ROS) during metabolic processes in plants. Plants under salt stress conditions can upregulate excessive production of ROS such as O_2^- (superoxide anion), H_2O_2 (hydrogen peroxide), OH (hydroxyl radical). Hydroxyl radicals (OH) and superoxide anions (O_2^-) are the ionic states ROS, while hydrogen peroxide (H_2O_2), and singlet oxygen ($^1\text{O}_2$) are the molecular states ROS (Mittler *et al.*, 2011). Thus, ROS production act as an early adaptation signal cascade during unfavourable ionic condition in the root.

Role of Phytohormones in Stress Signalling: Phytohormones act as chemical messenger that regulate plant growth and development in both ideal and challenging environments. Phytohormone levels fluctuate downstream of the initial salt signalling

step and salt-induced signalling cascades ultimately leading to adaptive responses. Several plant hormones, must be integrated and coordinated in order to respond and adapt to salt stress, such as abscisic acid (ABA), auxin, gibberellic acid (GA), ethylene, cytokinin (CK), salicylic, brassinosteroids (BR) and jasmonic acid (Van Zelm *et al.*, 2020).

Salinity-Tolerant Plants: Certain plant species, known as halophytes naturally thrive in saline environments. Salt tolerance genes primarily come from two sources: wild relatives of the plants and other halophytes, such as the common seepweed herb, samphire, *Oryza coarctata*, *Taxodium ascendens* etc. Regulation of gene expression in salinity stress includes a wide array of mechanisms that are used by plants to upregulate or downregulate (increase or decrease) the production of specific gene products (protein or RNA).

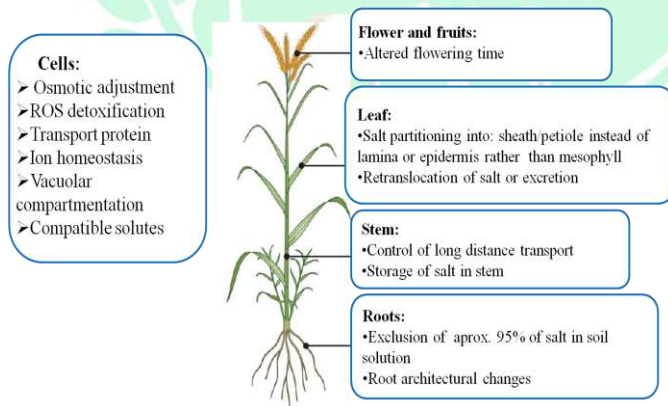


Fig. 1: Schematic representation of adaptive strategies for salt tolerance in plants

Recently, more studies have aimed to investigate the functional mechanisms of plants in response to abiotic stresses which includes salt stress. Plant development and their responses to natural changing environments and stressful conditions

are often regulated by complex regulatory networks that include various types of molecular components, such as transcription factors, regulatory RNAs. Crop improvement efforts aim to develop salt-tolerant varieties of common crops like rice, wheat, and barley through conventional breeding and biotechnological approaches.

Conclusion

Salinity stress poses a major challenge to sustainable agriculture and food security. Soil salinity will continue to threaten crop production and food security in the future. Cultivation of salt-tolerant crops is the most effective way to overcome this environmental problem. In the last three decades, extensive efforts have contributed to our understanding of the mechanisms of salt stress tolerance in plants. However, application of this fundamental knowledge to improve salt stress tolerance of crops in the field is a slow and challenging process. With the aid of gene editing technologies and advances in efficient genetic transformation in different species, improvement of salt stress tolerance of crops will become more feasible. Halophytes have developed special molecular mechanisms or special cellular structures to tolerate high concentration of salts. Growing halophytes in saline soils can greatly increase the area of arable land and also improve salt conditions in the soil. Understanding the mechanisms of plant responses to salinity and adopting effective management practices, such as using salt-tolerant crops, improving irrigation practices, and soil reclamation, are essential to mitigate the adverse

effects of salinity on crop productivity.

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The Climate Change: A Race Against Time

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Introduction

One of the most urgent issues facing humanity today is climate change. Ecosystems, economies, and communities around the world are under danger due to the alarming rate at which environmental degradation, extreme weather, and rising global temperatures are occurring (Feliciano *et al.*, 2022). The vulnerability of the agricultural sector is a situation that is of worldwide concern since it threatens adequate output and food supplies because of irreversible weather variations. Global feeding habits are being challenged as a result, especially in nations where agriculture plays a significant role in both economic growth and overall productivity. Due to changes in the ideal temperature ranges, climate change has also jeopardized the life and integrity of numerous species, hastening the loss of biodiversity by gradually altering ecological systems (Abraham and Chain, 1988). Certain foodborne, waterborne, and vector-borne illnesses are more likely to occur in certain climates; a recent example is a coronavirus pandemic (Song *et al.*, 2021). Antimicrobial resistance, another concern to human health brought on by the rise in resistant pathogenic diseases, is also accelerated by climate change. There has never been a more pressing need to take action as scientists warn of disastrous outcomes. Our planet's destiny will be determined by our collective response to the race

against climate change.

The Science behind Climate Change

Human activity is the main cause of climate change, especially the use of fossil fuels like coal, oil, and natural gas. Global warming results from the release of greenhouse gases into the atmosphere, such as carbon dioxide (CO₂) and methane (CH₄), which trap heat. By decreasing the Earth's ability to absorb CO₂, industrial activities, deforestation, and unsustainable farming practices all contribute to the situation' worsening (Huang *et al.*, 2016). The average temperature of the Earth has already increased by around 1.1°C since the pre-industrial era, according to scientific reports from the Intergovernmental Panel on Climate Change (IPCC). We run the risk of exceeding the crucial 1.5°C threshold if present trends continue, which would cause irreparable harm to human society and ecosystems.

Consequences of Inaction

Globally, the effects of climate change are already noticeable. Extreme weather events like hurricanes, wildfires, and droughts are growing more common and severe, and coastal towns and small island nations are at risk from rising sea levels (Diffenbaugh *et al.*, 2017). Temperature and precipitation variations cause resource disputes, affect food production and jeopardize biodiversity. Climate change is also increasing the threats to health.

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Every year, heatwaves claim thousands of lives, respiratory illnesses are made worse by air pollution, and infectious diseases like dengue fever and malaria are made easier to spread by shifting ecosystems (Costello *et al.*, 2009). The number of climate refugees worldwide is also rising as a result of the millions of people who are being displaced by climate-related calamities.

The Need for Immediate Action

To combat climate change effectively, immediate and sustained action is essential. Governments, businesses, and individuals all have a role to play in reducing carbon emissions and fostering sustainable practices. Some key strategies include:

Transitioning to Renewable Energy: Phasing out fossil fuels and investing in renewable energy sources like solar, wind, and hydroelectric power is crucial in cutting greenhouse gas emissions. A sustainable future and the fight against climate change depend on the switch to renewable energy. Even if there are obstacles, this change can be accelerated by concerted efforts from individuals, corporations, and governments. The world can lower carbon emissions, improve energy security, and promote economic growth while preserving the environment for coming generations by giving sustainable energy solutions top priority.

Enhancing Energy Efficiency: Implementing energy-efficient technologies in industries, transportation, and homes can significantly reduce energy consumption. Adopting renewable energy reduces air pollution, improves public health, and enhances

energy security by diversifying energy sources.

Reforestation and Conservation: Protecting and restoring forests, wetlands, and other natural carbon sinks is vital in absorbing CO₂ from the atmosphere. Reforestation helps rebuild natural habitats, supporting biodiversity and ecosystem services. Preventing deforestation is more effective than replanting in reducing CO₂ emissions.

Sustainable Agriculture: One of the most important ways to mitigate and adapt to climate change while maintaining food security for coming generations is through sustainable agriculture. It includes agricultural methods that preserve biodiversity, lower greenhouse gas emissions, conserve water, and maintain soil health. Adopting eco-friendly farming practices, reducing food waste, and promoting plant-based diets can help lower emissions.

Stronger Climate Policies: To lessen the worst consequences of climate change, stronger climate policies are necessary. In order to lower greenhouse gas emissions and advance sustainability, governments, corporations, and individuals all have a part to play. Governments must enforce stringent regulations, carbon pricing mechanisms, and international agreements like the Paris Accord to limit global warming.

Public Awareness and Education: Raising awareness about climate change and promoting behavioral changes can empower individuals to contribute to sustainability efforts. We can lessen the negative effects of climate change and work toward a sustainable future by taking action and educating others.

Hope for the Future

Despite the scary nature of climate change, there is still hope. Green solutions are being developed and implemented by nations, organizations and communities all around the world. Promising routes to a low-carbon future are provided by developments in carbon capture technologies, electric vehicles, renewable energy, and sustainable urban planning. In addition, the youth-led climate movement has been essential in holding leaders responsible and promoting immediate action. Time is running short, yet the fight against climate change is far from over. Future generations will be shaped by the decisions we make today. We cannot guarantee a sustainable and habitable Earth unless we take decisive, swift, and coordinated action. The worldwide crisis of climate change necessitates swift and ongoing response. To cut carbon emissions, switch to renewable energy, and save our world for coming generations, governments, corporations, and individuals must cooperate. The consequences of inaction will be severe and irrevocable, therefore now is the moment to take action.

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Success Story on Nutritional Garden: A Sustainable Model to Develop Food and Nutritional Security

Pragya Ojha, Diksha Patel, Pankaj Kumar Ojha and Shyam Singh

Situation analysis/ Problem statements: Smt. Gomti w/o Sri Dharmendra Kumar, a 41 years old graduate farm woman belongs to Chahitara village, Badokhar Khurd Block, Banda. She have 5 acres of land and involved in crop production. Most of farmers in Badokhar Blocks are small and marginal farmers having monocropping system. So they depend on weekly bazaar, away from villages for their family needs of vegetables. Due to unavailability of fruits and vegetables on daily basis, there is less diversity in their diet. For easy availability of vegetables to the villagers, Mrs Gomti established a backyard nutrition garden of 250 sq.m after the intervention of KVK.

Plan, Implement and Support: KVK Banda took initiative to organize farmer's trainings on Awareness regarding Nutrition Garden to combat malnutrition and demonstration on preparation of nutrition garden. About 100 rural women were trained for management of nutrition gardens in their villages. After training KVK, Banda prepared Nutrition Garden seed kit containing 15 types of

vegetables and 4 types of fruit seedlings under the project SCSP funded by ICAR. In total, 100 households in 5 villages were trained and inputs were provided to 100 families under SCSP scheme. The model of Nutrition Garden was also developed at the KVK Farm and women farmers trips arranged to see nutrition garden. So, she was the one who got training on organic farming and started organic vegetables production. The layout is given according to space available at backyard for Nutritional Garden at villages. KVK formed its own kitchen garden model at KVK Farm (350 sq.m) in which 25 types of vegetables grown in 250 sq.m area and NADEP, Vermi composting in 100 sq.m area.



Output: After fulfilling the requirement of own family, she started to sale the vegetables by making

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weekly basket to nearer city places. It gave her extra income. After getting higher demand, she has expanded the area for nutrition garden.



Recognition: KVK Banda has recognized her achievements at various platforms in the district and presented her as a role model to other fellow farmers specially women farmers.

Impact: By seeing the success of Smt. Gomti, other women are being motivated to nutrition garden concept. She motivated 100 women in her village to form SHGs and promoted to start their own Nutrition Gardens. About 100 farm women started Organic Nutrition Gardens.

Backyard Poultry: A Source of Profit for Women

Pragya Ojha, Diksha Patel, Pankaj Kumar Ojha and Shyam Singh

Situation analysis/ Problem statements: Sunto is an innovative farmwoman, who lives in Chandrapura village in Naraini block of Banda District, Uttar Pradesh. The local ecology is suitable for rice production, especially during the *Kharif* season; environmental conditions offer very limited alternatives for growing rice. Rice production provides seasonal employment and an essential staple for the year. After the *Kharif* season, most farmers grow wheat.

Plan, Implement and Support: Sunto's family owns 2 acre land but her family only cultivated 13 gunth (0.33acre). Innovation is a necessity for her five member family, including her mother-in-law as family is entirely dependent on her small farm. She along with her husband asked themselves, "How can they lift their family out of this trap? Farming is vital, but they need to find ways to earn additional income". Under the SCSP training was imparted and a model was developed for framing in their backyard. Various inputs like improved vegetable seeds, seasonal fruit planting materials were provided. Poultry chicks were kept in a small poultry unit made

of thatched room with mud. Previously they have two cows. Hybrid Napier was introduced as fodder for feeding these cows. The KVK team also arranged exposure visit of the farmers to different institutes for knowledge gain and skill development.

Output: The family started earning money through selling of eggs and milk in the local market. The yield of milk also enhanced due to feeding of Napier grass and balanced feed. They have also raised nutritional garden with proper technology. They were able to get seasonal leafy vegetables, for their daily household consumption. The surplus vegetables they sold in their village market. Thus they were not only able to increase their income but also enhanced their nutritional status. The annual income of the family increased to Rs 1,24,000 per year due to the intervention made by KVK, Banda.



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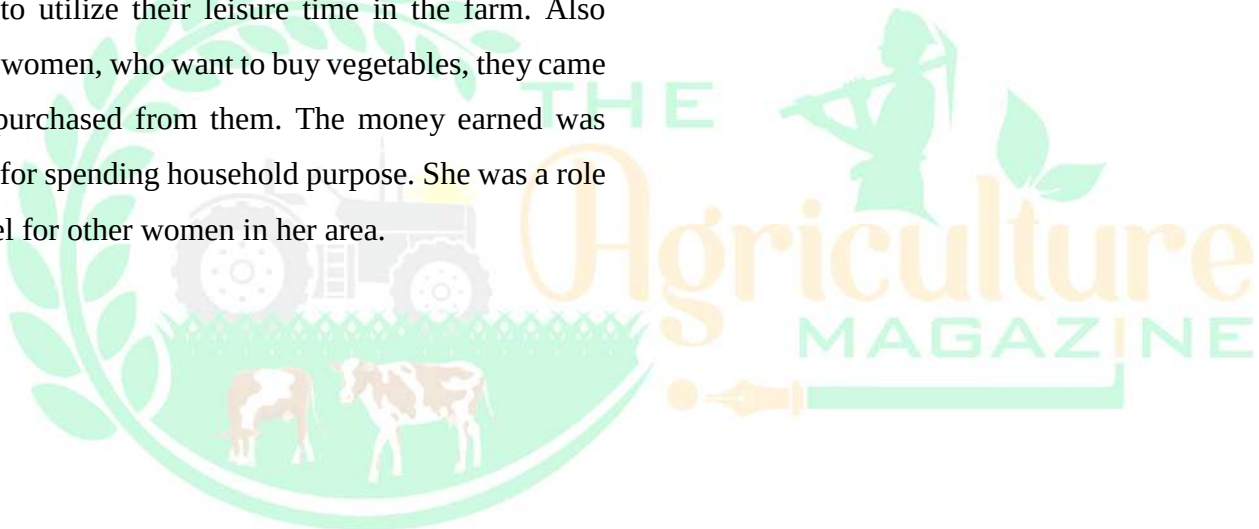
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Recognition: KVK Banda has recognized her achievements at various platforms in the district.



Impact: The introduction of IFS is adjacent to the home helped Smt. Sunto and her mother-in-law are able to utilize their leisure time in the farm. Also rural women, who want to buy vegetables, they came and purchased from them. The money earned was used for spending household purpose. She was a role model for other women in her area.



Success through Scientific Vegetable Production

Pragya Ojha, Diksha Patel, Pankaj Kumar Ojha and Shyam Singh

Situation analysis/ Problem statements: Mrs. Ramrati aged 34 years is an energetic farm woman with a progressive mind set and indomitable spirit having 8 years of experience in farming from Darda-Kanwara village of Badokhar block of Banda district, U.P. She owns 4 acres of agricultural land. She mainly cultivates vegetable crops like pumpkin, bitter gourd, papaya, okra, cowpea, cabbage, cauliflower, carrot etc. during *kharif* and *rabi* season in 3 acres of land and vegetable in 2 acres of land. She also grows pulse crop like black gram and green gram in 1 acre of land. She also practices vermi-composting, preparation of farm yard manure (FYM), cattle rearing and goat rearing for supplementing family income.

Plan, Implement and Support: She came in contact with KVK, Banda in 2021. Thereafter, through the hand holding support by the KVK Banda team she was exposed to improved technical knowledge and guidance on cultivation practices of vegetable crops, black gram, green gram and use of different women friendly ergonomically improved tools and equipments through training and demonstrations.

Output: After adoption of women friendly New Agricultural Technologies, her farm income increased to a greater extent i.e., 30-35% with utilization of improved tools and equipments, quality seeds with improved package of practices, advanced technical knowhow and back stopping led to reduction of drudgery, improvement in women labour and their efficiency resulting in higher yield and production at her farm land. Apart from family consumption Mrs. Ramrati earns Rs.2,20,000/- of gross income per annum out of which she earns a profit of Rs. 1,18,000/-



Outcome: Mrs. Ramrati with her dedication has keenness to exchange and share innovative technical knowledge availed from KVK Banda. Farm women

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from nearby villages of Darda- Kanwara have come forward and takeoff the innovative ideas from her for improving their production and productivity in their agricultural crops.



Impact: She is truly a role model for other farm women in the locality. She has proven that the adoption of women friendly New Agricultural Technologies in farming will facilitate in maximizing the profit and the technical back stopping supported with guidance, mentorship and timely help about the latest trends in agriculture sector help in reaping benefits.

Nano-Biochar: A Next-Gen Soil Amendment for Climate-Smart Farming

Saravanan S. and Priyanka A. S.

Abstract

As climate change continues to stress agriculture, the demand for smarter, more sustainable farming practices is rising. One promising solution gaining attention is nano-biochar, a highly refined version of traditional biochar. With its ultra-fine structure, nano-biochar enhances soil health, boosts crop yields, and supports carbon storage, all while being eco-friendly. Its ability to improve water retention, reduce fertilizer needs, and foster microbial life makes it a powerful ally for farmers facing erratic weather and declining soil fertility. This article dives into how nano-biochar works, why it matters, and how it could shape the future of farming, especially in countries like India.

Introduction

Farming today is not what it used to be. Unpredictable rain, shrinking groundwater, and tired soils are challenging even the most experienced growers. While fertilizers and irrigation help, they often come with side effects, polluted water, rising costs, and weakened soil biology. The solution may lie not in using more, but in using better. That's where nano-biochar comes in. This isn't a new miracle chemical, it's a modern twist on an ancient practice. Farmers have used charred plant material for centuries to enrich soil. Now, by turning that biochar into ultra-fine particles, we can unlock new possibilities for sustainable and efficient agriculture.

What is Nano-Biochar and why is it Special?

Nano-biochar is made by taking regular biochar, essentially carbon-rich charcoal from organic materials and grinding it down to nanoparticles

(less than 100 nanometers in size). At this tiny scale, its structure and activity are significantly enhanced.

Here's what makes it stand out:

Super fine surface: More room to hold nutrients and water.

High porosity: It creates micro-habitats for beneficial microbes.

Greater reactivity: It interacts better with soil nutrients and plants.

Sustainable: Made from crop waste, it's a zero-waste product.

Unlike traditional biochar, nano-biochar works more quickly and effectively because it can blend seamlessly with soil, fertilizers, and even compost.

How Nano-Biochar Helps the Soil and the Farmer

Boosts Soil Fertility Naturally: Nano-biochar helps soils retain key nutrients like nitrogen and potassium

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instead of letting them wash away with the rain. This not only saves farmers money on fertilizer but also reduces pollution in nearby rivers and lakes.

Makes the Most of Every Drop of Water: Thanks to its sponge-like texture, nano-biochar can hold water much more efficiently than untreated soil. This is especially useful in dry or drought-prone regions. Crops can access moisture longer, which means fewer irrigation rounds and better plant survival during dry spells.

Supports Soil Microorganisms: Healthy soil is alive and nano-biochar gives the soil's living community a big boost. It provides shelter and food for helpful bacteria and fungi that, in turn, help plants absorb nutrients and fight off disease.

A Partner for Smart Fertilizer Use: When nano-biochar is used along with fertilizers, it slows down how quickly the nutrients release into the soil. That means plants get what they need, when they need it, without the excess being wasted.

Locks Away Carbon and Fights Climate Change: Because it's stable and doesn't break down easily, nano-biochar holds carbon in the ground for decades. That means less carbon dioxide in the atmosphere, a small but meaningful step toward reducing agriculture's carbon footprint.

What Research Says

Indian researchers and institutions are now actively studying nano-biochar. Some highlights:

- ✓ At ICAR-IARI, nano-biochar-treated wheat fields yielded 21% more grain and showed a notable increase in soil carbon.

- ✓ In Punjab, rice fields showed improved nitrogen efficiency and used less urea without hurting yields.
- ✓ CIMMYT India found that in Gujarat, maize fields with nano-biochar needed 40% less irrigation water.

These studies show it's not just theory, it works in the field.

Real-World Uses and Crop Benefits

Across different Indian states, nano-biochar is quietly making its mark. Here's a snapshot of how farmers are using it:

Crop	How It's Used	What Farmers Notice
Wheat and Rice	Mixed with fertilizers during sowing	15-25% yield increase, better grain quality
Vegetables	Applied in nursery trays or raised beds	Stronger seedlings, less transplant shock
Pulses	Coated on seeds or top-dressed	Quicker sprouting, better drought tolerance
Fruit Crops	Fed through drip with compost	Healthier trees, more uniform fruiting

Blending with Other Green Practices

Nano-biochar isn't a silver bullet, but it fits well into broader sustainable farming strategies:

- ✓ Use it with vermicompost or organic manures for a microbe-rich mix.
- ✓ Combine it with microbial biofertilizers to stimulate root growth.
- ✓ Integrate it into precision farming to reduce input waste and monitor results.

It's especially powerful in rainfed areas, where holding onto nutrients and moisture can mean the difference between a successful crop and a failed one.

What's holding it back?

Despite its benefits, some barriers remain:

Cost and access: Grinding biochar into nano size requires equipment not readily available to most small farmers.

Lack of awareness: Many growers have never heard of it or are unsure how to use it.

No clear rules yet: The government is still figuring out how to regulate nanomaterials in farming.

But with training, affordable units for nano-biochar production, and the right incentives, these roadblocks can be overcome.

The Way Forward

For nano-biochar to go mainstream, a few steps are crucial:

Policy support: Include nano-biochar under fertilizer or organic farming subsidies.

Public-private partnerships: Encourage startups to build low-cost nano-biochar grinders using farm waste.

Farmer training: Use Krishi Vigyan Kendras and FPOs to teach application techniques.

Monitoring and trials: More state-level demonstrations to build farmer trust.

Key Applications and Benefits of Nano-Biochar in Agriculture

Sourced from Agri Waste: Made from rice husks, coconut shells, or sugarcane bagasse, turning farm waste into valuable input.

Produced via Pyrolysis & Milling: Created by heating organic material in low-oxygen (pyrolysis), followed by ball milling or ultrasonic treatment to get nano-size particles.

Nano Size Advantage: With particles under 100

nanometers, it offers greater surface area for soil interaction compared to regular biochar.

Improves Nutrient Retention: Binds essential nutrients like nitrogen, phosphorus, and potassium, reducing nutrient loss from leaching.

Boosts Water Holding: Enhances moisture retention in sandy or light soils by 30-40%, helping crops withstand dry spells.

Balances Soil pH: Acts as a buffer, especially useful in acidic soils, and helps plants access nutrients more efficiently.

Sequesters Carbon: Stores carbon in a stable form for decades, contributing to lower greenhouse gas emissions.

Promotes Microbial Life: Its porous structure creates a favorable habitat for beneficial microbes like nitrogen-fixing bacteria and mycorrhizae.

Integrates with Organic Inputs: Works synergistically with compost, farmyard manure, and biofertilizers, enhancing their effectiveness.

Flexible Application: Can be mixed with topsoil, blended into compost, coated onto seeds, or delivered through drip irrigation systems.

Supports Crop Productivity: Reported yield increases of 10-25% in field trials, especially in cereals and legumes.

Eco-Friendly Impact: Reduces chemical runoff, recycles carbon-rich waste, and supports long-term soil regeneration.

Conclusion

Nano-biochar is more than just a scientific curiosity, it's a practical, home-grown solution that

can help farmers grow more with less. In the face of climate change, rising input costs, and soil exhaustion, nano-biochar stands out as a tool rooted in nature, refined by science, and ready for the field. For farmers seeking to future-proof their land and livelihoods, nano-biochar isn't just an option. It might just be the edge they need.

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Living Roots: The Power of Cover Crops in Regenerating Indian Soils

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Abstract

As Indian agriculture faces increasing pressure from soil degradation, climate change, and input costs, the use of cover crops has emerged as a natural, cost-effective solution to restore soil health and productivity. Cover crops, plants grown not for harvest but to protect and enrich the soil, offer wide-ranging benefits including improved organic matter, enhanced microbial activity, erosion control, and natural weed and pest suppression. This article explores the role of cover crops in soil regeneration, their application in Indian farming systems, and the future prospects for scaling their adoption among smallholder farmers.

Introduction

Healthy soil is the foundation of productive agriculture. Yet in India, years of intensive farming, chemical overuse, and poor land management have stripped much of our farmland of its vitality. According to the Indian Council of Agricultural Research (ICAR), nearly 30% of Indian soils are degraded, lacking organic matter, compacted, or eroded. In this context, cover crops offer a nature-based solution. These are crops like legumes, grasses, or brassicas, grown not to harvest but to cover and protect the soil between main crop cycles. They keep the “living roots” in the soil year-round, feeding microbes, building structure, and storing carbon. For Indian farmers facing declining yields and rising costs, cover crops are not just a conservation tool, they’re a pathway to resilience.

Why Indian Soils Need Regeneration

India’s soil health crisis is driven by multiple factors:

Loss of Organic Matter: Continuous tillage and chemical inputs have reduced soil carbon, impacting structure and water retention.

Erosion: Water and wind erosion remove topsoil, especially in sloped regions and during heavy monsoon rains.

Nutrient Imbalance: Over-reliance on nitrogen, phosphorus, and potassium (NPK) fertilizers has led to micronutrient deficiencies.

Soil Compaction: Repeated ploughing and mechanization compact the soil, reducing root growth and aeration.

Studies from the Indian Institute of Soil Science (IISS) show that adding organic matter through green manuring and cover crops can reverse these trends in just a few cropping cycles.

What are Cover Crops?

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Cover crops are plants grown primarily to benefit the soil, not the farmer's immediate harvest. Some common types include:

- ✓ Legumes (e.g., cowpea, sunhemp, dhaincha): Fix nitrogen from the air, enriching soil fertility.
- ✓ Grasses (e.g., sorghum, oats): Improve soil structure, prevent erosion, and suppress weeds.
- ✓ Brassicas (e.g., mustard, radish): Break up compacted soils with deep roots and reduce pests through biofumigation.

These plants are typically sown between main crop seasons or intercropped in wide-spaced systems. The key is maintaining living roots throughout the year to continuously support the soil ecosystem.

Scientific Evidence and Case Studies

- ✓ A study by ICAR-Indian Institute of Farming Systems Research (IIFSR) showed that integrating *sunhemp* cover cropping before wheat improved yield by 18% and reduced nitrogen use by 25%.
- ✓ In Andhra Pradesh, groundnut farmers using horse gram as a cover crop reported 20% higher pod yields due to better soil aeration and pest control.
- ✓ In Maharashtra's dryland areas, growing sorghum cover crops before cotton helped retain soil moisture and reduced soil erosion by 40%.

Integrating Cover Crops into Indian Farming

Here's how small and marginal farmers can incorporate cover crops effectively:

Rice-Pulse-Green Manure Rotation: After harve-

sting rice, grow pulses, then incorporate a green manure crop before the next rice cycle.

Intercropping in Orchards: Legume cover crops in mango or citrus orchards provide nitrogen and suppress weeds.

Relay Cropping: Sow cover crops into standing main crops a few weeks before harvest to ensure a continuous cover.

Challenges and Solutions

Challenge	Suggested Solution
Lack of awareness	Promote through KVKs and agricultural extension campaigns
Seed availability	Develop local seed hubs for green manure and cover crop species
Short planting window	Use fast-growing cover crops like cowpea and sunhemp
Fear of yield loss	Demonstrate through pilot trials and Farmer Field Schools (FFS)

Key Benefits and Applications of Cover Crops in Indian Agriculture

Improving Soil Fertility: Leguminous cover crops like Dhaincha and Sunhemp fix atmospheric nitrogen, naturally enriching the soil. In rice-wheat and rice-pulse systems, farmers can reduce chemical fertilizer use by up to 40%.

Suppressing Weeds Naturally: Fast-growing covers such as mustard, cowpea, and sorghum shade the ground and outcompete weeds. In states like Punjab and Haryana, they help control aggressive weeds like *Phalaris minor* without chemicals.

Enhancing Soil Moisture Retention: Crops like oats and horse gram leave behind a protective mulch that holds soil moisture. In dryland regions of Telangana and Maharashtra, this improves water efficiency by 10-15%.

Preventing Soil Erosion: Deep-rooted species like

Napier grass, vetiver, and barley anchor soil and reduce erosion during rains. Particularly useful in sloped areas like Himachal Pradesh and Meghalaya, where runoff is a major issue.

Supporting Natural Pest Control: Plants like mustard, marigold, and sunhemp attract beneficial insects and act as trap crops. They help reduce pesticide use in vegetables and improve biodiversity.

Boosting Soil Microbial Life: Diverse root systems from mixed legume-grass cover crops feed microbes and build living soil. These systems encourage earthworms, fungi, and bacteria essential for healthy plant growth.

Capturing and Storing Carbon: Cover crops add organic carbon to the soil through their roots and decaying biomass. This helps sequester 0.2-0.3% more carbon per year, contributing to India's climate mitigation efforts.

Providing Extra Farm Income: Dual-purpose cover crops like cowpea, green gram, or guar can be harvested for fodder or market. They let small and marginal farmers regenerate their soil without losing seasonal income.

Government Support and Policy Integration

Soil Health Card Scheme: Can integrate cover crop recommendations based on test results.

National Mission on Sustainable Agriculture (NMSA): Supports on-farm trials and demonstrations for soil management.

PM-PRANAM Yojana: Incentivizes states for reducing fertilizer use, making cover crops a viable alternative.

ICAR and state agricultural universities are actively researching region-specific cover crop models. Scaling up adoption requires collaboration between researchers, policymakers, and farmer groups.

Conclusion

Cover crops are more than just a farming practice, they are a philosophy of working with nature to restore what we've lost. For Indian farmers, especially those struggling with degraded soils, erratic weather, and shrinking margins, living roots in the ground offer a low-cost, sustainable lifeline. As the country moves toward regenerative and climate-smart agriculture, cover crops will play a central role in reviving the health of our soils and securing the future of our farms.

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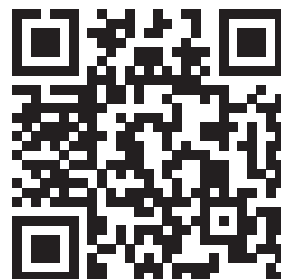
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