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A STEP TOWARDS AGRICULTURE

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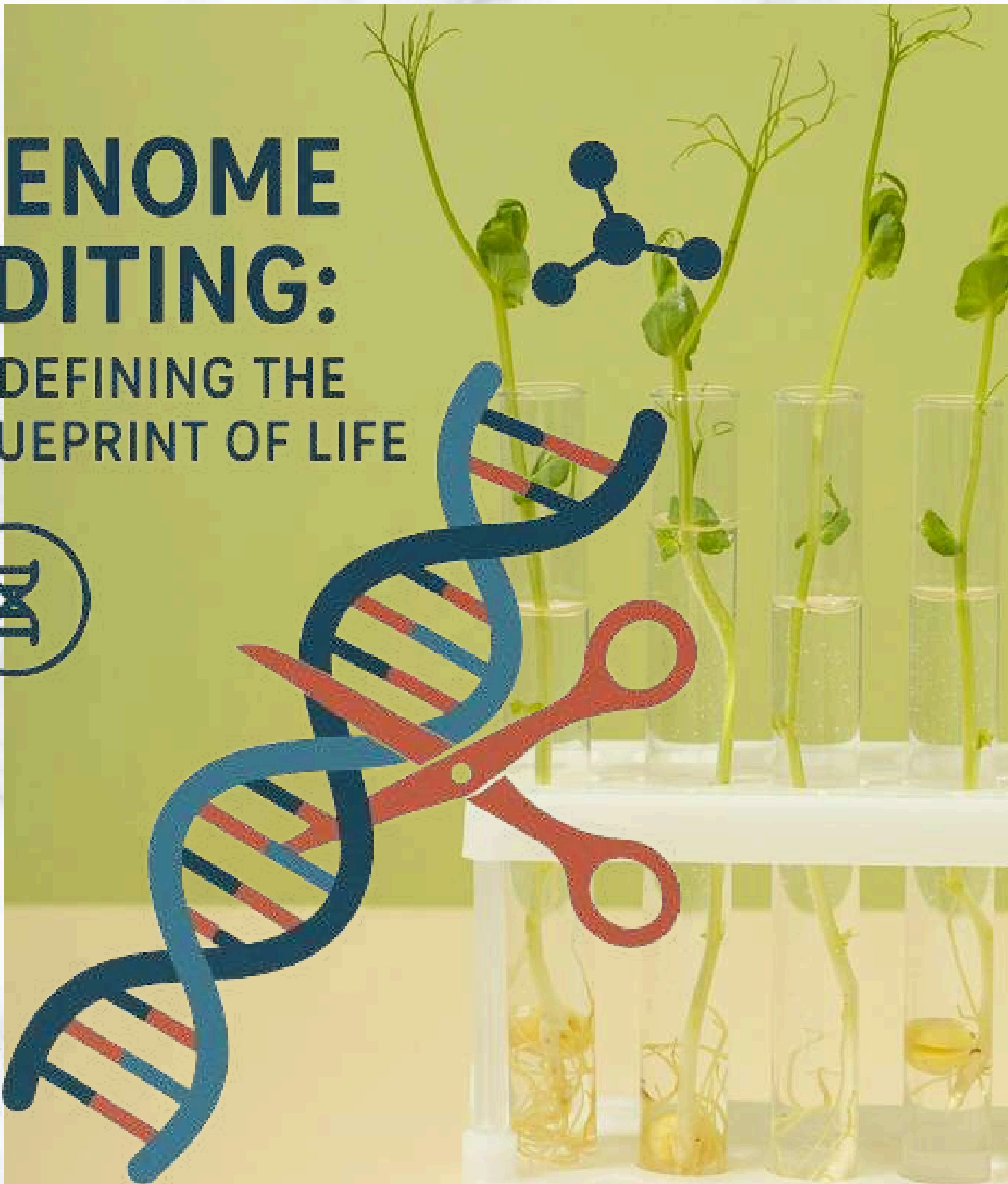
GENOME EDITING:

REDEFINING THE BLUEPRINT OF LIFE



"Genome editing is not just rewriting DNA”

"GENOME EDITING IS NOT JUST REWRITING DNA; IT'S REWRITING POSSIBILITIES FOR LIFE, HEALTH, AND THE FUTURE"

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The rapid advancements in genome editing are ushering in a new era of biological innovation, fundamentally transforming our understanding of life and its possibilities. Techniques like CRISPR-Cas9, TALENs, and zinc-finger nucleases have moved genome manipulation from a complex, time-consuming process to a precise, accessible, and cost-effective tool. This shift is not only redefining research in genetics but also revolutionizing agriculture, healthcare, and environmental sciences.

In agriculture, genome editing is fostering the development of high-yield, climate-resilient, and disease-resistant crops, offering sustainable solutions to global food security challenges.

Environmental applications, such as controlling vector-borne diseases or engineering microbes for bioremediation, further demonstrate its far-reaching potential.

However, this unprecedented power also brings profound ethical, ecological, and regulatory questions. Where should we draw the line between therapeutic interventions and genetic enhancement? How do we ensure equitable access and prevent misuse of this technology? These debates are critical as we navigate the balance between innovation and responsibility.

Dr. Deepak Kumar
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Genome Editing: Redefining the Blueprint of Life

ARTICLE ID: 0239

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The dawn of genome editing has opened an era where the very code of life can be read, rewritten, and redefined with precision. Unlike conventional breeding or genetic modification, which often rely on random or broad-scale changes, genome editing provides an unprecedented ability to target specific genes with surgical accuracy. This technology, epitomized by the CRISPR–Cas9 system, has rapidly transformed from a laboratory breakthrough into a cornerstone of modern biological research. Its promise spans diverse fields, from correcting genetic disorders in humans to engineering climate-resilient crops and even restoring ecological balance. At the same time, genome editing stirs debates on ethics, safety, and equitable access, reminding us that science never advances in isolation from society. As a rapidly evolving frontier, it challenges both scientists and policymakers to balance innovation with responsibility. Genome editing thus represents not just a technical revolution, but also a profound shift in how humanity interacts with nature at its most fundamental level.

Molecular Instruments of Genome Editing

a). CRISPR–Cas9: The Revolutionary Tool

Derived from bacterial immune systems, CRISPR–Cas9 has become the hallmark of modern genome editing. Guided by a synthetic RNA sequence, the Cas9 enzyme introduces targeted breaks in DNA, allowing researchers to modify, replace, or silence specific genes with remarkable accuracy.

b). TALENs (Transcription Activator-Like Effector Nucleases)

TALENs, an earlier technology, employ engineered proteins that recognize particular DNA sequences and induce site-specific cuts. While precise, they are more complex and less adaptable compared to CRISPR systems.

c). ZFNs (Zinc Finger Nucleases)

ZFNs represented the pioneering generation of genome editing tools. Although powerful, their design is intricate and costly, making them less favorable in the current landscape.

Applications Across Disciplines

1. Human Health and Medicine

Genetic Therapy: Disorders such as sickle-cell anemia, cystic fibrosis, and muscular dystrophy—once considered irreversible—may be corrected at their molecular root.

Oncology: Immune cells engineered via genome editing are being programmed to identify and destroy cancerous cells more effectively.

Vaccine Innovation: Genome editing accelerates the development of vaccines by streamlining antigen design and immune response studies.

2. Agriculture and Food Security

Enhanced Nutrition: Staple crops are being modified to contain higher levels of vitamins, minerals, and proteins, combating malnutrition.

Pest and Disease Resistance: Plants edited for resistance reduce dependency on chemical pesticides.

Climate Resilience: Crops adapted for drought tolerance, salinity resistance, and heat endurance are essential in the face of climate change.

3. Environmental Sustainability

Bioremediation: Engineered microorganisms can degrade pollutants, plastics, and toxic substances.

Biodiversity Conservation: Genome editing offers novel approaches to protect endangered species or control invasive populations.

Risk of Unintended Consequences

Although highly precise, genome editing is not infallible. Off-target modifications may produce unforeseen biological outcomes, necessitating robust safety protocols and regulatory oversight.

Examples

1. Crop Improvement

Disease-Resistant Rice

Researchers used CRISPR–Cas9 to knock out genes in rice that made it susceptible to bacterial blight (caused by *Xanthomonas oryzae*). The edited rice lines showed strong resistance without loss of yield.

Powdery Mildew-Resistant Wheat

By editing the MLO gene, scientists created wheat varieties resistant to powdery mildew, a widespread fungal disease.

Tomatoes with Longer Shelf Life

CRISPR-edited tomatoes were developed by targeting genes that control fruit ripening, delaying softening and extending shelf life.

High-Yield Maize

Genome editing was applied to modify regulatory genes controlling ear size and kernel number, leading to improved maize productivity.

Drought-Resistant Soybean

TALENs and CRISPR have been used to alter genes associated with water-use efficiency, helping soybean plants withstand drought stress.

2. Nutritional Enhancement

Tomatoes with Higher Lycopene Content

Genome editing boosted the nutritional value of tomatoes by enhancing lycopene, a compound linked with reduced cancer risk.

Rice with Higher Yield and Nitrogen Use Efficiency

Editing the DEP1 gene in rice improved grain number per panicle and made plants more efficient in nitrogen uptake.

CRISPR-Edited Bananas

Scientists are working on bananas enriched with vitamin A and resistant to Panama disease, a devastating fungal infection.

Seedless Fruits (Tomato & Watermelon)

By targeting specific genes related to seed development, researchers are producing seedless varieties that appeal to consumers.

Improved Oil Content in Rapeseed and Soybean

Genome editing modified fatty acid biosynthesis genes to create healthier oils with higher oleic acid content.

3. Environmental & Sustainable Agriculture

Herbicide-Tolerant Crops

CRISPR-edited rice and maize have been engineered for tolerance to herbicides, allowing more effective weed management.

Cassava Resistant to Mosaic Virus

CRISPR was applied to disrupt viral DNA in cassava, protecting it from cassava mosaic disease, a major threat in Africa.

Conclusion

Genome editing represents a watershed moment in the biological sciences. Its potential to reshape medicine, revolutionize agriculture, and restore ecological balance is extraordinary. Yet the power to alter the genetic fabric of life compels us to exercise caution, foresight, and collective wisdom. As we enter this new era of biological innovation, the challenge lies not only in advancing the science but also in ensuring that it serves humanity and the planet with fairness and integrity.

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Seasonal Incidence of Major Pests in Rice and Wheat

ARTICLE ID: 0240

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Rice (Oryza sativa) and wheat (Triticum aestivum) are the two most important staple food crops of India and the world. Together, they form the backbone of food security and rural livelihood. However, both crops are attacked by a wide range of insect pests at different growth stages, leading to considerable yield losses. The activity and abundance of these pests vary with seasons, cropping pattern, temperature, rainfall, and relative humidity. Understanding the seasonal incidence of pests is essential for forecasting outbreaks and adopting timely integrated pest management (IPM) strategies.

Seasonal Incidence of Major Pests in Rice

A. Rice Stem Borer (*Scirpophaga incertulas, Chilo suppressalis*)

Seasonal Incidence: Peak activity during July–October in Kharif season, coinciding with high humidity and moderate temperature. Two distinct peaks are seen: early infestation causes "dead hearts" in tillering stage, while later infestation at panicle initiation causes "white ears."

Favorable Conditions: Cloudy weather, intermittent rains, and continuous rice cultivation.

B. Brown Planthopper (BPH) (*Nilaparvata lugens*)

Seasonal Incidence: Appears from September onwards and reaches peak in October–November. In Rabi rice (Andhra Pradesh, Tamil Nadu), it peaks from December–February.

Favorable Conditions: High humidity (>70%), dense planting, excessive nitrogen use, and stagnant water.

C. Rice Leaf Folder (*Cnaphalocrocis medinalis*)

Seasonal Incidence: Most abundant during August–October in Kharif rice, especially at vegetative to booting stage.

Favorable Conditions: Humid and cloudy weather with moderate rainfall.

D. Gall Midge (*Orseolia oryzae*)

Seasonal Incidence: Occurs from July to September, particularly in rainfed and transplanted rice. Peaks coincide with the tillering stage of rice.

Favorable Conditions: Continuous wet spells and high humidity.

E. Rice Hispa (*Dicladispa armigera*)

Seasonal Incidence: Appears after the onset of monsoon in July–August and may persist up to October.

Favorable Conditions: High rainfall, excessive cloudiness, and young crop stage.

F. Rice Gundhi Bug (*Leptocorisa acuta*)

Seasonal Incidence: Incidence increases during September–October, coinciding with grain filling and milk stage.

Favorable Conditions: Warm and humid conditions, late planted rice fields.

Seasonal Incidence of Major Pests in Wheat

A. Wheat Aphids (*Rhopalosiphum maidis, Sitobion avenae*)

Seasonal Incidence: First appear in December–January and reach peak in February–March during grain filling.

Favorable Conditions: Cool and moist climate, excessive nitrogen use.

B. Armyworm (*Mythimna separata*)

Seasonal Incidence: Infestation starts in December, peaks in January–February, especially at the seedling and tillering stage.

Favorable Conditions: Cloudy weather and lush green crop fields.

C. Termites (*Odontotermes spp., Microtermes spp.)*

Seasonal Incidence: Active from sowing to maturity, but most destructive during November–January in irrigated and rainfed wheat.

Favorable Conditions: Warm soil moisture conditions and presence of crop residues.

D. Pink Stem Borer (*Sesamia inferens)*

Seasonal Incidence: Incidence starts from December and peaks in January–February. Larvae bore into stem causing dead hearts and white ears.

Favorable Conditions: Mild winter and continuous cropping system.

E. Shootfly (*Atherigona naqvii, A. oryzae*)

Seasonal Incidence: Severe during November–December on late sown wheat, causing dead hearts in seedlings.

Favorable Conditions: Late sowing, high temperature at germination stage.

Integrated Pest Management (IPM) Strategies

Timely Sowing: Adjusting sowing time of wheat (before 15th November) reduces shootfly attack.

Resistant Varieties: Use of pest-resistant varieties like stem borer-resistant rice and shootfly-tolerant wheat.

Field Sanitation: Removal of stubbles, alternate hosts, and maintaining clean bunds.

Biological Control: Egg parasitoid Trichogramma japonicum against rice stem borer. Predators like coccinellids and syrphid flies against wheat aphids.

Botanical Control: Use of neem seed kernel extract (NSKE 5%) and neem oil sprays for sucking pests.

Chemical Control

Rice: Imidacloprid, fipronil, chlorantraniliprole for stem borer and leaf folder.

Wheat: Imidacloprid seed treatment for termites, foliar sprays of dimethoate or thiamethoxam for aphids.

Conclusion

The seasonal incidence of pests in rice and wheat is closely linked with climatic conditions, crop stage, and agronomic practices. In rice, stem borers, planthoppers, leaf folders, gall midge, hispa, and gundhi bug are major pests with peak activity during the monsoon and post-monsoon months. In wheat, shootfly, termites, armyworms, pink stem borer, and aphids are important, with maximum incidence during the cool winter months (November–February). Understanding these seasonal patterns is critical for developing pest forecasting systems and implementing timely IPM measures. Adoption of eco-friendly strategies with minimal reliance on chemicals ensures sustainable crop production and food security.

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Nutraceutical Properties of Coriander: A Review of Health Benefits and Indian Prospects

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Coriander (*Coriandrum sativum*), commonly referred to as dhaniya in India, is one of the most extensively used herbs in Indian households. Traditionally cherished for its culinary applications, coriander has now emerged as a promising nutraceutical. Nutraceuticals, which are food components offering medical or health benefits, are gaining immense attention across India due to rising awareness of natural wellness approaches. Coriander possesses a rich phytochemical profile, including essential oils, vitamins, minerals, and antioxidants, all of which contribute to its medicinal value. This article explores the nutraceutical potential of coriander in the Indian context, emphasizing its nutritional profile, therapeutic applications, and future opportunities in the health and wellness sector.

India has a rich legacy of using herbs and spices for both culinary and therapeutic purposes. Among these, coriander (*Coriandrum sativum*), an annual herb from the Apiaceae family, has been an integral part of Indian kitchens and traditional healing systems such as Ayurveda. Native to the Mediterranean and Western Asian regions, coriander is cultivated widely in India for its seeds and fresh leaves. The recent boom in the global nutraceutical market has revived interest in ancient herbs, especially those with proven medicinal value. With the Indian nutraceutical market projected to reach USD 18 billion by 2025, there is an urgent need to explore native, easily accessible plants like coriander for functional food development. This article delves deep into coriander’ s journey from a spice to a scientifically validated nutraceutical. The term "nutraceutical" is derived from "nutrition" and "pharmaceutical." It was coined in 1989 by Dr. Stephen DeFelice and refers to food-derived substances that provide health benefits beyond basic nutrition. These products include dietary supplements, functional foods, and fortified products aimed at preventing or treating diseases. In India, where traditional medicine and natural healing have long-standing roots, nutraceuticals offer a bridge between modern science and age-old wisdom.

Botanical Overview and Cultivation in India

Coriander is an aromatic herb whose all parts are edible—seeds, leaves, and roots. It thrives in tropical to subtropical climates and is grown extensively in Rajasthan, Madhya Pradesh, Uttar Pradesh, Gujarat, and Andhra Pradesh. India ranks among the top producers and exporters of coriander seeds globally.

The seeds are oval, ridged, and yellow-brown, used whole or powdered in cooking. The fresh green leaves, known as cilantro, are widely used for garnishing and flavoring. Both parts contain bioactive compounds, making them significant from a nutraceutical standpoint. Nutraceuticals are particularly relevant today, with rising lifestyle-related diseases such as obesity, diabetes, cardiovascular issues, and mental health disorders.

Nutritional Profile of Coriander

Essential oils: Linalool, borneol, cineole, and geraniol contribute to aroma and therapeutic activity.

Vitamins: Rich in vitamin A, C, and K, coriander supports immune health, vision, and blood clotting.

Minerals: It provides calcium, magnesium, potassium, and iron essential for metabolic and bone health.

Bioactive Compounds: These include flavonoids (quercetin, rutin), phenolic acids, tannins, alkaloids, and saponins—all known for their antioxidant, anti-inflammatory, and antimicrobial activities.

Health Benefits and Nutraceutical Applications

Antioxidant Properties: Free radicals are unstable molecules that contribute to aging and chronic diseases. Coriander's flavonoids and polyphenols help neutralize these radicals, reducing oxidative stress. Studies have shown that coriander extract increases antioxidant enzymes like glutathione and superoxide dismutase, which are vital for cellular defense.

Digestive Support: Coriander has been used for centuries to treat indigestion, nausea, and flatulence. Its essential oils stimulate digestive enzymes, reduce spasms in the intestines, and relieve bloating. Ayurvedic texts classify coriander as a "pachak" (digestive), commonly used in home remedies such as coriander seed water for stomach ailments.

Anti-Diabetic Effects: Scientific studies suggest that coriander seeds can help regulate blood sugar levels. Linalool and other phytochemicals in coriander enhance insulin secretion, improve glucose uptake by cells, and inhibit enzymes responsible for carbohydrate breakdown. This makes coriander particularly beneficial in managing Type 2 diabetes, which is a growing concern in India.

Cholesterol and Heart Health: Animal studies have demonstrated that coriander seed powder can lower LDL (bad cholesterol) and triglyceride levels while increasing HDL (good cholesterol). This lipid-regulating effect is attributed to its antioxidant and hepatoprotective action, making coriander supportive of cardiovascular health.

Antimicrobial Action: Coriander oil exhibits significant antibacterial and antifungal properties. It can inhibit common foodborne pathogens like *E. coli*, *Salmonella*, and *Staphylococcus aureus*. This makes coriander valuable in food preservation, natural cosmetics, and herbal formulations aimed at skin infections.

Liver Detoxification: The liver is the body's detox hub, and coriander assists in cleansing it. Its active compounds boost bile secretion, improve liver enzyme levels, and help flush out heavy metals such as mercury and lead from the body. Regular consumption of coriander leaves in salads or juices is a simple way to support liver health.

Neuroprotective Effects: Emerging research shows that coriander extracts may have protective effects on the brain. The antioxidants in coriander can help prevent neurodegenerative diseases like Alzheimer's by reducing amyloid plaque formation and protecting neurons from oxidative damage.

Current Market and Consumer Trends in India

The rise in organic farming, clean-label products, and Ayurvedic supplements has made coriander a focus for both domestic and international nutraceutical companies. Brands are incorporating coriander into teas, digestive tablets, detox waters, and herbal powders. Urban consumers, especially in metro cities, are more health-conscious and willing to explore herbal alternatives. The Indian government has also launched initiatives like the Ayushman Bharat scheme and the Ministry of AYUSH to promote traditional healing systems. These programs are providing a boost to herbs like coriander by funding clinical trials, research, and product development.

Conclusion

Coriander is more than just a flavorful herb it is a powerhouse of nutrients and medicinal compounds that make it an ideal nutraceutical. Its traditional use in Indian households, combined with modern scientific validation, positions coriander as a bridge between culture and innovation. With increasing health consciousness, support from the nutraceutical industry, and government encouragement for natural remedies, coriander's transformation from a spice to a health supplement is not only timely but necessary. Harnessing its full potential requires multidisciplinary research, awareness campaigns, and standardization of production. As India strides forward in health and wellness, coriander could well be one of the leading symbols of our return to roots through science-backed nutrition.

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Zero Energy Cool Chamber: Affordable Storage for Small-Scale Farmers

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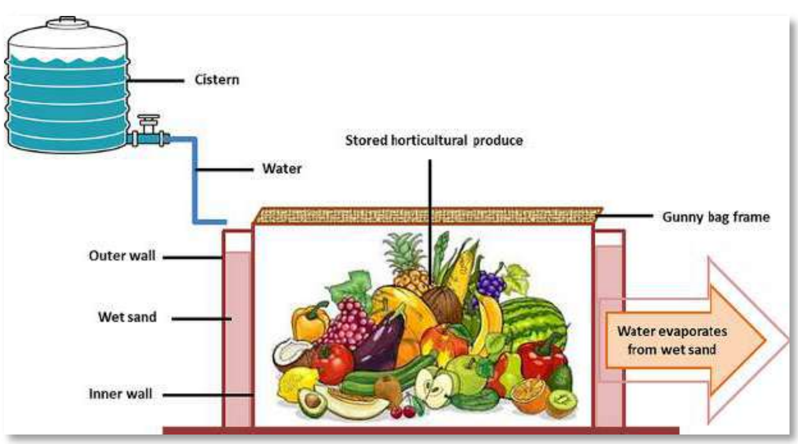
Horticultural produce is inherently perishable and begins to deteriorate immediately after harvest. In India, a tropical country, post-harvest losses of fruits and vegetables are particularly significant. The lack of adequate storage and processing infrastructure results in a considerable proportion of produce being spoiled after harvesting. Given that most Indian farmers have small landholdings, they are compelled to sell their produce promptly, as refrigeration often required for effective storage is prohibitively expensive. To address this challenge, a low-cost refrigeration chamber was developed by IARI Pusa, New Delhi (Roy and Khurdiya, 1983). In many developing countries, more than 40 percent of losses occur at various points along the post-harvest supply chain, reducing the per capita availability of fruit to approximately 80 grams per day about half the amount recommended for a balanced diet. The Zero Energy Cool Chamber (ZECC) does not require electricity and can be installed on farms. Operating on the principle of evaporative cooling, the ZECC reduces spoilage by lowering temperature and raising relative humidity. Although the technology was introduced some time ago, efforts to promote this affordable on-farm storage solution have gained momentum only recently. It lowers the temperature and raises humidity within the chamber, which can help extend the shelf life of fruits and vegetables without the need for electricity.



Construction of ZECC

Zero energy cool chambers can be readily assembled with locally available resources. For a 100 kg capacity chamber, approximately 400 bricks are necessary, along with sand, bamboo, khas-khas or other grasses for the top cover, a thatched shed, a water tank, pipes, tubes, poly sheet for water supply, and 5–6 perforated plastic crates to store horticultural products. Labour is also required for construction. The following steps outline the recommended procedure for building the chamber:

- Begin by identifying an elevated area or floor that has access to water supply.
- The ZECC floor should have dimensions of 165 cm x 115 cm and be constructed with bricks.
- Construct a double brick wall with a height of 67.5 cm, leaving a 7.5 cm gap between the two walls for river sand filling.
- Uniformly textured riverbed sand, soaked with water, can be used to fill the cavity between the double walls.
- Cover the top of the structure with bamboo straw or other locally sourced materials to protect the chamber from direct sunlight or rainfall.

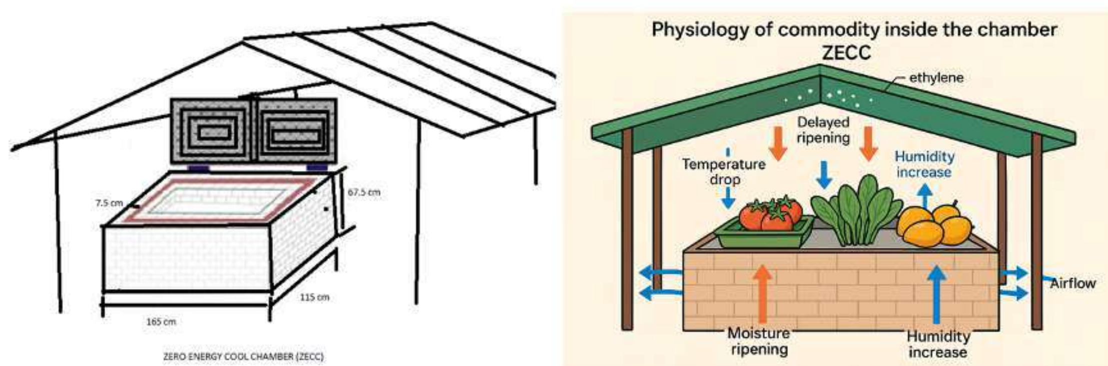


Fig. 1 An image showing dimensions and physiology of commodity placed in ZECC

Guidelines for Optimising Chamber Performance

- Keep the sand, bricks, and top cover of the chamber moist by watering twice daily once in the morning and once in the evening or by installing a drip irrigation system to help achieve the desired temperature and humidity.
- Cover crates with polyethylene sheets.
- The cool chamber should be rebuilt every three years using new bricks.

Both temperature and relative humidity are critical factors in storing fruits and vegetables. While temperature predominantly influences the rate at which fresh produce deteriorates, maintaining appropriate humidity levels during storage is also essential. The ZECC can be easily constructed by farmers using locally sourced materials such as grasses, leaves, bamboo, sand, and bricks. This system preserves vegetable freshness for 7–12 days, enabling farmers to access wholesale markets and thus avoid loss-making local sales through intermediaries.

The National Horticulture Board offers grants for constructing this type of chamber. It is suitable for storing a variety of crops such as citrus fruits, bananas, potatoes, tomatoes, and onions (with no water supplied during the rainy season). In apple-growing regions, these chambers are also used postharvest until apples are sold. Studies indicate that the shelf life of horticultural products increases significantly when stored in ZECC compared to room temperature. For example, storage durations observed include:

cauliflower (12 days), peas (10 days), turnip (10 days), potato (97 days), carrot (12 days), pointed gourd (5 days), okra (6 days), and amaranth (3 days). For fruits: kinnow (60 days), guava (15 days), grapefruit (70 days), lime (25 days), mango (9 days), sapota (14 days), banana (20 days), and aonla (18 days). It works best in hot and dry climates where evaporative cooling is most efficient. Root and bulb crops like onions and garlic are not ideal for ZECC due to their preference for dry conditions.

Recommended ZECC Storage Conditions for Common Fruits and Vegetables

Produce (Fruits and Vegetables)	Temp (°C)	R H (%)
Tomato, Brinjal, Chili, Okra, Leafy greens, Potato	12–15	85–95
Onion and Garlic	ZECC not ideal for storage	
Mango, Papaya, Banana, Guava, Lime	10–15	85–90

Conclusion

This zero energy cooling chamber (ZECC) is a low-cost structure that can lower temperatures by 10–15°C and maintain relative humidity up to 95%. It has been shown to extend the shelf life and preserve the quality of stored produce. Therefore, removing field heat and applying cooling soon after harvest can increase the storage life of horticultural products. ZECCs may be considered an alternative to high-cost refrigeration chambers for small-scale farmers and contribute positively to environmental sustainability. Proper installation and usage can provide practical storage solutions for marginal farmers.

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Insect Pests of Mango and Their Control

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Mango (Mangifera indica L.) is one of the most important tropical fruit crops, widely cultivated for its delicious taste, nutritional value, and economic importance. However, the productivity of mango is severely affected by several insect pests which damage flowers, leaves, shoots, and fruits. These pests not only reduce yield but also deteriorate fruit quality. Hence, understanding their biology and adopting proper control measures is essential for sustainable mango cultivation.

Major Insect Pests of Mango

1. Mango Hopper (*Idioscopus spp.*)

Scientific Classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Hemiptera

Family: Cicadellidae

Nature of Damage: Both nymphs and adults suck sap from inflorescences, causing drying of flowers and poor fruit set. Their sugary excreta encourages sooty mold growth, which reduces photosynthesis.

Control Measures: Spraying of neem oil (3%) during flowering. Application of Imidacloprid (0.005%) or Thiamethoxam (0.01%). Orchard sanitation and pruning to improve aeration.

2. Mango Fruit Fly / Seed Weevil (*Sternochetus mangiferae*)

Scientific Classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Curculionidae

Nature of Damage: The grub bores into developing fruits and feeds on the seed kernel, leading to premature fruit drop and internal rotting.

Control Measures: Collecting and destroying fallen fruits. Bagging of young fruits. Spraying of Carbaryl (0.2%) or Lambda-cyhalothrin (0.01%) before fruit maturity.

3. Mango Mealybug (*Drosicha mangiferae*)

Scientific Classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Hemiptera

Family: Pseudococcidae

Nature of Damage: Both nymphs and adults suck sap from shoots and inflorescences, causing wilting and flower drop. Honeydew secretion supports the growth of sooty mold.

Control Measures: Installation of grease bands on tree trunks to prevent upward movement of nymphs. Release of predators like Cryptolaemus montrouzieri. Spraying of Dimethoate (0.05%) in case of severe attack.

4. Mango Stem Borer (*Batocera rufomaculata*)

Scientific Classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Cerambycidae

Nature of Damage: Grubs bore deep tunnels inside stems and branches, causing drying of twigs and, in severe cases, death of the tree.

Control Measures: Cutting and burning of infested branches. Injection of Dichlorvos or kerosene into boreholes, followed by mud sealing. Maintenance of orchard hygiene.

Integrated Pest Management (IPM)

For effective and eco-friendly control, IPM practices should be adopted, which include:

- Regular monitoring of pest populations.
- Use of neem-based biopesticides.
- Encouragement of natural enemies.
- Cultural practices such as pruning, sanitation, and timely irrigation.
- Need-based application of chemical insecticides.

Conclusion

Mango cultivation is threatened by a wide range of insect pests, among which mango hoppers, fruit flies, mealybugs, and stem borers are the most destructive. Effective management requires an integrated approach combining cultural, biological, and chemical methods. Adoption of Integrated Pest Management (IPM) not only ensures better control of pests but also promotes sustainable and profitable mango production.

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The Agricultural Significance of Cow Dung and Urine: A Scientific Insight

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Cow dung and cow urine are vital by-products of livestock rearing, playing a crucial role in sustainable agriculture. These organic resources are rich in diverse microorganisms, including bacteria, fungi, actinomycetes, and protozoa, which contribute significantly to ecological balance and agricultural productivity. The microflora present in cow dung and urine enhances soil fertility, facilitates nutrient cycling, and suppresses plant pathogens, making them integral components of organic farming and sustainable agroecosystems. Cow dung is particularly abundant in cellulose-degrading bacteria that accelerate the decomposition of organic matter, while cow urine harbours nitrogen-fixing and antimicrobial microorganisms. Together, they form an efficient, natural nutrient-recycling system essential for maintaining soil health and crop productivity. Microorganisms isolated from cow dung are extensively applied in the production of biofertilizers, biopesticides, and composting agents. Likewise, cow urine is valued for its therapeutic properties and has been traditionally utilized for its antimicrobial and bioenhancing potential.

Cow Dung

Cow dung, the undigested residue excreted by herbivorous bovines, is a mixture of faeces and urine in a 3:1 ratio. It primarily contains lignin, cellulose, and hemicellulose, along with 24 minerals, including nitrogen, potassium, and trace amounts of sulphur, iron, magnesium, copper, cobalt, and manganese. In Ayurveda, it is valued as a natural purifier and finds applications in agriculture, energy production, environmental conservation, and therapeutics. Notably, dung from indigenous cattle contains higher levels of calcium, phosphorus, zinc, and copper compared to crossbred cattle.

Microbial Diversity and Agricultural Benefit

Cow dung harbours diverse microbial populations, including bacteria, fungi, and protozoa. These microorganisms contribute significantly to soil health by promoting nutrient mobilization and plant growth.

- **Phosphorus and Zinc Solubilization:** Microbial genera such as Sphingomonas, Gemmatimonas, Pseudomonas, Bradyrhizobium, and *Bacillus subtilis* are utilized in phosphorus solubilisation. For zinc solubilization, species like *Bacillus megaterium* and *Pseudomonas kilonensis* play a vital role.
- **Sulfur Oxidation:** Bacteria, including species from Hydrogenophaga and *B. subtilis* are effective in sulfur oxidation, aiding plant nutrient uptake.
- **Growth-Promoting Compounds:** *Bacillus amyloliquefaciens*, *B. subtilis*, and *Lysinibacillus xylanilyticus* contribute to the production of indole-3-acetic acid (IAA), a critical plant hormone.

Biocontrol and Disease Resistance

Microbial species present in cow dung exhibit strong biocontrol properties. Fungi like *Aspergillus niger* and *Trichoderma harzianum*, as well as bacteria such as *Bacillus cereus*, inhibit seedling blight in crops like cowpea and maize. Additionally, *B. subtilis* is effective against pathogens such as *Fusarium oxysporum* and *Botryodiplodia theobromae*.

Bioremediation Potential

Cow dung microflora exhibits the capacity to degrade both organic and inorganic pollutants, making it an eco-friendly solution for environmental restoration. Microbial species such as Pseudomonas, Bacillus, and Aspergillus are effective in breaking down petroleum derivatives, agricultural pesticides, and biomedical waste. Fungal species like Periconiella have shown remarkable efficiency in decomposing biomedical waste, while cow dung slurry aids in the remediation of harmful agrochemicals.

Therapeutic Applications

Cow dung is a key constituent of the traditional *Panchgavya* and has been reported to possess therapeutic properties against ailments such as cancer and diabetes. The bacterium *Mycobacterium vaccae*, isolated from cow dung, exhibits anti-depressant activity and shows potential in the treatment of asthma, cancer, and leprosy. Additionally, cow dung serves as a substrate for the production of fibrinolytic enzymes with established applications in cardiovascular therapy.

Biogas Production

Cow dung is a vital resource for biogas production, generating sufficient fuel to meet the cooking needs of an average family. Microbes like Methanosarcina and Methanobrevibacter play pivotal roles in methane production, contributing to renewable energy solutions (Kusmiyati et al., 2023).

Food Preservation

Lactic acid bacteria (LAB) derived from cow dung, including *Bacillus smithii* and *Lactobacillus equigenerosi*, exhibit antimicrobial properties and potential as natural food preservatives. Bacteriocin production by these bacteria ensures safer, chemical-free food preservation (Dhiman et al., 2021).

Table1: Comparison of soil properties with addition of dung

Characteristics	Dung	Dung + Soil (1:3)
pH	5.10	6.50

OC (%)	37.10	40.20
N (ppm)	40.10	86.30
P (kg/ha)	121.00	135.30
K (g/kg)	0.276	0.997
Moisture (%)	68.00	71.00

(Dhiman et al., 2021)

Cow Urine

- Cow urine, or "Gomutra," has long been recognized in traditional Ayurvedic medicine for its germicidal, antibiotic, and antimicrobial properties. Scientific studies have highlighted its ability to inhibit harmful pathogens like *Salmonella typhi*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus epidermidis*, and *Streptococcus pyogenes*.
- On average, a healthy cow excretes 6-10 litres of urine per day. Thus, two cows can produce approximately 4,380 litres of urine annually, contributing about 65 kg of nitrogen, equivalent to roughly 136 kg of urea, making it a valuable input for sustainable farming systems.
- Nutrient cycling via cow urine is significant, as cows retain only about 20% of their nitrogen intake, excreting approximately 52% in urine and 28% in dung. Owing to its low carbon content and high nutrient concentration, cow urine serves as an effective natural fertilizer, enhancing crop health and productivity while reducing reliance on synthetic agrochemicals.

Table 2: Physicochemical and Bioactive Properties of Cow Urine

S. No.	Constituents	Concentration
1.	pH	7.4–8.4
2.	Specific gravity	1.025–1.045
3.	EC	>23.7 mS/cm
4.	Urea nitrogen	23,000–28,000 mg/L per day
5.	Total nitrogen	6800–21,600 mg/L per day
6.	Ammonia nitrogen	1000–1700 mg/L per day
7.	Allantoin	770–3400 mg/L per day
8.	Calcium	100–140 mg/L per day
9.	Chloride	10–110 mg/L per day
10.	Creatinine	15–20 mg/L per day
11.	Phenols	4.7580 mg/100 mL
12.	Urea	440 mg/L
13.	Hippuric acid	5.96–8.93 mg/L

14.	Total phosphorus	305 mg/L
15.	Amylase	90.236 units
16.	Magnesium	3.7 mg/L per day
17.	Potassium	14.4–27 mg/L per day
18.	Sodium	4300–6100 mg/L per day
19.	Ammonia	20mg/L
20.	Sulfate	3-5 mg/L per day
21.	Uric acid	150-530 mg/L per day
22.	Leucocyte	<15 µL

(Devasena and Sangeetha, 2022)

Agricultural Benefits of Cow Urine

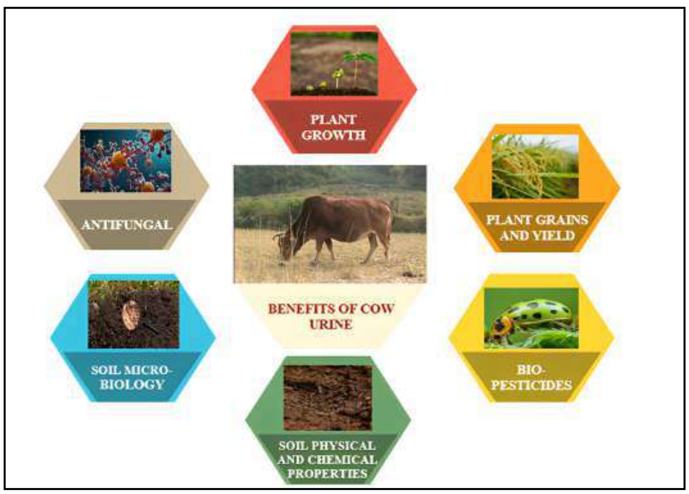

Fig. 1: Benefits of Cow Urine

Plants growth

Cow urine is a potent bioresource for enhancing soil fertility, crop productivity, and quality. A study conducted in Sikkim reported that its application significantly improved growth parameters of buckwheat (*Fagopyrum esculentum*), yielding values of 116.2 cm plant height, 0.64 cm stem girth, 13.5 leaves per plant, 12.6 cm root length, 102 seeds per plant, and a test weight of 22.4 g.

Bio Pesticides

Cow urine, when enriched with neem leaves, serves as an effective biopesticide. These natural biopesticides are environmentally safe, do not persist in the food chain, and mitigate the adverse effects associated with synthetic chemical pesticides.

Soil Physical and Chemical Properties

A field experiment in Nepal demonstrated that foliar application of nitrogen at 150 kg/ha using cow urine yielded the highest soil pH (6.0), organic matter content (5.43%), available phosphorus (147 kg/ha), and nitrogen (0.31%), all significantly higher than the control (Sharma et al., 2016).

Soil Microbiology

Cow urine has a significant effect on soil microbial population. A study conducted in Karnataka showed that the application of FYM at 12.5 t/ha combined with cattle urine at 34,300 L/ha significantly increased the soil microbial population, including bacteria (47.0 × 10^5 cfu/g), fungi (34.6 × 10^4 cfu/g), and actinomycetes (40.0 × 10^3 cfu/g) (Veeresha et al., 2014).

Antifungal Properties

Cow urine exhibits antifungal activity, inhibiting the growth of *Fusarium oxysporum*, *Rhizoctonia solani*, and *Sclerotium rolfsii*.

Conclusion

Cow dung and cow urine play a pivotal role in sustaining microbial diversity and promoting soil health. Their rich microbial communities facilitate nutrient cycling, enhance soil fertility, and stimulate plant growth. These microorganisms also accelerate the decomposition of organic matter, thereby improving soil structure and increasing water-holding capacity. Additionally, the microbial properties of cow dung and urine offer valuable applications in sustainable agriculture, composting, and organic farming systems. A comprehensive understanding of their microbial significance is essential for advancing eco-friendly agricultural practices and fostering long-term environmental sustainability.

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Transformative Role of Remote Sensing in Advancing Horticulture: Optimizing Sustainability, Efficiency and Resilience

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Remote sensing has become a cornerstone in advancing horticulture, offering innovative approaches to optimize sustainability, efficiency and resilience. By employing satellite data, unmanned aerial vehicles (UAVs) and multispectral and hyperspectral sensors, remote sensing provides precise and timely insights into crop growth, soil moisture, nutrient dynamics and pest infestations. These technologies facilitate precision horticulture by enabling site-specific interventions that reduce input costs, enhance water-use efficient and minimize environmental impacts. In addition, remote sensing plays a vital role in climate-smart horticulture, offering early warning systems for drought, floods and disease outbreaks, thereby enhancing adaptive capacity and reducing risks to farmers' livelihoods. Integration with Geographic Information Systems (GIS), machine learning and artificial intelligence further strengthens predictive modelling, allowing for better yield forecasting, sustainable resource allocation and long-term planning. The application of remote sensing also extends to post-harvest management, quality monitoring, and supply chain optimization, ensuring higher profitability and food security. As demand for high-value horticultural crops continues to grow, remote sensing provides an indispensable pathway for achieving productivity while safeguarding natural resources. This paper explores how remote sensing technologies are reshaping horticultural practices to meet global challenges of sustainability and resilience in the 21st century.

Horticulture, which encompasses the cultivation of fruits, vegetables, flowers, plantation crops, and spices, is central to food and nutritional security. It provides not only essential dietary components but also contributes significantly to farmer incomes and rural livelihoods. However, horticultural systems are increasingly challenged by climate change, land degradation, water scarcity and rising global demand for high-quality produce. To address these challenges, technological interventions are essential.

Remote sensing (RS), which refers to the acquisition of information about the Earth's surface without direct contact through satellites, drones, or advanced sensors, has emerged as a transformative tool in agriculture. In horticulture, RS plays a crucial role in improving productivity, conserving resources, and enhancing resilience against climatic uncertainties. When combined with Geographic Information Systems (GIS), Internet of Things (IoT), and Artificial Intelligence (AI), RS enables precision horticulture by offering insights into crop health, soil conditions, water status, and pest or disease outbreaks.

This article highlights how RS optimizes sustainability, efficiency and resilience in horticultural systems, supported by recent scientific evidence.

Remote Sensing for Sustainability

Water Management and Irrigation Efficiency

Water scarcity is a major constraint in horticulture. Conventional irrigation often results in wastage, while crops like grapes, citrus, and vegetables require precise water scheduling. Remote sensing techniques such as multispectral and thermal imaging provide insights into evapotranspiration, canopy temperature, and soil moisture variations. For instance, the Crop Water Stress Index (CWSI) derived from thermal imagery is used to identify water-stressed areas in orchards, enabling site-specific irrigation (Kharrou *et al.,* 2021). Microwave-based sensors like Synthetic Aperture Radar (SAR) also estimate soil moisture even under cloudy conditions (Das & Paul, 2020). Such applications contribute to water savings of up to 30%, improving sustainability.

Soil Health and Nutrient Management

Healthy soils are the foundation of sustainable horticulture. Hyperspectral RS enables the assessment of soil organic matter, salinity, and nutrient deficiencies by analyzing reflectance in specific bands (Thenkabail et al., 2016). Nutrient stress detection, particularly nitrogen and potassium, allows growers to apply fertilizers only where needed, minimizing excess application and reducing environmental pollution. When integrated with GIS, RS data generates fertility maps that support precision fertilization, leading to cost savings and reduced ecological footprint (Aggarwal *et al.,* 2021).

Environmental Benefits

Precision interventions supported by RS lower the dependence on fertilizers and pesticides. For example, UAV-based imaging in vineyards enabled a 40–50% reduction in pesticide usage by detecting localized disease stress (Baluja *et al.,* 2012). This minimizes chemical residues in horticultural produce and reduces contamination of soil and water ecosystems, thereby improving environmental sustainability.

Remote Sensing for Efficiency

Crop Health Monitoring and Disease Detection

Early detection of biotic stresses is vital for horticultural crops, which are often highly perishable and sensitive. Hyperspectral imaging can identify disease symptoms and physiological changes before they become visible, enabling timely interventions (Mahlein, 2016). Machine learning models using RS data achieved over 90% accuracy in identifying diseases in orchards (Lu & Wang, 2020). This ensures precise management, reducing crop losses and input costs.

Yield Estimation and Forecasting

Accurate yield predictions help farmers and policymakers plan harvesting, storage, and market supply chains. RS-based vegetation indices such as NDVI (Normalized Difference Vegetation Index), EVI (Enhanced Vegetation Index), and LAI (Leaf Area Index) strongly correlate with crop biomass and fruit yield (Boegh *et al.,* 2013). In apple orchards in Himachal Pradesh, RS combined with climatic data predicted yields with >85% accuracy, improving resource allocation (Sharma *et al.,* 2020). Similar techniques are applied in mango, banana, and citrus cultivation for harvest planning.

Crop Mapping and Land Use Zoning

Mapping crop distribution is important for optimizing land use and guiding policy decisions. RS and GIS have been applied in Andhra Pradesh, India, to map potential mango-growing areas using high-resolution imagery (Rao *et al.,* 2018). This ensures expansion in agro-ecologically suitable zones, thereby enhancing both efficiency and long-term sustainability.

Remote Sensing for Resilience

Climate Adaptation and Risk Management

Horticultural crops are highly vulnerable to climate extremes such as drought, frost, and storms. Remote sensing improves resilience by monitoring climatic variability and providing early warning signals. For example, MODIS-derived NDVI and Temperature Condition Index (TCI) are used to monitor drought impacts on horticultural systems in Africa, enabling adaptive management (Gebrehiwot *et al.,* 2016). Such applications allow farmers to adjust irrigation, adopt protective measures, and shift planting dates.

Democratization for Smallholders

RS applications are no longer confined to large-scale commercial farms. Free satellite data (Sentinel, Landsat) and low-cost drone technologies have made RS accessible to smallholder farmers. Platforms like Farmonaut in India provide smartphone-based RS services for monitoring crop health, soil moisture, and pest risks (Kumari & Singh, 2022). By empowering smallholders, RS enhances resilience and inclusivity in horticulture.

Post-Disaster Assessment

Extreme weather events often damage horticultural crops, resulting in economic losses. RS facilitates rapid post-disaster assessments, helping in compensation and insurance planning. For example, NDVI anomalies derived from satellite imagery were used to estimate flood damage in fruit orchards, ensuring quick relief distribution (Kogan *et al.,* 2019).

Emerging Innovations in Remote Sensing

Integration with Artificial Intelligence

Deep learning and AI models are increasingly applied to RS datasets for disease detection, yield forecasting, and stress classification. Hyperspectral RS combined with AI achieved over 95% accuracy in detecting grapevine diseases, enabling proactive management (Kamilaris & Prenafeta-Boldú, 2018).

LiDAR and 3D Canopy Mapping

Light Detection and Ranging (LiDAR) provides 3D canopy measurements that estimate fruit load, canopy volume, and pruning requirements. Such applications are valuable in orchards like citrus and apples, where canopy management is key to productivity (Wallace *et al.,* 2016).

Ground-Penetrating Radar and Thermal Imaging

Ground-Penetrating Radar (GPR) is emerging as a tool to assess below-ground root systems and soil compaction, which are crucial in perennial horticultural crops (Lal & Shukla, 2021). Meanwhile, thermal sensors provide canopy temperature data for heat-stress management in crops such as strawberries and lettuce.

Bee-Inspired UV Remote Sensing

Novel systems inspired by pollinator vision use UV-sensitive cameras to detect flower density in crops like strawberries, assisting in pollination management (Collett *et al*., 2022). Such technologies highlight the future direction of RS in integrating biological insights with digital tools.

Conclusion

Remote sensing has transformed horticultural practices by enabling sustainability through resource efficiency, productivity through precision monitoring, and resilience against climatic variability. Its applications in water management, soil health, disease detection, yield estimation, and disaster recovery are reshaping how horticultural crops are cultivated and managed. The democratization of RS technologies through open-source data, drones, and mobile platforms ensures that even smallholders benefit from these advances. Future prospects involve multi-sensor integration (optical, thermal, LiDAR, microwave), AI-driven analytics and blockchain-based applications for supply chain transparency. As the world moves towards sustainable food systems, remote sensing stands as a cornerstone of climate-smart horticulture.

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Lisianthus: A Profitable Cut Flower Crop with Modern Cultivation Practices

ARTICLE ID: 0246

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Introduction

- Lisianthus (*Eustoma grandiflorum*), also called *prairie gentian* or *Texas bluebell*, is a high-value cut flower crop.
- Native to North America (prairies of Texas, Mexico).
- Popular due to its rose-like blooms, wide color range (white, pink, blue, purple, bicolor), and long vase life (10–15 days).
- Cultivated mainly for cut flowers, potted plants, and bedding decoration.

Climatic Requirements

- **Temperature:** Optimal 20–25 °C (day), 15–18 °C (night). Sensitive to high temperatures (>30 °C).
- **Light:** Long-day plant; requires 14–16 hrs light for flower initiation. Supplemental lighting may be needed in winter.
- **Humidity:** 60–70% RH is ideal.
- Sensitive to sudden temperature fluctuations.

Soil / Growing Media

- Well-drained sandy loam or peat-based substrates.
- **pH:** 6.0–6.8 (slightly acidic).
- EC: 1.2–1.8 mS/cm.
- Raised beds (1–1.2 m wide) with good drainage recommended.
- **Common Potting Mixture:** Cocopeat + perlite + vermiculite (3:1:1).

Propagation

- Seed propagation (main method).
- Tiny seeds (≈20,000 seeds/g), often pelleted for easy sowing.
- Germination takes 10–15 days at 22–25 °C.
- Seeds need light for germination (do not cover deeply).
- Seedling stage: 8–10 weeks in plug trays before transplanting.
- Vegetative propagation is rarely used due to poor rooting.

Planting

- Transplant seedlings (6–8 true leaves) to main field or greenhouse.
- Spacing: 15 × 15 cm (intensive cut flower culture) or 20 × 20 cm (open field).

- Support netting required for tall cultivars.
- Crop duration: 5–6 months from sowing to harvesting.

Nutrient Management

- **Basal Application:** Well-decomposed FYM (20 t/ha) + NPK (12:12:12) before transplanting.
- **Fertigation (Per Crop Cycle)**
  N: 180–200 kg/ha
  P: 60–80 kg/ha
  K: 180–200 kg/ha
- Micronutrients: Foliar sprays of Ca, Mg, Fe, and B improve flower quality.
- Balanced nutrition prevents physiological disorders (e.g., bud drop).

Irrigation

- Requires frequent light irrigation; avoid waterlogging.
- Drip irrigation + fertigation is recommended.
- Mulching conserves soil moisture and reduces weeds.

Growth Regulation

- Pinching usually not practiced (single stem crop).
- GA_3 sprays (50–100 ppm) enhance stem elongation.
- CCC (chlormequat chloride, 500–1000 ppm) controls excessive height in pot plants.

Pest and Disease Management

Pests: Aphids, thrips, whiteflies, leaf miners.

Management: Yellow sticky traps, neem oil, biological control (predatory mites), systemic insecticides if needed.

Diseases

- *Botrytis cinerea* (grey mold) – avoid high humidity, fungicide sprays.
- Fusarium wilt – soil sterilization, crop rotation.
- Pythium root rot – good drainage, fungicide drenching.
- Viral diseases (TSWV, INSV) spread by thrips – strict vector control.

Harvesting

- Flowers harvested at 1–2 open buds stage for long vase life.
- Harvesting time: Early morning or late evening.
- Stems should be cut with sharp knives and immediately placed in clean water.
- Yield: 150,000–200,000 stems/ha under good management.

Postharvest Handling

- Remove lower leaves before bunching.
- Use floral preservatives (sucrose + germicides) to extend vase life.
- Storage at 2–4 °C with 90% RH possible for 2–3 weeks.
- Grading based on stem length, bud size, and color.

Commercial Uses

- Cut flowers for bouquets and floral arrangements.
- Potted plants (dwarf cultivars).
- Landscaping and garden displays.

Conclusion

Lisianthus (*Eustoma grandiflorum*) has emerged as a premium cut flower in global floriculture due to its rose-like beauty, wide color range, and long vase life. Successful commercial cultivation requires precise management of climate, light, and nutrient supply, as the crop is highly sensitive to environmental fluctuations. The adoption of advanced production technologies such as protected cultivation, fertigation, photoperiod manipulation, and tissue culture propagation ensures uniform growth, higher yields, and year-round availability. Integrated pest and disease management further enhances quality and reduces postharvest losses. With increasing demand in domestic and international markets, lisianthus cultivation holds great potential as a profitable venture, especially under controlled conditions. Continuous research on improved varieties and sustainable production practices will strengthen its role as a key flower in the cut flower industry.

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Use of Biopesticides in Spice Crops

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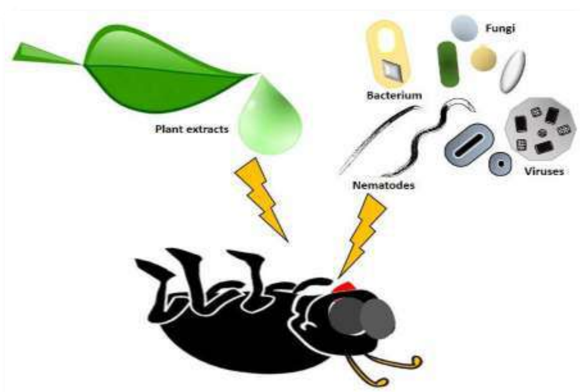
Spices occupy an integral place in Indian and global agriculture due to their wide use in culinary, medicinal, and industrial applications. India, being the "Land of Spices," is the largest producer, consumer, and exporter of spices such as black pepper, cardamom, turmeric, ginger, coriander, cumin, chili, clove, nutmeg, and fennel. However, spice crops are highly vulnerable to insect pests, diseases, and nematodes that significantly reduce yield and quality. Conventional chemical pesticides, though effective, have resulted in pesticide residues, pest resistance, and environmental degradation. In this context, biopesticides have emerged as sustainable alternatives. Derived from natural organisms such as bacteria, fungi, viruses, nematodes, and plants, biopesticides offer eco-friendly and safe pest management solutions. Their use is gaining importance in spices, where export markets demand residue-free produce. Understanding their types, applications, advantages, and limitations is crucial for promoting sustainable spice cultivation.



Types of Biopesticides and Their Relevance in Spice Crops

Biopesticides are broadly categorized into several groups:

1. Microbial Biopesticides

Bacteria: *Bacillus thuringiensis* (Bt) produces endotoxins effective against caterpillars like shoot borers in cardamom and fruit borers in chili. *Pseudomonas fluorescens* is widely used in turmeric and ginger to control rhizome rot and leaf spot diseases.

Fungi: *Trichoderma harzianum* and *T. viride* act as antagonists against soil-borne pathogens such as *Fusarium, Rhizoctonia,* and *Pythium* affecting black pepper and turmeric. *Beauveria bassiana* and *Metarhizium anisopliae* infect insects like thrips and whiteflies.

Viruses: Nuclear polyhedrosis viruses (NPVs) control lepidopteran larvae such as Helicoverpa in chili and cardamom.

Nematophagous Fungi: *Paecilomyces lilacinus* helps manage root-knot nematodes in coriander and black pepper.

2. Botanical Pesticides

Plant-derived products such as neem (Azadirachtin), pongamia oil, garlic extract, and chili extracts are effective against sucking pests, mites, and fungal pathogens. For example, neem oil sprays are extensively used in chili, turmeric, and coriander for aphid and thrips control.

3. Biochemical Pesticides

These include naturally occurring substances such as pheromones and plant growth regulators. Pheromone traps are used in black pepper and cardamom plantations to monitor and mass trap shoot and capsule borers.

4. Entomopathogenic Nematodes (EPNs)

Species like Steinernema and Heterorhabditis are effective against soil-inhabiting insect pests in ginger and turmeric.

Relevance

Each type of biopesticide plays a critical role in spice crops: microbials suppress soil-borne diseases, botanicals control foliar pests, pheromones help in monitoring and reducing pest populations, while EPNs protect roots and rhizomes from soil pests. This integrated use makes them highly relevant for residue-free and export-oriented spice production.

Major Spice Crops and Biopesticide Applications

1. Black Pepper (*Piper nigrum*)

Major Pests: pollu beetle (Longitarsus nigripennis), top shoot borer (*Cydia hemidoxa*), nematodes.

Biopesticides: *Trichoderma harzianum* for root rot, neem cake for nematodes, pheromone traps for shoot borers, *Pseudomonas fluorescens* for foot rot suppression.

2. Cardamom (*Elettaria cardamomum*)

Pests: thrips, capsule borer, root grubs.

Biopesticides: Neem oil sprays for thrips, NPVs for capsule borer, *Metarhizium anisopliae* for root grubs.

3. Chili (*Capsicum annuum*)

Pests: thrips, mites, fruit borers, aphids.

Biopesticides: Neem seed kernel extract (NSKE 5%) for sucking pests, *Bacillus thuringiensis* for fruit borers, *Verticillium lecanii* for aphids and whiteflies.

4. Turmeric (*Curcuma longa*) & Ginger (*Zingiber officinale*)

Pests: rhizome rot pathogens (*Pythium, Fusarium*), shoot borer (*Conogethes punctiferalis*).

Biopesticides: *Trichoderma viride* and *Pseudomonas fluorescens* for rhizome protection, neem cake for nematode management, Beauveria bassiana for shoot borer.

5. Coriander, Cumin, and Fennel

Pests: aphids, powdery mildew, and root-knot nematodes.

Biopesticides: Neem oil and *Verticillium lecanii* for aphids, *Paecilomyces lilacinus* for nematodes, *Trichoderma spp.* for soil-borne fungi.

6. Clove and Nutmeg

Pests: leaf spot, stem borer, and fruit borers.

Biopesticides: Neem oil sprays, *Trichoderma* for collar rot, and *Beauveria bassiana* for borers.

Advantages of Biopesticides in Spice Crops

1. **Eco-friendly and Sustainable:** They decompose rapidly, leaving no harmful residues on spices, ensuring compliance with export quality standards.

2. **Target-specific**: Most biopesticides affect only target pests without harming beneficial insects like pollinators and natural enemies.
3. **Resistance Management**: Multiple modes of action help in delaying pest resistance compared to synthetic pesticides.
4. **Improved Soil Health**: Products like *Trichoderma* and neem cake enhance soil microbial diversity and plant vigor.
5. **Market Advantage**: Residue-free spice produce fetches premium prices in international markets.
6. **Safe for Farmers and Consumers**: Low toxicity ensures reduced occupational hazards.
7. **Compatibility with IPM and Organic Farming**: Easily integrated into existing pest management practices.

Limitations of Biopesticides

1. **Slow Action**: Unlike chemical pesticides, biopesticides act gradually, making them less suitable for emergency pest outbreaks.
2. **Short Shelf Life**: Many microbial formulations require proper storage and have limited shelf stability.
3. **Environmental Dependence:** Efficacy is influenced by temperature, humidity, and soil conditions, which may vary across spice-growing regions.
4. **High Cost and Limited Availability**: Quality formulations are sometimes costly and not easily available in rural spice belts.
5. **Lack of Awareness**: Farmers often prefer chemical pesticides due to immediate visible effects and limited knowledge about biopesticides.
6. **Field Efficacy Variability**: Performance may differ between laboratory trials and field applications.

Future Prospects

The future of pest management in spice crops lies in expanding the use of biopesticides through:

- Development of next-generation formulations with longer shelf life and higher field efficacy.
- Greater investment in research and extension to educate farmers.
- Policy support for subsidies and promotion of biopesticides under Integrated Pest Management (IPM) and organic farming programs.
- Development of consortia products (mixtures of microbes like *Trichoderma* + *Pseudomonas*) for broad-spectrum disease suppression.
- Wider use of nanotechnology-based biopesticides for better delivery and stability.

Conclusion

Spice crops face diverse pest and disease challenges that threaten both yield and export potential. Biopesticides, with their eco-friendly and sustainable attributes, have proven effective in managing pests of black pepper, cardamom, chili, turmeric, ginger, coriander, and other spices. Despite limitations such as slow action and dependency on environmental factors, their advantages far outweigh the drawbacks when integrated with cultural and mechanical control measures. By promoting biopesticide use, the spice industry can meet global standards while ensuring sustainability and profitability for farmers.

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Corn Silk: A Natural Source of Phytochemicals and Therapeutic Agents

ARTICLE ID: 0248

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Corn silk, also known as *Maydis stigma*, refers to the soft, thread-like yellowish fibers that serve as the stigmas of the female corn flower. Despite being produced in large quantities as a by-product during corn cultivation, corn silk is often discarded, even though it holds significant nutritional and medicinal value. As an indigenous herb, it remains vastly underutilized despite its considerable health potential. While its chemical composition is less documented compared to corn kernels, corn silk has been reported to contain a diverse range of essential nutrients and bioactive constituents, including carbohydrates, proteins, lipids, phenolic compounds, flavonoids, sterols, polysaccharides, organic acids, volatile oils, vitamins, and minerals such as potassium, calcium, and magnesium. It also exhibits noteworthy antioxidant properties, particularly in combating gamma radiation and oxidative stress.

India holds the fourth position globally in maize cultivation area and ranks seventh in terms of production, contributing nearly 4% of the world's maize area and about 2% of global production. Maize stands as the country's third most important food crop following rice and wheat. Notably, around 47% of the maize produced in India is utilized as poultry feed.

Health Benefits of Corn Silk (*Stigma maydis*)

1. Abundant in Phytochemicals: Corn silk contains a variety of bioactive compounds, making it a valuable traditional herbal remedy across cultures.
2. Antioxidant Activity: Its rich antioxidant profile helps protect the body from oxidative stress and related chronic disorders.

3. Anti-Diabetic: Properties Corn silk is traditionally employed in managing diabetes due to its blood sugar-lowering capabilities.
4. Blood Pressure: Regulation Corn silk extract can reduce hypertension by inhibiting angiotensin-converting enzyme (ACE).
5. Weight Management: It may assist in controlling body weight and has been used as a natural anti-obesity aid.
6. Lipid-Lowering Effect: Evidence suggests that it can lower blood lipid levels, thereby supporting cardiovascular health.
7. Widespread Ethnomedicinal: Use Corn silk has been used in traditional medicine systems in countries like China, France, Turkey, and the United States for treating various ailments.
8. Therapeutic Metabolites: It contains beneficial compounds such as maysin and polysaccharides that contribute to its medicinal properties.

Nutritional and Bioactive Composition of Corn Silk

Proximate Nutrients: Includes moisture, ash, crude fat, protein, fiber, and carbohydrates — providing a strong

nutritional foundation.

Polysaccharides: Demonstrated anti-diabetic, lipid-lowering, and antihypertensive effects.

Dietary Fiber: Both soluble and insoluble fibers aid in weight control and reduce cholesterol levels.

Minerals: Contains essential elements like potassium, calcium, magnesium, sodium, and iron. Potassium helps lower blood pressure and acts as a diuretic, beneficial for kidney and urinary tract health.

Vitamins: Rich in vitamins C, E, and K, contributing to its immune-boosting and antioxidant activities.

Phenolic Compounds: Provide antihypertensive and anti-fatigue benefits and enhance exercise tolerance.

Flavonoids: Includes maysin, luteolin, apigenin, and formononetin — offering antioxidant, anti-obesity, and anti-cancer (notably prostate cancer) effects.

Antioxidant Capacity: Evaluated using DPPH, ABTS, and FRAP methods, indicating strong free radical scavenging potential.

Carotenoids: Such as β-carotene and zeaxanthin, support vision, immunity, and increase serum vitamin A levels.

Phytosterols: Stigmasterol and β-sitosterol offer anti-inflammatory, antioxidant, anti-cancer, and cardiovascular protective effects.

Healthy Corn Silk Recipes

1. **Corn Silk Tea**: Boil 1–2 tablespoons of fresh or dried corn silk in 2 cups of water for 10–15 minutes. This tea is traditionally consumed for its diuretic, anti-inflammatory, and kidney-protective properties.
2. **Corn Silk Lemon Water**: Simmer 1 tablespoon of corn silk in 1 liter of water, then cool and mix with lemon juice and mint leaves. This refreshing drink helps with detoxification, hydration, and urinary system support.
3. **Corn Silk Soup**: Used in Asian traditional remedies, this soup involves tying fresh corn silk into bundles and simmering them with corn kernels, ginger, garlic, and vegetable broth. It provides

digestive support, relieves inflammation, and offers natural antioxidants.

4. **Corn Silk Tincture**: Prepare by soaking dried corn silk in alcohol (such as vodka) for 4–6 weeks. A small amount (diluted) may be used to help manage urinary tract infections, fluid retention, and mild hypertension under professional guidance.

Who Should Limit or Avoid Corn Silk

- Pregnant and Breastfeeding Women Due to its mild diuretic and potential uterine-stimulating properties, corn silk should be avoided during pregnancy. Its safety during breastfeeding is not well established and requires medical consultation.
- Individuals on Diuretics or Blood Pressure Medications Corn silk may enhance the effects of diuretic or antihypertensive drugs, potentially leading to electrolyte imbalance or hypotension.
- Patients with Kidney Disorders or Hypokalemia The increased excretion of potassium due to corn silk's diuretic action may worsen conditions like hypokalemia or adversely affect individuals with chronic kidney disease.
- People Taking Anticoagulants or with Bleeding Disorders Because corn silk contains vitamin K and certain flavonoids, it may interfere with blood clotting and should be used cautiously by those on anticoagulant therapy (e.g., warfarin) or those with bleeding disorders.

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Examining Soil Science's Dynamic World: Career Opportunities and Contributions to Sustainable Land Management

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A career in soil science offers an exciting and impactful journey into the world beneath our feet. Soil scientists uncover critical insights into environmentally responsible farming and sustainable land use by exploring the intricate relationships among soil plants water and the environment. The pathway to a career in soil science begins with education. A bachelor's degree in soil science, agronomy, environmental science or a related field provides the foundational knowledge needed. Students can choose from various specializations such as soil microbiology chemistry or physics allowing them to align their studies with personal interests and career goals. Hands-on experience is vital. Internships research projects and fieldwork provide practical knowledge about soil behaviour and management techniques. Networking further enhances opportunities. Attending seminars conferences and workshops helps aspiring professionals build relationships with industry leaders and opens doors to collaboration and employment. Professional certification adds value. Credentials such as becoming a Certified Professional Soil Scientist demonstrate expertise and commitment to the field. Career paths in soil science are diverse. Agricultural consultants improve crop production through sustainable practices while environmental consultants assess soil quality and contamination. Researchers in academic government and private sectors advance scientific understanding. Land use planning and conservation roles are crucial in public service and industries such as mining forestry and agriculture rely on soil expertise to operate safely and sustainably.

Lifelong learning is essential. As technology and scientific understanding evolve ongoing education through workshops and professional development keeps practitioners current. Communication skills also play a key role i.e. translating complex soil science concepts for diverse audiences from policymakers to the general public is critical. By pursuing a career in soil science individuals can unlock the secrets of the soil and contribute meaningfully to sustainable agriculture land use and environmental stewardship.

Soil, the complex layer beneath our feet, plays a vital role in supporting ecosystems, agriculture and natural resource management. Often overlooked, soil is a dynamic mix of minerals, organic matter, water, air and living organisms. Its physical, chemical and biological properties influence water retention, nutrient availability, erosion control and plant growth. Soil science explores these intricate interactions to better understand and manage the Earth's surface. As the global population grows and environmental challenges intensify, soil science has become increasingly important. It informs sustainable land management practices that enhance crop productivity while minimizing environmental harm. Innovations like precision agriculture rely on soil data to optimize irrigation and nutrient use, improving efficiency and sustainability. Soil science is inherently interdisciplinary, connecting with biodiversity, climate change, and water quality. Soil scientists collaborate with ecologists, hydrologists, agronomists and engineers to develop solutions for global challenges such as soil degradation and pollution. Careers in this field offer opportunities in research, conservation, agriculture and environmental protection. Far from being inert dirt, soil is the foundation of life on Earth. A career in soil science offers a meaningful path to explore and protect this essential resource, uncovering its hidden complexity and critical importance to a sustainable future.

ICAR–Indian Institute of Soil Science (IISS), Bhopal

Mission: Enhancing soil productivity with minimum environmental degradation

Established: 16 April 1988

Location: Nabibagh, Berasia Road, Bhopal – 462038, Madhya Pradesh

Affiliation: Indian Council of Agricultural Research (ICAR)

Mandate and Research Focus

- Basic and strategic studies on soil processes affecting nutrients, water and energy use
- Develop technologies for sustaining soil health and input-use efficiency
- Coordinate research with national and international institutions

Key Research Areas

- Integrated Nutrient Management
- Long-term Cropping Impact
- Enriched Compost Technologies
- GIS-based Soil Fertility Mapping
- Organic Farming

- Soil Carbon Sequestration
- Soil Pollution and Remediation
- Microbial Diversity and Biofertilizers

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Career in Soil Science are Highlighted To Explores The Various Fields

Interdisciplinary Nature

Soil science is a cross-disciplinary field that integrates biology, chemistry, physics, geology and environmental science. This broad knowledge base helps soil scientists understand how soils support ecosystems, agriculture, and environmental health.

Key Research Areas

- **Pedology**: Studies soil formation, classification and mapping.
- **Soil Chemistry**: Examines nutrient cycles, pH and pollutant interactions.
- **Soil Physics**: Investigates water movement, porosity and compaction.
- **Soil Microbiology**: Explores the role of microorganisms in nutrient cycling and ecosystem resilience.

Societal Impact

Soil science supports:

- **Agriculture**: Enhancing crop yield through nutrient management and erosion control.
- **Environmental Sustainability**: Aiding land-use planning, urban development and ecological restoration.
- **Global Challenges**: Addressing food security, climate change and soil contamination.

Career Path Steps

Education

- Start with a bachelor's in soil science, agronomy, geology, biology, or environmental science.
- Pursue a master's or Ph.D. for research or academic roles.

Coursework

- Focus on soil science, biology, chemistry, hydrology and environmental science.

Experience

- Gain fieldwork, lab research, or internship experience for practical skills.

Networking

- Attend conferences and seminars; connect with professionals in the field.

Specialization

- Choose a niche like soil fertility, conservation, chemistry, or microbiology.

Certification

- Obtain credentials such as Certified Professional Soil Scientist (CPSS) through organizations like the Soil Science Society of America (SSSA).

Soil Science Career Options

Agriculture: Agriculture soil scientists research soil fertility, fertilizer management and irrigation techniques in an effort to increase crop productivity.

Environmental consultation: For building or conservation projects, soil scientists evaluate soil contamination, erosion and the suitability of the area.

Academia and Research: Pursue a career in academia or research institutions, conducting studies to advance our understanding of soils and their impact on ecosystems.

Government Agencies: Work for the governmental organizations in charge of land management, environmental rules and soil conservation at the federal, state, or local levels, land-use planning and natural resource management.

Private sector: Join the forestry, mining, or land development sectors that require managing and evaluating soil.

Continuing Education: Attend workshops, conferences and other continuing education opportunities to stay current on the most recent developments in soil science. With the development of new technology and research, the discipline of soil science evolves.

Communicator: For complicated soil scientific knowledge to be effectively communicated to a range of audiences, including farmers, policymakers and the general public, effective communication is a necessity.

What Are The Job Roles?

Soil Scientist: Specializations in soil scientist career

Pedologist: Pedology, which studies soil in its natural setting, includes topics including soil classification, soil morphology and pedogenesis (the process by which soil is formed as a result of location, climate and history). To create strategies for preserving the environment's quality and discover fresh approaches to enhancing crop growth, soil pedologists sample and assess the soil.

Edaphologist: Edaphology is the study of how soil affects fungi, plants and other living things. An edaphologist might specialise in either of the two subfields of edaphology: agricultural soil science or environmental soil science. You'll concentrate on topics including chemical and physical weathering, soil texture and material disintegration.

Soil Physicist: The field of soil physics studies the motion of the solid, liquid and gaseous phases of the physical soil constituents. A soil physicist solves issues in agriculture, engineering, and ecology by using the principles of physics, meteorology and engineering.

Soil Chemist: The chemical makeup of the soil is studied by soil chemistry. Numerous elements, including organic matter and environmental conditions, have an impact on these contents. The acidity or alkalinity of a soil, frequently expressed as the pH of the soil, is one of the most crucial chemical characteristics of a soil. You will assess the soil's composition, including its pH, granite content and nutrient levels, as a soil chemist. These elements will decide whether the soil is suitable for crop growth.

Career Pathway: Soil Scientist

Eligibility Criteria (Entry Level)

❖ **Minimum Academic Qualification (10+2 or equivalent):**

- Subjects required: Physics, Chemistry and Biology *(or Mathematics, depending on specialization)*
- Recommended stream: Science

❖ **Undergraduate Degree (UG)**

After completing higher secondary education, candidates can pursue a Bachelor's degree in any of the following disciplines:

- B.Sc. (Agriculture)
- B.Sc. (Horticulture)
- B.Sc. (Forestry)
- B.Sc. (Plant Science)
- B.Sc. (Botany)
- B.Sc. (Environmental Science)

Duration: 3–4 years

Mode of Admission: ICAR AIEEA (UG), State Entrance Exams, University-specific entrance/merit

❖ **Postgraduate Degree (PG)**

After a relevant Bachelor's degree, candidates can pursue a Master's degree (M.Sc./ M.Tech.) in:

- Soil Science / Soil Science and Agricultural Chemistry
- Plant Science
- Botany
- Agricultural Science
- Environmental Science

Duration: 2 years

Admission: ICAR AIEEA (PG), university-level entrance exams

❖ **Doctorate Degree (Ph.D.)**

For advanced research, academic and high-level policy or consultancy roles, a Ph.D. is strongly recommended or required.

Ph.D. Specializations

- Soil Science / Soil Science and Agricultural Chemistry
- Soil Physics / Soil Microbiology / Soil Fertility
- Agroecology
- Land Resource Management
- Environmental Soil Science

Eligibility Criteria for Ph.D.

- M.Sc./M.Tech. in Soil Science or a relevant discipline with minimum OGPA 6.5/10 or 65% marks
- NET (ASRB/UGC/CSIR) preferred or required in many institutions
- Some institutes require performance in Ph.D. entrance tests (e.g., ICAR AICE-JRF/SRF, institutional exams)
- Duration: 3–5 years

Includes:

- Coursework
- Comprehensive exam
- Research and Thesis Submission
- Viva Voce (oral defense)

Institutes Offering Ph.D. in Soil Science

- ICAR-IARI (Indian Agricultural Research Institute)
- GBPUAT, Pantnagar
- TNAU (Tamil Nadu Agricultural University)
- PAU, Ludhiana
- IISc, IITs (interdisciplinary programs)
- International Institutes (e.g., Wageningen University, Cornell, University of California Davis, etc.)

Top colleges in India offering Soil Science course

- Punjab Agricultural University, Ludhiana
- Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST-J and SKUAST-K)

- Chaudhary Charan Singh Haryana Agricultural University, Hisar
- Bihar Agricultural University, Sabour
- Dr. Panjabrao Deshmukh Krishi Vidyapeeth (PDKV), Akola
- Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur
- Indian Institute of Soil Science (IISS), Bhopal
- G.B. Pant University of Agriculture and Technology, Pantnagar
- Acharya N.G. Ranga Agricultural University (ANGRAU), Guntur
- Odisha University of Agriculture and Technology (OUAT), Bhubaneswar
- AKS University, Satna

Top Universities Abroad for Soil Science

United States

1. University of California, Davis (UC Davis)

- **Reputation**: Global leader in agricultural and environmental sciences
- **Programs**: Soil Biogeochemistry
- Soil Fertility and Nutrient Management
- Land, Air, and Water Resources (graduate degrees)
- Highlights**:** Strong research funding, global impact, USDA collaborations

2. Cornell University

- **Reputation**: Ivy League institution with a strong College of Agriculture and Life Sciences
- **Programs**: Soil and Crop Sciences (M.S., Ph.D.)
- Soil Health, Agroecology, Soil Chemistry
- **Highlights**: Focus on sustainable agriculture and global food systems

3. North Carolina State University (NC State)

- **Reputation**: Renowned for applied soil science, environmental management and agronomy
- **Programs**:

  Soil Science (M.S., Ph.D.)

  Soil Physics, Hydrology, Environmental Soil Chemistry
- **Highlights**: Leading research in soil erosion, digital soil mapping

4. Iowa State University

- **Reputation**: Historic leader in agricultural sciences
- **Programs**:

  Soil Microbiology, Soil Chemistry, Soil Genesis

  Integrated graduate programs in Agronomy and Soil Science
- **Highlights**: Strong Midwestern agricultural research ties

5. **Purdue University**

- **Reputation**: Leading land-grant university in agriculture and engineering
- **Programs**:

  Soil Science specialization within Agronomy

  Soil & Water Management, Soil Conservation
- **Highlights**: Combines soil science with remote sensing and climate models

6. Colorado State University

- **Reputation**: Strong in natural resources, soil and water sciences
- **Programs**:

  Soil & Crop Sciences (M.S., Ph.D.)

  Environmental Soil Science, Precision Agriculture
- **Highlights**: Strong sustainability and climate change research

Canada

7. University of Guelph

- **Reputation**: Top Canadian university for agriculture and environment
- **Programs**:
  Environmental Sciences with Soil Science focus
  Soil Ecology, Soil Chemistry, Land Resource Management
- **Highlights**: Excellent field and lab facilities; applied research focus

Australia

8. University of Adelaide

- **Reputation**: Leading soil science research in arid environments
- **Programs**:
  Soil Science in Agricultural Sciences (M.S. and Ph.D.)
  Soil Salinity, Soil-Water-Plant Relationships
- **Highlights**: Focus on sustainable land use in dryland farming systems

9. University of Queensland

- **Programs**:
  Soil Science as part of Agricultural Science and Environmental programs
  Soil Carbon, Soil Health, Tropical Soil Management
- **Highlights**: Strong research partnerships across Southeast Asia and Pacific

United Kingdom

10. University of Reading

- **Reputation**: One of the UK's best for soil and environmental science
- **Programs**:
  M.Sc. in Soil Science
  Soil-Plant Interactions, Soil Conservation, Land Reclamation
- **Highlights**: Research links with FAO, UK Environment Agency

11. University of Aberdeen

- **Programs**:
  M.Sc./Ph.D. in Soil Science and Environmental Management
  Soil Microbial Ecology, Organic Matter Dynamics
- **Highlights**: Strong environmental and climate-change-focused research

International Organizations & Research Institutes

- **International Rice Research Institute (IRRI), Philippines**: Soil fertility, rice-soil interactions
- **International Institute of Tropical Agriculture (IITA), Nigeria**: Soil health in tropical systems
- **CIMMYT, Mexico**: Soil-plant nutrient management in cereal systems

Conclusion

In conclusion, a career in soil science offers a fascinating and varied trip into the core of the planet's ecosystems. Soil science sets the path for ground-breaking answers to today's most serious environmental and agricultural problems due to its interdisciplinary nature, wide range of research topics and extensive social effect. The importance of soil science is highlighted by the fact that it is crucial in determining how our planet will be sustained as we learn more about the hidden world beneath our feet. Deep inquiry into the basis of life on Earth is possible through the study of soil science. This introduction lays the groundwork for an in-depth investigation of the many rewarding career prospects in soil science, highlighting its importance to sustainable agriculture, environmental management and the welfare of both the present and the next generation.

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The Biochemistry Behind Natural Secondary Metabolites and Their Significance

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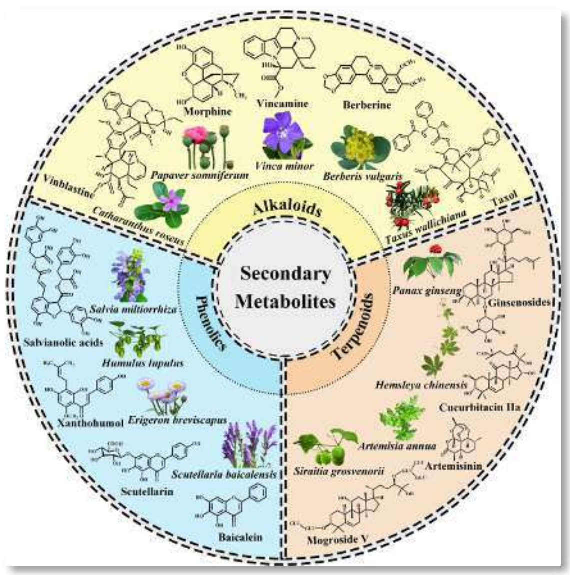
Natural products are chemical compounds derived from living organisms, and their study involves understanding their biosynthesis, extraction, identification, quantification, and chemical characteristics. These compounds arise from primary or secondary metabolic processes—complex enzymatic reactions within cells that support growth, development, and environmental adaptation. While primary metabolites such as carbohydrates, proteins, and fats are essential for plant growth and reproduction, secondary metabolites do not directly contribute to these functions but play vital roles in plant interaction with their surroundings. These secondary metabolites, which include alkaloids, tannins, flavonoids, and phenolic compounds, are often localized in specific plant parts such as leaves, roots, stems, or bark, and tend to be unique to particular species or groups. Once thought to be mere metabolic byproducts, secondary metabolites are now recognized for their distinct structures and significant ecological functions. They protect plants against biological threats like pathogens and herbivores, as well as abiotic stresses including drought, temperature extremes, and heavy metals. Moreover, they contribute to the coloration of flowers and seeds, facilitating pollination and seed dispersal, thus supporting plant reproduction. Beyond their ecological roles, many secondary metabolites are utilized commercially as natural aromas, resins, flavoring agents, insecticides, and herbicides. Importantly, their diverse pharmacological properties have made them



invaluable in pharmaceutical research and drug development. This article reviews the major classes of plant secondary metabolites, common extraction and phytochemical analysis techniques, and emphasizes their key pharmacological activities.

Classes of Secondary Metabolites in Plants

Plant secondary metabolites (SMs) are commonly classified based on factors like chemical structure, composition, solubility, and biosynthetic pathways. Among these, the biosynthetic pathway is the most widely used criterion, dividing SMs into three main groups: terpenes, phenolic compounds, and alkaloids.

Terpene: Terpenes represent the largest class of plant secondary metabolites, with over 40,000 known compounds. They are non-saponifiable lipids, meaning they do not involve fatty acids in their synthesis. Also referred to as isoprenoids, terpenes are built from isoprene units and classified by the number they contain. Hemiterpenes have one unit, while others include monoterpenes (2 units), sesquiterpenes (3), diterpenes (4), triterpenes (6), tetraterpenes (8), and polyterpenes (10 or more). Found in many aromatic plants such as lemon, mint, and basil, these compounds contribute to plant scents. Terpenes play roles in both primary metabolism—as pigments, electron carriers, membrane components, and growth regulators—and in secondary metabolism as defense compounds, insect deterrents, and attractants for pollinators. They are synthesized via two main pathways: the mevalonic acid (MVA) pathway in the cytosol and the methylerythritol phosphate (MEP) pathway in chloroplasts, both producing isopentenyl diphosphate (IPP) as a key intermediate.

Phenolic Compounds: Phenolic compounds are a broad group of plant secondary metabolites that feature a hydroxyl group bonded to an aromatic ring. They vary widely in structure, with phenol being the simplest form. Based on carbon content, phenolics are classified into types such as simple phenols, flavonoids, coumarins, tannins, quinones, xanthones, and others. Some, like lignans and tannins, are larger polymers with complex structures. These compounds are synthesized in plants via the shikimic acid pathway, malonate/acetate pathway, or both. The shikimic pathway produces amino acids and derivatives like phenylpropanoids and coumarins, while the polyacetate pathway gives rise to compounds like quinones. Flavonoids typically originate from both pathways. Phenolic compounds serve many purposes: they act as antioxidants, inhibit seed germination, absorb UV radiation, and give fruits their color and scent to attract animals for seed dispersal. They also play roles in plant competition (allelopathy) and defense, by forming toxic phytoalexins or producing bitter tastes that deter herbivores.

Alkaloids: Alkaloids are a large and varied group of nitrogen-containing secondary metabolites, primarily found in vascular plants, but also present in fungi, bacteria, and animals. Each plant typically produces a complex mix of alkaloids, often dominated by one main type. Their concentration can vary between different plant parts. Alkaloids are usually toxic, reactive, and can be identified by common precipitation reactions.

They are commonly classified based on their biosynthetic origin into:

- **True Alkaloids**: Derived from amino acids, contain nitrogen within a heterocyclic ring, and are the most common type.
- **Protoalkaloids**: Also amino acid-derived, but nitrogen is located outside the ring structure.
- **Pseudoalkaloids**: Contain nitrogen in a ring but are not amino acid-derived; nitrogen is added later, such as in terpenoid alkaloids.

These compounds often occur as salts in plants and perform various biological functions, including defense.

Bioactivity – Antimicrobial Activity

The growing prevalence of antibiotic resistance in microorganisms has become a significant concern for the global scientific community. Many herbal preparations used in traditional medicine by indigenous cultures worldwide are known to possess antimicrobial properties. This traditional knowledge has inspired modern research focused on discovering plant-based compounds with antibacterial and antifungal potential for pharmaceutical development.

Terpenes: Terpenes extracted from plant bark have shown antibacterial effects against *S. faecalis*, MRSA, and *P. aeruginosa*. Ethanol extracts of *Morinda citrifolia* leaves, rich in terpenoids, are effective against *P. aeruginosa* and *S. epidermidis*. Studies on plant families such as Asteraceae, Lamiaceae, and Rutaceae also highlight strong antimicrobial activity of terpenes. While terpenoids play a major role, other phytochemicals may also contribute to the observed antimicrobial effects.

Phenolic Compounds: Many naturally occurring phenolic compounds exhibit antimicrobial properties that help protect plants from phytopathogens. For example, studies on secondary metabolites extracted from grapes and almond plants have shown antibacterial activity against gram-negative bacteria like *Xylella fastidiosa*.

Alkaloids: Alkaloids have been used for centuries as active ingredients in traditional herbal remedies, though some are also known for their abuse potential and toxicity to humans due to their cytotoxic effects. Various Middle Eastern plants, including *Datura stramonium*, *Peganum harmala*, and *Achillea millefolium*, have been widely studied. Denatured alkaloids extracted from these species have shown effectiveness against several pathogens, including *E. coli*, *S. aureus*, *P. aeruginosa*, *K. pneumoniae*, and *Proteus mirabilis*.

Therapeutic Potential of Plant Secondary Metabolites in Modern Medicine

Phytochemicals are widely utilized as sources for plant-derived drugs and have been a key component of traditional and folk medicine for centuries. In modern medicine, they are valued for their antimicrobial, antioxidant, and anti-diabetic properties [36]. Advances in genetic engineering and bioinformatics have made it possible to identify, analyze, and mass-produce novel secondary metabolites with pharmaceutical potential. Contemporary extraction methods are more efficient in terms of time and energy and require less raw material. Additionally, recombinant DNA (rDNA) technology is employed to minimize toxicity and enhance the consistency and reliability of the desired bioactive compounds.

Anti-Cancer Potential of Plant Secondary Metabolites

Cancer is a complex, multi-stage disease characterized by uncontrolled cell growth that leads to the formation of malignant tissue. While synthetic chemotherapy drugs often damage healthy cells, there is increasing interest in naturally derived anti-cancer compounds. Various plant secondary metabolites—including alkaloids, diterpenes, triterpenes, and polyphenols—have demonstrated significant potential as anti-cancer agents in recent research. Studies indicate that some of these compounds exhibit cytotoxic effects specifically targeting cancerous cells. However, many promising metabolites face challenges in clinical use due to poor bioavailability. Additionally, some plant-derived compounds can be toxic to normal human cells but show strong anti-tumor activity. By chemically modifying these metabolites to reduce their toxicity, they may become viable options for cancer treatment. Curcumin, a lipophilic phenolic substance with an orange-yellow crystalline appearance, is extracted from turmeric (*Curcuma longa* L.). Turmeric rhizomes contain 2-5% curcumin and have long been used in traditional Chinese and Indian medicine. The regular dietary use of turmeric is linked to health benefits such as anti-inflammatory, antioxidant, and cancer-preventive properties, possibly contributing to the low rates of gastrointestinal cancers in South Asia. Many laboratory studies demonstrate curcumin's effectiveness in cancer treatment by influencing multiple cellular pathways to induce cancer cell death, while having little harmful impact on healthy cells.

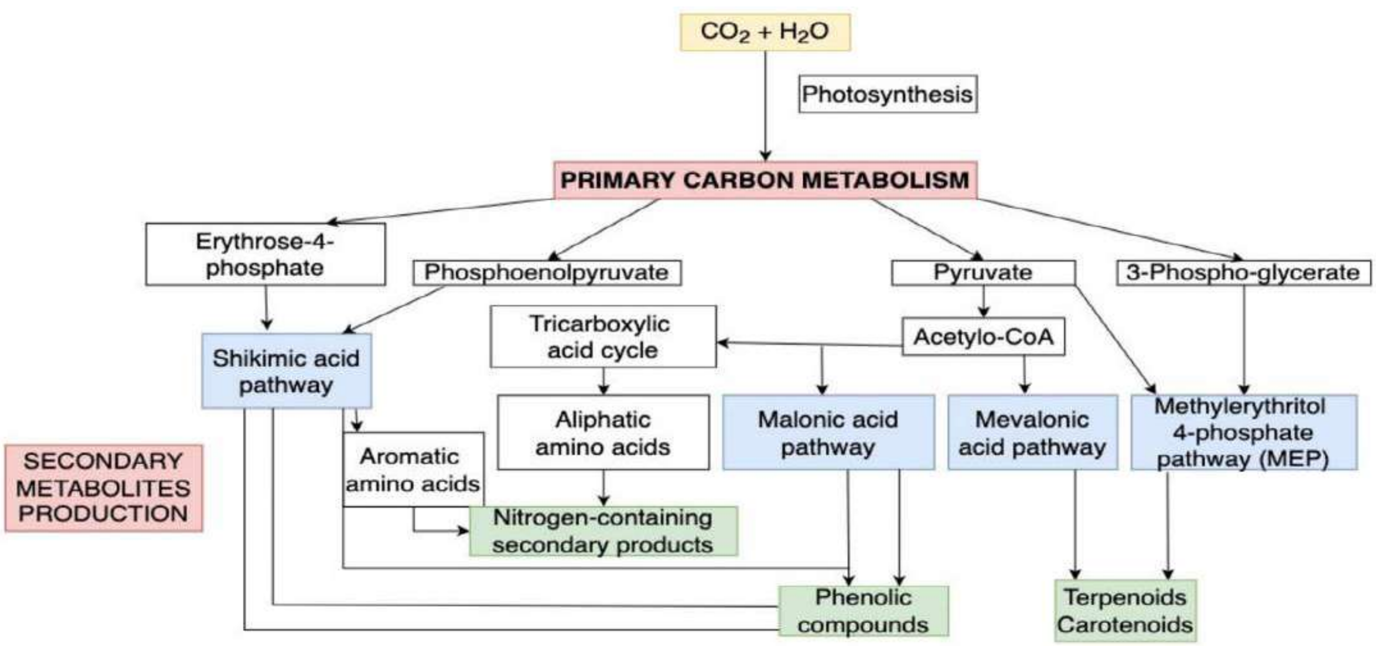


Figure-1 Main pathways for the synthesis of secondary metabolites in trees

Conclusion

Plant secondary metabolites represent a diverse group of naturally occurring compounds that, while not essential for plant growth, play crucial roles in plant defense, ecological interactions, and survival under stress. These compounds—primarily terpenes, phenolic compounds, and alkaloids—are synthesized through distinct biosynthetic pathways and are distributed variably among plant organs. Their unique structures and bioactivities have not only ecological importance but also immense pharmaceutical value. Traditionally used in herbal medicine, secondary metabolites are now central to modern drug discovery for their antimicrobial, antioxidant, and anti-cancer properties. Advances in biotechnology, including genetic engineering and rDNA technology, have significantly enhanced the extraction, analysis, and development of these compounds for therapeutic purposes. Particularly, their role in combating drug-resistant pathogens and targeting cancer cells while minimizing harm to healthy tissues highlights their potential as safe and effective alternatives to synthetic drugs. Overall, secondary metabolites bridge traditional knowledge and modern science, offering sustainable and powerful tools in the development of future medicines.

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Jeevamrit: A Natural Growth Booster for Crops

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The importance of natural farming practices is increasing as farmers have realized the benefits in terms of soil fertility, soil health and sustainable productivity. Farmers are well aware of the use of Jeevamrit liquid organic manure as organic farming practices, which play a vital role in promoting crop growth and yield. There are many practices adopted in natural farming to achieve the goal of successful crop production. Most of them have been developed by the farmers themselves. One such practice whose main objective is to enrich the soil micro-flora is the use of Jeevamrit.

What is Jeevamrit?

Jeevamrit is a fermented mixture of cow dung, cow urine, jaggery, pulses, and water. Jeevamrit is made up of two words, "*Jeeva*" which refers to organisms and *Amrut* which refers to nectar. Jeevamrit is basically the "nectar of life". It plays a special role in improving the nutritional power of the soil and promoting the growth of healthy plants. Jeevamrit is a storehouse of beneficial microorganisms. Jeevamrit plays an important role in providing essential elements to the plants. It is a catalytic agent to promote natural activities in the soil. Jeevamrit can be made very easily and as per requirement. Jeevamrit is a liquid organic manure that is a good source of natural carbon and biomass which contains essential micronutrients for crops. Jeevamrit is a type of organic fertilizer and soil modifier prepared using natural elements and beneficial microorganisms.

According to Dr. Subhash Palekar, Jeevamrit is a liquid solution made from cow dung, cow urine and local ingredients like pulses and old tree soil which, increase the number of microorganisms in the soil.

Jeevamrit is not only used as organic fertilizer but also used bio- starter which provide beneficial bacteria to establish a healthy biological solution. Application of Jeevamrit to the soil promotes immense biological activity in the soil and makes the nutrients available to the crop. It provides a good environment for the beneficial microbes. Many scientific research proved that application of Jeevamrit to the soil improve the fertility of the soil significantly. Jeevamrit also contains a huge microbial load, which increases manifold and acts as a soil tonic. These beneficial microorganisms increase the availability of essential nutrients to the plant better growth development and protection. Beside this many scientific studies reported that Jeevamrit also help in protect the plant from various disease.

The Components of Jeevamrit

Cow Dung: An essential component of Jeevamrit, cow dung is abundant in healthy microorganisms. It improves the soil's microbial life, which is crucial for the cycling of nutrients.

Cow Urine: Well-known for having high levels of potassium, phosphorus, and nitrogen, cow urine serves as a natural insecticide and fertilizer for plants.

Jaggery: This sweetener contributes carbon, which is essential for the microbial development that improves soil fertility.

Pulses: By introducing nitrogen-fixing bacteria into the soil, pulses such as gram or peas increase the soil's nutrient content.

Water: These ingredients can ferment and promote the growth of helpful microorganisms when they are dissolved in water, the all-purpose solvent.

Old Tree Soil: Old tree soil is mixed in Jeevamrit to supply beneficial microbes, which multiply during fermentation and make it more effective for soil fertility and plant health.

Method of Making Jeevamrit

The following ingredients are required to make Jeevamrit:

- A plastic drum of 200 liters capacity
- 10 kg cow dung of a local cow
- 10 liters cow urine of a local cow
- 2 kg jaggery
- 1.5-2 kg gram flour (moong urad)
- 500 gm of old tree soil like (peepal or banyan)
- 180 liters water

Put the above ingredients in a plastic drum and mix. Keep the container of the solution in the shade and stir it for 2 minutes with a wooden stick in the clockwise direction every morning and evening. The drum is covered with a jute sack so that no insects can enter it from outside. Allow the mixture to ferment for 48-72 hours. It is important to stir it once or twice a day to facilitate proper fermentation. Once fermented, the Jeevamrit is ready to be applied to the soil, either by drenching the soil or spraying on the crops.

Method of Use of Jeevamrit

Jeevamrit is generally used in the following ways:

1. With irrigation (Mix 100-200 liters of Jeevamrit per acre with the irrigation water or apply directly to the soil during irrigation)
2. Foliar spray (Dilute Jeevamrit to a concentration of 5-10% with water and spray it on the plants at regular intervals.)

Benefits of Jeevamrit

1. Improve soil health

Soil health depends on the physical, chemical and biological properties of soil. Jeevamrit these soil proprieties in many ways which helps to improve crop production in sustainable manner.

(a) Physical Properties of Soil

Jeevamrit improves soil physical properties by increasing porosity, aeration, and water retention by the addition of beneficial microorganisms that breakdown organic matter and improve soil structure. Increased organic matter and enhanced soil structure create a more stable soil that resists erosion and compaction.

(b) Chemical Properties of Soil

Jeevamrit improves soil chemical properties by providing a rich source of nutrients, stimulating microorganisms that fix nitrogen and solubilize nutrients, increasing organic carbon content, and maximizing pH. This leads in higher soil fertility, a more balanced supply of macro and micronutrients, and improved cation exchange capacity.

(c) Biological Properties of Soil

Jeevamrit improves soil biological properties by introducing a varied population of beneficial microorganisms, increasing soil organic matter through mineralization, improving soil enzymes, and increasing earthworm activity. These beneficial bacteria not only improve nutrient availability and nurture a healthy, rich soil environment for sustainable agriculture, but they also aid in nitrogen fixation and phosphorus solubilisation.

2. Enhance Crop Productivity As Growth Promoter

Jeevamrit acts as a natural growth stimulant by giving essential nutrients and increasing microbial activity in the soil. It promotes root growth, increases nutrient uptake, and fosters a healthy soil environment, resulting in higher crop output and quality in vegetables such as tomato, brinjal, chilli, okra, and cucumber.

3. Resistance To Diseases and Pests

Jeevamrit boosts the natural immunity of plants by promoting beneficial microbial activity in the soil. The diverse population of microbes suppresses harmful pathogens, reduces the chances of pest and disease outbreaks, and strengthens the plant's defense system.

4. No dependency on chemical

Jeevamrit functions as a natural source of nutrients and growth-promoting bacteria, reducing the need for chemical fertilizers and pesticides. Its regular application increases soil fertility, promotes plant health, and naturally controls pests and diseases. As a result, farmers become self-sufficient by preparing it with locally available ingredients, reducing the need for expensive chemical inputs.

5. Eco Friendly

Jeevamrit is fully eco-friendly because it is made with natural ingredients including cow dung, cow urine, jaggery, pulse flour, and soil. Unlike chemical fertilizers and pesticides, it leaves no toxic remains in the land, water, or air.

6. Sustainable And Cost Effective

Jeevamrit is a sustainable and cost-effective bio-fertilizer since it is prepared from locally available, low-cost materials such as cow dung, cow urine, jaggery, and pulse flour. Its continuous use improves soil fertility, enhances crop yield, and reduces the long-term dependence on expensive chemical inputs. This makes farming more economical while promoting sustainable agricultural practices that conserve resources and maintain soil health**.**

7. Toxic Free Produce

Jeevamrit ensures toxin-free produce by eliminating the usage of synthetic fertilizers and chemical pesticides, which leave dangerous residues in crops. The naturally prepared solution enriches soil bacteria while providing balanced nutrients to plants, resulting in safe, healthy, residue-free food. These crops are not only good for human consumption, but they also promote environmental and ecological safety.

Conclusion

By using Jeevamrit, farmers can produce better quality crops because it improves the biological, physical, and chemical conditions of the soil. It also helps reduce the harmful effects of chemical fertilizers on human health. When soil fertility increases, the main reason is the rise in the number of earthworms and microorganisms in the soil. This increase mostly comes from the nutrients found in cow dung and cow urine of indigenous cows. Although cow urine is not available in large amounts, farmers prepare Jeevamrit by mixing cow dung and urine with jaggery (gur) and gram flour (besan). These ingredients act like food for the microbes, and they multiply very quickly, which helps make the soil more fertile.

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Impact of Natural Disasters on Fisheries in India: A Growing Threat

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India, with its diverse geography and varied climate, is highly prone to natural disasters. From the towering Himalayas in the north to the vast coastline in the south, the country regularly experiences a wide range of catastrophic events such as floods, earthquakes, cyclones, landslides, and droughts. In recent years, climate change has intensified the frequency and severity of these disasters, leading to greater loss of life, property, and ecological balance. India, with its vast coastline of 11098.81 km, extensive inland and marine water resources, and millions dependent on fishing for livelihood, has one of the largest and most diverse fisheries sectors in the world.

However, the increasing frequency and severity of natural disasters driven largely by climate change are posing significant threats to this vital sector. Floods, cyclones, landslides, and glacial lake outburst floods are not just destroying infrastructure but are severely disrupting fish production, aquaculture systems, livelihoods, and food security. India is among the most disaster-prone countries globally. About 12% of its land is flood-prone, and 76% of its coastline is vulnerable to cyclones and tsunamis. The fisheries sector, being closely linked with water bodies and coastal zones, is directly exposed to these threats. India's fisheries can be broadly categorized into: Marine fisheries (both capture and culture), Inland capture fisheries and Aquaculture (freshwater, brackish water, and mariculture) Natural disasters affect all these sub-sectors in different ways ranging from direct destruction of habitats and infrastructure to long-term ecological and economic impacts.

1. Types of Natural Disasters in India

India is vulnerable to multiple natural hazards, mainly due to its unique topography and climatic conditions. The major types include:

Floods: Common during the monsoon season across the Gangetic plains, Northeast, and South India.

Landslides: Frequently occur in the Himalayan and Western Ghats regions.

Cyclones: Affect the eastern coast, particularly Odisha, Andhra Pradesh, and West Bengal.

Droughts: Impact arid and semi-arid regions like Rajasthan, Maharashtra, and Karnataka.

Earthquakes: The Himalayan belt is especially seismically active.

Glacial Lake Outburst Floods (GLOFs): Common in the upper reaches of Uttarakhand and Sikkim.

2. Causes of Increasing Disasters in India

1. Climate Change: The biggest factor behind the increasing intensity and frequency of disasters is climate change. Rising global temperatures have led to erratic monsoons, glacier melting, rising sea levels, and extreme weather events like cyclones and cloudbursts.

2. Unregulated Development: Infrastructure development in ecologically fragile regions like roads, hydropower projects, and hotels in the Himalayas has increased the vulnerability of these regions to disasters.

3. Urbanization and Poor Planning: Rapid urban growth without proper drainage systems, floodplains being encroached upon, and lack of green spaces have made cities like Mumbai, Chennai, and Bengaluru prone to flooding.

4. Deforestation and Land Use Change: Tree cover helps hold soil and regulate water flow. Rampant deforestation, especially in the Western Ghats and Himalayas, has made these areas prone to landslides and floods.

3. Recent Natural Disasters and Their Impact on Fisheries

1. Cloudburst and Flash Flood in Uttarkashi, Uttarakhand (2025)

On 5 August 2025, a devastating cloudburst struck Dharali in Uttarkashi district, triggering flash floods that washed away roads, homes, and infrastructure. Flash floods damaged several small-scale trout farms situated along mountain streams. These farms, a vital part of the local hill economy, lost entire stocks of rainbow trout as floodwaters washed away tanks and disrupted water flow systems. Its impact on Fisheries: Loss of infrastructure (ponds, raceways, pipelines), Mortality of stocked fish, Siltation of water sources affecting future stocking, Economic loss to marginal fish farmers

2. Landslide in Wayanad, Kerala (2024)

The Wayanad landslide in 30 July 2024 a massive landslide hit Mundakai, Chooral, and Mala in Wayanad district of Kerala following days of incessant rainfall. Entire hill slopes collapsed, burying homes and cutting off remote areas. The landslide caused widespread destruction and loss of life. Affected hilly areas where small-scale integrated farming, including aquaculture, is practiced. The destruction of land and water sources disrupted pond ecosystems and water supply for fish culture. Its impact on Fisheries: Destruction of integrated farms (rice-fish systems), Water contamination and reduced oxygen levels in ponds, Loss of fish stock and fingerlings, Setback to eco-fisheries and community-based aquaculture in tribal areas

3. Glacier Floods in Chamoli, Uttarakhand (2021)

One of the most tragic disasters in recent times was the glacial lake outburst flood (GLOF) that occurred on 7 February 2021 in Chamoli district. A portion of a glacier broke off near Raini village, releasing a massive amount of water and debris into the Dhauliganga river. The resulting flash flood swept away two under-construction hydropower plants and caused the death of over 200 people. The glacial outburst flood in Chamoli not only caused widespread destruction but also impacted cold-water fisheries in the upper reaches of Uttarakhand. The Dhauliganga and Rishiganga rivers experienced heavy sedimentation and altered flow regimes, severely affecting native fish biodiversity like snow trout. Its impact on Fisheries: Loss of native fish habitat, Disruption of spawning cycles, Heavy sediment load reducing water quality and Long-term impact on riverine fisheries and biodiversity

4. Assam Floods (2020)

Assam's annual monsoon floods are infamous, but the 2020 floods were especially harsh. Torrential rains led to rivers like the Brahmaputra breaching their banks, submerging villages, displacing thousands, and destroying crops. Over 5 million people were affected, including thousands of fishers and fish farmers. Fish ponds were overtopped, and escape of cultured species like rohu, catla, and mrigal caused both economic losses and biodiversity imbalances. Its impact on Fisheries: Escape of cultured fish and seed, Damage to pond dykes and cages, Spread of diseases due to contaminated water, Disruption in fish seed supply chain, Livelihood loss to over 100,000 fish farmers

5. Cyclone Fani: Odisha & Bengal (2019)

Cyclone Fani, which made landfall in May 2019, was one of the most powerful storms to hit the eastern coast since the 1999 super cyclone. With wind speeds reaching over 200 km/h, it caused massive damage in Odisha, especially in Puri and Bhubaneswar, and later affected West Bengal. This caused extensive damage to coastal fisheries infrastructure. Traditional fishers lost boats, nets, and houses, while aquaculture farms—especially shrimp farms were inundated with saline water. Its impact on Fisheries: Loss of boats, gears, and ice plants, Destruction of hatcheries and shrimp ponds, Salinization of freshwater aquaculture areas, Unemployment among coastal fishers, Reduced fish landing and exports for months

6. Kerala Floods (2018)

The August 2018 floods in Kerala were the worst in nearly a century. Unprecedented monsoon rainfall led to the opening of multiple dams, including the Idukki and Mullaperiyar, causing widespread flooding across the state. It disrupted both inland aquaculture and coastal fisheries. Flooding of hatcheries and seed farms affected fish seed availability across South India. Fish ponds were destroyed, leading to the release of invasive species like tilapia into natural water bodies. Its impact on Fisheries: Spread of invasive species into rivers and lakes, Infrastructure loss in brackish water and freshwater aquaculture, Post-flood water quality deterioration, Reduced fish production and increased prices, Psychological impact on fishers due to asset loss

7. Jammu & Kashmir Floods (2014)

In September 2014, intense rainfall triggered flooding in Srinagar and other parts of the Kashmir Valley. The Jhelum river overflowed, submerging entire towns. It was Kashmir's worst flood in 50 years, with around 200 deaths in India and 264 in Pakistan-administered Kashmir. It affected cold-water aquaculture, especially carp farms in Anantnag and Pulwama. Thousands of fish farmers lost stocked fish due to the submersion of farms for over 10 days. Its impact on Fisheries: Loss of broodstock and seed, Damage to hatchery infrastructure, Delayed stocking cycles, Livelihood impact in a region already facing economic stress

8. Kedarnath Flash Flood & Cloudburst (2013)

The June 2013 cloudburst and subsequent flash floods in Kedarnath, Uttarakhand, remain etched in national memory. This known for its massive human toll, also devastated cold-water fish habitats in the Mandakini river. Changes in river morphology and pollution from debris hampered fish breeding grounds. Its impact on Fisheries: Displacement of aquatic fauna, Long-term loss of biodiversity in affected rivers, Disruption of eco-tourism related to angling

4. Broader Impacts of Natural Disasters on Fisheries

Beyond individual case studies, natural disasters have cumulative and system-wide impacts on India's fisheries:

1. Economic Losses: According to government estimates, India loses hundreds of crores of rupees annually due to damage to fishery infrastructure. Cyclones and floods lead to heavy losses in coastal states like Andhra Pradesh, Tamil Nadu, and Odisha.

2. Disruption of Fish Supply Chains: Disasters interrupt fish landings, cold chain operations, transportation, and export schedules, especially in marine sectors.

3. Ecological Imbalances: Floods and storms often lead to, invasion of non-native species, loss of native biodiversity and spread of fish diseases.

4. Food and Nutritional Security: Fish is a vital source of affordable protein. Loss of fish production due to disasters affects both food availability and nutritional outcomes, especially for low-income populations.

5. Mental Health and Livelihood Crisis: Fishers often live on the margins of poverty. Disasters push them further into debt traps, especially when they lose their boats, gear, or ponds. Many are forced to migrate or seek non-fishing work.

5. India's Disaster Management Efforts

India has significantly improved its disaster preparedness, especially after the 2004 Indian Ocean tsunami. Key institutions include:

- **National Disaster Management Authority (NDMA)**: Coordinates response and mitigation strategies.
- **State Disaster Response Forces (SDRFs) and National Disaster Response Force (NDRF)**: Specialized forces for rescue and relief.
- **IMD (India Meteorological Department) and INCOIS:** Provide early warnings for cyclones, tsunamis, and extreme rainfall.
- **Dam Rehabilitation and Improvement Project (DRIP):** Aims to improve dam safety.

- **Climate Resilient Cities Mission:** Supports cities in adapting to climate risks.

Despite these, there is still a long way to go in integrating climate resilience, sustainable development, and community-based disaster preparedness into mainstream planning.

6. Conclusion

India's fisheries sector is under growing threat from the increasing intensity of natural disasters. The recent events from Uttarkashi (2025) to Chamoli (2021) and Odisha (2019) show that no part of the country is immune. As climate change continues to disrupt weather patterns and ecosystems, fishers already among the most vulnerable—will bear the brunt unless immediate and long-term adaptive strategies are adopted. Protecting the livelihoods of millions of fishers, ensuring food security, and preserving aquatic biodiversity now depend on how effectively India integrates disaster risk reduction, sustainable fisheries management, and climate resilience into its policy and practice.




Kerala flood


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Major Pests of Ornamental Plants

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Ornamental plants can be affected by a variety of pests that can cause damage to their foliage, stems, flowers, and overall health. Here are some major pests commonly found on ornamental plants:

1. Aphids: Small, soft-bodied insects that suck sap from plants, leading to curled leaves and stunted growth. They can

2. Spider Mites: Tiny arachnids that create fine webs on the undersides of leaves. They feed on plant sap, causing stippling and yellowing of leaves.

3. Whiteflies: Small, white flying insects that also suck sap from plants. They can cause leaf yellowing and are known for producing honeydew, which can lead to

sooty mold.

4. Scale Insects: These pests appear as small, waxy bumps on stems and leaves. They feed on plantsap and can weaken plants significantly.

5. Mealybugs: White, cottony-looking insects that feed on plantsap. They can cause leaf drop and stunted growth and are often found in clusters.

6. Thrips: Tiny, slender insects that can cause damage by feeding on flowers and leaves, resulting in silvery streaks or spots. They can also transmit viruses.

7. Fungus Gnats: Small flies whose larvae feed on organic matter in the soil but can also damage roots of young plants.

8. Caterpillars: Larvae of moths and butterflies that can cause significant defoliation by feeding on leaves.

9. Slugs and Snails: Mollusks that feed on leaves, stems, and flowers, leaving irregular holes and slime trails.

10. Japanese Beetles: These beetles feed on the foliage and flowers of many ornamental plants, causing skeletonization of leaves.

11. Borers: Insects like the lilac borer or dogwood borer that tunnel into stems and trunks, weakening the plant and potentially leading to its death.

12. Leafhoppers: Small, jumping insects that feed on sap and can transmit diseases to plants.

13. Root Weevils: These pests feed on roots and can cause wilting and decline in overall plant health.

Conclusion

To manage these pests, it's essential to regularly inspect plants, maintain good cultural practices, and consider integrated pest management (IPM) strategies, which may include biological control, cultural practices, and targeted pesticide use when necessary.

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Pests of Chrysanthemum and Their Control Strategies

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Chrysanthemum (Chrysanthemum morifolium), popularly known as "Queen of the East," is one of the most important ornamental crops cultivated worldwide for its beautiful flowers and economic value in the floriculture industry. These flowers are widely used in landscaping, garland making, decoration, and as cut flowers in the international market. In India too, chrysanthemum occupies a significant place in floriculture due to its diverse colors, long vase life, and high demand during festivals and ceremonies. However, like many other ornamental crops, chrysanthemum is highly vulnerable to various insect pests and mites. These pests not only reduce the vigor of the plants by feeding on their sap, tissues, and flowers, but also cause indirect losses by transmitting viral diseases or facilitating secondary infections. The presence of pests affects both the quantity and quality of flowers, ultimately reducing their market value. Therefore, identifying major pests and adopting effective control measures is essential for sustainable chrysanthemum cultivation.

Major Pests of Chrysanthemum and Their Damage

A. Aphids (*Macrosiphoniella sanborni, Myzus persicae)*

Aphids are small, soft-bodied insects that usually colonize on the tender shoots, buds, and young leaves. They suck plant sap, leading to curling, yellowing, and distorted growth. Heavy infestation results in stunted plants and poor flower development. The excretion of honeydew encourages the growth of sooty mold fungi, which interferes with photosynthesis.

B. Thrips (*Thrips tabaci, Frankliniella occidentalis)*

Thrips are tiny, slender insects that scrape the epidermal cells of leaves, petals, and tender shoots and then suck the oozing sap. Damaged leaves and flowers show silvery white streaks, curling, and browning at the margins. Flower buds often fail to open properly, leading to malformed blooms.

C. Leaf Miners (*Liriomyza trifolii*)

The adult flies lay eggs inside leaf tissues, and upon hatching, the maggots tunnel within the leaf mesophyll, creating serpentine mines. This reduces the photosynthetic area and weakens the plant. In severe infestations, leaves become blotched and dry prematurely.

D. Caterpillars (*Helicoverpa armigera, Spodoptera litura*)

Caterpillars feed voraciously on foliage, tender shoots, and flower buds. They chew irregular holes in leaves and bore into flower heads, thereby spoiling their appearance and quality.

E. Whiteflies (*Bemisia tabaci)*

Whiteflies congregate on the undersides of leaves and suck plant sap. Infested leaves show yellowing, curling, and early drying. Like aphids, whiteflies also excrete honeydew, which attracts sooty mold. More dangerously, they transmit viral diseases such as

F. Spider Mites (*Tetranychus urticae*)

Spider mites are minute pests that colonize on the undersides of leaves and feed by piercing and sucking plant cell sap. Infested leaves develop yellowish speckles, bronzing, and ultimately dry off. Severe infestation results in webbing across leaves and buds.

Control Strategies

Management of chrysanthemum pests should not rely solely on chemical control, as this leads to pesticide resistance, residue problems, and harm to beneficial organisms. Instead, Integrated Pest Management (IPM) is the most sustainable strategy.

A. Cultural Practices

- Maintain field sanitation by removing weeds, alternate hosts, and infested plant parts.
- Ensure proper spacing and ventilation in polyhouses or fields to reduce humidity, which favors many pests.
- Timely pruning and removal of old leaves discourage pest colonization.

B. Mechanical and Physical Control

- Hand-picking and destruction of caterpillars and infested leaves.
- Installation of yellow sticky traps for whiteflies and aphids, and blue sticky traps for thrips.
- Use of pheromone traps for monitoring and mass trapping of caterpillar pests.

C. Biological Control

- Release of predators like ladybird beetles (Coccinella septempunctata) against aphids.
- Use of parasitoids like Encarsia formosa against whiteflies and Diglyphus isaea against leaf miners.
- Predatory mites (Phytoseiulus persimilis) for controlling spider mites.
- Microbial insecticides like Bacillus thuringiensis (Bt) for caterpillars.

D. Botanical Control

- Application of neem seed kernel extract (NSKE 5%) or neem oil (2%) against sucking pests.
- Sprays of other plant-based formulations like pongamia or garlic extracts.

E. Chemical Control

- Aphids & Whiteflies: Imidacloprid, thiamethoxam.
- Thrips: Spinosad, fipronil.
- Leaf miners: Abamectin.

- Caterpillars: Emamectin benzoate, indoxacarb.
- Mites: Fenazaquin, abamectin.
- Chemicals should be used judiciously, in rotation, and only when pest populations exceed the economic threshold level (ETL).

Integrated Pest Management (IPM) Framework for Chrysanthemum

1. Regular Monitoring: Weekly inspection for pest symptoms.
2. Threshold-based Intervention: Apply chemicals only when pest population crosses ETL.
3. Combination of Methods: Integrate cultural, biological, botanical, and chemical control measures.
4. Resistance Management: Rotate insecticides with different modes of action.
5. Eco-friendly Approach: Prioritize biological and botanical options to reduce chemical load.

Conclusion

Pests of chrysanthemum pose serious challenges to commercial flower production, as they damage foliage, buds, and flowers, thereby reducing both yield and market quality. Among them, aphids, thrips, leaf miners, caterpillars, whiteflies, and mites are the most common and destructive. Effective pest control cannot rely on a single method. Instead, an integrated approach that combines cultural practices, natural enemies, botanicals, and judicious use of safe insecticides ensures sustainable production. By adopting IPM strategies, farmers can achieve higher productivity, reduce chemical residues, and preserve environmental health while ensuring that the beauty and market value of chrysanthemum flowers remain uncompromised.

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