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Biofortified Vegetables: Fighting Hidden Hunger Naturally

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Introduction

In recent decades, agriculture has made tremendous strides in increasing food production to meet the caloric needs of a growing population. However, beyond the visible battle against hunger lies a more subtle and pervasive issue - hidden hunger. 'Hidden hunger' is a term used to describe human deficiencies in essential vitamins and minerals, also known as micronutrients. Micronutrient deficiencies affect an estimated two billion people, or almost one-third of the world's population (Thompson & Amoroso, 2014). Hidden hunger results from inadequate intake of essential vitamins and minerals such as iron, zinc, and vitamin A. In India, this remains a silent epidemic, particularly among women and children. Biofortification is the process of increasing the nutrient content of food crops through breeding or biotechnology that offers a cost-effective and sustainable solution that works at the very root of the problem (Garg *et al.*, 2018). Among various food groups, vegetables hold a unique place in human diets due to their richness in micronutrients, antioxidants, and dietary fiber. When biofortified, they not only address nutritional deficiencies more efficiently but also blend seamlessly into daily meals without altering food habits. As India moves towards the goal of nutritional security, biofortified vegetables emerge as a natural, farm-based strategy to fight hidden hungerright from the soil to the serving plate.

Methods of Biofortification

1) Conventional Plant Breeding: This is the most widely accepted and environmentally sound method for biofortifying vegetables. It involves selecting and cross-breeding parent lines with naturally high nutrient content over multiple generations to develop stable, high-yielding biofortified varieties.

2) Genetic Engineering or Biotechnology: In crops where conventional breeding is limited by genetic variability, transgenic approaches are applied. Genes responsible for biosynthesis or accumulation of target nutrients are inserted into the plant genome.

3) Mutation Breeding: Mutation breeding uses physical or chemical agents (like gamma rays or EMS) to induce genetic variability, from which high-nutrient mutants are selected.

4) Microbial Biofortification: Use of beneficial soil microbes such as mycorrhizae, plant growth-promoting rhizobacteria (PGPR) and biofertilizers to enhance nutrient solubilization and uptake. Rhizobacteria that increase iron and zinc uptake in leafy vegetables.

Nutritional Importance of Vegetables

1) Rich Source of Micronutrients

a. **Iron:** Found in leafy greens like spinach (Spinacia oleracea) and amaranthus (Amaranthus spp.); vital for preventing anemia.

b. **Zinc:** Present in peas, beans and pumpkin; important for immune function and wound healing.

c. **Vitamin A:** Abundant in carrots, sweet potatoes, and pumpkins; essential for vision and skin health.

d. **Vitamin C:** High in capsicum, tomatoes and broccoli; enhances iron absorption and boosts immunity.

e. **Folate:** Found in leafy vegetables and okra; crucial during pregnancy to prevent neural tube defects.

f. **Calcium and Magnesium:** Present in green leafy vegetables like fenugreek and moringa.

2) Dietary Fiber and Digestive Health: Vegetables provide both soluble and insoluble fiber, which aid in digestion and bowel regularity and help regulate blood sugar and cholesterol levels.

3) Protective Phytochemicals and Antioxidants: Many vegetables are rich in natural antioxidants such as flavonoids, glucosinolates, anthocyanins, and lycopene that neutralize harmful free radicals, reduce inflammation and protect against chronic diseases such as cancer, diabetes, and cardiovascular disorders.

4) Role in Combating Hidden Hunger: Regular and adequate consumption of vegetables directly addresses micronutrient deficiencies, also known as hidden hunger. In rural and low-income populations, where access to supplements is limited, vegetables serve as the most affordable and accessible nutritional intervention.

Examples of Biofortified Varieties of Vegetable Crops in India

Crop	Variety	Institution	Special Feature
Carrot	*Pusa Meghali*	ICAR-IARI, New Delhi	High beta-carotene (~14.5 mg/100g); suitable for raw and cooked use
Pumpkin	*Arka Suryamukhi*	IIHR, Bengaluru	High carotenoid content; good keeping quality
Sweet Potato	*Bhu Sona, Bhu Krishna*	ICAR-CTCRI, Trivandrum	Orange and purple-fleshed, rich in beta-carotene and anthocyanins
Amaranthus	*COAAm-1*	TNAU, Coimbatore	High iron (17–20 mg/100g) and calcium content
Spinach (Palak)	*Pusa Bharati*	ICAR-IARI	High iron content; rich in chlorophyll
French Bean	*Arka Arjun*	IIHR, Bengaluru	Rich in iron and fiber
Garden Pea	*Arkel* (improved line)	ICAR-IARI	Protein content >7%; tender pods, good taste
Cowpea	*Kashi Unnati*	ICAR-IIVR, Varanasi	High protein and drought-tolerant; suitable for kharif season
Tomato	*Arka Saurabh, Arka Rakshak*	IIHR, Bengaluru	Rich in lycopene and Vitamin C; multiple disease resistance
Tomato	*Pusa Hybrid-8*	ICAR-IARI	High Vitamin C and lycopene content
Chilli	*Pusa Sadabahar*	ICAR-IARI	Rich in capsaicin and vitamin C

These varieties are promoted under Poshan Abhiyan and ICAR's Nutri-Sensitive Agricultural Resources and Innovations (NARI) initiative. Krishi Vigyan Kendra (KVKs) are actively involved in demonstrations, seed distribution, and farmer awareness programs on these biofortified vegetables. Efforts are ongoing to include these varieties in mid-day meal schemes, anganwadi nutrition programs, and kitchen gardens across the country.

Conclusion

Biofortified vegetables represent a powerful, sustainable, and locally adaptable solution to the pressing problem of hidden hunger in India. By enhancing the micronutrient content of commonly consumed vegetables through scientific breeding and innovative agronomic practices, we can significantly improve the nutritional status of vulnerable populations. These nutrient-rich varieties not only support better health outcomes but also align with traditional dietary habits, making them an effective and culturally acceptable innovation. As India progresses towards its nutritional security goals, integrating biofortified vegetables into mainstream agriculture, public health programs, and daily diets will be a key step in ensuring a healthier, stronger, and more resilient nation.

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Carbon Credits in Modern Agriculture: Integrating Ecology with Economy

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Introduction

In recent years, as the climate crisis deepens and the greenhouse gas (GHG) emission intensifies, agriculture has increasingly been recognized not merely as a source of emission but also as a powerful solution. In India, 18 percent of the total greenhouse gas emission comes from agriculture,farming systems across the world are traditionally associated with methane, nitrous oxide, carbon dioxide emission. However, they are now being weaponised for battling with climatic issues and mitigating environmental crisis. The concept of carbon credit is one of the most promising innovations leading this transformation.

Understanding Carbon Credits: A New Currency for Climate Action

A carbon credit represents a tradable certificate that grants its holder the right to emit one ton of carbon dioxide (CO_2) or its equivalent greenhouse gases, such as methane (CH_4) nitrous oxide (N_2O). If a farmer or agricultural enterprise implements practices that reduce or capture emissions, they earn measurable "carbon credits". These credits can even be sold in the carbon market, generating revenue while contributing to global emission reduction targets and sustainable development goals.

It encourages widespread adoption of sustainable farming practices like no-till farming, organic manure use, agroforestry or any other technique for soil health restoration. on the other hand, it provides farmers with a new income stream, particularly beneficial in times of price volatility, yield uncertainty and rising input costs.

Measurement of Carbon Credits

Quantifying carbon credits requires rigorous scientific measurement and independent verification. Typically, one carbon credit equals one ton of CO_2 (or equivalent GHG) reduced, avoided or captured from the atmosphere.The measurement is processed integrating several key methodologies:

- **Soil Carbon Testing:** Measuring the amount of carbon stored in soils, through organic matter accumulation.
- **Tree and Forest Biomass Calculation:** Estimating the carbon, captured by growing trees and vegetation in agroforestry systems.
- **Methane Monitoring:** Assessing methane reductions in paddies and livestock systems (vulnerable for high carbon emission)

using advanced sensors and emission models.

With the rise of Agri-tech companies and digital platforms, data collection has become more precise and transparent. Remote sensing, satellite imagery and AI-based soil analytics are increasingly used to measure carbon sequestration at field level, ensuring reliability, scalability and proper precision.

How Can Farmers Sell Carbon Credits?

Effectively sell of the carbon credits converts sustainability into a tangible and reliable income source. Farmers start the programme by registering their projects under recognized standards, such as no-till cultivation, organic manure application, cover cropping or agroforestry models. The projects undergo verification and certification by accredited agencies to ensure authenticity and compliance with international carbon market protocols.

Once certified, the credits can be listed and sold in voluntary or compliance markets. Several organizations, cooperatives and Agri-startups now act as intermediaries, connecting farmers with global buyers who seek verified credits to offset their emissions. This has democratized carbon trading, allowing even smallholders to participate and benefit from sustainable practices.

Who Buys Carbon Credits?

The demand for carbon credits is growing rapidly, driven by industries, governments and investors seeking to fulfil their climate commitments.

- Industries such as oil, steel, cement, aviation and shipping purchase credits to balance their unavoidable emissions.
- Governments buy credits to meet international climate pledges and maintain compliance with environmental agreements.
- Investors and traders view carbon credits as a new green asset class, offering both financial returns and environmental benefits.
- Food and Agribusiness companies invest in credits to build 'net-zero' or 'carbon-neutral' supply chains, aligning their operations with consumer demand for sustainability.

This broad base of buyers ensures a strong and growing market for carbon credits, encouraging continuous investment in climate-positive agricultural practices.

Role of Carbon Credits in Modern Agriculture

Agriculture accounts for nearly 18% of global GHG emissions, primarily through methane from livestock, nitrous oxide from fertilizers and carbon dioxide from soil degradation and deforestation. Again, agriculture also holds an immense potential to become a carbon sink rather than a carbon-source.

By adopting regenerative practices, such as reduced tillage, composting, intercropping, organic nutrient management, farmers can store large amounts of carbon in soil and vegetation. When these actions are scientifically measured, verified and eventually sold in the market as carbon credits: they not only mitigate climate change, fight for sustainability but also additionally provide farmers with asustainable income stream. Thus, carbon credits transform the farm from a site of emissions into a hub of climate resilience and economic opportunity. They integrate ecology with economy, allowing farmers to safeguard both their livelihoods and the planet's health.

Real-World Examples of Success

Several countries and organizations have already pioneered successful carbon credit models in agriculture:

These show how different geographies,

United States	Indigo Ag pays farmers for regenerative farming practices that capture the soil carbon, per acre. The initiative integrates advanced digital tools for monitoring and verification.
Kenya	Agroforestry programs funded by carbon projects enable small farmers to plant trees, improving soil fertility while generating credits for international sale.
India	Agroforestry and organic agriculture projects supported by various organizations are helping farmers earn carbon revenue while enhancing biodiversity and resilience.
Brazil	Carbon finance mechanisms, tied to Amazon rainforest conservation, protect vast ecosystems while generating income for local forest tribes committed for their indigenous land use patterns.

climates and farming systems can successfully integrate carbon finance into agricultural sustainability strategies.

Conclusion

The carbon credit mechanism represents a significant shift in how we perceive agriculture: from a traditional livelihood sector to a key player in global climate mitigation. However, for this system to reach its optimum potential, several challenges must be addressed. As carbon markets mature and climate finance becomes more inclusive, farmers can be weaponised to play an increasingly dominant role in the fight against global warming. Each ton of carbon sequestered on a farm, each tree planted or each acre sustainablymanaged brings us one step closer to a low-carbon future and strong climate finance. Carbon credits in modern agriculture symbolize more than just financial transactions, they represent a partnership between people and the planet, where every sustainable act on the field contributes to global environmental restoration.

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Seaweed Extracts: Multiple Quality

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Introduction

Seaweeds and sea plants are an integral part of the coastal ecology and landscape. Seaweeds such as the brown algae *Ascophyllum nodosum* (commonly known as Norwegian Kelp) grow in abundance with in the littoral zone, that area periodically covered by rising or receding tides. For centuries, agricultural areas close to the coastal zones have utilized seaweeds as a valuable source of organic matter for various soil types and for many different fruit and vegetable crops. Today, seaweed meals and soil amendments are available in ready-to-apply dry form for use in crop soils and home gardens alike. Moreover, high quality liquid and powder sea weed extract products can be found in pure form, or in recipe formulations with or without ingredient sranging from traditional (e.g., fertilizers, pesticides, etc.) to non-traditional products (e.g., humates, fish products, etc.) (2-4) of all the seaweeds and extract products currently on the market, *Ascophyllum* is the most widely used and researched seaweed species in agriculture. Seaweed extracts are natural, organic-derived products used in agriculture as biostimulants, meaning they improve plant growth and resilience. They are derived from marine algae, particularly brown algae, and contain a range of bioactive compounds like polysaccharides, vitamins, and growth-promoting hormones. These extracts can enhance crop vigor, improve yield, and help plants resist stress, making them a sustainable alternative to chemical fertilizers and pesticides.

Other Important Points about Seaweed Extracts

Seaweeds are a natural marine resource containing many bioactive compounds such as amino acids, lipids, carbohydrates, proteins, phytohormones and antimicrobial compounds. Since ancient times, seaweeds have been used in various sectors, including medicine, food, and the cosmetic industry. Currently, seaweeds are a promising alternative to reduce the application of harmful chemicals in agriculture. Seaweed and its derived products have been utilized for plant growth promotion, immunity enhancement, and the reduction of biotic and abiotic stresses. In the current global scenario, synthetic fertilizers and chemical pesticides are commonly used to increase agricultural crop production to meet the growing demands of the world population. However, these chemicals pose significant threats to the health of people, livestock, plants, soil and the entire environment. In contrast, seaweed-based products are emerging as a newer option for stress mitigation and reduction, offering an alternative to synthetic chemicals. This article explains the use of seaweed extracts to increase the tolerance of plants to biotic and abiotic stresses. We also address the functions of various bioactive compounds present in seaweed extracts and the mechanisms by which they promote plant growth and induce defense against different stresses.

Seaweeds and seaweed-based products in agriculture: Seaweeds are macroscopic, multicellular organisms rich in lipids, proteins, carbohydrates, enzymes, and bioactive compounds and have the capacity to tolerate adverse situations such as high temperatures, salinity, and light (Shukla *et al.,* 2016; Gunupuru *et al.,* 2019; Patel *et al.,* 2020). *Ascophyllum, Fucus,* and *Laminaria* are the main genera belonging to the brown algae. The use of seaweeds enduring ancient in agriculture as fertilizer, organic matter, and a biostimulant (Sujeeth *et al.,* 2022). Seaweeds contain many constituents, such as sterol, nitrogen-containing compounds, and micro- and macro-nutrients, which show growth-promoting activities (Khan *et al.,* 2009 and Craigie, 2011). In the cosmetic and pharmaceutical industries, many bioactive seaweed compounds are identified and used, but less is known about their plant growth-promoting activities. In addition, the focus is now on the use of marine algae in agriculture and their bio stimulating activities.

Key aspects of seaweed extracts

Biostimulants: They act as plant growth regulators, stimulating various physiological processes, including nutrient absorption and stress tolerance.

Organic and Sustainable: Derived from natural sources, they offer a more environmentally friendly approach to agriculture compared to synthetic fertilizers.

Diverse Benefits: They can improve seed germination, root development, overall plant vigor, and even enhance crop quality.

Stress Tolerance: They help plants cope with abiotic stresses like drought, salinity, and high temperatures, as well as biotic stresses like diseases and pests.

Nutrient Rich: They provide essential nutrients like calcium, magnesium, phosphorus, and potassium, as well as trace elements needed for healthy plant growth.

Application Methods: They can be applied through foliar sprays, soil incorporation, or even through seed treatments.

Seaweed extract positive relation with agriculture

Agricultural fertile land is shrinking globally due to the harmful effects of climate change, urbanization, industrialization, random application of harmful chemicals, and several other anthropogenic activities. Moreover, several biotic stresses like fungal, bacterial, and viral pathogen attacks on crop plants affect the world's agricultural production. These stresses reduce the quality, quantity, growth, and yield of crops. More than 50% loss in the average yield was reported to be due to abiotic stresses in many crops . Additionally, changes in environmental conditions can make the plant susceptible to different plant pathogens. There are many other factors that threaten crop productivity, such as the development of resistance in plant pathogens against pesticides, which are continuously in use to manage different plant diseases. Therefore, many experiments have been conducted to establish alternative methods for the management of plant biotic and abiotic stresses to enhance crop health and development. The current global scenario is experiencing a demand for organic and agro ecological farming, which can avoid the harmful effects of synthetic agrochemicals and focus on natural resources to enhance plant growth attributes. Abiotic factors in plants, including drought and salinity stress, serve as limiting factors for plant development and crop yield, and they also disrupt the physiological characteristics of plants. These changes affect plant morphology and the gene expression responsible for metabolism, stomatal activity, and photosynthesis. Conversely, several phytohormones, including salicylic acid, ethylene, and abscisic acid, aid in overcoming these adversities and triggering stress tolerance responses. In addition, farmers rely on the excessive use of synthetic chemicals and fertilizers to protect the crops from biotic stresses. These chemicals leave short-term and long-term harmful effects on the environment. Therefore, there is a requirement for healthy and natural alternative strategies to reduce the dependency on synthetic chemicals. Seaweeds and products based on seaweed act as biostimulants and have the capacity to lower the enormous use of organic fertilizers and chemicals. The use of bio stimulants through natural extracts from seaweeds can be a sustainable technology for the increment in food production without adversely impacting the environment. Recently, reported successful seaweed extract use in controlling several diseases in wheat, including wheat head blight. Similarly, in peas, the infection of powdery mildew was successfully controlled with the application of seaweed extracts. In addition, the use of seaweed extracts in soybean plants was successful in reducing the harmful effects of abiotic stresses.The current analysis in this article is based on the use of seaweed and seaweed-based products for the production and protection of crops. Seaweed extracts are currently used in agricultural practices and have already been commercialised. Sea weed is available in a number of types, including LSF (Liquid Seaweed Fertilizer), granular, and powder.

Effect on Germination

Many researchers have recorded the beneficial effects of seaweed on agricultural crop germination. Higher germination percentage, shoot and root length, and seedling vigor index was observed when rice seeds were soaked in lower concentrations of seaweed extracts. In the case of maize, a similar result was also published. Seeds soaked in lower concentrations (5%) of both seaweed saps (*Kappaphycus* and *Gracilara* species) displayed a higher rate of germination, while seeds soaked in higher concentrations (15%) of extracts inhibited germination. At low concentrations of seaweed extracts, an increase in germin-ation and seedling vigor may be due to the presence of growthpromoting substances such as auxins, gibberellins, and phenyl-acetic acid and other micro-nutrients. The use of seaweed sap at a 15% concentration of either *Kappaphyccus* or *Gracilara* sap improved wheat germination significantly. However, when the concentration is either decreased to 2.5 percent or increased to 20 percent, germination is greatly reduced. The reduction may be due to high salt concentration in seaweed saps. Development promoting factors such as IAA and IBA Gibberlins (A & B), micronutrients, vitamins, and amino acids, which have a significant impact on crop germination, could explain the higher germination percentage at lower concentrations.

Effect on Crop Growth

With higher concentrations of seaweed extract, rice yield attributing characters such as the number of panicles hill-1 and number of effective grains panicle-1 increased, and the highest value was obtained for 15% K sap, which was statistically comparable to 10 and 5% K sap concentrations. Furthermore, the applica-tion of both *Kappaphyccus* sap and *Gracilaria* sap at the same concentration improved the absorption of N and P by grain. When compared to a control, seaweed application increased crop growth while also increasing the number of active nodules. This may be because many cytokinins found in brown algal extracts, such as trans-zeatin riboside and its dihydro derivatives, are present. Due to increased plant height, number of pods plant-1, number of grains plant-1, number of branches, and improved nutrient uptake by plant, 15% seaweed extract from *Kappaphycus alvarezii* resulted in a 57% increase in grain yield in soybean. Effect of Seaweed Extracts on Plant Growth Over the decades, seaweed extracts have been highly explored for possible use in crop production for improving biomass yield and produce quality. These extracts have been shown to positively affect seed germination and plant growth at all stages up to harvest and even post-harvest. Seaweed products have been shown to promote increased germination rates and cause significant increases in seedling vigor by enhancing root size and density. The extracts have also been shown to protect seedlings from transplantation shock in tomato, cabbage, and marigold. The improved rooting architecture could be a result of small levels of phyto hormones present in the extracts such as auxins as well as various stimulatory processes engaged in the plant system upon treatment with these extracts. The enhancement of root systems of plants treated with seaweed extracts was also observed in vegetatively propagated plants. For instance, cuttings from floricult-ural plants such as marigold treated with an extract from *E. maxima* led to an increase in root density. Results of a study in spinach treated with *E. maxima* extracts showed the increase of plants' endogenous cytokinins, isopentyladenine, dihydroze-atin, and cis-zeatin which have all been linked to positive plant growth. At the plant's vegetative stage, application of *A. nodosum* in tomato and sweet pepper led to the increased chloroph-yll content of leaves which was probably due to inhibit-ion of chlorophyll degrada-tion caused partly by betaines present in the extract. These betaine compounds in the seaweed extracts suspend photosynthetic activity loss by the inhibition of chlorophyll degradation. Similarly, a significant increase in chlorophyll content, stomatal conduct-ance, photosynthetic rateand transpiration rates were recorded in asparagus plants treated with *A. nodosum*. Treatment of willow plants with an extract of *E. maxima* enhanced the electron transfer rates of both photosy-stems. These increases in flower numbers and fruit set inevitably led to an improve-ment in yields. Recent studies have shown that seaweed extracts and their components can modulate the expression of genes responsible for the endogenous biosynth-esis of growth hormones includi-ng auxin, cytokinin, and gibberellin. This was reported in tomato and sweet pepper plants treated with extracts of *A. nodosum, S. vulgare*, and *A. spicifera.*

Effect on Yield

In rainfed soybean production, foliar applications of seaweed extracts could be a promising choice for yield enhancement. The addition of seaweed to sunflower seed significantly increased oil content, oil yield, K, Na and crude protein. It was confirmed that applying 0.6% concentrations of *Gracilaria dendroides*, and *Ulva lactuca* to sunflower resulted in higher oil content of 34.05 and 30.55%, respectively. To increase potato growth and yield, supplementing the prescribed fertiliser dose with extracts of either *Kappaphycus alvarezii* (K sap) or *Gracilari aedulis* (G sap) at a 10% concent-ration could be used. Spraying seaweed extract on potato tubers 30 and 60 days after planting resulted in higher tuber yield, increased nitrogen, total soluble solids, and protein content. In the case of rice, a 15% *Kappaphyccus* (K) or *Gracilaria* (G) sap application resulted in an 18.0% increase in rice grain yield as compared to control. The application of 7.5% and 5.0% concentr-ations of *K. alvarezii* and *G. edulis* sap, respectively, increased wheat grain yield by 19.74% and 13.16%, respectively, over the control.

Conclusion

Generally, the positive impacts of seaweed extract-based biostimulants on crop production and the environment warrant their prescription for applications in different cropping systems. Published reports so far confirmed the positive effects on plant growth, vigor, enhanced tolerance to pests, diseases, and abiotic stresses, as well as an overall improvement in plant productivity. The positive effects of the seaweed products are dependent on the type of the seaweed resource, quality, and composition of the extract, and the method, concentration, and frequency of application. All the enhanced growth effects have been observed only with the whole extract, which underlines the very interactive nature and synergistic activity of the seaweed extract components on plant growth and functions. However, the synergistic activities and interactions of biomolecules and their molecular functions on the plants are largely unresolved due to its complexity. There is strong evidence to support the role of seaweed extract applications in altering the microbiome of the rhizosphere and phyllosphere. Further studies into this area should verify the effect of introduced and native beneficial microbes in order to improve the microbial plant growth promotion. There is also a necessity to understand the basic level of communication between the plant and microbial systems' interface as influenced by seaweed extracts. Emerging studies also support the compatibility of seaweed extracts and products with other agricultural chemical and non-chemical inputs. Although using seaweed extract as a sole input or standalone method may not be sustainable, it is ideal to use a minimum dose of pesticides which can synergize the seaweed effects and benefit the overall crop production phenomenon. The seaweed extract formulations are available as liquid concentrates which limits their shelf life. Efforts are needed to produce user-friendly and stable solid formulations that can have improved shelf-life. The soil application of seaweed extract remains economically challenging due to the high levels of input needed. Alternative means including root feeding, foliar misting, and drip application need to be optimized for the crops and growing systems. Although seaweed biomass is renewable, due care should be taken to prevent over-exploitation and disturbance to the marine or coastal biodiversity. The recent excessive inflow of Sargassum weed in the pacific and Atlantic currents are posing serious challenges to the marine and coastal biodiversity.

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Azolla: A Highly Potential Aquatic Ferns

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Introduction

Urbanization and population growth can lead to increased pollution levels. Rising per capita consumption and a growing human population are depleting natural resources. Biotechnological techniques are widely used to improve environmental sustainability in plant areas. Azolla, a well-known biotechnological product, has global potential for environmental sustainability (Rehman *et al.*, 2022). The name Azolla comes from the Greek words azo (to dry) and allyo (to kill), reflecting the plant's vulnerability in dry environments. Azolla is an aquatic fern that floats freely and belongs to the genus Azolla in the Salviniaceae family (Katole *et al.*, 2017). This tiny, rapidly spreading free-floating fern is found worldwide in marshy ponds, ditches, and damp soils. Azolla is a free-floating, dichotomously branched aquatic fern that naturally grows in marshy ponds, ditches, and damp soils. Indian species are generally triangular in shape, with lengths of 1.5 to 3.0 cm and widths of 1 to 2 cm. The fronds have short, branched stems called rhizomes covered in tiny, alternating, overlapping leaves, and tiny roots typically attached to rich microphylla (Roger and Renaud, 1979). Each leaf of the sporophyte is divided into dorsal and ventral lobes, with the ventral lobe being thin, nearly colorless, and only one cell thick in the distal half (Peters and Calvert, 1983). The sporophyte has a dorsiventral arrangement with many stomata, single-celled papillae, and multilayered mesophyll adaxial and abaxial epidermal tissues on the aerial dorsal leaf lobe. The adaxial epidermis folds to form an ellipsoidal hollow in the dorsal leaf lobe. The mucilage lining the gas-filled cavity contains the cyanobiont Anabaena Azollae and a gram-positive, non-nitrogen-fixing bacterium known as Arthrobacter species (Grilli Caiola *et al.*, 1988).

Fig 1: Constructing an artificial pond for cultivating Azolla

Aspects of plant benefits

The tests have shown that Azolla can overcome nutritional limitations that impede plant growth by enhancing nutrient acquisition. Azolla provides various benefits to both the environment and plants, depending on the plant variety and growth conditions and practices:

- Improved flowering and fruiting
- Decreased disease incidence
- Increased plant establishment and

survival at seedling or transplanting

- More robust and healthy plants
- Improved drought tolerance, allowing for less watering
- Optimized use of fertilizers, particularly nitrogen
- Increased tolerance to soil salinity
- Improved soil quality and nutrient cycling

Azolla in rice production as a biofertilizer

Azolla is used as a biofertilizer for rice due to the following reasons:

1. Azolla fixes nitrogen at significant rates.
2. Azolla grows rapidly.
3. Being a floating plant, Azolla does not compete with rice for space and light.
4. Azolla thrives best under partial shade, which is provided by the rice canopy during its early and intermediate growth stages.
5. Azolla deteriorates as rice matures, releasing nutrients into the environment.
6. Upon decomposition, Azolla releases fixed nitrogen, phosphorus, and other nutrients back into the environment, benefiting rice growth.
7. Azolla can store potassium in its tissues and release it for rice uptake when decomposing.
8. A dense layer of Azolla mats in a rice field helps suppress weed growth.

The green manure of Azolla

Azolla can be used as green manure in the cultivation of water bamboo, arrowhead, taro, wheat, and rice (Van Hove, 1989). When Azolla was used as green manure on water-logged soil, 60–80% of the nitrogen was released within two weeks, leading to rapid mineralization (Ito and Watanabe, 1985). Sharma *et al.*, (1999) observed the highest wheat yields when 20 tonnes of Azolla and 60 kg of nitrogen were applied.

Bioenergy and Azolla

When Azolla-Anabaena is cultivated in a nitrogen-free atmosphere or a nitrate-containing water medium, the nitrogenase in the symbionts uses water as a source to evolve hydrogen instead of fixing nitrogen, resulting in the production of a high-energy, non-polluting fuel. Hall *et al.*, (1995) demonstrated that exposure to a microaerobic environment, a partial vacuum, an atmosphere enriched with carbon dioxide or argon, or the immobilization of Anabaena Azollae cells separated from the fern can all enhance the rate of hydrogen production.

Azolla as a food ingredient for human consumption

Some researchers have tried making Azolla meatballs or soups for human consumption, but these recipes have not been officially published. In the 16^{th} century, Shi and Hall (1988) wrote a book in China that discussed the therapeutic benefits of Azolla. In Tanzania, Wagner (1997) reported that Azolla has been used effectively as a traditional remedy for coughs. In Western countries, Azolla is occasionally eaten as a salad due to its high protein content.

Azolla as an ingredient in the space diet

Azolla was suggested as a potential component of the diet for life on Mars by Katayama *et al.*, (2008) in collaboration with the Space Agriculture Task Force. It was found to meet human nutritional requirements in that environment.

Azolla as a livestock nutrient supplement

Various species, such as fish, pigs, rabbits, chickens, and ducks, can benefit from Azolla as a food supplement. Azolla is collected in large quantities and used as feed for pigs and cattle. Broilers fed with Azolla showed similar growth and body weight values compared to those fed with maize-soybean meal. Additionally, digested Azolla slurry from biogas production can be used as fertilizer for fish ponds. Research has shown that Azolla can be used as a feed ingredient for lactating cows without affecting milk yields and fat percentage when compared to conventional feeds.

Fig 2: All-weather friend of farmers: Azolla, boosts production also

Saline soil reclamation using Azolla

Azolla is relatively sensitive to salt, but after two years of cultivation in a saline environment, the salt content decreased from 0.35 to 0.15. The desalination rate was 71.4%, which is 1.8 times faster than water leaching and 2.1 times faster than Sesbania. Additionally, it reduced the electrical conductivity, increased the calcium content of the soil, and lowered the pH of acidic soil (Anjuli *et al.,* 2004).

As a mosquito repellent and weed control, Azolla

Azolla can be used for insect control as it inhibits mosquito hatching and adult emergence by forming a dense mat on the water's surface. Research has shown that breeding of *Anopheles* spp. was significantly inhibited in water bodies covered with Azolla. A study by Rajendran and Reuben (1988) found that A. pinnata reduced oviposition and adult emergence of Anopheles culicifacies and Culex quinquefasciatus, but did not affect larval survival. Egg hatchability was also slightly reduced.

Additionally, Azolla has been found to suppress weed growth. Research by Krock *et al.,* (1991) demonstrated that an Azolla cover reduced the overall weed population, particularly the challenging weed Monochoria vaginalis, which is often resistant to traditional weed control methods.

Azolla in production of biogas

Methane gas, a potential fuel source, is generated through the anaerobic fermentation of Azolla (or Azolla and rice straw). The residual effluent, rich in nutrients originally present in the plant tissues, except for a small amount of nitrogen lost as ammonia, can serve as a fertilizer. Das *et al.,* (1994) found that a combination of cow dung with Azolla residue in a ratio of 1:0.4 resulted in 1.4 times higher gas production compared to cow dung alone.

Conclusion

Extreme environmental changes brought on by human activity pose a threat to humanity; thus, we must research and create alternate methods of managing our business. Azolla's use as biofertilizer and for all other purposes is crucial to preserving or enhancing the condition of the environment worldwide. In the future, biotechnology interventions will undoubtedly be required to more effectively use the Aquatic Pteridophyte's potential. In order to make Azolla less labor-intensive and more resilient to environmental fluctuations, a combination of basic and applied research methods should be used. This will increase and diversify its actual use in industry, agriculture, and environmental management. Azolla is referred to as "a green gold mine" in a review, yet this fact is disregarded when considering its potential replacement for inorganic fertilizer and other crucial applications outlined above for environmental preservation and sustainable agriculture.

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Integrating Microbial Community Dynamics into Sustainable Pleurotus Mushroom Production

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Introduction

Mushrooms are a type of macrofungus that can have either epigeous or hypogeous fruiting bodies. The most widely farmed fungus in India is Agaricus bisporus, followed by *Pleurotus* spp. Pleurotus species are among the most widely farmed edible mushrooms in the tropics (Quimio *et al.,* 1990). Oyster mushrooms may be grown in both temperate and tropical climates because of the temperature range in which they thrive. Wheat straw, a substrate frequently used for oyster mushroom production, is increasingly being substituted in recent years by alternative cellulose substrates derived from the food and agriculture sectors. Cultivating mushrooms is the most economical biotechnology currently available for recycling lignocellulose organic waste, combining the production of high-protein food with pollution avoidance. The most cultivated species of Pleurotus are *P. ostreatus* (PO), *P. sajor-caju* (PSC), PF (Pleurotus flabellatus) and *P. eous* (PEO), particularly *P. florida* (PF) and *P. sajor-caju* (PSC) are the most popular. Worldwide, there is growing awareness of the nutritional worth of mushrooms and their possible health advantages. Proteins, carbohydrates, dietary fiber, water-soluble vitamins, vital amino acids, and minerals are abundant in Pleurotus. Research conducted suggests mushrooms to be a nutritionally sound food that are of greater value to vegetarians. Additionally, mushrooms contain a variety of vitamins and mineral salts, especially those in the B and certain D families. 5.3-14.8g of dry matter, 1.5-6.7g of carbs, 1.5-3.0g of protein, and 0.3-0.4g of fat are all present in 100 g of fresh mushrooms. Mushroom species are known to have wide range of metabolites such as antitumor anti-cholesterol and anti-cancerous properties, antioxidant, antigen toxic antiplatelet aggregating, antihyperglycemic, antifungal, antibacterial and antiviral activities, anti-inflammatory, hepatoprotective, antidiabetic, hypolipidemic, hypotensive and cytotoxic properties.

Agroclimatic Requirement: According to Bumanlag *et al.,* (2018), one of the most important factors in producing the best yields is optimizing the growth circumstances, which include temperature, humidity, and light levels. Although oyster mushrooms can be grown all year long, for commercial purposes they need particular environmental factors including temperature and relative humidity. The optimum temperature and relative humidity for maximum mycelial growth is 25-30ºC and 75-90 per cent respectively (Ragupathi *et al.,* 2016). Variations in any of the factors directly affect the primordial initiation, yield and biological efficiency. Thakur *et al.*, (2000) conducts their experiment for ten successive months (January to October) and noticed that January to March were the most favourable months for early spawn run, pin head initiation and maximum biological efficiency (58.54-63.62%). In the months of May and June there was no spawn run observed. This denotes that high temperature with low relative humidity slow down the growth of mycelium. Uddin *et al.*, (2011); Chitra *et al.*, (2018); Deora *et al.*, (2021) reported that the most favourable months for higher production and best biological efficiency were during the winter (December to February).

Cultivation of Pleurotus

Addition of supplements (rice husk) to waste paper significantly increase spawn running, pin head formation, fruit body formation and mushroom yield (Tesfaw *et al.*, 2015, Ruiz-Rodriguez *et al.*, 2010). The substrates used for cultivation of oyster were used again for other cultivation. The reused of substrates that contained additional supplements exhibited better growth on both pasteurized and sterilized substrates (Tesfaw *et al.*, 2015).

Microbial community for Mushroom cultivation: The amount and quality of mushroom production yields can be directly impacted by the composition of the substrate. Thus, mushroom production may be strongly impacted by the microbial populations and dynamics of the compoting substrates. During the culture phase, modifications to the microbial diversity and substrate composition can affect the yield of high-quality substrates and provide a high level of biological efficiency. Research on coexisting micro-organisms in mushr-oom could greatly advance the field and aid in the creation of methods that would allow scientists to improve the quality and productivity of mushrooms.

Methods

Substrate preparation

The substrates used for Pleurotus cultivation must be soaked in water to have an initial moisture content around 70%. Based on the studies conducted so far, it can be inferred that mainly four techniques have been employed to sterilize the substrate or reduce the substrate borne contaminants (Rajarathnam and Bano, 1987). In the first technique, substrate was autoclaved at 121°C for one hour or more and cooled to an ambient temperature before spawning. Pasteurization, aimed to selective killing of microbes, was another method introduced for large scale cultivation of Pleurotus. In this method, the substrate was subjected to 60 to 100°C for a few hours and then cooled before spawning. In the third technique, namely hot water treatment, the substrate was dipped in water at 65 ± 5°C for a minimum period of 10 min. In the final technique, wet substrate was allowed to ferment before its processing. However, several studies on substrate preparation have been conducted and various workers suggested modifications of the above techniques. Pleurotus has the characteristic ability to colonize plant wastes with low nitrogen content and to produce fruiting bodies of high nitrogen content. But preparation of substrate into an ideal form, suited for mushroom growth is important in mushroom cultivation (Rajarathnam and Bano, 1987). Early workers used composted substrate for Pleurotus cultivation (Block *et al.*, 1959). Later it was found that the cumbersome method of composting or fermenting the substrate practiced in case of Agaricus cultivation was not necessary for Pleurotus cultivation. Bano and Srivastava (1962) used wet paddy straw without pasteurization for cultivation of P. flabellatus. Pankow (1984) has also tried to culture P. florida and P. ostreatus on non pasteurized wheat straw. The yield obtained was 4.5 kg and 3.1 kg respectively per 14 kg dry wheat straw. Zadrazil (1973) reported that fermentation of substrates was not necessary for Pleurotus cultivation. Pleurotus species can break down and transform lignocellulosic materials into biomass that is high in protein (Mamiro and Mamiro 2011). They can also assist in the management of agricultural wastes, whose disposal has become problematic (Das and Mukherjee 2007). Compared to other grown mushroom species, it showed better earliness, sporophore yield, and colonization rates on various agro wastes (Philippoussis *et al.,* 2001). A variety of lignocellulosic materials are typically used to grow Pleurotus species (Khan and Tania 2012; Poppe, 2000). *Pleurotus* spp. is characterized by its rapid growth on agro-wests such as paddy straw (Maheshwari *et al.,* 2007), wheat straw (Gregori *et al.,* 2007; Deora *et al.,* 2021), wheat straw- cotton straw (Akyuz and Yildiz 2007), cotton waste (Oh *et al.,* 2000), cotton seed (Girmay *et al.,* 2016), grasses (Singh and Singh 2011; Bumanlag *et al.,* 2018); Maize stover (Fanadzo *et al.,* 2010). When Pleurotus ostreatus grows on 40-60% tea leaf waste resulted in high yield and biological efficiency (Yang *et al.,* 2016).

Preparation of spawn: Spores or a small portion of a certain fungus can be used to harvest mycelium. The pure culture was maintained on test tube slants with 2% malt extract agar media by periodic subculturing, and the pure culture was multiplied using this medium. The slants must be inoculated and then maintained at 25°C in an incubator until the required growth is achieved. After pure culture is achieved, mother spawn and planting spawn are raised on grains. A mushroom's mycelium grows on grains, which are then used for seeding, or what is commonly referred to as spawn (Chang and Hayes 1978; Chang and Miles 1989). The term "spawn" refers to the mushroom's seed. Cereal grains are utilized as the substrate for spawn preparation. After being soaked in water overnight, high-quality grains are cooked for 20 to 25 minutes the next morning. After boiling, any extra water is decanted off. The grains are thereafter laid out on a blotting sheet to dry on the surface for half an hour. These semicooked grains are enriched with 1% calcium carbonate on a wet weight basis. Grain clumping can be avoided and grain pH can be regulated with $CaCO_3$. The pH range of 7.5 to 7.8 is optimal for the substrate. The grain is blended well and then poured two-thirds of the way into glass bottles and polypropylene bags. The mouth of the container is then tightly sealed with a cotton plug, covered with aluminium foil or paper and secured with a rubber band to hold it in place. For 30 minutes, these bottles and bags are sterilized at 20 pressures (126.5°C) in an autoclave after sterilization these bags are kept for cooling. After cooling at room temperature, each bag and bottle should be violently shaken and transferred in a laminar air flow chamber. These bags and bottles undergo a 20-minute UV exposure process to remove surface contaminants (Netam *et al.,* 2018).

Mother spawn: Mother grain spawn or completely developed pure culture tubes are used to inoculate bottles. It is best to inoculate within the laminar air flow in an aseptic environment. The vials are filled with either 8-10 g of mother spawn grains or one pure culture tube. Fourteen to fifteen bottles can be inoculated by a single fully grown mother grain spawn bottle (Monmoon *et al.,* 2010; Netam *et al.,* 2018; Sarita *et al.,* 2021).

Planting/ commercial spawn: The planting spawn is for seeding. The sterilized bags receive the same inoculation as the mother spawn. Bags are inoculated with mature mother grain spawn. Fill sterilized bags with 15-20 g of mother spawn grains and gently shake to evenly distribute inoculums. After 10-12 days, the spawn run is complete and the bags are filled with white mycelium. Spawn is stored in a cont-rolled condition to ensure its viability before being used to inoculate the developing substrate (Knop *et al.,* 2015). Mushroom production relies heavily on high-quality spawn processed under sterile conditions to prevent substrate contamination.

Sterilization of substrate: A crucial phase in the mushroom-growing process is sterilizing the substrate, which stops bacteria, mold and other fungi like Aspergillus and Coprinus from colonizing it. Since fungicides and insecticides are employed to suppress saprophytes and fungal insect infestations, chemical treatments produced a greater yield. Yields are reduced by at least 20% when substrate is treated with immersion in hot water (IHW) treatment as opposed to other straw treatments such as steam treatment, chemical treatment, or untreated wheat straw. According to Mejía and Albertó (2012), the loss of these nutrients would result in a reduction in yield. Cut the straw into 1 to 3 cm pieces and soak it for 16 to 24 hours in clean water. After soaking and disinfecting, excess water should be removed from the straw by spreading it on a high wire mesh frame (1996). When the excess water decanted, spread the straw on a poly sheet by weighing 3-4 kg of wet straw. Techniques for preparing the substrate are intended to produce an environment that is sterile or semi-sterile and favourable for the coloniz-ation and growth of mushrooms. (Feeney *et al.,* 2014).

Spawning: The yield and biological efficiency of oyster mushrooms are also influenced by the rate of spawn and the amount of substrate. Up to a certain point, the rise in spawn rate is closely correlated with the yield growth. Three and four kilograms of substrate (Kumar 2005, Patel and Trivedi 2014; Deora *et al.,* 2021) with a five percent spawn rate (Ram and Pant 2004; Chauhan, 2013; Kumar *et al.,* 2021; Deora *et al.,* 2021) are ideal for increased production and biological efficiency. A clean and orderly environment is ideal for spawning. Three kilograms of moist substrate are filled with 14 by 20-inch polybags. Ten to twelve tiny holes should be created in the bags to allow the mycelium to breathe. Layer spawning or mixed spawning are two methods for spawning. The commonly used method is the mixed spawning method where sterilized straw thoroughly mixed with healthy spawn and fill in the polybags.

Crop management and harvesting of mushroom: In closed racks, spawned bags are kept at a temperature of 24±2°C and a humidity of 80-85%. Water is sprayed on the walls and floor twice a day to maintain these conditions. The spawn run phase lasts anywhere from a few weeks to a couple of months, though it varies according on the species of mushroom and the surrounding conditions (Singh and Singh 2011). When the bags are completely coated in white mycelium and the spawn run is over. After gently removing the polybags, watering begins a day after the polythene cover is removed. The first primordia show up three to four days after the polybags are taken out. Usually, it took these primordia 1-2 days to mature. Matured mushroom is identified by curl margin of cap and harvested by twisting it clock wise to uproot from the base. In a single life cycle of mushroom 3-4 flushes appeared.

Methods used for Analysis of Microbial communities: More information about the microbial community, particularly the bacterial and fungal communities in composted or grown substrates, must be obtained in order to highlight how the biodiversity of microorganisms impacts the cultivation.

Both culture-dependent and culture-independent approaches have been used to study the microbial population. In addition to using complementary approac-hes for the investigation of microbial diver-sity, culture-independent methods have been employed to unveil the vast diversity of uncultured organisms. However, due to the limits of pure culture techniques and traditional enrichment methods, not all the microbial diversity in the system can be accessed via culture methods. Numerous approaches and strategies, including as high- throughput sequencing, DGGE, ARDRA and T-RFLP have been used in this field of research. The majority of these techniques rely on the PCR.

Denaturing Gradient Gel Electrophoresis (DGGE): A limited overview has been provided by research that concentrated on specific time periods during the composting process because many compost bacteria and fungi are not easily cultivable. Numerous phyla are involved in the microbial community during mushroom growth and more recent DNA sequencing studies have demonstrated the existence of more bacteria in compost and their roles. Almost all microorganisms in system can be found using DNA sequencing techniques without the requirement to cultivate them. Researchers can create bacterial and fungal consortia by using the knowledge they gain from studying the microbiology of substrates. These might then be applied to bioaugme-ntation to maximize the quality of the substrate and to find and confirm biomarkers that could be used to evaluate the compost's quality prior to cropping. The electrophoretic separation of dsDNA generated by PCR in a polyacrylamide gel with chemical denaturants is the foundation of the DGGE technology. The makeup of microbial communities is represented by the bands that are evident in DGGE gels. The complexity of the environment increases with the number of bands visible.

Amplified Ribosomal DNA Restriction Analysis (ARDRA): ARDRA relies on the fact that rDNA sequences in both prokaryotic and eukaryotic species are conserved. The restriction enzymes break down the rDNA fragments after they have been amplified by universal or particular primers. After that, the pieces are separated using polyacrylamide gels. An analysis of the microbial diversity is then conducted using a restriction enzyme map. But the ARDRA techniques can save a lot of time and money when excess of isolates need to be examined. In addition, the technique has some benefits and is quite reliable for quickly identifying common microbe species.

Terminal Restriction Polymorphism (T-RFLP): T-RFLP technology is an advanced version of ARDRA technology. Using fluorescent dye-labeled primer, 16S or 18S rDNA gene is amplified in this method. Following that, one or more restriction enzymes with four base-pair recognition sites break down the amplified fragment. Differences in 16S or 18S rDNA gene sequences are reflected in the size of the terminal restriction fragments. Thus, it is feasible to assess the dynamics of microbial community structure and to examine the phylogeny of various microbial populations.

High-Throughput Sequencing: The use of next-generation sequencing (NGS) in bioinformatics analysis has significantly advanced our understanding of microbial communities by enabling the display of intricate microbial communities and the data pertaining to their metabolic capability. When describing and comparing microbial population, a biotype, also known as an operational taxonomic unit (OTU), is utilized rather than a species.

Conclusions

Globally, "waste-to-wealth" management is crucial for more sustainable farming, and expanding India's mushroom output appears to be a feasible and alluring alternative. By increasing people's knowledge of the nutritional and health benefits of mushrooms, we can improve our gastronomic experiences while also reaping a host of other health advantages. Bringing emphasis to the incorporation of mushroom technology into effective livelihood, national nutrition, agriresidue management, women's empowerment, and rural development programs is also crucial. This review research concludes that knowledge of the production technol-ogy and favorable environmental conditions, including room temperature, relative humidity, dark time and proper aeration, are essential for increasing Pleurotus mushroom productivity. The most frequent causes of bacterial and fungal infections are unfavorable temperature, relative humidity, and improper aeration.

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Designing of Retail Packaging Boxes

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Introduction

Retail packaging refers to the packaging of products that are sold directly to consumers through retail outlets or online platforms. The design of retail packaging boxes plays a crucial role in product marketing, brand identity, protection, and consumer experience.With the rise of e-commerce and increased competition in the marketplace, packaging is no longer just about enclosing a product. It is now a strategic tool used by businesses to influence buying decisions, communicate brand values, and create a memorable customer journey. Designing retail packaging boxes is a multifaceted process that intertwines aesthetics, functionality, sustainability, and brand identity. Designing retail packaging boxes is a dynamic process that requires a balance between creativity and practicality. By focusing on the elements outlined above, you can create packaging that not only protects and promotes your product but also resonates with consumers and stands out in the competitive retail landscape.

The Design Process

Step 1: Understanding the Product: Size, weight, fragility, and shelf life must be analysed.

Step 2: Knowing the Target Market: Designs for children vs. adults, luxury vs. daily-use items differ significantly.

Step 3: Brand Integration: Ensuring the design reflects the company's identity (e.g., minimalism for tech, rustic for organic goods).

Step 4: Prototype Creation: 3D modelling, mockups and physical sampling.

Step 5: Testing and Feedback: Durability tests, user testing, and feedback from stakeholders.

Step 6: Final Production: Once approved, the design is sent for mass printing and manufacturing.

Materials Used in Retail Packaging Boxes

a) Paperboard: Lightweight and printable; used for everyday retail items.

b) Corrugated Cardboard: Consists of fluted layers; durable and ideal for e-commerce.

c) Plastic: Clear, waterproof, but increasingly avoided due to environmental concerns.

d) Glass and Metal: Used in premium packaging for their strength and aesthetic.

e) Sustainable Alternatives: Bamboo fiber, recycled craft paper, mushroom-based packaging.

Challenges in Retail Packaging Design

a) Balancing Cost and Creativity

- Innovative designs can be expensive to produce.

b) Sustainability vs. Durability

- Some eco-materials may not protect products as well as traditional ones.

c) Logistics and Compliance

- Must meet shipping regulations and safety standards (especially for food and pharma).

d) Storage and Shelf Space

- Bulky packaging may not be practical for retail shelves.

Specialty Boxes in Retail

a. Subscription Boxes: Custom-designed to be shipped monthly or quarterly to customers. Often corrugated.

- Encourages brand loyalty
- Must balance durability and aesthetics

b. Display Boxes: Designed to showcase products directly on retail shelves.

- Used in cosmetics, candies, small electronics
- Often have perforations or open fronts

c. Custom Die-Cut Boxes: Tailor-made shapes using die-cut machines.

- Unique shapes for brand distinction
- Ideal for limited editions and promotions

d. Eco-Friendly Boxes: Made of recycled or biodegradable materials.

- Examples: Kraft boxes, mushroom-based foam, corn-starch plastic
- Popular among environmentally conscious brands

Conclusion

Packaging boxes in retail serve more than functional purposes they are tools for communication, marketing, and customer satisfaction. Understanding the various types of retail packaging boxes helps businesses. Select the right combination of form, function and sustainability. As consumer expectations evolve, so must packaging design, integrating innovation with responsible practices. Retail packaging design is both an art and a science. It serves as a bridge between product and consumer, merging aesthetics with functionality. A well-designed retail packaging box does more than protect it communicates, attracts, and delights. As consumer demands evolve and environmental concerns grow, the packaging industry must innovate to meet new expectations.

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Innovative Disease Resistance Screening in Cauliflower for *Alternaria brassicicola* (Schw)

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Introduction

Cauliflower (*Brassica oleracea* var. *botrytis*) is a nutritionally rich and economically important vegetable crop widely cultivated across India. It is valued for its high content of vitamin C, dietary fiber, potassium, and health-promoting phytochemicals such as glucosinolates and flavonoids. With an annual production of approximately 9.1 million tonnes over 0.46 million hectares, India ranks as the second-largest producer globally (NHB, 2023). Its short growing cycle, adaptability to diverse agro-climatic conditions, and high consumer demand make it a key crop in both subsistence and commercial farming systems. However, productivity is frequently challenged by foliar diseases such as Alternaria leaf spot, caused by *Alternaria brassicicola*, which can result in severe yield and seed quality losses (Prasad & Vishunavat, 2006). Conventional field-based screening for disease resistance is time-consuming, environmentally dependent, and resource-intensive, limiting its scalability and precision. To address these limitations, the Detached Leaf Assay (DLA) has emerged as an effective laboratory-based method for screening genotypes under controlled conditions. DLA involves inoculating excised, surface-sterilized leaves with a standardized spore suspension and assessing disease severity through lesion development and necrosis (Singh *et al.*, 2022). The method enables rapid, uniform, and reproducible evaluation of resistance, reducing the reliance on field trials and chemical fungicides. Its efficiency, scalability, and alignment with sustainable agricultural practices make DLA an essential tool in modern cauliflower breeding programs aimed at developing disease-resilient cultivars.

What is Detached Leaf Assay (DLA)?

The Detached Leaf Assay (DLA) is a laboratory-based method used to evaluate the resistance or susceptibility of cauliflower to specific pathogens, such as *Alternaria brassicicola*. Fully expanded, healthy leaves are carefully excised from cauliflower plants at a standardized growth stage. These leaves are surface sterilized and placed on a moist, sterile substrate (such as water-agar medium or moistened filter paper) in Petri dishes. Pathogen inoculation is performed by applying a spore suspension (typically 1 × 105 spores/mL) to the adaxial leaf surface. The inoculated leaves are incubated under controlled conditions (e.g., 22–25°C, >90% relative humidity, 12-hour light/dark cycle). Disease symptoms, including lesion formation, chlorosis, and necrosis, are observed at regular intervals. Disease severity is quantified based on lesion size, number, or percent leaf area infected, allowing for a precise assessment of resistance or susceptibility. The DLA in cauliflower provides a rapid, reproducible and space-efficient approach for disease resistance screening, making it an essential tool in breeding programs.

Why is DLA Innovative and Sustainable?

The Detached Leaf Assay (DLA) is an innovative and sustainable method for disease screening in cauliflower (*Brassica oleracea* var. *botrytis*), offering several key advantages over traditional field-based evaluations:

Uniformity and Precision: DLA ensures consistent exposure of all detached cauliflower leaves to a standardized inoculum concentration under controlled conditions, minimizing variability caused by environmental factors.

Time-Efficiency: Disease symptoms develop rapidly in DLA, allowing for early and accurate assessment of resistance or susceptibility within days, unlike field screening, which may require an entire growing season.

Resource Conservation: DLA significantly reduces the need for extensive field space, water, pesticides, and manual labor, making it a cost-effective method for large-scale screening of genotypes.

Environmental Sustainability: By eliminating the need for field applications of fungicides during initial screenings, DLA minimizes the environmental impact associated with chemical usage and soil contamination.

Methodology for Detached Leaf Assay (DLA) in cauliflower (Singh *et al.*, 2022)

1. Leaf Selection: Fully expanded, healthy, and disease-free leaves are carefully detached from cauliflower (*Brassica oleracea* var. *botrytis*) plants at a standardized growth stage (typically the 4^{th} or 5^{th} fully developed leaf from the top of the plant). Leaves are collected in the morning to ensure turgidity and are immediately transferred to the laboratory for further processing.

2. Surface Cleaning: The detached leaves are initially rinsed with running tap water to remove any adhering soil or debris. Subsequently, they are cleaned using sterile distilled water to eliminate surface contaminants, ensuring the leaves are free of dust, epiphytes, or other microorganisms that may interfere with the assay.

3. Inoculation: A standardized spore suspension of *Alternaria brassicicola* is prepared, maintaining a concentration of 1 × 105 spores/mL. The spore suspension is prepared in sterile distilled water, ensuring uniform spore distribution by gentle vortexing. A 10 µL droplet of the prepared spore suspension is carefully applied to marked spots (usually 2-3 spots per leaf) on the adaxial (upper) surface of each leaf. To ensure uniformity, all leaves are inoculated at the same time using a micropipette. Control leaves are treated with sterile distilled water in the same manner to account for any non-specific responses.

4. Incubation: The inoculated leaves are placed on moist, sterile filter paper (or water-agar medium) in sterile Petri dishes or trays. The setup is maintained under controlled environmental conditions: Temperature: 25 ± 2°C, Relative Humidity: =90%, Light Conditions: 12-hour light/dark cycle. The moist environment is maintained by regularly checking the filter paper to prevent desiccation.

5. Disease Assessment: Disease symptoms, including the appearance of lesions, necrosis, and chlorosis, are monitored at specified intervals (24 hrs, 48hrs, 72 hrs, 96 hrs, 120 hrs etc., post-inoculation). Quantitative disease assessment is performed using the following parameters:

- **Lesion Diameter (mm):** Measured using a digital caliper for precise measurement of each lesion.

- **Necrotic Area (mm^2):** Calculated using image analysis software for accurate estimation of tissue damage.
- **Disease Severity Index (DSI):** Calculated using the formula:

$$DSI = \frac{\sum(n \times v)}{(N * V)}$$

where:

n = Number of leaves in each disease category, v= Disease score for each category

N = Total number of leaves assessed, V = Maximum disease score

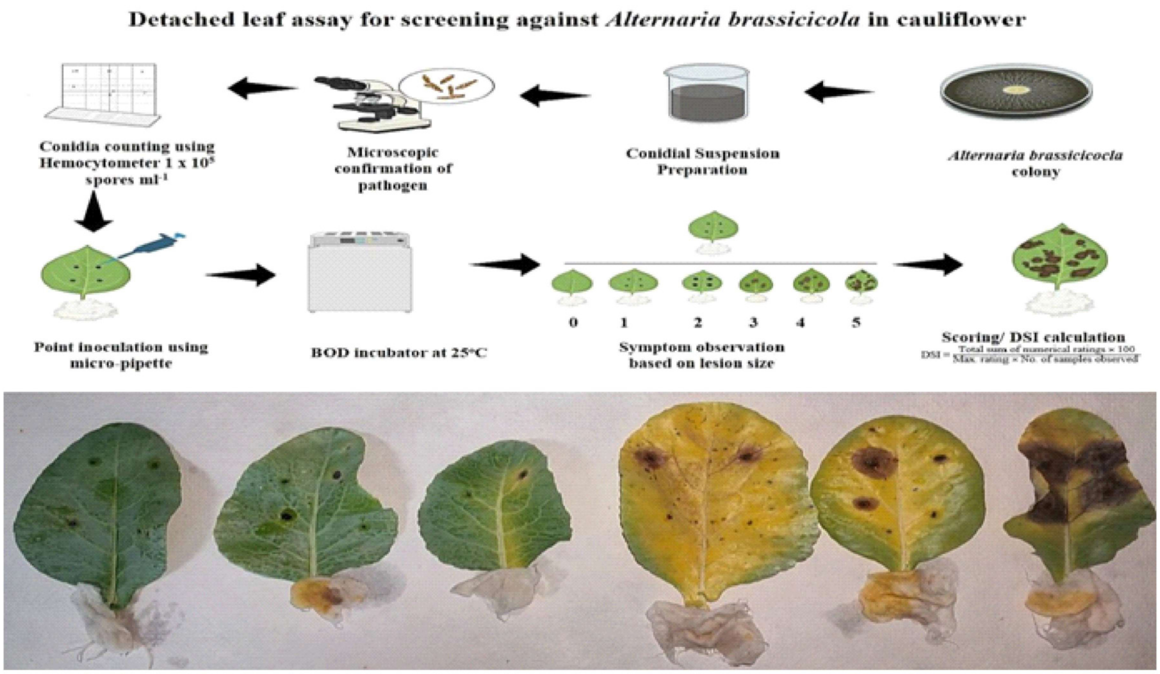

Figure 1: Detached leaf assay for ALS resistance screening in cauliflower

Application of Detached Leaf Assay (DLA) in Cauliflower Breeding Programs

The Detached Leaf Assay (DLA) has become an essential tool in resistance breeding programs for cauliflower (Brassica oleracea var. botrytis) and other Brassica crops. By enabling rapid, uniform, and controlled screening of multiple genotypes for disease resistance, DLA significantly accelerates the selection process. It allows breeders to evaluate dozens of genotypes or breeding lines in a laboratory setting, minimizing the need for extensive and resource-intensive field trials.Resistant lines identified through DLA are subsequently validated under natural field conditions, ensuring their practical utility. This two-step approachinitial screening via DLA followed by field validation enhances the efficiency, cost-effectiveness, and reliability of disease resistance breeding. DLA is particularly valuable for screening against foliar pathogens like *Alternaria brassicicola*, where early-stage selection can significantly reduce the incidence of disease in advanced generations.

Contribution to Sustainable Horticulture

The DLA method contributes to sustainable horticulture in several key ways:

Reduction in Pesticide Usage: By identifying disease-resistant cauliflower genotypes at an early stage, DLA minimizes the need for chemical fungicides in field cultivation, promoting environmentally friendly practices.

Development of Resistant Varieties: DLA facilitates the selection of naturally resistant cauliflower lines, supporting the development of robust cultivars that require minimal chemical protection.

Environmental Conservation: With reduced field spraying and optimized resource use, DLA lowers the risk of environmental contamination and health hazards associated with chemical residues.

Efficient Resource Utilization: DLA allows for large-scale screening using minimal space, water, and labor, making it a cost-effective approach for early-stage disease resistance evaluation.

Future Perspectives

The Detached Leaf Assay (DLA) is evolving into a sophisticated platform for high-throughput disease resistance screening in cauliflower, integrating advanced technologies for enhanced precision:

Image-Based Lesion Quantification: Automated image analysis enables accurate measurement of lesion size and disease severity, minimizing observer bias.

AI-Driven Disease Scoring: Artificial intelligence (AI) algorithms are being developed to automatically assess and score disease symptoms, increasing the speed and objectivity of DLA.

Molecular Marker Validation: Resistant genotypes identified through DLA can be further validated using molecular techniques, including quantitative PCR (qPCR), transcriptomics, and marker-assisted selection, ensuring their genetic stability.

Biochemical Profiling: DLA can be coupled with biochemical assays (such as antioxidant enzyme analysis, phenolic content determination, or glucosinolate profiling) to gain insights into the underlying mechanisms of resistance.

Conclusion

The Detached Leaf Assay (DLA) is more than just a laboratory techniqueit represents a step toward precision breeding, efficient screening, and eco-conscious crop protection in cauliflower. By providing a rapid, reliable, and sustainable method for assessing disease resistance, DLA supports the development of robust, disease-resilient cauliflower varieties. As the demand for sustainable agriculture grows, DLA will continue to play a central role in breeding programs, ensuring food security without compromising environmental health.

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Pruning Breathes New Life into Sikkim's Dalle Chilli

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Introduction

In the lush green hills of South Sikkim, the fiery red Dalle chilli holds a special place in every kitchen and every heart. Its round, cherry-like shape and strong aroma make it one of the most prized spices of the region. But like many chilli plants, Dalle often loses its vigour after the first year, leaving farmers with fewer fruits and lower income. At the College of Horticulture, Bermiok, a simple but innovative practice "pruning under low-cost polyhouse is bringing a fresh lease of life to this iconic spice. In the first year, Dalle chilli plants were raised from seed under a polyhouse. Once the crop had finished fruiting, the plants looked tired, and their branches weak and less productive. Instead of uprooting them, in January the plants were pruned back to just 20 cm from ground level.

Within weeks, the plants sprouted vigorous new shoots. By the start of the second year, the rejuvenated Dalle bushes were healthier, greener, and fruited much earlier than the unpruned ones. "It was like giving the plants a second life," says a farmer from the nearby village who observed the trial. "The pruned chillies came back stronger and produced more fruits than the old, unpruned ones."

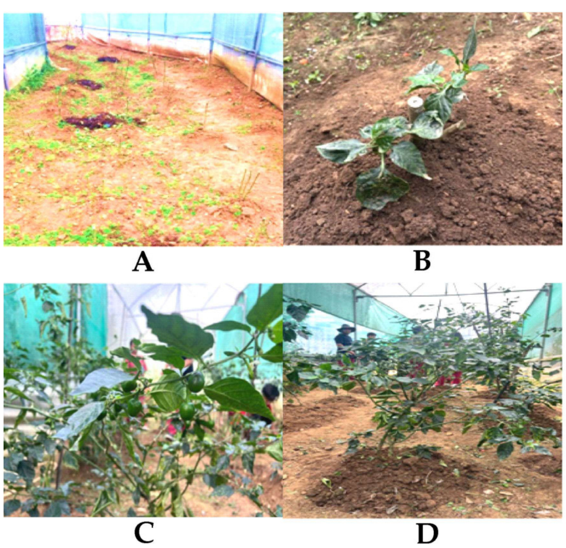

Fig 1:
A) Field view of pruned Dalle Chilli
B) 4 weeks old pruned Dalle Chilli
C) & D) Dalle Chilli in fruiting stage
E) & F) Ripened fruits of Dalle Chilli after 3 months of pruning

Not only did pruning boost the yield, but it also enhanced the quality of the fruit. The ratoon (second-year) crop yielded chillies that were:

- More vibrant red
- More aromatic
- Tastier

To top it off, using poultry manure gave the fruits an extra advantage. This organic manure not only improved soil health but also infused the chillies with a natural scent, flavor, and color intensity that are highly sought after by both households and the market.

Fig. 2: Unpruned Dalle Chilli in 2nd year of fruiting

For Sikkimese farmers with small holdings, this technique offers a cost-effective advantage. Instead of buying new seeds and investing in fresh planting every year, they can extend the life of their chilli plants through pruning and ratooning. This method can save farmers both money and labour, while also giving them higher and earlier yields.

With the increasing demand for organic spices and the worldwide popularity of Dalle chilli, these practices can improve both farmers' livelihoods and the reputation of Sikkim's unique spice.

Pruning, combined with organic manure application, shows that sometimes the simplest interventions can make the biggest impact. For Dalle chilli, it means more than just yield, it means keeping alive the fiery tradition and flavour of Sikkim for generations to come.

Conclusion

The practice of pruning Dalle chilli plants in low-cost polyhouses has proven to be an effective and sustainable way to revive old plants and improve productivity. By encouraging early and strong regrowth, pruning not only boosts yield but also enhances fruit quality in terms of color, aroma, and flavor. Adding organic inputs like poultry manure further improves soil health and fruit quality, making this approach ideal for Sikkim's organic farming systems. For smallholder farmers, this method provides a cost-effective and labor-saving option compared to annual replanting. This ensures better returns and long-term sustainability. As global demand for organic spices grows, such simple yet innovative practices can help strengthen the economic viability of farming communities while preserving the cultural and culinary heritage of Sikkim's Dalle chilli.

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Biofortification for Nutritional Security

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Introduction

Biofortification is the process by which the nutrient contents in food crops is increased through conventional plant breeding and improved agronomic practices without sacrificing any quality traits preferred by consumers.

Micronutrient malnutrition, also known as 'hidden hunger' affects more than one-half of the developing world's population, especially the women and preschool children. The crop development process includes screening of germplasm for available genetic diversity, pre-breeding parental genotypes, developing and testing micronutrient-dense germplasm, conducting genetic studies and developing varieties or hybrids for enhanced nutritive value. Breeding for nutrient enhancement provides a long-term strategy of delivering more micronutrients and to alleviate micronutrient malnourishment. Micronutrient enriched staple plant foods can significantly improve the amount of these nutrients in the population. Biofortified crop varieties can be developed through breeding programmes. Once biofortified varieties are developed, these can be maintained without additional expense for getting good nutrition. Biofortification of staple crops such as wheat, rice, pearl millet and maize issustainable and cost-effective means of delivering target micronutrients to populations who do not have access or cannot afford nutrient diverse diets.

The United Nations General Assembly adopted a resolution, sponsored by India and supported by more than 70 countries, declaring 2023 as the International Year of Millets. The declaration is intended to increase public awareness of the nutrition and health benefits of millets and their suitability for cultivation under tough conditions marked by climate change.

Advantages of biofortification

- Biofortification helps in achieving overall health improvement in the people.
- It has the potential to reach the poorest section of society and also benefit farmers.
- It is highly cost-effective since once the initial research is done, the process can be easily replicated and maintained.
- Biofortification done through traditional plant breeding methods and a better alternative than GM crops.
- India faces huge nutritional challenges thus biofortification is a sustainable and cost effective method to resolve this challenge.
- Thus biofortification is promising to solve those nutritional problems leading to nutritional security.

Malnutrition: Malnutrition is a condition that results from eating a diet which does not supply a healthy amount of one or more nutrient.

Over-nutrition: It is a for mofmalnutrition that arises due to intake of a diet having insufficient energy and nutrient amount.

Hidden hunger: It describes a state of deficiency of essential vitamins and minerals in the human diet.

Conventional breeding: It is a process of development of new varieties of crops by using conventional techniques without using the latest molecular plant biological tools.

New breeding techniques (NBTs): These are crop improvement techniques that make specific changes with the plant DNA in order to change the trait of interest. These modifications may vary from single base pair addition, deletion, substitution in an organism.

Transgenic breeding: It refers to the genetic improvement of crop plants in relation to various economic traits useful for human beings by means of genetic engineering.

Geneticen gineering: It is a process of using the recombinant DNA technology to change genetic make-up of an organism.

Pearl millet has been recognized for its climate-resilient crop with ability to grow on arid lands with minimum inputs. Millets are suitable for cultivation under adverse, changing climatic conditions. Iron content in pearl millet has the potential to improve global nutritional insecurity and can be sustainable alternative to major staples for the growing population amid climate change. Millets are considered as nutri-cereals. They are highly nutritious compared to cereals like rice and wheat. Millet grains contain high protein, fibre, micro and macronutrients. They are gluten free. They contain protein with well balanced amino acid profile. They are good source of methionine, cystine and lysine. Pearl millet has the highest content of fat and micronutrients.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has released a high-iron pearl millet variety known as Dhanshakti. The said variety is the first mineral biofortified crop cultivar to be officially released and reaching farmers' fields in India. Open-pollinated varieties (Dhanashakti) and hybrids (ICMH1202, ICMH1203 and ICMH1301) of pearl millet with a high grain yield and high levels of iron (70–75 mg kg-1) and zinc (35–40 mgkg-1) densities have been developed and released first in India. Currently, India is growing >70,000 ha of biofortified pearl millet, and furthermore more pipeline cultivars are under various stages of testing at the national (India) and international (West Africa) trials for a possible release. The market demand for these varieties is likely to increase only after an investment in crop breeding and the integration into the public distribution system. Biofortification efforts have led to the release of several cultivars, including Dhanashakti, the world's first biofortified pearl millet variety, and hybrids such as ICMH 1202, ICMH 1203, and ICMH 1301, with 70–75 mg kg-1 iron and 35–40 mg kg-1 zinc (Velu *et al.*, 2016). A 250 g serving of these improved varieties can meet up to 80% ofthe daily iron requirement and 100% ofthe zinc requirement for adults.

Today, several breeding programmes within the CGIAR network have biofortification as a core trait. The new varieties developed in these programmes, having both good agronomic performance and high nutrient concentration. Today, the current global challenge of Fe and Zn deficiencies in human populations can be prevented with timely and adequately. The biofortification strategies which tend to reach the most affected population groups especially malnourished rural populations with low dietary diversity. Biofortification has shown itself to be a sustainable strategy aimed at increasing the concentrations of Fe and Zn in edible crop plants, reducing the negative consequences of commonly consumed Fe and/or Zn deficient crops, alleviating Zn and Fe deficiency in people, and intended to help in eradicating the hidden hunger of the growing population by 2030.

Wheat grain makes a major contribution to the human diet as it is staple food of millions of peoples. Therefore, wheat produ-ction is required to be double by 2050 for global food security. Wheat germplasm has been extensively screened for its mineral contents of Fe, Zn, Mn, Mg and vitamins. The dedication of the International Maize and Wheat Improvement Center (CIMMYT) gene bank and the Harvest Plus project has resulted in biofortified wheat culivarsa. Five biofortified wheat cultivars have been released, cv. Zincol 2016 in Pakistan, cv. Bari Gom 33 in Bangladesh and cv. Zinc Shakti (Chitra), WB02 and HPBW-01 in India. Ranges of Fe concentrations of 20–60 mg kg-1 and Zn concentrations from 15 to 35 mg kg-1 in a set of high yielding genotypes were reported. This confirmed that sufficient genetic variation exists within the wheat gene pool. It will contribute to combat hidden hunger. Enhancing the concentration of Zn and Fe in the most edible part, the endosperm, is not simple to achieve through agronomic practices, nevertheless, an increase in concentration of Fe and Zn through soil application has been reported.

Rice is particularly highlighted for micronutrient improvement due to its global role as one of the major staple food crops. It gives a huge potential for rice biofortification to alleviate malnutrition globally. Provitamin 'A' biofortified "Golden Rice" has proved itself as a cost- effective intervention in the areas where rice is the staple crop. Rice is a staple food for nearly two-thirds of the Indian population, with an average per capita consumption of ~220 g per day (ICAR, 2023). While rice contributes significantly to caloric intake, milling and polishing drastically reduce its micronutrient content. To address this, several biofortified rice varieties have been released in India since 2015, under the AICRIP program. High-zinc varieties include Chhattisgarh Zinc Rice-1, DRR Dhan 45, DRR Dhan 48, DRR Dhan 49, Zinco Rice MS, CR Dhan 315, and DRR Dhan 63, with zinc levels >24 ppm in polished rice (Yadav *et al.,* 2021).

Maize is often considered a cash crop, but it is also a staple in many countries and provides food for humans and animals globally. Exogenous application of Zn inthe form of seed priming, foliar spray, or incorporated in the soil enhance the germination of maize seed, seedling vigor, and tolerance against different stresses. Among 1000 CIMMYT maize lines, concentration ranges of Zn, Fe, and provi-tamin A have been reported, and maize lines with15–35 mg kg-1 Zn, an average of 20mg kg-1 Fe, and about0–15 mg kg-1total provitamin A concentration have been identified.

Conclusion

Biofortified crops are highly nutritious crops feeding poor populations in Asia and Africa. Scientific research has led to develop biofortified varieties in various crops to combat micronutrient malnutrition. With significant amounts of essential amino acids, minerals, and vitamins, bioavailability of nutrients need further improvement by reduction of ant nutrients. Establishment of mini core collection of each crop species will accelerate the characterization of genetically diverse germplasm of various food crops for nutritional traits.

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Resin Art: A Creative Blend of Craft and Shine

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Introduction

Resin art is one of the most popular and modern forms of artwork today. Art has always been a way for people to express their feelings, ideas, and creativity. Among the many modern art forms, resin art has gained huge popularity in recent years. With its glossy finish, vibrant colors, and endless possibilities, resin art has become a favorite for both professional artists and hobby lovers. It is not only an art but also a perfect example of how creativity and science can work together. Resin art, which has become very popular in recent years, is seeing a rapid rise in demand and is a medium to open up many opportunities for artists in the field of art in the future. Nowadays, its demand has increased a lot and many people want to learn it. There are many products made of resin available in the market such as key chains, coasters, trays, photo frames, customized name plates and many other home decor and gift items. Even now, resin is used in architecture and designer furniture. Everyone wants to learn it and create their own masterpieces for gifting or business purposes.

What is Resin Art?

Resin art is created by mixing resin (a thick liquid) with a hardener. When these two are combined in the right ratio, they slowly solidify and form a hard, shiny, and glass-like surface. Artists use this property to make paintings, jewelry, furniture tops, coasters, and many decorative items. Every resin artwork is unique, because the flow of resin and colors can never be copied in the exact same way.

Why Resin Art is so special?

Unlike traditional painting, resin art provides a shiny and smooth surface that looks almost like crystal or glass. This allows artists to add different colors, pigments, stones, shells, flowers or even glitter to make each artwork unique. No two resin artworks can ever look exactly the same, making them extremely special and unique.

Glossy Finish: Resin gives a glass-like shine that makes colors appear brighter and more attractive.

Durability: Once hardened, resin is strong and long-lasting.

Versatility: It can be used on canvas, wood, glass, metal, or even in molds.

Uniqueness: No two pieces of resin art can ever look alike, which makes it more special than traditional painting.

Preparation Methods of Resin Art

Resin art requires both creativity and precision. To achieve high-quality results, every step from preparing the workspace to finishing the artwork must be done carefully.

1) Materials and Tools Needed

To create resin art, some basic materials are required:

1. Resin and Hardener- the main ingredients.
2. Digital Scale or Measuring Cups (for accurate mixing)
3. Pigments, inks, or powders – to add color and effects.
4. Mixing cups and sticks – for blending (plastic/wood/silicone).
5. Molds or base surface – depending on the type of art.
6. Protective gloves and mask – because resin is a chemical and needs safe handling.
7. Toothpicks – to fish out bits of dust
8. Dust cover – to protect your work while it cures
9. Paper towel and ethanol – to clean sticky tools
10. Decorative Items – dried flowers, glitter, shells, beads, stones, etc.
11. Heat Gun or Torch (to remove bubbles).
12. Safety Gear – nitrile gloves, safety glasses, mask/respirator, apron Well-ventilated Workspace

2) Workspace Preparation

• Choose a clean, dust-free, ventilated area.
• Cover the working surface with plastic sheet or newspaper.
• Keep children and pets away.
• Ensure good ventilation or use an exhaust fan.

3) Mold or Base Preparation

• Clean silicone molds to remove dust/hair.
• If using wood/canvas, seal or prime the surface to avoid resin absorption and air bubbles.
• Fix decorative items firmly so they do not float during pouring.

4) Mixing Resin and Hardener

• Most important step – Follow the exact mixing ratio (commonly 1:1 or 2:1).
• Measure with a digital scale for accuracy.
• Stir slowly and evenly for 3–5 minutes. Scrape sides and bottom while mixing.
• Avoid stirring too fast, otherwise bubbles will form.
• Some resins require a short resting time before pouring – check instructions.

5) Adding Colors and Decorations

• Add pigments, mica, or alcohol inks in small amounts to avoid opacity.
• Alcohol inks can create swirl effects.
• Ensure decorative items (flowers, shells) are completely dry, otherwise bubbles will appear.

6) Pouring Techniques

• Pour resin slowly into molds or on canvas.
• For larger projects, use layer pouring (multiple thin layers, allowing each to partially cure).
• Techniques include dirty pour, puddle pour, swipe, bloom, geode style – best practiced on small pieces first.
• To keep heavy items in place, pour a thin resin layer first, let it set slightly, then place items before pouring the rest.

7) Removing Bubbles

• After pouring, small bubbles rise to the surface. Remove them by:
• Using a heat gun or small torch (move quickly, don't overheat).
• Popping small bubbles with a toothpick/needle.
• Pre-warming resin slightly to reduce bubble formation.

8) Curing (Drying and Hardening)

• Leave the artwork in a dust-free area.
• Initial curing: 24–48 hours (depends on resin brand).
• Full curing: 5–7 days for maximum hardness.
• Ideal curing temperature: 20–25°C with low humidity.

9) Demolding and Finishing

- Remove resin piece only after it is fully cured.
- Sand edges using 400 → 800 → 1200 grit sandpaper for smooth finish.
- Apply a clear resin coat or polish for glossy shine.
- Use buffing compounds for a professional finish.

10) Safety Notes

- Always wear nitrile gloves, safety glasses, and a mask.
- Work in ventilated areas – resin fumes can be harmful.
- Keep away from food, children, and pets.
- Dispose of waste resin properly according to local rules.

Creative Possibilities with Resin

i. Resin art opens endless doors for creativity. Some of the most common uses are:

ii. Home Décor: Coasters, trays, wall clocks, tabletops, and showpieces.

iii. Jewelry Making: Earrings, rings, pendants, and bangles.

iv. Preservation Art: Sealing flowers, shells, photographs, or small memories inside resin forever.

v. Abstract Paintings: Flowing designs with metallic powders and vibrant pigments.

Resin Art as a Hobby and Profession

For many people, resin art is not just a hobby but also a source of income. Handmade resin items are in high demand in markets and online platforms because of their uniqueness. With creativity, practice, and patience, resin art can turn into a small business opportunity.

A blend of art and science

What makes resin art really fascinating is that it is not just about creativity, but also about an understanding of science. While colors, designs, and imagination represent the artistic side, the correct mixing of resin and hardener represents the scientific aspect. The success of any resin artwork depends on the correct mixing ratio, proper drying time, and careful safety measures. If the resin is not mixed properly, the artwork may remain sticky or may not harden at all. Similarly, drying requires patience, as the resin takes hours or sometimes days to completely harden and set into a glossy form.

This process teaches artists the importance of precision and patience. The artistic side gives freedom of expression, while the scientific side develops discipline and technical understanding. Both of these together make resin art a unique field where imagination flows like colors, but the results depend on precision and care. Thus, resin art is a beautiful balance of art and science, providing both enjoyment and learning to those who practice it.

Important Safety Tips

Since resin is a chemical, safety must be taken seriously. Always use gloves, masks, and work in a well-ventilated area. Keep it away from direct skin contact and children. Once it hardens, resin is completely safe and non-toxic.

Conclusion

Resin art is more than just a craft—it is a creative journey where imagination flows freely. With its shine, strength, and beauty, resin art has inspired countless people to try their hands at something new and modern. Whether you create it for fun, for decorating your home, or as a business idea, resin art always leaves a sparkling impression.

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Gene Pyramiding for Plant Health Management

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Introduction

The green revolution in late 70's especially in Indian subcontinent has resulted in substantial yield improvement of important staple food crops like wheat and rice. The Food and Agriculture Organization estimated the demand of food production to 70% by 2050. Thus, in order to meet the increasing food demand, smart and rapid plant breeding tools are required to improve multiple agronomic and nutritional traits simultaneously. The advancement of molecular genetics and related technologies are promising tools for the selection of new crop cultivars and hybrids.

Gene pyramiding or stacking can be defined as a process of combining two or more genes from multiple parents to develop elite lines and varieties. Pyramiding entails stackingmultiple genes leading to the simultaneous expression of more than one gene in a variety. There are conventional methods to transfer gene for disease resistance in to new cultivars. Those are as below:

1. **Pedigree breeding:** is a method of genetic improvement of self-pollinated species in which superior genotypes are selected from segregating generations and proper records of the ancestry of selected plants are maintained at each stage of selection.
2. **Back crossb reeding:** crossing of hybrid with one of there parentlines.
3. **Recurrent selection:** is an efficient and modified form of progeny selection, where selection for some specific trait(s) is conducted within consecutive segregating progeny generations on the basis of phenotypic characteristics.

But by using conventional methods we can transfer one or two genes for disease resistance. These breeding techniques are time consuming. In order to transfer many genes for disease resistance in short possible time, we have to go for gene pyramiding.

a. Marker assisted selection(MAS)

Crop breeding techniques has been improved to a great extent in recent years. Now precision breeding has become possible ina shortest possible time withthe advent of modern molecular tools. Gene pyramiding through marker assisted selection (MAS) have accelerated the development ofdurable resistant/ tolerant lines with highaccuracy in the shortest possible period of time for agricultural productivity. Selection of a trait in plants through molecular markers normally involves genomic regions identification, which play important role in the expression of desirable genes. The marker assisted selection involves DNA-based markers that are directly linked with the targeted gene to help phenotypic evaluation and improvement of breeding efficiency by selecting the target genes within the germplasm.

b. Marker-assisted back crossing (MABC)

Marker-assisted backcrossing (MABC) iscurrently being widelyapplied in molecular breeding. Marker-assisted backcrossing targetsone or more genes or QTLs transfer fromone donor parent into superior cultivar or genotype to improve a targeted trait. In comparison to conventional backcrossing, MABC depends on the alleles of a marker linked with desirable genes or QTLs instead of phenotypic performance. Through MABC, the gene can be transferred within a shorter period of time (about two years). It can be utilized in any crop breeding programme. Markers are helpful in the backcross selection for the desired genes, which are difficult to select based on phenotypic observations. MABC gene pyramiding involves three levels of selection. Crossing is done between the recurrent parent donorparents for the F1hybrid, which is then backcrossed up to three generations to obtain best parent. It is further crossed with another donor parent for pyramiding two or more genes for disease resistance. Although this technique is considered to be time consuming, its precision for gene pyramiding is precise. In conventional breeding technique, the recurrent parent is crossed with donor parents for 6 to 7 backcross generations.

c. Marker Assisted Recurrent Selection

Recurrent selection is considered an efficient approach for pyramiding multiple traits in plants. However, its efficacy of selection is not satisfactory because phenotypic selection depends on environments while genotypic selection takes much time. Marker assisted recurrent selection is anim proved system that enables genotype selection and intercrossing in one cropping season, which can facilitate the efficacy of recurrent selection and expedite the selection process, and help in integrationof many favourable genes. Maker assisted recur-rent selection F3-derived individuals are generally satisfactory and multiplied through a single- seed decent strategy for increasing the seedto conduct multiplication trials. Large numbers of plants are preferred, to rely on the accuracy of QTL mapping. QTL can be evaluated after geno-phenotypic analysis for the selection of markers and suitable alleles. The best population is selected for recombination. At each cycle, geno-typing is performed to identify the best F1 individuals, which could be used again in the next cycle of recombination

Through the use of random amplified polymorphic DNA (RAPD), restriction fragment length polymorphism (RFLP), micro-satellite markers and sequence tagged sites have been developed successfully in tomato (*Lysopersicon esculentum* L.), rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.) and many other food crops.

Rice (*Oryza sativa* L.) is considered a majorstaple food crop for billions of population across the globe. Bacterial blast is the common disease causing substantial yield loss in rice around the world. The host-plant resistance can be ideally improved through pyramiding of major R-genes/ QTLs for multiple diseases. Till date, 46 resistance genes have been identified from the different sources of rice. Thegenes are most frequently utilized in hybridization programme areXa4, xa5,Xa7,xa13, Xa21, Xa33 and Xa38 for developing bacterial blight resistant cultivars.

In case of wheat it is used to develop genotypes for leaf rust resistance. The gene stacked were Lr 41, Lr 42 and Lr 43. For powdery mildew resistance of wheat the genes stacked were Pm2 + Pm4a, Pm2 + Pm21 and P4a + Pm21.

In case of soybean the technique is used to develop genotypes for resistance soybean mosaic virus. The gene sacked were Rsv 1, Rsv 3 and Rsv 4.

In case of barley gene pyramiding is used to develop genotypes for resistance to yellow mosaic virus. The gene sacked were rym 5, rym, rym 9 and rym 11.

Advantages of genepyramiding

Widely used for combining multiple disease resistance genes for specific races of a pathogen. It is useful when we want to develop 'durable' disease resistance against different races. It is mainlyused to improve existing elite variety. It eliminates extensive phenotyping. It can be used to nullify the effect of linkage drag. It reduces breeding cycle duration.

Conclusion

1. Genepyramiding is an important strategy for germplasm improvement.
2. It requires that breeders consider the minimium population size that must beevaluated to have a reasonable chance of obtaining the desired genotype.
3. Molecular marker genotyping can facilitate the gene pyramiding process by reducing the number ofgenerations that breeders must evaluateto ensure theyhave the desired gene combination.

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Climate Change and Its Impact on Agriculture: Adaptation Strategies

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Introduction

Climate change has emerged as one of the most critical challenges facing the global agricultural sector. The effects of rising temperatures, altered precipitation patterns, extreme weather events and shifting growing seasons are already being felt worldwide. Agriculture, as both a significant contributor to and a victim of climate change, is at the forefront of adaptation efforts. This article explores the impact of climate change on agriculture and examines various adaptation strategies that farmers are employing to sustain food production.

Impact of Climate Change on Agriculture

The agricultural sector is highly sensitive to changes in climate. Rising global temperatures, changing rainfall patterns, and an increased frequency of extreme weather events such as droughts and floods have disrupted farming practices, particularly in vulnerable regions. Below are some key areas where climate change is affecting agriculture:

1. Temperature Variability: Higher average temperatures can shorten growing seasons, reduce crop yields, and exacerbate pest and disease outbreaks. For example, studies have shown that a 2°C rise in global temperatures could reduce crop yields by 10-25% in tropical and subtropical regions.

2. Water Availability: Changes in precipitation patterns affect water availability for irrigation. Prolonged droughts, especially in arid and semi-arid regions, have led to water scarcity, while erratic rainfall has caused both droughts and flooding, damaging crops and reducing yields.

3. Soil Degradation: Climate change accelerates soil erosion and reduces soil fertility due to increased instances of heavy rainfall and drought. This degradation affects the long-term productivity of agricultural land.

4. Pests and Diseases: Warmer climates allow pests and diseases to proliferate, especially in previously temperate zones. The expansion of invasive species and crop-damaging insects can reduce crop yields and increase the need for pesticides.

Adaptation Strategies in Agriculture

To address these challenges, farmers and agricultural stakeholders are adopting various strategies aimed at mitigating the impact of climate change and ensuring sustainable food production. These adaptation strategies range from technological innovations to changes in agricultural practices:

A. Climate-Resilient Crop Varieties

Climate change poses significant risks to global agriculture, with rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events threatening crop yields and food security. One of the most promising strategies for mitigating these risks is the development and adoption of climate-resilient crop varieties. These varieties are specifically bred or genetically modified to withstand the challenges posed by changing climate conditions, ensuring that agriculture remains productive and sustainable.

Key Characteristics of Climate-Resilient Crops

1. Drought Tolerance: Drought-resistant crop varieties are designed to survive and maintain productivity under water-scarce conditions. They often have deeper root systems, enhanced water-use efficiency, or physiological adaptations that reduce water loss. For example, drought-tolerant maize varieties have been developed to perform better in arid and semi-arid regions by using water more efficiently and sustaining yield under limited water availability.

2. Heat Tolerance: As temperatures rise, crops need to be able to withstand higher temperatures without significant reductions in yield. Heat-tolerant varieties can endure prolonged periods of high temperatures and still maintain their productivity. For instance, heat-tolerant wheat varieties are bred to resist heat stress during critical growth stages, such as flowering, which is crucial for grain development.

3. Flood Resistance: Flood-resistant crops are developed to survive prolonged periods of water logging and flooding. They often have traits such as the ability to respire under submerged conditions or to quickly recover once water levels recede. Flood-tolerant rice varieties, such as the Sub1 strain, have been engineered to survive under deep water conditions and recover rapidly, thus minimizing yield losses during flood events.

4. Pest and Disease Resistance: Climate change can exacerbate pest and disease problems by expanding the range of many pathogens and insects. Climate-resilient crops often include traits for enhanced resistance to pests and diseases. Genetically modified (GM) crops with built-in resistance to pests, like Bt cotton, or to diseases, such as resistant varieties of potatoes, help to reduce crop losses and reliance on chemical pesticides.

5. Nutrient Use Efficiency: Efficient use of soil nutrients is crucial in a changing climate, where nutrient availability may fluctuate. Crops with improved nutrient use efficiency can grow better in less fertile soils or under variable nutrient conditions. For example, nitrogen-efficient maize varieties can grow effectively with lower nitrogen inputs, which is beneficial in areas with limited fertilizer availability.

Breeding and Biotechnology Approaches

1. Conventional Breeding: Traditional breeding methods involve crossing different crop varieties to combine desirable traits. This approach has been used for decades to develop climate-resilient crops. For example, breeding programs have successfully developed rice varieties that can tolerate both drought and submergence by selecting for natural genetic variations that confer these traits.

2. Genetic Engineering: Genetic modification involves directly altering the DNA of a crop to introduce specific traits. Advances in biotechnology have enabled the development of GM crops with enhanced resilience to climate-related stresses. For instance, genetically engineered tomatoes with genes that protect against heat stress have been developed to maintain fruit quality and yield under high temperatures.

3. Genomic Selection: Genomic selection uses advanced genomic techniques to predict the performance of plants based on their genetic makeup. This approach allows breeders to identify and select the best candidates for climate resilience more efficiently. It accelerates the development of new varieties by focusing on genetic markers associated with desirable traits.

4. Marker-Assisted Selection: This technique involves using molecular markers to track the presence of specific genes associated with climate resilience. By identifying these markers in breeding populations, scientists can select plants that are more likely to exhibit the desired traits. For example, marker-assisted selection has been used to develop wheat varieties with improved heat tolerance.

Challenges and Considerations

1. Access and Equity: The benefits of climate-resilient crops need to be accessible to all farmers, particularly those in developing countries who are often the most vulnerable to climate change. Ensuring equitable access to these varieties involves addressing issues related to seed distribution, affordability, and local adaptation.

2. Biodiversity: While developing new crop varieties is crucial, it is also important to maintain agricultural biodiversity. Overreliance on a few resilient varieties can lead to a loss of genetic diversity, making crops more susceptible to new pests, diseases, or changing climate conditions.

3. Ecosystem Impact: Introducing new crop varieties into existing ecosystems must be done carefully to avoid unintended environmental impacts. It is essential to assess the ecological consequences of planting new varieties and ensure that they do not negatively affect local flora and fauna.

4. Acceptance and Regulation: The adoption of GM crops and other biotechnological innovations can face regulatory hurdles and public resistance. Building trust through transparent research, effective communication and robust safety assessments is vital for the successful integration of these technologies into agriculture.

B. Improved Water Management

Water is a critical resource for agriculture, and effective water management is essential for maintaining crop yields and ensuring food security. Climate change, characterized by altered precipitation patterns and more frequent extreme weather events, has increased the urgency of developing and implementing improved water management practices. These practices not only help farmers adapt to changing conditions but also promote sustainable water use and protect vital water resources.

Key Strategies for Improved Water Management

1. Efficient Irrigation Systems

- **Drip Irrigation:** Drip irrigation delivers water directly to the root zone of plants through a network of tubes and emitters. This method minimizes water waste by reducing evaporation and runoff, and it allows for precise control of water delivery. Drip irrigation is particularly effective for high-value crops and in arid regions where water scarcity is a concern.
- **Sprinkler Irrigation:** Sprinkler systems distribute water over crops in a manner similar to natural rainfall. Modern, low-pressure sprinklers can improve water use efficiency by reducing water loss due to wind drift and evaporation. Variable rate technology can further optimize water application based on soil moisture and crop needs.
- **Subsurface Irrigation:** This system involves placing water delivery pipes below the soil surface, providing water directly to the root zone and minimizing evaporation and runoff. It is beneficial for deep-rooted crops and can reduce water use compared to surface irrigation.

C. Agroforestry

Integrating trees into agricultural systems (agroforestry) helps protect crops from extreme weather, improves soil quality, and enhances biodiversity. Trees act as windbreaks, reduce soil erosion, and increase water retention in the soil.

D. Conservation Agriculture

Techniques such as no-till farming, cover cropping, and crop rotation help maintain soil health, reduce greenhouse gas emissions and improve resilience to extreme weather events. Conservation agriculture is a sustainable approach that reduces reliance on chemical inputs and enhances biodiversity.

2. Precision Agriculture: Technological innovations such as drones, satellite imagery and sensors are being used in precision agriculture to monitor crop health, soil moisture and nutrient levels. These technologies enable farmers to make data-driven decisions, optimize input use and minimize environmental impacts.

Policy and Institutional Support

Governments and international organizations play a crucial role in facilitating agricultural adaptation to climate change. Policy measures that support farmers include subsidies for climate-resilient technologies, investments in agricultural research, and the promotion of sustainable farming practices. Moreover, initiatives such as the Paris Agreement and the United Nations Framework Convention on Climate Change (UNFCCC) emphasize the importance of addressing climate change in the agricultural sector.

Conclusion

Climate change poses significant challenges to agriculture, but with effective adaptation strategies, the sector can become more resilient and sustainable. By adopting climate-resilient crops, improving water management and utilizing modern agricultural technologies, farmers can continue to produce food while minimizing the negative impacts of climate change. The success of these efforts will depend on collaborative action between farmers, researchers, policymakers, and global institutions to create an agricultural system that is adaptive and sustainable in the face of a changing climate.

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Growth and Yield Responses of Cherry Tomato (*Solanum lycopersicum* var. *cerasiforme*)

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Introduction

Cherry tomato (*Solanum lycopersicum* L. var. cerasiforme) is a significant horticultural crop, prized for its flavor and high soluble solids, making it suitable for both fresh markets and protected cultivation. The growth and yield of cherry tomatoes are heavily dependent on various environmental and management factors including temperature, light, soil quality, water availability, nutrient management, and cultivation practices like spacing and pruning. This article conducts a comprehensive review of the key growing factors affecting vegetative growth, phenology, fruit setting, and yield components, offering practical recommendations tailored for optimizing production in both open-field andprotectedenvironments. The research emphasizes the importance of regulated irrigation, balanced fertilization-especially with nitrogen and potassium-temperature management in protected cultivation, and optimal plant density along with proper pruning techniques to enhance light distribution and improve fruit quality. Cherry tomatoes, characterized by their small size resembling miniatures of standard tomatoes, are typically consumed raw to elevate the flavor of various dishes. Their relatively short crop cycle, indeterminate growth pattern in many varieties, and high harvest index contribute to their quick responsiveness to environmental stimuli and agricultural practices. This article underscores the necessity of understanding the interplay between different growing conditions and tomato cultivation techniques, promoting adjustments that can enhance productivity and fruit quality based on traditional horticultural knowledge and contemporary research findings.

Growth stages and yield components

Important stages of growth include planting seedlings, growing leaves, flowering, setting fruit, growing fruit, and ripening fruit. The number of fruits per plant, the average weight of the fruits, the size distribution of the fruits, and the total marketable yield (t per ha or kg per plant) are all common ways to show yield components. Environmental factors affect these parts by changing the way flowers start to grow, pollination, fertilisation, assimilate partitioning, and fruit development.

Effect of temperature and light

- **Temperature:** The growth of cherry

tomatoes and the setting of their fruit depend on the temperature. The best temperatures during the day are usually between 22 and 28 degrees Celsius, and at night they are between 15 and 20 degrees Celsius. High daytime temperatures (>32–35°C) or high night temperatures (>24°C) can make pollen less viable and make it harder for fruits to set. On the other hand, low temperatures (<12–15°C) for a long time can slow down growth and flowering. Maintaining the best difference between day and night temperatures in protected cultivation (greenhouses or high tunnels) helps set and improve the quality of fruit.

- **Light intensity and photoperiod:** Light affects the rate of photosynthesis, the health of plants, and the quality of fruit (soluble solids, colour). When the light is brighter, more dry matter builds up, which usually leads to higher yields and better fruit colour. Supplemental lighting in protected cultivation can speed up early crop growth and boost earliness and total yield in areas or seasons with low light.
- Soil and growing media
- **Soil texture and drainage:** Cherry tomatoes grow best in well-drained soils. When grown in heavy or poorly drained soils, the plants often suffer from root diseases and a lack of oxygen, which leads to weak root growth and reduced yields. Using raised beds or well-structured growing media can help promote healthier roots and better plant performance.
- **Soil pH:** Optimal soil pH is typically 6.0–6.8. pH outside this range can limit nutrient availability, especially of phosphorus, iron and manganese.
- **Growing media for containers / soilless culture:** In substrates, a balance of water-holding capacity and aeration (e.g., peat-perlite or coir-based mixes) supports vigorous root growth. Soilless culture, combined with fertigation, allows precise control of root-zone conditions, and is widely used for high-density cherry tomato production.

Water management and irrigation

Adequate and timely water supply is essential for consistent fruit set and to avoid physiological disorders such as blossom end rot. Regulated deficitirrigation and drip fertigation are common approaches:

- Drip irrigation delivers water near the root zone, reduces disease pressure by keeping foliage dry, and conserves water.
- Irrigation frequency and amount should be matched to growth stage-seedling and flowering stages are sensitive to water stress; stress during fruit set reduces fruit number more than size.
- Blossom end rot is commonly linked to calcium deficiency aggravated by irregular soil moisture; maintaining uniform soil moisture reduces its incidence.

Nutrient management

- **Nitrogen (N):** Promotes vegetative growth and yield, but excessive N may delay fruiting, increase vegetative growth at the expense of fruit set, and reduce soluble solids.
- **Phosphorus (P) and Potassium (K):** P supports root development and early growth; K is crucial for fruit size, quality, and sugar accumulation. Adequate K improves fruit firmness and shelf life.
- **Calcium (Ca) and magnesium (Mg):** Calcium is important for cell wall integrity (reduces blossom end rot); magnesium is central to chlorophyll and photosynthesis.
- **Fertigation:** In protected culture, fertigation enables steady supply of nutrients tuned to crop demand and growth stage, improving nutrient use efficiency and yield.

Cultural practices: spacing, trellising, pruning and training

- **Plant spacing and density:** Optimal spacing balances light interception and per-plant yield. High densities increase overall yield per unit area but may reduce individual fruit size and increase disease pressure if ventilation is poor.

- **Trellising and staking:** Supports indeterminate varieties, improves light penetration, facilitates pruning and harvest, and reduces fruit contact with soil.
- **Pruning (suckering):** Removing side shoots (suckers) controls vegetative growth and directs assimilates to fruit. Moderate pruning improves fruit size and quality in high-input systems; however, excessive pruning can reduce total yield.

Protected cultivation vs open-field

Protected cultivation structures such as greenhouses, polytunnels, and high tunnels help regulate the microclimate by controlling temperature and humidity. They also improve pest and disease management, often leading to earlier and higher yields than open-field farming. These systems allow the use of soilless growing methods, precise fertigation and supplemental lighting. However, they require higher initial investment and ongoing operational costs.

Pest and disease interactions with growing conditions

Crowded planting and high humidity create favorable conditions for leaf diseases such as early blight and powdery mildew. Warm and moist environments also encourage pests like aphids and whiteflies, which can spread viruses. Adopting integrated pest management (IPM), maintaining proper sanitation, ensuring adequate spacing for air circulation and choosing resistant varieties can help minimize these problems.

Yield responses and examples of management strategies

- Early maturing and high-light conditions commonly shift the harvest window earlier and increase total marketable yield.
- Balanced N and high K fertilization tends to increase fruit size and improve soluble solids, thereby increasing market value per fruit.
- Consistent irrigation with drip systems reduces physiological disorders and increases the proportion of marketable fruits.

Practical recommendations for growers

1. Select appropriate cultivar for the production system (open-field vs protected) and target market (fresh vs processing).
2. Maintain optimum temperature in protected cultivation-target 22–28°C day / 16–20°C night for best fruit set.
3. Use drip irrigation and fertigation to supply uniform moisture and nutrients; avoid wide fluctuations in soil moisture.
4. Provide balanced fertilization: moderate N, adequate P, higher K during fruiting and ensure calcium sufficiency.
5. Adopt trellising and timely pruning to improve light penetration and harvest efficiency.
6. Plant at densities that provide adequate light and ventilation; adjust according to cultivar vigor and training system.
7. Monitor and manage pests/diseases proactively with IPM practices; space and prune to reduce humidity in the canopy.

Conclusion

The growth and yield of cherry tomatoes are greatly influenced by the growing environment. Proper management of temperature, light, water, nutrients, and cultural practices can significantly enhance both productivity and fruit quality. In intensive or protected cultivation systems, the use of trellising, drip fertigation, balanced fertilization, and climate control leads to superior results. Farmers should consider local conditions such as climate and soil type, along with the characteristics of the chosen variety, to develop an effective management strategy.

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"Care and Management Practices of Poor Man's Cow (Goat)"

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Introduction

Goat is called the "Poor mains cow" because they are low-cost, low-maintaining and versatile source of milk, meat and manure that is more accessible to small and landless farmer than a cow. They are affordable to purchase and rear require less land and feed, and can be managed by women and children. Goat farming involves the raising and breeding of domestic goats (*Capra aegagrus hircus*) as a branch of animal husbandry. Goat farming is the practice of raising goats for income and sustenance, providing meat, milk and manure. It is aversatile and low cost enterprise, especially beneficial for small and marginal farmers in rural areas due to the animal's ability to thrive in diverse environments and utilize, low-quality forages Goats serve as significant economic asset, after a source of nutrition, and act as valuable safety net against financial hardship for farmers.

Goat farming is rewarding venture that can generate significant profits and provide a suitable source of Income.

Goat milk and meat are highly nutritious, easy to digest, and in significant demand, especially with the growing trend for organic and free-rage protein. Goat requires less space and specialized housing compare to other large livestock.

The following major points to be practiced during the goat raring

1. Determination of Age.
2. Identification.
3. Disbudding and Dehorning.
4. Castration
5. Exercise
6. Hoof Trimming
7. Physiological Norms
8. Selecting the Doe
9. Selection of Buck
10. Care of Bucks

Determination of Age

The age of a goat id judged form it's front teeth (incisors) on the lower jaw. There are no teeth on the upper jaw. The kid at birth, or shortly afterwards, has no tooth on the lower jaw. These are known as sucking teeth. They are small and sharp in kids, when the kid is 12 to 14 months old the central pair is shed and is replaced by two large permanent teeth. When24 to 26 months two more old small teeth shed and replaced by two large permanent teeth, one on each side of the first pair, when 36 to 38 month old there are sic permanent teeth; and when 48 to 50 month old a complete set of four pairs of permanent teeth are present.

Identification

Each goat in a herd should be marked in the same manner by using some identification mark such as tattering, metal ear tags or notching of the ears.

Disbudding and Dehorning

This should be done when the male kid is 2 to 5 days old and the female kid is up to 12 days old. The hairs should be clipped from around the horn bud and this area should be covered with petroleum jelly to protect it from caustic soda or potash, which should be thoroughly rubbed on the bud until the horn bud is well blistered. Caustic soda should not come in contact with the eyes. An electric dehorner can also be used safely.

Castration

Male goats are mainly raised for meat not for breeding. For this reason males are castrated with an emasculator, or torsion forceps. The best time for castrating buck is when they are six months old the Burdizzo instrument. This avoids all sick's of infection. Castration improves the flesh of the adult buck. A castrated male is called Wether.

Exercise

The goats require exercise for maintaining themselves in a good condition. Stock on range receives sufficient exercise while grazing. Stall fed goats should be let loose in a large paddock for at least 3 to 4 hrs. a day. Grazing on wet grass with dew is likely to result in tympanites and intestinal inflammation.

Hoof Trimming

Hoof trimming is necessary for the well-being of goats. If neglected it can weaken legs, ruin feet and lower milk production. The goats soon become used to trimming as a monthly routine. Sharp pen-knives or curved hard pruning shears can be used effectively.

Physiological Norms

The normal body temp. of a goat is 38.9°C to 40°C (102°-104°F). Respiration rate 12 to 20 per minute and pulse (heart beat) 70-80 beats/minute while at rest. The pulse maybe taken by placing the finger on a artery lying near the surface on the inside of lower dow or nearby placing the hand over the heart.

Selection of Doe

Selection of a doe should be made with great care. Good body development is essential for high milk production. The doe should be well grown, healthy in appearance, and stand squarely on her feet. The body should be wedge-shaped and sharp at the wither. The depth of the fibs demotes capacity for coarsening large amount of food. Well attached udder of fair size.

- The Skin should be loose.
- The neck should be thin and he heal narrow.
- The eyes should be clear and bright
- The teats should be pointed slightly forward.

Selecting the Buck

The buck should have a strong, well developed frame, and good conformation and breed characters.

- Good depth of sibs in essential
- Legs should be straight and well placed under the body.
- The buck should be healthy and face from external and internal parasites.
- He should be chosen from a good willing strain & should be the progeny of doe

having good performance record.

♦ When18 to 24 months old he may be permitted to service 25 to 30 does, when fully mature 50 to 60 does in a breeding season.

Care of Bucks

Buck kids under from highly pedigreed does or form does with good performance seconds are rarely worth retaining. They should be castrated shortly after both or within two weeks. Male goats are fertile when quite young and if left with young females are capable of breeding and causing early kidding.

♦ Goods for slaughter should be raised on milk or first six weeks.

♦ They can be sold or Slaughter when 3 month old for meat which is considered excellent.

♦ The Buck shoves should be regularly attended to as otherwise foot-rotor lameness may develop.

♦ The bucks should always be kelp separate from the does.

Mating Season

The does are more careless continuous breeders. The sign of heat in the does usually are uneasiness, tail shaking, pink and swollen genitalia, frequent urination, restlessness, bleating and little mucous discharge for one to three days.

♦ Heat period b/w varies18 to 21days

♦ Better to inseminate the doe on the second day of the heat period.

♦ Breeding season will vary with breed, locality and climate.

Mating of the Doe

Does may be mated when 10 to15 months old but as a rule not be mated until it is one year old.

♦ Average gestation period 151±3days.

♦ The goats reach their maximum efficiency at the age of 5 to 7years.

♦ In exceptional case they continue to be Serviceable even up to 12 years and in rare case up to 14 years.

Goats in kid

A temporary increase in milk yield after mating is considered to be an indication of pregnancy, but the first sign that a doe is in kid is the cessation of the periodical return of estrus, during the first 3 months of pregnancy there is alittle alteration in the shape of the in-kid does.

An average goat can rear well 2 kids. Goats are known to give birth to as many as five kids at a time, but birth of such large no. affects the health of the goat.

♦ The Beetal goats produce an average 35% singles, 54% twins, 6% triplets.

♦ Jampunapari the percentage of twinning varies from19%to50%.

♦ Barbari from 47% to 70 & twinning.

(Data from Hisar Farm)

Housing

In Indian villages goats are mostly kept under widespread shady trees when the climate is dry.

- **Lean-to Type Shed:** Such a shed for a family of two goats should be 1.5m wide and 3.0 m long. This length provides 0.3m for the manger and 1.2m for the goats, the remaining 1.5m space is sufficient for two milking does with a stub wall between them. The height nearest the wall should be 2.3m and on the lower side 1.7m giving a slope of 0.6m on the roof, which may be tiled or thatched.

- **Shelter for Buck:** The buck should be housed separately. A singles tall measuring 2.5mx2.0m with the usual fittings for food and water would be suitable for the bucks. Two bucks should not be kept together, particularly during the breeding season, because they might fight and injure each other.

Space for Goats

0.75 wide and 1.24 long. Goats kept luger in a pen should have a floor space of 2 meter square.

Segregation shed

When the herd in large, pro vision for a small segregation shed, about 3.6 mx 5 m is very desirable.

Hay Racks Feedings

Goats are sensitive animal with peculiar feeding goats eat nothing that is dirty or foul-smelling. They Goat are reinvents. They are very fond of leguminous fodder. Goats do not Relish hey, Lucerne, berseem, Napier grass, Arhar, Cowpea & Soyabean. The common dry fodder liked goats are straws of arhar, urd mury, gram, dry leaves of trees and Lucerne or berseem hay.

Production of ration

- ¼ Part of wheat bran
- ½ Part of maize grain
- ¼ of linseed cake

Or

- 2 parts of maize grain
- 1 Part of barley
- 2 part of mustard cake
- 3 part of gram husk.

Or

- 1 part of wheat bran
- 2 part of barley grain
- 3 part of ground cake

Or

- 2 parts of gram grain
- 1 parts of wheat bran.

These above mixture should also contain 2% each of mineral mixture and salt.

Mineral Mixture

The more important of these salts are calcium and phosphorous the requirement of calcium and phosphorus for maintenance are 6.5 and 3.5 gm. respectively. Per 50 Kg. body weight. Goats required slightly large quantities of calcium than sheep. The mineral Mixture may be included in the concentration at the rate of 0.2 percent.

Goat Products

1. Milk - 4.5% fat
2. Butter -
3. Ghee - The Goat milk is rarely.
4. Meat - Best Meat is obtained for 6-12 months old.
5. Skin -
6. Hair - Angora goats for blankets, etc.
7. Manure - Goat manure is good for soil.
   - Richer in nitrogen content and phosphoric acid then those of cow and buffalo.
   - Goat urine is equally rich in both nitrogen and potash.
   - Because of leaves in graze diet.

Conclusion

Goat farming offers a profitable and sustainable agricultural opportunity, particularly for small-scale and marginal farmers, due to the growing demand for its products and low initial investment. Success hinges on careful breed selection, adherence to scientific rearing practices, proper management of health and nutrition, and effective marketing strategies. With the planning and dedication, Goat farming can provide reliable income, improve rural livelihood, and contribute to food security.

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Cotton to Closet: The Hidden Agricultural Cost of Fast Fashion

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Introduction

The Price of Cheap Clothing: In today's world, clothes are more affordable and trends change faster than ever before. Consumers purchase garments in bulk, often discarding them within months. This phenomenon, known as fast fashion, has reshaped the textile industry, making it one of the fastest-growing and most polluting sectors globally. While people see fashion as glamour, very few realize the hidden cost paid by farmers, natural resources and rural communities. Agriculture provides the raw materials – cotton, wool, silk, jute, hemp– but the excessive demand for fibres has led to enormous pressure on soil, water, land, and ecosystems. Understanding the link between agriculture and fashion is crucial if we want to protect both farmers' livelihoods and the environment. It takes more than 200 years for textile waste to decompose in landfills. Not only does untreated waste pollute the environment, its collection and sorting in the absence of proper infrastructure risks the health and livelihoods of informal workers who do the bulk of this processing.

Pic 1: Cotton cultivation in farm

Cotton Cultivation: The Backbone of Fast Fashion

Fast fashion refers to the rapid production of inexpensive clothing to meet the latest trends. It relies on low-cost labor, cheap synthetic materials, and a system designed to encourage frequent buying and discarding. Cotton is often called "white gold" because of its importance in the global textile industry. It accounts for about 25% of the world's fibre use. But this "gold" comes at a high cost: Cotton cultivation covers 2.5% of global farmland. It uses 6% of the world's pesticides and 16% of insecticides, making it one of the most chemical-intensive crops. These chemicals affect soil fertility, ground-water, and the health of farming communities. Many cotton farmers face a paradox: while global demand for cotton rises, their incomes remain unstable due to fluctuating prices, rising input costs, and unsustainable practices encouraged by industrial textile supply chains. Due to its high demand, the required cotton produc-tion also contributes to its excessive environmental impact.

The High Cost of Cotton

To make a single cotton shirt, about 2,700 liters of water is required-roughly the amount one person drinks in 2.5 years. Below are some threatening facts about cotton crop.

Water-Intensive Crops

Cotton is one of the thirstiest crops on Earth. It takes about 2,700 litres of water to make a single cotton shirt-roughly what one person drinks in two and a half years. In water-scarce regions, cotton production can divert essential freshwater from communities and ecosystems. The fashion industry's dependence on water is staggering. From the cotton fields to dyeing processes, water flows everywhere in the value chain.In water-scarce areas, prioritizing cotton threatens food security, forcing farmers to make tough choices.

Chemical Pollution

To dye fabrics and treat materials, fast fashion relies on a toxic cocktail of chemicals. These include azo dyes, heavy metals, and formaldehyde-all of which often end up in rivers and lakes due to inadequate wastewater treatment. In many places in India, entire waterways have been rendered biologically dead because of fashion-related pollution.

Microfibers Pollution

Synthetic fabrics like polyester shed tiny plastic particles-microfibers-each time they're washed. These particles are too small to be filtered by wastewater treatment plants and end up in rivers, lakes, and oceans. Microfibers now make up a significant portion of aquatic plastic pollution, threatening marine life and contaminating drinking water sources.

India's Textile Waste Crisis: A Circularity Failure

India faces broken cotton circularity due to significant waste generation,Between 2019 and 2023, with less than half of the ~7.8 million tons of textile waste annually being reused or recycled, and much of it ending up in landfills or lower-value applications like blankets. The fashion industry faces many Challenges. Less than half of this waste is currently reused, repaired, or undergoes high-grade recycling, with a large percentage being land filled or incinerated. A lack of proper mechanisms for collecting, sorting, and processing post-consumer waste from households leads to much of it being sent to landfills. Current recycling technologies are limited in their ability to process heavily contaminated or blended materials, such as dyed cotton or cotton-polyester blends, reducing their potential for high-value recycling.

While informal sectors in areas like Panipat, Haryana recycle waste, they primarily produce low-value products like coarse yarn for blankets, offering minimal contribution to true circularity. Recycled yarns often fail to meet global quality standards, making them unsuitable for higher-value applications and further limiting the circular loop.

Pic 2: Cotton clothes in closet and waste generation after use

Carbon Footprint: Fashion and Climate Change:

The fashion industry is responsible for 2-8% of global carbon emissions. If unchecked, it could rise to 26% by 2050. Energy-intensive textile production, synthetic fibre manufacturing (made from petroleum), and transport of clothes worldwide drive this footprint. For agriculture, climate change caused by rising emissions means: increased droughts and floods in cotton-growing regions, reduced soil fertility and water availability, shifts in crop suitability, affecting fibre as well as food crops, thus, fast fashion not only drains resources from agriculture today but also worsens the climate risks that threaten farming tomorrow.

Farmers and Rural Communities: The Human Cost

The human cost in cotton farming includes economic hardship, with high costs of cultivation, volatile market prices, and precarious income for smallholder farmers, especially due to climate change impacts. It also entails health challenges, as women are particularly vulnerable to infectious diseases and heat stress from extreme weather. Additionally, there are issues of land rights and displacement, as seen in Brazil, where indigenous communities face violence and intimidation from agribusinesses expanding onto their traditional lands. Finally, labor conditions are affected, with shifts from human to machine labor on larger farms, potentially impacting employment for rural populations. Meanwhile, rural communities living near textile factories face polluted water, degraded soil, and fewer resources for farming. The glamour of fast fashion hides this human and agricultural struggle.

Towards Sustainable Solutions

Reducing fast fashion's agricultural costs requires a shift to a circular economy through industry-wide changes in production and design, government policy, and consumer behaviour. Solutions include using more sustainable and recycled materials, increasing textile recycling and repair infrastructure, promoting supply chain transparency, adopting circular business models, and educating consumers to buy less and buy better, support ethical brands, and participate in clothing reuse and repair. Some other possible solutions includes: invest in recycling and repair, design for durability & recyclability, government regulation and focus on quality over quantity and Consumer Awareness can may be some effective solutions.

Conclusion

The journey from cotton to closet is not just about style; it is about land, water, farmers, and ecosystems. Every shirt, every dress, and every pair of jeans carries an agricultural footprint that is often ignored. If consumers, policymakers, and the fashion industry come together, we can reduce the burden on agriculture and ensure that fibre crops are grown responsibly. Fast fashion doesn't have to mean a fast path to resource depletion. With sustainable practices, it can become a system that supports farmers, protects water, reduces waste, and respects the environment. Ultimately, what we wear should not come at the cost of what farmers grow or what future generations inherit. It's time to make fashion truly sustainable from cotton fields to closets.

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Biofortification of Vegetables: Improving Nutrition to Mitigate Hidden Hunger

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Introduction

Biofortified vegetable crops are vegetables that have been intentionally enhanced to contain higher levels of essential nutrients, such as vitamins, minerals, or antioxidants; through methods like conventional plant breeding, agronomic practices, or genetic engineering. Unlike traditional fortification, which adds nutrients during food processing, biofortification increases the nutrient density during the plant's growth. This process aims to address micronutrient deficiencies ("hidden hunger") by delivering more nutritious vegetables directly through the diet. Common examples include iron-rich beans, beta-carotene-enriched sweet potatoes, and zinc-enhanced spinach. Biofortified vegetable crops provide a sustainable, cost-effective approach to improving public health, especially for populations with limited access to diverse or commercially fortified foods.

Definition and Principles of Biofortification

Biofortification is the process of enhancing the nutrient content; especially vitamins and minerals of food crops through conventional plant breeding, improved agronomic practices, or biotechnology. The principle is to naturally increase nutrient density in crops during growth without compromising yield or consumer preference. Biofortified crops aim to reduce micronutrient deficiencies, also known as hidden hunger, sustainably and cost-effectively. This approach ensures nutrients are present in the harvest itself, making improved nutrition accessible even in regions with limited diets or food fortification infrastructure.

There are three principal strategies for biofortification

1. Conventional Breeding

This approach exploits genetic diversity found either naturally or in wild relatives; to develop new varieties with higher concentrations of key nutrients like iron, zinc, or provitamin A. It is the most widely accepted and sustainable pathway because it uses traditional cross-breeding without introducing foreign genes.

2. Agronomic Biofortification

Here, the nutritional profile of a crop is improved with agricultural practices such as fertilizer application or soil amendments that boost the accumulation of nutrients in edible tissues. For example, applying zinc-rich fertilizers increases grain and vegetable zinc content rapidly, though its effect may be more temporary and setting-specific.

3. Genetic Engineering

This more modern method involves directly introducing or editing genes responsible for nutrient uptake or accumulation. Genetic engineering can achieve rapid and significant gains, sometimes yielding profiles not normally attainable by conventional breeding. Acceptance varies widely depending on regulatory standards and public perception, but the potential for impact remains high.

Why Biofortified Vegetables: The Future Imperative

Micronutrient malnutrition, commonly referred to as hidden hunger, remains one of the most persistent public health challenges across the globe. Despite progress in food production, billions of people still lack adequate intake of essential vitamins and minerals such as iron, zinc and vitamin A. This deficiency is particularly severe in low-income regions, where diets are often dominated by a few staple foods like cereals and tubers that provide sufficient calories but lack micronutrient diversity. The consequences impaired immunity, poor cognitive development, stunted growth, and higher susceptibility to disease are profound and long-lasting.

Vegetables already serve as natural reservoirs of essential vitamins, minerals, antioxidants, and phytonutrients. When biofortified, their nutritional potential is significantly amplified, making them powerful tools in the fight against hidden hunger. Biofortification enhances the nutrient density of vegetables during plant growth through methods such as conventional breeding, agronomic practices, or genetic engineering. This means that nutrients are delivered directly in the foods people already grow and consume, making the approach both sustainable and cost-effective. Examples include iron-rich beans, zinc-enhanced spinach, beta-carotene-rich sweet potatoes, and antioxidant-rich colored carrots and potatoes.

For future generations, biofortified vegetables offer a pathway to sustainable nutrition security. Unlike supplementation programs or post-harvest food fortification, which often face challenges of affordability, logistics, and accessibility, biofortification builds nutrition into the crop itself. This makes it especially impactful for rural and marginalized populations who may lack access to diverse foods or fortified products. Moreover, many biofortified vegetable varieties are bred for resilience providing better tolerance to pests, diseases, and climatic stress. This dual benefit not only improves dietary quality but also strengthens farmer livelihoods and food system stability.

As climate change and population growth continue to strain global agricu-lture, ensuring food sufficiency will not be enough. The real challenge lies in guaranteeing nutrient-rich diets that support long-term health and product-ivity. Integrating biofortified vegeta-bles into mainstream agricultural and nutri-tion programs is no longer optional; it is an imperative. By embedding vital micronutrients directly into commonly consumed crops, biofortific-ation has the potential to fuel healthier societies, reduce healthcare burdens, and empower communities to break the cycle of malnutrition making it one of the most transformative innovations for global food and nutrition security.

These varieties are typically developed using a combination of germplasm screening, cross-breeding with wild relatives, or in some cases, genetic engineering.

Further Notable Examples

Examples of Biofortified Vegetable Crops

Numerous vegetable crops have been successfully biofortified, either through breeding, agronomy, or biotechnology. Below are some prominent and widely adopted examples:

Crop	Biofortified Variety	Enhanced Nutrient	Noteworthy Benefits
Cauliflower	Pusa Beta Kesari-1	Beta-carotene	Tackles vitamin A deficiency
Sweet Potato	Bhu Sona	Beta-carotene	Immune support, vision, antioxidant
Sweet Potato	Bhu Krishna	Anthocyanin	Potent antioxidant
Potato	Kufri Neelkanth	Anthocyanin	Antioxidant, cardiovascular health
Carrot	Pusa Rudhira, Ooty-1	Carotene, phenols	Vision, cancer prevention
Radish	Pusa Gulabi, Pusa Jamuni	Carotenoids, Vitamin C	Immunity, antioxidants
Brinjal	Pusa Safed Baigan 1	Phenol, antioxidants	Reduces cellular oxidative stress
Cowpea	Pant Lobia-1, Pant Lobia-2	Iron, zinc	Reduces risk of anemia
Broccoli	Sprouting and hybrid varieties	Glucosinolates	Detoxification, anti-cancer properties
Okra	High iron and calcium variants	Iron, calcium	Bone and metabolic health

- **Beans:** Biofortified common beans with higher iron and zinc are widely grown and consumed in Africa and Latin America.
- **Pumpkin and Squash:** Varieties with intensified beta-carotene content support vitamin A intake.

Lettuce: Red leaf and other colored lettuces are often bred for enhanced anthocyanins and vitamin.

Mechanisms: How Biofortification Improves Nutrition

Biofortification refers to enhancing the nutritional quality of food crops through conventional breeding, modern biotechnology, or agronomic practices. The goal is to increase the density of essential micronutrients and phytonutrients in edible plant parts so that they directly improve human health upon consumption.

1. **Iron and Zinc Enrichment**
   - **Mechanism:** Iron and zinc are often bound in soils or poorly bioavailable in plant tissues. Biofortification uses genetic selection for varieties that accumulate higher levels of *bioavailable* Fe and Zn in seeds, pods, and roots. In some cases, anti-nutritional factors (like phytic acid) are reduced to enhance absorption.
   - **Crop Examples:** Biofortified beans, cowpea, okra.
   - **Health Benefits:** Regular intake improves hemoglobin formation, reduces anemia prevalence, and supports physical growth, immunity, and cognitive development-particularly beneficial for vegetarian populations where meat-based iron sources are absent.
2. **Vitamin A (β-carotene) Enhancement**
   - **Mechanism:** Crops are bred or engineered to accumulate higher levels of carotenoids (especially β-carotene, the precursor of vitamin A) in roots, tubers, and fruits. Human enzymes convert β-carotene into active vitamin A upon digestion.

- **Crop Examples:** Carrot, sweet potato, pumpkin, maize with high provitamin A.
- **Health Benefits:** Reduces night blindness and xerophthalmia, boosts immunity, lowers infection-related child mortality, and supports normal growth and development.

3. Vitamin C Fortification

- **Mechanism:** Breeding for increased ascorbic acid content enhances both antioxidant defense and iron absorption. Vitamin C reduces ferric to ferrous iron in the gut, improving its uptake.
- **Crop Examples:** Radish, broccoli, spinach, mustard greens, and amaranthus.
- **Health Benefits:** Improves immunity, reduces oxidative stress, enhances iron absorption from plant-based foods, and lowers the risk of scurvy.

4. Anthocyanins and Polyphenols

- **Mechanism:** Biofortification targets enhanced synthesis of secondary metabolites (anthocyanins, flavonoids, phenolic acids) that act as antioxidants and anti-inflammatory agents.
- **Crop Examples:** Purple carrot, red/purple radish, colored potato varieties.
- **Health Benefits:** Provide protection against oxidative damage, lower risk of cardiovascular diseases, diabetes and certain cancers, and slow down age-related degeneration.

5. Calcium Biofortification

- **Mechanism:** Some crops naturally accumulate calcium; biofortification enhances calcium transport and deposition in edible tissues, making them a stronger source of dietary calcium.
- **Crop Examples:** Okra, beans, and selected leafy vegetables.
- **Health Benefits:** Supports bone and teeth development, reduces osteoporosis risk, and is critical for maternal and child health during pregnancy and lactation.

6. Demonstrated Health Impacts

Observational and intervention studies across Asia, Africa, and Latin America show measurable improvements in po-pulations consuming biofortified crops:

- Improved iron status (higher ferritin, hemoglobin, reduced anemia in women and children).
- Increased vitamin A levels (higher blood retinol concentrations, reduced prevalence of night blindness).
- Better immunity and growth (lower incidence of infections, improved child development indicators).
- Overall reduction in micronutrient deficiency burden, contributing to better productivity, learning ability, and long-term health outcomes.

Conclusion

Biofortified vegetable crops offer a powerful, sustainable solution to the global challenge of micronutrient malnutrition. By naturally enriching vegetables with critical nutrients such as iron, zinc, vitamin A, vitamin C, calcium, and directly into commonly consumed vegetables, biofortif-ication ensures that improved nutrition is delivered naturally through the daily diet. Unlike supplementation or industrial forti-fication, this approach empowers farmers and communities, reducing reliance on external interventions while enhancing crop resilience to environmental stresses. Robust evidence from multiple regions confirms significant health benefits, including reduced anemia, improved immune function, and better vitamin A status. While challenges remain in scaling adoption, ensuring nutrient bioavailability, and fostering policy and consumer acceptance, continued investment and awareness are vital. Ultimately, biofor-tified vegetables can become foundational to future food systems, promoting nutrient-rich diets that reduce hidden hunger and strengthen the health and productivity of vulnerable populations worldwide.

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Nanotechnology & Nano sensors for Soil, Plant, and Water Monitoring: A Smart Revolution in Agriculture

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Introduction

Agriculture has always been a science of observation—farmers watch the soil, the plants, and the weather to decide when and how to act. But in the 21st century, observation is going microscopic. Thanks to nanotechnology, we can now measure soil nutrients, detect plant diseases, and monitor water quality at scales far smaller than a human hair, enabling precision agriculture like never before.

Among the most promising applications are Nano sensors—tiny devices capable of detecting and transmitting information about the agricultural environment in real time. With climate change, resource scarcity, and food security challenges intensifying, Nano sensors could transform farming into a data-driven, ultra-efficient enterprise.

What Are Nano sensors?

A Nano sensor is a sensor with at least one dimension in the nanometer range (1–100 nm). At this size, materials often behave differently-gold nanoparticles, for example, can change color with particle size; carbon nanotubes can conduct electricity with extreme efficiency.

These unique properties allow nanosensors to:

- Detect ultra-low concentrations of chemicals, pathogens, or toxins.
- Operate with minimal power consumption
- Be embedded directly into plants, soil, or irrigation systems without major disturbance

Types of Nanosensors in Agriculture

Nanosensors can be broadly classified based on the parameter they monitor:

1. Soil Nanosensors

These measure

- Nutrient levels (e.g., nitrogen, phosphorus, potassium).
- Soil moisture content.
- pH and salinity.

Example technologies:

- **Graphene-based sensors:** Extremely sensitive to ion concentrations, allowing real-time nutrient mapping.
- **Zinc oxide nanowires:** Detect changes in soil pH and heavy metal contamination.

2. Plant Nanosensors

These detect:

- Early signs of disease or pest attack through plant stress biomarkers.
- Water stress and photosynthetic activity.
- Levels of plant hormones like ethylene or abscisic acid, which indicate ripening or drought response.

Example technologies

- Carbon nanotube sensors embedded in

leaves to measure hydrogen peroxide spikes—a sign of pathogen attack—days before visible symptoms.

- Quantum dot-based optical sensors for tracking nutrient uptake.

3. Water Nanosensors

These monitor

- Irrigation water quality (e.g., salinity, dissolved oxygen).
- Presence of pesticides or heavy metals.
- Real-time flow and nutrient content in fertigation systems.

Example technologies

- Nanoparticle-coated electrodes for detecting arsenic or nitrates.
- Nanoscale colorimetric strips that change color when contaminants are present.

How They Work: From Nano to Farmer's Phone

A nanosensor works in three key stages:

1. Detection: The nanosensor's active surface interacts with the target (e.g., nitrate ions, ethylene gas). This causes a measurable change-such as electrical resistance, fluorescence, or optical absorption.

2. Signal Processing: The change is converted into an electronic signal by a microcontroller or integrated circuit.

3. Communication: The data is transmitted wirelessly (via Bluetooth, LoRaWAN, or NB-IoT) to a gateway or directly to a smartph-one app, where it is analyzed and visualized.

Benefits of Nanosensors in Agriculture

1. Precision Resource Use

Instead of applying fertilizer uniformly across a field, nanosensors enable site-specific nutrient management. This saves money, reduces chemical runoff, and improves yields.

2. Early Disease Detection

Plant nanosensors can detect stress signals days or weeks before symptoms appear, allowing farmers to intervene early with targeted treatments.

3. Real-Time Monitoring

Continuous feedback allows farmers to adapt to changes instantly—whether that means delaying irrigation after unexpected rain or adjusting fertilizer mid-season.

4. Environmental Protection

By preventing overuse of chemicals and detecting pollutants quickly, nanosensors help reduce environmental impact and protect surrounding ecosystems.

5. Integration with Other ICT Tools

Nanosensors can feed data directly into IoT platforms, AI decision-support systems, or even autonomous robots, enabling a fully connected farm ecosystem.

Case Studies & Emerging Research

1. MIT Plant Nanobionics Project: Researchers embedded carbon nanotubes in spinach leaves, enabling them to detect explosives in groundwater and wirelessly send signals to a handheld device.

2. Indian Agricultural Research Institute (IARI): Developed nanostructured biosensors for detecting urea levels in soil, improving nitrogen efficiency in rice fields.

3. EU SmartNanoTox Initiative: Explores nanosensors for detecting multiple soil contaminants simultaneously, important for sustainable farming in polluted areas.

Challenges to Adoption

While the promise is huge, several challenges remain:

- **Cost:** Advanced nanosensors can still be expensive for smallholder farmers.
- **Durability:** Sensors must survive harsh outdoor conditions—heat, moisture, UV exposure—for months or years.
- **Data Overload:** Farmers need simple, actionable insights, not raw data streams.
- **Regulation & Safety:** The environmental and health impacts of deploying nano-materials at scale require careful regulation.
- **Scalability:** Moving from lab prototypes

to field-ready devices remains a bottleneck.

Future Outlook

In the next decade, we can expect:

- Biodegradable nanosensors that dissolve harmlessly after use, eliminating waste concerns.
- Self-powered nanosensors that harvest energy from sunlight or plant metabolism.
- Integration with drones and satellites for multi-scale monitoring-combining ultra-local data from nanosensors with wide-area imagery.
- AI-powered predictive farming-nano-sensor data will feed machine learning models to forecast disease outbreaks, yield potential, and irrigation needs with high accuracy.

Governments and private companies are already investing heavily. For example, India's "MahaAgri-AI" initiative (2025) aims to integrate nanosensors into statewide soil and crop monitoring platforms, while the EU's Horizon projects are funding open-source nanosensor designs for climate-smart agriculture.

Conclusion

Nanotechnology and nanosensors are taking agriculture beyond observation—into the realm of micro-scale precision management. By measuring exactly what plants and soils need, when they need it, farmers can produce more food with fewer inputs, protecting both their profits and the planet.

The journey from lab to field is still in progress, but the direction is clear: the farms of the future will not only be green with crops—they will be dotted with invisible sentinels, quietly measuring, thinking, and helping us grow.

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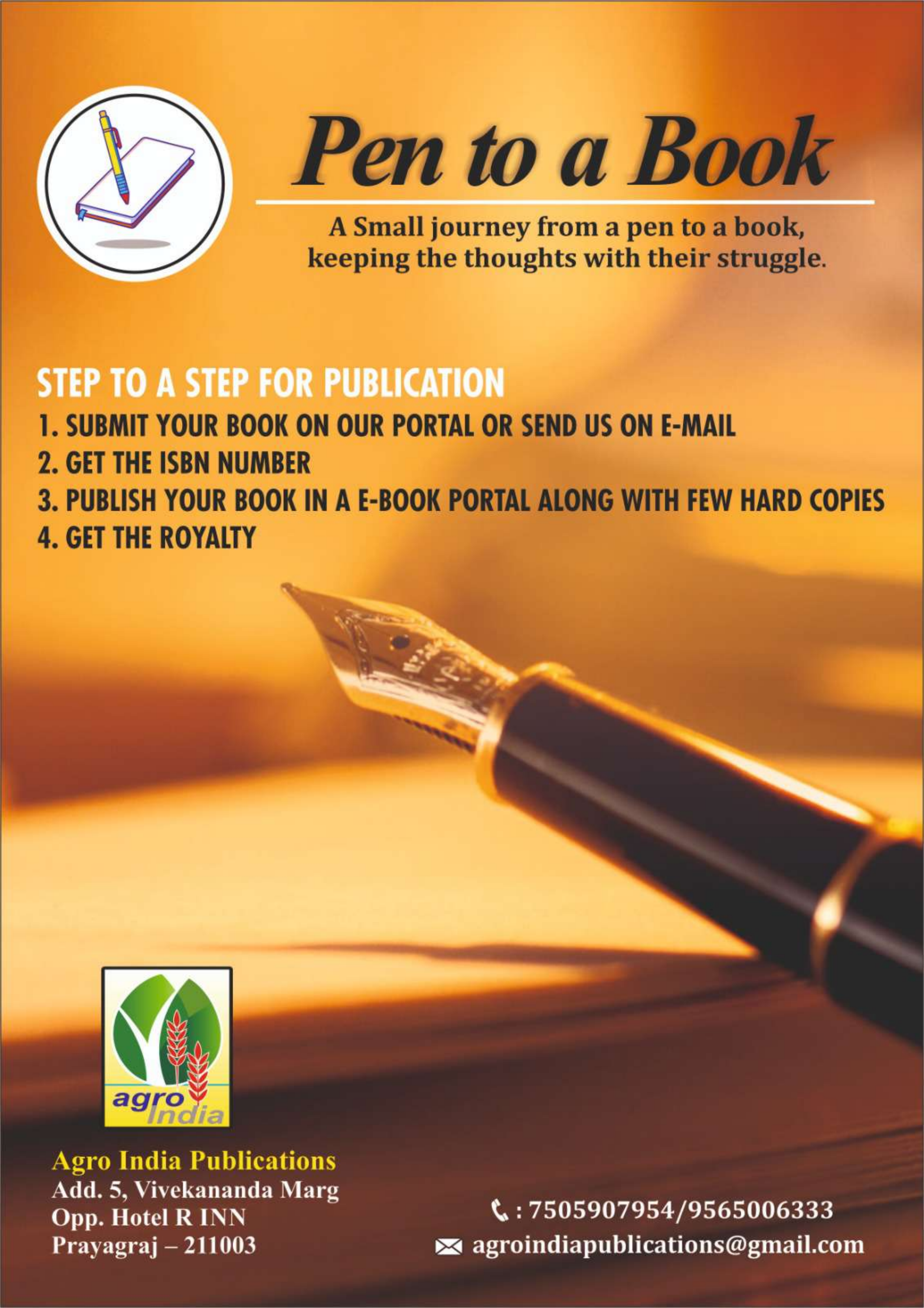
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Khejri: Lifeline of Thar Desert

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Introduction

Khejri (*Prosopis cineraria* L.) glorified as the Kalptaru of the Thar desert is very useful plant of dry-land farming systems in north-western part of India. It is known by many names *shami* (Sanskrit), *janti/jand* (Delhi, Haryana, Punjab), *sumi/ sumari* (Gujarat), *banni* (Karnataka), *vanni* (Tamil Nadu), *kandi* (Sindh), *ghaf* (UAE). Khejri is indigenous to India. It is worshipped by Hindus andthe Bishnoi community holding deep cultural and ecological significance. It not only tolerates the extreme edaphic-climatic conditions of hot arid and semi-arid regions including parts of Rajasthan, Gujarat, Haryana, Punjab, Delhi and some parts of southern India with the lush-green foliage but also bears fruits during the driest period.

Sangri and Khokha

Khejri is a multi-functional tree which provides nutrition rich leaf-fodder, pods, seeds and fuel-wood.Thetree having a deep tap root system and nitrogen fixing ability enriches soil with organic matter, nitrogen, phosphorus, calciumand lowers pH level, thus improving the field productivity without competing for moisture and nutrients with other crops grown close to it.

Khejri is much valued for its leaf-fodder (loong or loom) and is a major source of nutrition for animal, both green and dry loong is highly palatable and feeding in winters is much beneficial when no other green fodder is available in the Thar Desert. Tender pods (sangri) is used for vegetable and pickles and is the main constituent of Panchkutta vegetable. Traditionally, the rural people collect pods for fresh use or dehydration purpose. Whereas ripen pods (khokha) are used for flour making, and alsomixed with wheat or bajra flour to make chapatisand for preparation of bakery items.

Khejri provide good quality wood and used in house-building as rafters, posts, doors, boxes, tool-handles and agricultural implements. Its wood contains high calorific value fuel (5000kcal/kg) and good for charcoal making.

Nutrient content of khejri fruits

Protein	23.2%
Carbohydrate	56.0%
Fat	2.0%
Fibre	20%
Vitamin A	-
Vitamin B2	-
Vitamin C	523.0 mg/100gm
Calcium	414.0 mg/100gm
Phosphorus	400.0 mg/100gm
Ferrous	19.0 mg/100gm
Energy	334.8 Kcal/gm

Source- Gupta *et al.*, 1984.

Importance of khejri

Different parts of khejri plants have long been used by desert people in a variety of uses. Its highly nutritious leaves constitute important source of fodder for livestock while nutritious pods are valued as vegetable for human beings. The immature pods are rich in crude protein, carbohydrates and minerals. *Prosopis cineraria* fruit is very rich in vitamin C and calcium and phosphorus contents. (Saroj *et al.,* 2002)

Propagation

Khejri can be multiplied by seed, budding and air layering. However the most common method of propagation is patch budding from March to April and July to October on pencil thick (2-2.5mm diameter) 6-9 months old *P.cineraria* seedling rootstock. (Pareek andPurohit 2002, Rawat *et al.*, 1982)

Varieties

Thar Sobha: Thar Shobha is the first variety to develop uniform plantations for better quality and high sangri production on commercial scale and recommended in 2007 by CAIH. Bud-grafted plants are thornless and have spreading growth, dense foliage and longer branchlets. Marketable stages tender pods are light-green, straight, roundish-flat, 13.1–20.2 cm length, 0.17–0.42cm diameter and 0.97–1.75g weight. Average yield is 5.25kg/plant. (Samadia, 2015)

Khejri Selection–2: Identified in year 2007 from regional diversity and evaluated in-situ for horticultural potentials. This established through bud-grafting technique and studied ex-situ at CIAH, Bikaner during 2013–2017 and it is high yielding (5.62kg/plant). Bud-grafted plants are thornless and have compact growth, dense-leaf and longer branch-lets.

Orchard establishment

For field planting, 9-10 months old seedlings should be used and it should be started with the on-set of monsoon rains from July-September which gives 80-90% establishment.Khejri can be planted at a spacing of 5×5 m as a sole crop in arid region, however, mixed crop with 8-10 m spacing is considered optimum.

Training and pruning

Training and pruning are essential practices for plant structure, canopy management and harvest of crop produce khejri. Bearing of fruits takes place on those parts of canopy, which are open in light and air. Khejri should be looped in june just after the harvest of sangria to harvest both long and sangria every year. (Samadia, 2007)

Looping

The leaves and pods constitute a major source of fodder. The dried leaves of khejri called as loom or long are used as quality fodder for the animals during lean period. Trees are lopped at 3 years intervals, they produce 172-242% more leaf fodder by weight than those recurrently lopped. In general, annual lopping is common practice of khejri by the farmers, though annual lopping is not suggested for sangri production. The tree may be lopped after harvesting of the pods, in order to promote physiological maturity of the shoots for production of sangria next season.

Harvesting

The trees of seedlings origin come in bearing after 8-10 years but the vegetatively propagated plants came in fruiting after 3rd year. The plants flower during February March and fruit setting takes place in April-May. Only immature tender pods are used as vegetables, hence stage of harvesting is very essential, which should be done within fortnight of fruit setting in two-three consecutive operations. A mature tree gives on an average 7-8 kg green tender pod yield per year. The recovery is about 25-30% after dehydration of fresh sangri. However, there is high variation in market price of fresh sangri and dehydrated sangria (1500-2000/ kg). Ripe pods may be collected by hand picking or by shaking/beating the branches. Nearly 1.4 quintals of pods/ha can be obtained. The pod yield is signific-antly correlated with diameter at breast height of the tree. One tree of Khejri gives at least 5 kg of ripe pods. (Samadia *et al.,* 2006)

As agro-forestry component

Khejri is compatible perennial component of various agro-forestry systems in arid ecosystem because of its deep root system, leguminous nature, prone to lopping and capacity to tolerate various biotic and abiotic stresses. Farmers have retained the khejri plants in their fields and bunds as the trees have least or no adverse effect on several ground story crops.

In arid region of western Rajasthan, moth, guar, bajra, mixed with kachri, mattera, tinda, kakri etc. are being grown in association with natural growing khejri under rainfed condition since long back. The effect of khejri tree on vegetative vigour of fruit trees like aonla, ber, guava, pomegranate and bael grown under shade and in open conditions was also assessed. It was observed that the fruit trees grown under shade produced more vigorous growth with respect to plant height, canopy spread and tree volume as compared to those growing in open. The observations indicated that the khejri tree has not only positive effect on annual crop but it also improves the vegetative vigour of several fruit trees planted in their proximity. (Young, 1989)

Dehydration of sangri

The tender pods of khejri both fresh and dehydrated are utilized as vegetable. Now-a-days, khejri dishes are very popular in some of top class hotels. However, the dehydrated Sangri available in the market are not of ideal quality because of improper harvesting stages, uncleaned and unblanched before dehydration. 5 minute blanching in 2% salt solution gives light green colour after rehydration and liked by the people on organoleptic scoring as compared to either un-blanched (control) or blanching in boiling water only. However, the product of prolonged blanching (10 minutes) both in water and in 2% salt solution also was not liked by people.

Khejri cookies

Some attempt was made to prepare cookies from dried khejri pods (khokha). After proper cleaning and drying, the powder of khokha was made with and without seeds. Thereafter the 10%khokha powder was mixed with wheat flour while other ingredients remaining almost constant and its biscuits were prepared. 10% replacement of wheat flour by khokha powder without seeds was the best. With increasing ratio of khokha powder, the taste of biscuits becomes bitter. (Purohit *et al.,* 2004).

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Climate Resilient Zero Budget Natural Farming (CRZBNF)

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Introduction

Climate-Resilient Zero Budget Natural Farming (CR-ZBNF) is a holistic, low-cost agricultural system that empowers farmers to grow crops using locally available natural inputs, while enhancing soil health, biodiversity, and water efficiency-making farms more adaptable to climate extremes without relying on external financial or chemical resources. (CR-ZBNF) is a nature-based, agroecological farming approach that eliminates the need for synthetic inputs and external credit, while enhancing the resilience of farming systems to climate variability. It is centered on using locally available, biologically rich resources-like cow dung, cow urine, crop residues, and indigenous knowledge-to build soil fertility, conserve water, reduce greenhouse gas emissions, and protect crops from pests naturally. This method empowers small and marginal farmers by reducing dependency on costly inputs and increasing the farm's capacity to adapt to droughts, floods, erratic rainfall, and other climate-related stresses.

Key Features of CR-ZBNF

1. **Zero External Inputs:** No chemical fertilizers or pesticides. No need to purchase seeds, compost, or agrochemicals from the market. Promotes self-reliance and low-cost farming.
2. **Natural Resource-Based:** Uses locally available materials such as: Cow dung and urine from indigenous cows, Soil microorganisms, Mulch and green cover, Rainwater harvesting.
3. **Climate Resilience:** Increases soil organic matter, improving water retention during droughts. Promotes agro-biodiversity, which enhances pest and disease resistance. Encourages microclimate regulation on farms through tree cover and ground cover. Reduces greenhouse gas emissions by avoiding synthetic nitrogen inputs.
4. **Farm Ecology Approach:** Treats the farm as a living ecosystem. Integrates livestock, crop diversity, soil health, and human health.
5. **Social and Economic Empowerment:** Reduces debt risk by removing the need for loans. Promotes local knowledge and community practices. Supports nutritional security by encouraging diverse food crops.

Core Components of CR-ZBNF

1. **Jeevamrut (Microbial Soil Booster)**: A fermented liquid made from cow dung, cow urine, jaggery, pulse flour, and soil. Boosts microbial activity and soil fertility. Applied regularly to the soil to rejuvenate life in it.
2. **Beejamrut (Seed Treatment)**: A mixture of cow dung, cow urine, lime, and soil to treat seeds before sowing.Protects against fungal and bacterial infections. Ensures healthy germination and early plant vigor.

3. Mulching (Soil Covering): Use of organic material (crop residues, leaves, straw) to cover the soil. Reduces evaporation, improves moisture retention, and prevents weed growth. Enhances soil carbon and protects against temperature extremes.

4. Waaphasa (Soil Aeration): Encourages the right balance of moisture and air in the soil. Avoids over-irrigation, helping conserve water. Improves root health and supports microbial life.

Climate-Resilient Features of CR-ZBNF

1. Agroecological Crop Planning

Use of intercropping, multi-cropping, crop rotation, and polyculture systems. Enhances biodiversity, reduces pest risks, and stabilizes yields under changing climate.

2. Agroforestry / Tree Integration

Integration of trees and shrubs into farmlands (e.g., border trees, fruit trees). Provides shade, improves microclimate, fixes carbon, and reduces soil erosion.

3. Rainwater Harvesting & Soil Moisture Management

Use of bunds, trenches, farm ponds, and mulch to conserve rainwater. Improves resilience to droughts and erratic rainfall.

4. Use of Indigenous Seeds

Promotes climate-adapted local seed varieties. Ensures better resistance to local pests, diseases, and weather variability.

5. On-Farm Biodiversity

Maintains beneficial insects, birds, and microorganisms. Creates a self-regulating ecosystem that reduces the need for external inputs.

6. Community-Based Knowledge Sharing

Encourages farmer-to-farmer learning and local innovation. Builds social resilience and strengthens community climate responses.

Economic Benefits

- **Zero Input Cost:** No need to purchase synthetic fertilizers, pesticides, or hybrid seeds-reducing dependency on loans or credit.
- **Increased Profit Margins:** Lower costs lead to higher net returns, especially for small and marginal farmers.
- **Financial Independence:** Promotes farmer self-reliance and reduces debt-related distress.
- **Higher Resilience in Markets:** Diverse, chemical-free produce can attract premium prices in local and organic markets.

Environmental and Ecological Benefits

- **Soil Regeneration:** Natural inputs (e.g., Jeevamrutha) improve soil fertility, organic carbon content, and microbial health.
- **Water Conservation:** Techniques like mulching and Waaphasa reduce irrigation needs and improve rainwater absorption.
- **Enhanced Biodiversity:** Intercropping and the avoidance of chemical pesticides preserve beneficial insects, birds, and microbes.
- **No Pollution:** Prevents soil, water, and air contamination from chemical residues and runoff.
- **Agroforestry Integration:** Sequesters carbon, reduces erosion, and enhances farm biodiversity.

Climate Resilience Benefits

Adaptation to Climate Shocks

Better soil structure helps withstand droughts, floods, and temperature extremes. Polycropping and seed diversity reduce crop failure risk during erratic weather.

Mitigation of Greenhouse Gas Emissions

Eliminates synthetic nitrogen use, a major source of nitrous oxide (a potent GHG). Enhances carbon sequestration through organic matter and tree cover.

Social and Farmer Empowerment Benefits

Community Knowledge Sharing: Encourages farmer-to-farmer learning and revival of traditional practices.

Gender Inclusive: Practices like seed saving, composting, and mulching can involve women more actively.

Skill-Based Farming: Builds local capacity through low-cost, low-tech knowledge systems.

Reduced Farmer Stress: Lower financial risk = less stress and fewer cases of farmer distress or suicides.

Health and Nutritional Benefits

Chemical-Free Food: Safer for consumers, farmers, and the environment.

Nutrient-Rich Crops: Organic and naturally grown crops often retain more nutrients.

Clean Water and Soil: No toxic runoff means better quality of water in rural ecosystems.

Challenges of Zero Budget Natural Farming (ZBNF)

Reduced Yields during Transition: When shifting from conventional to natural farming, farmers often notice a temporary drop in crop productivity, which can affect income and food security.

Scarcity of Indigenous Cattle: ZBNF depends heavily on dung and urine from local (desi) cow breeds. However, not all farmers have access to these animals, limiting the practicality of the method.

Increased Labor Demands: Natural farming practices like preparing organic mixtures, mulching and manual weed control require more physical effort compared to mechanized or chemical-based farming.

Limited Scientific Evidence: There is a lack of extensive scientific studies and field data to validate ZBNF's effectiveness across different regions and crops, making experts cautious about recommending it widely.

Weak Market Support: Natural produce often lacks formal certification, making it difficult for farmers to access premium markets or earn better prices for their goods.

Insufficient Awareness and Training: A large number of farmers are either unaware of ZBNF or do not have adequate training to implement its techniques effectively.

Economic Uncertainty: During Shift the transition to ZBNF can involve financial risk, particularly for small-scale farmers who depend heavily on consistent yields for their livelihood.

Conclusion

Climate-Resilient Zero Budget Natural Farming (CR-ZBNF) represents a transformative approach to sustainable agriculture in the face of climate change. By eliminating chemical inputs and promoting low-cost, ecological farming practices, CR-ZBNF enhances soil health, conserves water, and increases farmers' resilience to climate shocks like droughts, floods and temperature extremes.

It empowers small and marginal farmers by reducing dependency on external inputs, lowering costs, and improving productivity in a sustainable manner. Moreover, CR-ZBNF aligns with national and global goals of sustainable development, carbon neutrality, and food security. As climate risks intensify, the widespread adoption of CR-ZBNF offers a promising pathway toward a more resilient and self-reliant agricultural future.

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Quality Strawberry Production through Various Mulching Methods

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Introduction

Strawberries are an important horticultural crop that is grown worldwide for processing as well as fresh consumption. Among the factors that influence the best results are soil management practices, disease and insect control, irrigation, fertilizer management, and cultivar selection. Among these, mulching is crucial because it modifies the microclimate of the root zone, prevents weed growth, and improves the quality of the fruit. Mulching is an important agricultural practice that affects the growth, yield, and quality of strawberry crops (*Fragaria × ananassa*). The impacts of various mulching materials, such as synthetic (like black polyethylene), biodegradable (like paper and starch-based films), and organic (like straw and sawdust), on many facets of strawberry production are reviewed and examined in this article. A number of factors are taken into account, including soil temperature, moisture retention, weed control, disease incidence, fruit quality, and yield. Strawberries are low-growing and delicate plants that greatly benefit from the protection and enhancement that mulch provides this article examines the effects of various types of mulching on strawberry fields, including organic, inorganic, and living mulches, and examines their influence on plant growth, fruit yield, soil health, pest management, and overall crop quality.

Types of Mulching Materials

Organic Mulches

- **Straw:** Widespread in temperate climates, straw is mostly used to suppress weeds and protect against winter. The classic and most popular mulch for strawberry fields. Outstanding for preserving fruit cleanliness, inhibiting weed growth, and retaining soil moisture. It must be replenished each season and may contain pests like slugs. Enhances fruit quality and yield by preserving optimal growing conditions and reducing fungal infections.
- **Sawdust or wood chips:** Effective for moisture retention but may deplete nitrogen. Long-lasting, good at suppressing weeds. Can deplete soil nitrogen during decomposition. Suitable for paths or between rows but not directly around plants without added nitrogen.
- **Compost and Leaf Mulch:** adds nutrients and organic materials, but it breaks down fast. Improves soil structure and provides nutrients. Can be costly; if poorly composted, it might promote the growth of weeds. Increases plant yield and growth when

applied correctly.

Synthetic Mulches

- **Black Polyethylene Film:** Popular due to its superior weed suppression, soil warming, and ease of use. Most common: absorbs heat and suppresses weeds. Long-lasting, excellent weed control improves fruit earliness and size. Non-biodegradable requires drip irrigation, disposal issues. Significantly increases early yields, maintains cleaner fruit, and improves harvest uniformity.
- **Clear Plastic:** Raises soil temperatures more than black plastic but is less effective at weed suppression.

Biodegradable Mulches

- **Starch-based Films and Paper Mulches:** Offer environmental benefits with good performance, though degradation rate can be variable. Eco-friendly, decomposes naturally, and combines the benefits of plastic and organic mulches. Still relatively expensive and less widely available. Comparable yield benefits to plastic mulch without long-term waste.

Objectives of different mulches are given below:

1. Reduces water loss through a low rate of evaporation.
2. Inhibits weed growth by blocking sunlight.
3. Keeps the root zone warmer in winter and cooler in summer.
4. Prevents soil from splashing onto the fruit
5. Can act as a barrier to certain soil-borne pests and pathogens.
6. Selecting the right type of mulch is crucial to optimizing these benefits.

Source: HRC, SVPUA&T

Effects of Mulching on Strawberry Cultivation

Soil Temperature and Microclimate

Mulches influence soil temperature by affecting heat absorption and radiation.

Mulch Type	Soil Temp Increase (°C) vs. Bare Soil
Black Polyethylene	+2.5–4.0
Straw	±0.5 (minimal change)
Paper Mulch	+1.5

Soil Moisture Retention

Mulches reduce water loss via evaporation:

- Straw mulch improved soil moisture retention by 15–20% (Teasdale & Mohler, 2000).
- While Black plastic mulch reduced irrigation needs by 25-30%(Kumar & Kumar, 2013).

Weed Control

Mulch Type	Weed Reduction (%)
Black Polyethylene	90–95
Straw	60–70
Paper Mulch	85–90

Disease and Pest Incidence

Mulching can influence humidity and pest habitats:

Straw mulch may harbour slugs and fungal spores (Ngouajio & Ernest, 2005).

Plastic mulch reduces soil-borne diseases but may increase spider mite infestations due to warmer microclimate (Poling, 2005).

Yield and Fruit Quality

Kumar and Kumar, 2013 find the data after 3-year trial on mulching materials for strawberry:

Mulch Type	Yield Increase (%) vs. Control	Soluble Solids (%)	Firmness (N)
Black Polyethylene	+40	9.2	1.8
Straw	+20	8.4	1.5
Biodegradable Film	+35	9.0	1.6

Fruit contamination with soil was least under synthetic mulches, improving market value.

Mulching on the basis environmental effect:

1. Plastic Mulch: Non-biodegradable, disposal issues, higher initial cost.

2. Biodegradable Mulch: Environmentally friendly, decomposes naturally, but more expensive and less durable in some climates.

Organic Mulch: Readily available and low-cost but needs more labour and can harbour pests. Cost-benefit analysis (Zhang *et al.*, 2019) found black polyethylene mulch to have the highest return on investment due to improved yield and reduced weeding labor.

Mulching on the basis of climatic condition

1. Temperate Climates: Straw mulch provides frost protection.

2. Tropical/Subtropical Climates: Black plastic increases early yield but requires careful irrigation.

3. Organic Farming Systems: Straw and paper mulches meet certification requirements.

An essential part of integrated strawberry management is mulching. Black polyethylene mulch continuously improves soil conditions, inhibits weed growth, and increases fruit output and quality among the tested techniques. A viable substitute that combines high performance with environmental sustainability is biodegradable mulch. Even though straw mulch produces less, it is still a good choice for organic systems or areas with limited access to synthetic resource.

Mulching materials suggested for farmers for strawberry cultivation.

1. For commercial growers: Black polyethylene or biodegradable films.

2. For organic or small-scale systems: Straw or paper mulch.

3. Future research: Long-term environmental impacts, cost-efficiency of biodegradable options and integration with precision irrigation.

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Papaya Waste Utilization: An Overlooked Goldmine in Agriculture

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Introduction

Papaya (*Carica papaya* L.), a fast-growing perennial tree belonging to the family Caricaceae, is a vital fruit crop in tropical and subtropical regions worldwide (Ming *et al*., 2008). India ranks among the world's top producers, with major cultivation in states like Andhra Pradesh, Gujarat and Karnataka. However, the fruit's highly perishable nature leads to substantial post-harvest losses, often reaching 40%, primarily due to improper handling, transportation, and market gluts (Sagar & Kumar, 2010). This generates enormous waste-peels, seeds, and unmarketable fruits-which is typically discarded in landfills, contributing to environmental pollution and greenhouse gas emissions.

Conversely, papaya waste is rich in bioactive compounds, enzymes, and nutrients, making it a valuable, yet underutilized, raw material. This article explores the multifaceted potential of papaya waste as a resource for sustainable agriculture, industry, and energy production, positioning it not as a problem, but as a promising solution within a circular economy framework.

Nutritional and Bioactive Profile of Papaya Waste

Papaya fruit is renowned for its high content of vitamins A and C, potassium, folic acid, and fibre (Dwivedi *et al*., 2020). Importantly, these nutrients are also concentrated in the waste streams:

- **Peels and Pulp:** Rich in carbohydrates, fibre, and minerals like potassium, calcium, and magnesium. They are also a significant source of bioactive compounds such as polyphenols, flavonoids (e.g., quercetin, kaempferol), and carotenoids (lycopene, β-carotene) (Soares, 2021; Iordanescu *et al*., 2021).
- **Seeds:** Contain approximately 25-30% protein and fats, along with unique compounds like benzyl isothiocyanate and carpaine, which exhibit antimicrobial and anti-parasitic properties (Saeed *et al*., 2014).
- **Latex:** The primary source of the proteolytic enzyme papain, which is commercially extracted from the latex of unripe fruits. Varieties like 'CO-2' from Coimbatore can yield 800-1200 mg of papain per fruit.

Valorization Pathways for Papaya Waste

Organic Fertilizer and Soil Conditioner

Papaya waste, with its high organic carbon and potassium content, is an excellent feedstock for composting. Composting this biomass enhances soil fertility, improves microbial diversity and increases water retention capacity (Rathod *et al*., 2018). Vermicomposting using earthworms (*Eisenia fetida*) further enriches the compost, producing a nutrient-dense humus teeming with beneficial microbes and plant-growth promoters (Ndegwa & Thompson, 2001).

Animal Feed Supplement

Dried and powdered papaya leaves and peels, which are high in crude fibre and digestible proteins, can be incorporated into livestock and poultry feed. The presence of papain aids in digestion and improves nutrient absorption (Ahmad *et al.,* 2011). After detoxification to reduce anti-nutritional factors, papaya seeds can also be included in feed formulations at levels up to 10% for poultry and fish.

Table: Mineral Content (mg/100g) at Different Ripening Stages of Papaya Peel (PP)

Sample of Peel	Ca	Na	K	P	Mg
Unripe	46.67	19.33	98.93	21.82	20.80
Hard Ripe	38.74	20.27	98.13	20.93	16.00
Very Ripe	30.73	20.67	96.80	15.37	13.60

Commercial Papain Extraction

Papain has extensive applications in the food industry (as a meat tenderizer), pharmaceuticals (as a digestive aid and in wound debridement), and in cosmetics and leather processing (Amri &Mamboya, 2012). Establishing small-scale, decentralized papain extraction units can provide farmers with an additional revenue stream from unmarketable green fruits.

Source of Bioactive Compounds

Extracts from papaya peels and seeds have demonstrated significant antimicrobial activity against pathogens like *E. coli, Salmonella*, and *Staphylococcus aureus* (Saeed *et al.,* 2014). These extracts can be utilized in developing herbal medicines, nutraceuticals, and natural food preservatives. Furthermore, fermented papaya preparation (FPP) has been studied for its immunomodulatory and antioxidant effects (Aruoma *et al.,* 2010).

Biogas and Bioenergy Production

The high carbohydrate and moisture content of papaya waste makes it an ideal substrate for anaerobic digestion, producing biogas with a methane content of 50-70% (Patil *et al.,* 2012). This biogas can be used for cooking or electricity generation, while the residual digestate serves as a liquid fertilizer. In a novel approach, papaya waste has also been successfully used as an organic substrate in microbial fuel cells (MFCs) to generate eco-friendly electricity (Rojas-Flores *et al.,* 2021).

Environmental Remediation and Industrial Applications

- **Wastewater Treatment:** Biochar produced from papaya peels acts as an effective, low-cost adsorbent for removing heavy metals like lead and cadmium from contaminated water (Ibrahim *et al.,* 2020).
- **Nanoparticle Synthesis:** Papaya peel extracts have been used for the green synthesis of gold nanoparticles (AuNPs), which have applications in biomedicine, drug delivery, and catalysis (Roopan *et al.,* 2015).
- **Other Uses:** Potential applications include natural dye extraction for textiles, starch-based bioplastics, and antioxidant-rich extracts for cosmetics.

Challenges

Despite its potential, the large-scale utilization of papaya waste faces several hurdles:

1. **Lack of Awareness and Technical Knowledge:** Among farmers and processors.
2. **Inadequate Infrastructure:** For efficient collection, transportation, and processing of waste.
3. **Need for Standardization:** Protocols for detoxification, extraction, and quality control are required to ensure product safety and efficacy.
4. **Initial Investment:** The capital cost for

setting up processing units can be a barrier.

Conclusion

Papaya waste is far from being a mere agricultural residue; it is a versatile and valuable biomass with immense potential across multiple sectors. By harnessing this "overlooked goldmine," we can transition towards a more sustainable and circular agricultural model that minimizes waste, reduces environmental impact, and enhances farmer incomes. To realize this potential, collaborative efforts involving policymakers, research institutions, and agri-entrepreneurs are essential to develop efficient value chains, create awareness, and incentivize investment in waste valorization technologies.

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Hydroponics and Aeroponics in smart cities: A Sustainable Path to Urban Food Security

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Introduction

In both wealthy and developing nations, urbanization has accelerated in the twenty-first century. Urban consumers' year-round desire for fresh, pesticide-free, high-quality veggies is placing an unprecedented amount of strain on food systems as a result of growing urbanization. Despite being the foundation of human survival for generations, traditional soil-based agriculture is finding it difficult to meet these new demands. Intensive farming, nutrient extraction, and the careless application of agrochemicals are all contributing factors to the degradation of soils. An essential agricultural input, water is becoming more and more limited, and conventional systems' ineffective use of it makes matters worse the face of growing climate challenges-such as irregular rainfall, rising temperatures, and recurring droug-hts-the sustainability of traditional soil-based agriculture is becoming increasingly uncertain. These environmental stressors not only reduce crop reliability but also threaten long-term food security.

Amid these concerns, soilless vegetable farming is emerging as a viable and innovative solution. By eliminating the need for natural soil and enabling cultivation in controlled environments, it significantly reduces dependency on unpredictable weather patterns. Moreover, this method conserves water, optimizes resource use, and enables year-round production, even in urban settings.

As a result, soilless farming is gaining momentum as a futuristic yet practical agricultural approach-one that supports the core objectives of sustainable agriculture and complements the infrastructure of smart urban development.

Soilless culture is a method of growing plants without natural soil, using alternative mediums such as water (hydroponics), mist (aeroponics), or inert substrates like coco coir or rockwool. Nutrients are delivered directly to the plant roots through these systems, allowing for controlled and efficient plant growth, especially in urban or space-constrained environments like smart cities. Soilless culture refers to the practice of growing plants without natural soil. Instead, it uses alternative growing mediums or liquid nutrient solutions to provide plants with the water, minerals, and support they need for growth.

Hydroponics is a soilless farming technique where plants are grown in a nutrient-rich water solution instead of soil. The plant roots are either fully submerged or periodically exposed to the water, which contains all the essential minerals needed for growth.

Aeroponics is an advanced soilless farming technique where plant roots are suspended in air and regularly misted with a nutrient-rich water solution. Unlike hydroponics, there is no growing medium-plants grow with their roots fully exposed to air. This method provides maximum oxygenation to roots, leading to faster growth and higher nutrient absorption, while using very little water. Aeroponics is ideal for high-efficiency farming in urban, indoor, or space-limited environments, and is often used in smart agriculture and aerospace research.

Importance

1. Space-Efficient Urban Farming: Hydroponics allows vertical and indoor farming, making it ideal for cities with limited land. Crops can be grown in rooftops, basements, containers, or skyscrapers.

2. Water Conservation: Uses up to 90% less water than traditional soil farming. Recirculates water through closed-loop systems, reducing waste.

3. Year-Round Production: Grows food in controlled environments, independent of weather or seasons. Ensures continuous supply of fresh produce in urban areas.

4. Reduced Carbon Footprint: Promotes local food production, cutting down on transportation emissions. No need for heavy machinery or large-scale land clearing.

5. Smart Technology Integration: Easily integrated with IoT, AI, and automa-tion for real-time monitoring of nutrients, pH, humidity, and temperature. Enhances precision agriculture and reduces human error.

6. Pesticide-Free & Cleaner Produce: Controlled environment minimizes pests and diseases. Results in healthier, chemical-free vegetables for urban consumers.

7. Economic Opportunities: Supports urban entrepreneurship, job creation, and local agribusiness. Can empower uses communities with small-scale or home-based hydroponic farms

8. Ultra-Efficient Water Usage: up to 95% less water than traditional farming. Ideal for water-scarce urban areas where conservation is critical.

9. Minimal Space Requirements: Aeroponics systems can be set up vertically or in compact indoor spaces. Perfect for dense cities with limited or expensive land.

10. High Productivity in Controlled Environments: Roots receive direct oxygen and nutrients, leading to faster growth and higher yields. Enables year-round production regardless of external climate.

11. Clean, Soil-Free Cultivation: No soil means no soil-borne diseases or pests, reducing the need for pesticides. Results in cleaner, healthier produce with minimal environmental impact.

12. Smart Technology Integration: Easily connected to IoT sensors, automa-tion, and AI for precise nutrient and mist control. Ideal for smart farming systems in modern cities.

13. Reduces Urban Food Miles: Facilitates local, on-site food production-even in buildings, rooftops, or abandoned spaces. Reduces dependency on rural supp-ly chains and lowers transport emissions.

14. Ideal for High-Value & Leafy Crops: Excellent for growing herbs, greens, and other high-demand crops in cities. Maximizes output per square meter, offering a high return on limited urban space

Scientific Basis of Soilless Farming

The success of soilless systems lies in their ability to create an optimized root environment. In soil-based cultivation, roots are often exposed to stresses such as water logging, compaction and nutrient imbalances. In contrast, soilless substrates like AFC provide a balanced combination of water retention and aeration, ensuring that roots receive sufficient oxygen while remaining adequately hydrated. Nutrients are supplied in soluble forms, making them readily available for uptake. Since the entire root zone is under the grower's control, it is possible to maintain optimal pH and electrical conductivity, leading to more efficient nutrient absorption. Water-use efficiency is another scientific advantage of soilless systems. Conventional soil farming loses large amounts of water through evaporation, seepage and runoff. In cocoponics and hydroponics, water and nutrients are applied directly to the root zone, minimizing losses and often allowing for recirculation. Studies at IIHR have demonstrated that soilless systems save up to 80 percent water compared to soil-based cultivation. Moreover, because substrates are free of soil-borne pests and pathogens, the use of pesticides is greatly reduced. This creates a healthier rhizosphere, fostering beneficial microbial activity and leading to higher plant vigour.

Conclusion

Hydroponics and aeroponics are vital for sustainable urban farming. They save water, require no soil, and produce fresh food year-round, ensuring food security and environmental balance in smart cities. Hydroponics and aeroponics offer sustainable, space-efficient, and resource-saving solutions for food production in smart cities. By enabling year-round cultivation with minimal water, soil, and land use, these technologies help ensure urban food security, reduce transportation emissions, and promote self-reliant communities. Integrating them into urban planning supports a greener, healthier, and more resilient future for cities.

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Importance of Horticulture Crops in Forest Area, Narayanpur (C.G.)

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Introduction

Horticulture plays a vital role in the agricultural economy of Chhattisgarh, offering immense potential for income generation, employment, and nutritional security. With its diverse agro-climatic zones and rich tribal culture, the state is well-suited for the cultivation of fruits like mango, guava, and amla, vegetables, spices, and medicinal plants. In forested and tribal districts like Narayanpur, Bastar and Dantewada, horticulture provides an eco-friendly livelihood alternative that complements forest-based income. The government actively promotes horticulture through schemes such as the National Horticulture Mission and Van Dhan Yojana, making it a key driver of rural development and sustainable agriculture in the state.

Location

- Narayanpur is a district in the Bastar Division of the state of Chhattisgarh, India. Narayanpur District+1
- The town of Narayanpur (its administrative headquarters) used to be part of Bastar district until May 11, 2007, when the district was formed

Area: ~ 6,640 km²

Crops & Growing Seasons

- **Kharif season (rainy season):**

The primary crop is rice. Besides that, farmers also cultivate maize, jowar (a type of millet), arhar (pigeon pea), and urad (black gram).

- **Rabi season (post-monsoon):**

Crops like til (sesame), moong (green gram), alsi (flaxseed), mustard, and gram are grown.

Major Challenges

- **Low irrigation**: most farming is rain-fed, making agriculture vulnerable to monsoon variability.
- **Limited double-cropping**: because of water constraints, land doesn't get used for more than one crop often.
- **Lack of modern inputs/techniques**: use of HYVs, soil testing, mechanization, etc., is not widespread. kvknarayanpur.org+1
- **Forestry pressure and forest-environment interface**: much of the district is forested; many people depend on minor forest produce. Land available for agriculture is constrained.

Horticulture in forest areas like Narayanpur (Chhattisgarh)-which is heavily forested and tribal-dominated- plays a critical and complex role. Here's an in-depth look at its importance, both economic and ecological:

1. Primary Livelihood for Forest-Dwelling Communities

♦ In forested regions, tribal and rural populations often rely on a combination of:

o Horticulture (mainly rainfed)

o Collection of forest produce (like tendu leaves, mahua, sal seeds, lac, etc.)

Horticulture becomes the backbone of food security and income when forest produce is seasonal or insufficient.

2. Subsistence and Food Security

♦ Most forest-region horticulture is subsistence farming, meaning crops are grown mainly to feed the family.

♦ Key crops like custard apple, tomato, chilli and other vegetables etc are grown not for sale but for household consumption.

This helps reduce dependency on market prices, and ensures cultural dietary habits are maintained.

3. Income Diversification

♦ While forest produce gives some seasonal income, horticulture offers:

o Fruits and mushroom for local sale

o Vegetables or cash crops (where feasible) for markets

o Scope for integrated farming (poultry, goats, fish farming)

This is crucial in breaking cycles of poverty and migration.

4. Utilization of Rainfall

♦ Forest areas like Narayanpur receive high rainfall (~1300 mm annually).

♦ Agriculture helps capture and utilize rainwater effectively if done sustainably-via:

o Rainfed paddy

o Contour bunding or water harvesting

5. Complementarity with Forests (Agroforestry)

♦ Agroforestry (growing crops with trees) supports:

o Soil conservation

o Moisture retention

o Additional income from timber, fruits, etc.

6. Reducing Pressure on Forests (When Done Right)

♦ If agriculture is improved (with productivity, water use, storage), it reduces dependence on forest exploitation- like illegal felling or overharvesting minor forest produce.

But poorly planned agriculture (like clearing dense forest for farming) harms biodiversity and leads to deforestation.

7. Climate Buffer and Ecological Stability

♦ Integrated forest-agriculture systems:

o Maintain tree cover

o Store carbon

o Control erosion and flood

Horticulture crops can be highly beneficial and sustainable in forest areas like Narayanpur and other forested regions of India.

Common Fruit Crops in Forest Areas

Fruit	Suitable For	Notes
Amla (Indian Gooseberry)	Tribal and forested zones	Drought tolerant, high demand in herbal industries
Mango	Well-drained soils	Suitable for intercropping in forest fringe areas
Guava	Grows well even in poor soils	Fast fruiting
Jackfruit	Shade-tolerant	Good for homestead agroforestry
Cashew	Dry, hilly regions	Export potential

Fruit	Suitable For	Notes
Custard Apple (Sitaphal)	Rocky, hilly terrains	Grows in degraded land
Banana & Papaya	Where water is available	High value, short cycle

These crops not only support livelihoods but also help in ecological conservation when planned properly. Here's a breakdown of horticulture crops suitable for forest areas and their importance:

1. Fruit Crops

These are ideal because they:

- Have long life cycles (perennial)
- Can be grown under partial shade
- Are often compatible with agroforestry systems

2. Vegetable Crops

Short-duration vegetables can be intercropped between trees or grown in small clearings:

- Tomato, brinjal, okra, chilly
- Cucurbits (bottle gourd, pumpkin, etc.)
- Tuber crops: Sweet potato, yam, Colocasia

Note: Vegetable farming is ideal in forest fringe areas or where some irrigation is possible.

3. Spices and Condiments

Spices are high-value and often thrive under shade:

- Turmeric
- Ginger
- Chillies
- Coriander
- Garlic

Example: Turmeric intercropped with trees in tribal regions is both profitable and eco-friendly.

Crop Type	Examples	Notes
Medicinal	Ashwagandha, Kalmegh, Tulsi, Safed Musli	Supported under govt. schemes like National AYUSH Mission
Plantation	Areca nut, Betel vine, Bamboo	Long-term income; Bamboo is especially encouraged in forest schemes

4. Floriculture (Flower Cultivation)

Benefit	Description
Sustainable Livelihoods	Perennial crops give recurring income
Eco-friendly	Less invasive than field crops; works with forest ecology
Income for Tribals	Especially through schemes like Van Dhan Yojana
Climate Resilient	Many crops are drought/heat-tolerant
Improves Nutrition	Promotes food diversity and dietary health

While less common, flowers like marigold, rose, and jasmine are gaining interest in forest-linked horticulture due to:

- High market demand
- Low land requirement
- Possibility for women-led income generation

5. Plantation & Medicinal Crops

These overlap with forestry but also fall under broad horticulture/agroforestry:

Benefits of Horticulture in Forest Areas

Government Schemes Supporting

- National Horticulture Mission (NHM)
- National Bamboo Mission
- Van Dhan Yojana (for value addition of minor forest produce)
- Tribal Sub-Plan (TSP) components in agriculture departments
- Krishi Vigyan Kendras (KVK) – like KVK Narayanpur – offer training and input

support.

Conclusion

Importance of Horticulture crops play a vital role in enhancing the ecological, economic, and social value of forest areas. Their cultivation supports biodiversity conservation, prevents soil erosion, and improves soil fertility through sustainable land use. Fruit trees, medicinal plants, and spices offer livelihood opportunities to forest-dependent communities, reducing pressure on natural forests. By integrating horticulture with forestry, we can promote eco-restoration, climate resilience, and rural development. Thus, horticultural development in forest regions is a key pathway toward sustainable resource management and improved food and income security.

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Importance of Organic Farming in Forest Area

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Introduction

Organic farming is an agricultural system that relies on natural processes, biodiversity, and cycles adapted to local conditions, rather than the use of synthetic inputs such as chemical fertilizers, pesticides, herbicides, or genetically modified organisms (GMOs). It emphasizes the use of organic inputs (like compost, green manure, and biofertilizers) to maintain soil fertility and ecological balance.Organic farmers use environmentally friendly methods to control pests and diseases, including biological control agents, botanical extracts like neem, and cultural practices such as trap cropping and intercropping. The core philosophy of organic farming is rooted in the principles of health, ecology, fairness, and care, as promoted by the International Federation of Organic Agriculture Movements (IFOAM). By working in harmony with nature, organic farming not only produces food that is free from chemical residues but also helps conserve natural resources, reduce pollution, and support the long-term sustainability of agricultural ecosystems. Although organic farming may result in lower yields initially, especially during the transition from conventional practices, it offers long-term benefits such as improved soil structure, increased biodiversity, and enhanced resilience to climate variability. Organic certification, though sometimes complex and costly, ensures that organic products meet established standards and can access premium markets. In India, the National Programme for Organic Production (NPOP) and the Participatory Guarantee System (PGS) support organic certification and promote organic agriculture among small and marginal farmers. Overall, organic farming plays a critical role in sustainable agriculture by promoting eco-friendly practices, improving food safety, and contributing to rural livelihoods and environmental conservation.

Core Principles of Organic Farming

According to the International Federation of Organic Agriculture Movements (IFOAM), organic farming is based on four key principles:

1. Health: Sustain and enhance the health of soil, plants, animals, and humans.

2. Ecology: Base farming practices on living ecological systems and cycles.

3. Fairness: Build relationships that ensure fairness regarding the environment and life opportunities.

4. Care: Manage systems in a precautionary and responsible manner to protect the environment and future generations.

"Components of organic farming refer to the essential elements and practices that together form a holistic, sustainable, and eco-friendly agricultural system. These components work in harmony to maintain soil health, manage pests naturally, conserve biodiversity, and produce safe, chemical-free food by relying on natural processes and organic inputs rather than synthetic chemicals."Organic farming promotes biodiversity by encouraging the presence of beneficial insects, birds and microorganisms, helping to naturally control pests and diseases. It produces chemical-free, nutritious food that is safer for both consumers and farmers, reducing health risks associated with pesticide exposure.

Component	Description
Soil Management	Enhancing soil fertility using organic matter like compost, green manure, and crop rotation. Emphasizes natural nutrient cycles and soil biodiversity.
Crop Management	Selection of suitable crop varieties, crop rotation, mixed cropping, intercropping, and cover cropping to maintain soil health and reduce pests.
Organic Manures & Fertilizers	Use of compost, farmyard manure (FYM), vermicompost, green manures, and biofertilizers (e.g., Azospirillum, Rhizobium) instead of synthetic fertilizers.
Pest and Disease Management	Use of biopesticides (neem oil, garlic extract), mechanical traps, predator insects, resistant varieties, and proper cultural practices.
Weed Management	Use of mulching, mechanical weeding, crop rotation, and biological controls instead of herbicides.
Animal Husbandry	Integrating livestock into farming systems; feeding animals organically and avoiding synthetic hormones or antibiotics.
Water Management	Efficient irrigation methods (like drip and sprinkler), water harvesting and conserving water through organic mulches and good soil practices.
Energy Management	Using renewable energy sources (solar, biogas), reducing fuel consumption, and promoting manual/livestock labor.
Biodiversity Conservation	Maintaining a variety of plants, animals, and microorganisms on the farm to create ecological balance.
Certification and Inspection	Following standards set by organic certification bodies (e.g., NPOP, USDA Organic) to ensure compliance and market access.
Post-Harvest Management	Use of organic methods for storage, processing, packaging, and transport without synthetic preservatives or contaminants.

Importance of Organic Farming in Forest Areas

Organic farming plays a vital role in forest and forest-adjacent areas, where the ecological balance is delicate and biodiversity is high. Unlike conventional agriculture, organic farming avoids the use of harmful chemicals, thereby preserving the natural ecosystem of forests while supporting the livelihood of local communities. Here's a detailed explanation:

1. Environmental Conservation

In forest areas, the land is often rich in biodiversity and sensitive to chemical disturbances. Organic farming helps: Preserve soil and water quality by avoiding chemical fertilizers and pesticides, Prevent deforestation, as it promotes agroforestry and sustainable land use, Maintain forest biodiversity, including beneficial insects, pollinators, and microorganisms.

2. Soil and Water Health

Forest soils are naturally fertile but can degrade quickly with misuse.

Organic methods improve soil structure and fertility through composting and green manures, Helps conserve soil moisture, which is crucial in forest ecosystems, Reduces runoff and water pollution, protecting forest streams and rivers.

3. Promotion of Agroforestry

Organic farming in forest zones encourages agroforestry systems, where trees are integrated with crops and livestock. Supports carbon sequestration and combats climate change,Provides diverse sources of income (timber, fruits, fodder, medicinal plants), Improves microclimate and enhances resilience to droughts and floods.

4. Livelihood Security for Tribal and Local Communities

Many forest dwellers and tribal populations depend on the land for subsistence. Organic farming offers a low-cost, sustainable model that aligns with traditional practices, Reduces dependence on costly chemical inputs, Increases income through the sale of organic produce and non-timber forest products (NTFPs).

5. Biodiversity and Wildlife Protection

Organic farming avoids practices that harm wildlife: No toxic chemicals = less risk to wild animals, birds, and insects. Encourages habitat conservation through mixed cropping and buffer zones, Promotes coexistence of farming and wildlife in buffer areas around protected forests.

6. Sustainable Ecotourism and Branding

Forest-based organic farms can: Attract eco-tourists interested in sustainable lifestyles, Develop organic forest-based products (like wild honey, herbs) with eco-labels and certifications.

7. Pollution-Free Farming

Eliminates risk of chemical runoff into forest streams and groundwater. Protects aquatic life and wildlife dependent on natural water bodies in forests.

8. Supports Agroforestry Systems

Integrates well with agri-silviculture, silvi-pasture, and agro-horti systems. Promotes multi-tier cropping which mimics forest canopy layers, increasing productivity per unit area.

9. Carbon Sequestration & Climate Resilience

Enhances carbon capture through tree-crop-livestock integration and organic practices. Builds resilience to droughts and floods by improving soil water-holding capacity and microclimate.

10. Livelihood Security for Forest Dwellers

Provides sustainable income through organic production of forest crops, NTFPs, and medicinal plants. Aligns with tribal knowledge systems and promotes low-input farming.

11. Reduces Deforestation Pressure

By making buffer zone agriculture more profitable, organic farming reduces the need for shifting cultivation and forest clearing. Promotes long-term land use planning in forest fringe areas.

12. Conservation of Indigenous Varieties

Encourages the cultivation of traditional crop varieties adapted to forest climates and resistant to pests/diseases. Helps in in-situ conservation of genetic diversity.

13. Health and Food Safety

Produces chemical-free, toxin-free food for local consumption and markets.Reduces health risks for forest communities and consumers from pesticide exposure.

14. Market Potential and Certification

Forest-based organic products (wild honey, herbs, spices) have high export value. Government schemes (e.g., NPOP, PGS-India) support certification and marketing.

15.Water Cycle Regulation

Forests help in groundwater recharge.

Maintain watershed health by regulating the flow of rivers and streams.

Conclusion

Organic farming in forest regions plays a vital role in promoting ecological harmony and sustainable development. By using natural methods and avoiding harmful chemicals, it helps maintain soil fertility, conserve biodiversity, and protect forest ecosystems. This approach not only supports the livelihood of local and tribal communities but also ensures the long-term health of the environment. Thus, organic farming in forest areas serves as a sustainable path toward food security, environmental conservation, and balanced rural development.

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Rooftop Gardening: A Solution for Energy Saving and Landscape Enhancement in Urban Areas

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Introduction

The challenges posed by rapid urbanization-such as the urban heat island effect, loss of green cover, poor air quality, and high energy consumption-have led researchers and city planners to explore green infrastructure solutions. As urbanization continues at a rapid pace, cities face growing challenges such as increased energy consumption, pollution, limited green spaces, and the urban heat island (UHI) effect. These issues call for innovative, sustainable solutions. One such approach is rooftop gardening, which transforms unused roof spaces into productive green areas. Among these, rooftop greening, including the cultivation of ornamental flowering plants (floriculture) on roofs, holds promise not only for aesthetic and biodiversity benefits but also for improving building energy efficiency.

Recent studies show that rooftop gardens and rooftop greenhouse systems can significantly reduce energy loads in hot climates and improve thermal comfort. For example, a 2024 experimental study in Egypt demonstrated that green roofs combined with photovoltaic (PV) installations reduced maximum indoor air temperatures by up to 10.75% in buildings with clay soil green roofs, leading to cooling energy savings of about 19.12% annually. Similarly, the physiological and biochemical responses of flowering and ornamental species in rooftop versus ground level conditions have been studied recently: a 2024 work comparing species like *Rosa hybrids, Hibiscus rosasinensis, Duranta*, etc., found that rooftop grown ornamentals develop higher air pollution tolerance indices, but show reduced water use efficiency compared to their ground level counterparts.

These adaptations are crucial for selecting species suitable for rooftop floriculture under urban climatic stress. There is also emerging literature on rooftop agriculture (inclusive of floriculture) regarding façade and rooftop green systems, which report electricity savings of about 5% per year compared to buildings without such systems, along with benefits in carbon emission reduction.

Roof top gardening

Rooftop gardening refers to the practice of cultivating plants on the roofs of buildings. These gardens can range from simple container gardens to complex green roofs with soil layers, irrigation systems, and even small trees or vegetable plots. Depending on design and purpose, rooftop gardens can be ornamental, edible, or ecological.

Type of roof top gardening

- **Extensive green roofs:** Lightweight systems with low-maintenance plants.
- **Intensive green roofs:** Heavier systems

that support trees, shrubs, and urban farming.

- **Container or raised bed gardens:** Using pots or beds for growing vegetables, herbs, or flowers.

History of Rooftop Gardens

The Ziggurats of Ancient Mesopotamia

The earliest known record of roof gardens are the Ancient Ziggurats of Mesopotamia. These massive stone structures were built between 4,000-600Bc.Built by Ur- Nammu, the first ruler of the Ur. Dynasty (Ur. 2113 -2095 BC), in an effort to surpass the magnificence of the Ziggurat Etemenaki, thought to be the Biblical Tower of Babel, Nanna is home to the best – preserved example of a Ziggurat roof garden. (Magill *et al.,* 2021).

The Hanging Gardens of Babylon

The Hanging Gardens of Babylon are one of the seven wonders of Ancient World and perhaps the most famous of roof gardens. King Nebuchadnezzar, a famous general in his time, built the Hanging Gardens for his wife, Amytis, who longed for her mountainous homeland of media.

The Villa of Mysteries, Pompeii

Reconstruction of the villa of mysteries, near pompeii, Italy, which sits on the road to Herculaneum. The luxurious villa was preserved after the eruption of Mt. Vesuvius in AD 79.The roof garden (in garden) functioned as an outdoor living room and the centre of social activity. The garden was supported by an arched stone colonnade (Magill *et al.,* 2021).

Norwegian Sod Roofs

Sod roofs, roofs topped with soil and planted with grasses and other plants to stabilize the earth on the roof, were part of the Norwegian vernacular. A similar sod roof technique was brought to the United States and Canada by Norwegian immigrants. A sod roof in milton, North Dakota, built by Ole Myrvik, a Norwegian Immigrant, c.1896.

Benefits of Rooftop Gardening

1. Energy Saving

Green roofs act as insulation layers, reducing heat transfer through the building envelope. This leads to:

- Reduced air conditioning use in summer.
- Improved heating efficiency in winter.

2. Reduction of Urban Heat Island Effect

Urban surfaces like asphalt and concrete absorb heat, raising city temperatures. Vegetated roofs reduce roof surface temperatures by up to 40°C, mitigating the UHI effect.

3. Improved Air Quality

Plants absorb pollutants like carbon dioxide (CO_2), nitrogen dioxide (NO_2), and particulate matter. Rooftop vegetation can also reduce greenhouse gas emissions indirectly through lower energy demand.

4. Enhanced Urban Landscape and Well-being

Rooftop gardens enhance the visual appeal of urban environments and contribute to mental health by providing recreational and aesthetic green spaces.

5. Stormwater Management

Green roofs absorb and retain rainwater, reducing surface runoff and lowering the risk of flooding.

6. Urban Agriculture and Food Security

Rooftop gardens can be used to grow vegetables, herbs and fruits, supporting local food production and reducing the environmental footprint of food transportation.

Challenges and Considerations

- **Structural Integrity:** Not all buildings are engineered to bear the extra weight of soil and vegetation.
- **Waterproofing and Drainage:** Essential to prevent leaks and water damage.
- **Installation Costs:** Initial costs can be high, though long-term energy savings may offset them.
- **Maintenance:** Requires consistent care, especially for food-producing gardens.

- **Selection of plants for roof top gardening**

Different depth of the substrate supports different vegetation. For example, in extensive green roof, moss and sedum can be grown in 4-10cm depth and moss, sedum and herbaceous plants can be grown in 5-11cm depth. In a depth of 15 -25 cm and herbaceous plants can be grown. In roof garden, lawn shrub and trees can be grown. Trees can be grown in more than 50 cm depth of the growing medium.

Shrubs	Annuals	Climbers	Ground cover plants
Ficus benjamina	*Tagetes spp.*	*Jasminum officinals*	*Alternanthera sessilis*
Plumeria alba	*Dianthus barbatus*	*Pyrostegia vinusta*	*Alternanthera rinukii*
Bauhinia tomentosa	*Calendula officinalis*	*Hiptage benghalensis*	*Cholophytum comosum*
Ixora coccinea	*Chrysanthemum grandiflora*	*Jasminum auriculatum*	*Tradescentia pallida*
Hibiscus rosa sinensis	*Helichrysum bracteatum*	*Jasminum grandiflorum*	*Sphgneticala trilobata*
Duranta erecta	*Dimorphotheca sinuta*	*Bauhinia vahlii*	*Catharanthus roseus*
Tecoma stans	*Gazania splendens*	*Bougainvillea spp*	*Portulaca grandifola*
Nyctanthes arbor-tristis	*Gypsophila elegans*	*Passiflora coccinea*	*Hamelia patens*
Tecoma stans	*Limonium sinuatum*	*Wisteria sinensis*	*Duranta erecta*

Global Success Stories

- **Singapore:** A global leader in rooftop greening through policies like the Skyrise Greenery Incentive Scheme.
- **New York City:** Brooklyn Grange operates the world's largest rooftop soil farms, producing over 50,000 pounds of organic produce annually.
- **Germany:** Over 10% of all flat roofs are greened due to strong government support and incentives.

Conclusion

Rooftop gardening is a multi-functional solution that aligns with sustainable urban development goals. It reduces energy consumption, mitigates environmental challenges and adds aesthetic and recreational value to city life. With proper policies, structural planning and public awareness, rooftop gardens can become a standard feature in urban architecture, contributing significantly to greener, healthier and more resilient cities.

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Photographs of Roof top gardening

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Gurmar as a Botanical Shield: Harnessing *Gymnema sylvestre* for Sustainable Pest Management in Horticultural Crops

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Introduction

Horticultural crops are fundamental to global nutritional security and farmer livelihoods but are highly susceptible to insect pests like aphids, whiteflies, fruit borers, and leaf miners, leading to substantial yield and quality losses (Dhaliwal *et al.*, 2010). While conventional chemical pesticides offer immediate control, their persistent use results in pest resistance, environmental contamination, bioaccumulation of toxic residues, and harm to non-target organisms, including pollinators (Popp *et al.*, 2013).

This critical scenario has accelerated the search for eco-friendly pest management solutions. Botanical insecticides, derived from plants with inherent defensive compounds, present a sustainable alternative. They are generally biodegradable, less prone to causing resistance, and safer for beneficial insects (Isman, 2020). *Gymnema sylvestre* (Retz.) R. bracteata ex Sm., commonly known as Gurmar or "the sugar destroyer," has been extensively studied for its medicinal value, particularly in managing diabetes. However, its rich repository of bioactive compounds also confers significant insecticidal properties, making it an underexplored but highly promising candidate for botanical pest management (Kaushik *et al.*, 2011).

Botanical Overview

Scientific Name: *Gymnema sylvestre*

Family: Apocynaceae (formerly Asclepiadaceae)

Common Names: Gurmar, Madhunashini, Australian Cowplant

Distribution: Tropical forests of India, Africa, and Australia.

Traditional Uses: Primarily used in Ayurveda for diabetes management, as well as for its antimicrobial, anti-inflammatory, and diuretic properties (Kanetkar *et al.*, 2007).

Key Phytochemicals: The plant's bioactivity is attributed to a range of compounds, including:

Gymnemic Acids: Triterpenoid saponins responsible for its anti-sweetness and insecticidal properties.

Saponins: General defensive compounds against pests and pathogens.

Flavonoids & Alkaloids: Contribute to antioxidant and insect growth-regulating effects.

Tannins: Act as feeding deterrents.

Mode of Action Against Insect Pests

The efficacy of Gurmar extracts against insects is multifaceted, targeting various physiological processes (Sharma *et al.*, 2019):

1. Antifeedant Activity: Gymnemic acids and other constituents interfere with the insect's ability to perceive host plants, leading to starvation (Prakash *et al.*, 2014).

2. Ovicidal Property: Extracts can penetrate egg masses, reducing hatchability and disrupting embryonic development.

3. Growth Disruption: The compounds inhibit molting hormones like ecdysone, leading to abnormal larval development, failed pupation, and mortality.

4. Repellent Action: Volatile compounds emitted by the extract deter insects from settling, feeding, and laying eggs on treated crops.

5. Synergistic Effect: When combined with other botanicals like neem (*Azadirachtaindica*), Gurmar's effectiveness is enhanced, providing broad-spectrum pest control (Mordue (Luntz) and Nisbet, 2000).

Practical Preparation and Application Methods

Fresh Leaf Extract

Ingredients: 1 kg fresh Gurmar leaves, 5 liters of water.

Preparation: Grind the leaves with water to form a slurry. Filter through a muslin cloth. Dilute the filtrate with 50 liters of water.

Application: Use as a foliar spray, ensuring thorough coverage of both leaf surfaces.

Dry Leaf Powder Extract

Ingredients: 100 g of shade-dried and powdered Gurmar leaves, 1 liter of water.

Preparation: Soak the powder in water for 12-18 hours. Filter and dilute the solution in 10 liters of water.

Application: Apply as a foliar spray.

Combination Formulation (Enhanced Efficacy)

Recipe: Mix the prepared Gurmar extract (from either method) with 2% neem oil or 5% neem seed kernel extract.

Application: This combination is highly effective against a wider range of sucking and chewing pests.

Optimal Spraying Schedule

Timing: Late afternoon (4–6 PM) is ideal to avoid photodegradation of active compounds and coincide with peak activity of many pests. Early morning (before 8 AM) is a suitable alternative.

Frequency

First Spray: At the vegetative stage or at first sign of pest incidence.

Follow-up Sprays: Repeat every 7–10 days.

Under High Infestation: Spray every 5–7 days for 2–3 rounds.

Target Pests in Horticulture

Gurmar extracts have shown efficacy against a broad spectrum of horticultural pests:

Sucking Pests: Aphids, whiteflies, jassids, thrips.

Chewing Pests: Caterpillars, leaf miners.

Boring Pests: Fruit and shoot borers in tomato, brinjal, and okra.

Advantages and Benefits

Eco-Friendly: Biodegradable and non-persistent, reducing environmental pollution.

Target-Specific: Safer for pollinators, predators, and parasitoids, thus preserving ecosystem balance (Pavela & Benelli, 2016).

No Harmful Residues: Ensures the production of safe, residue-free food.

Cost-Effective: Can be prepared on-farm using locally available materials, reducing input costs for farmers.

Organic Compliance: Ideal for organic farming systems and Integrated Pest Management (IPM) programs.

Limitations and Future Prospects

Despite its promise, several challenges need addressing:

1. Lack of Standardization: The potency of extracts can vary with plant age, season, and geography, necessitating standardized extraction protocols.

2. Limited Commercial Formulations: The absence of readily available, stable commercial products limits large-scale adoption.

3. Need for Field Validation: More extensive field trials across different agro-climatic zones are required to validate efficacy and establish precise dosage recommendations.

Future efforts should focus on research into commercial formulation development, large-scale field demonstrations, and farmer education programs to integrate Gurmar into mainstream pest management practices.

Conclusion

Gymnema sylvestre (Gurmar) represents a viable and sustainable botanical tool for pest management in horticulture. Its multifaceted mode of action, safety profile, and compatibility with organic agriculture make it an excellent alternative to hazardous chemical pesticides. To fully realize its potential, concerted efforts in research, development, and policy support are essential to promote its widespread adoption, contributing to a more sustainable and productive agricultural future.

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Food Retail Market in India: Transforming Taste, Trade and Technology

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Introduction

Indian food retail market has emerged as one of the most dynamic segments of the nation's economy, acting as the critical interface between agricultural production, food processing and transacting consumers. Encompassing a wide range of channels, from traditional kirana stores, open markets, modern supermarkets, hypermarkets, cloud kitchens and digital grocery platforms, it constitutes the final and most vital link in India's agri-food supply chain, encompassing a large part of monetary transactions. Accounting for nearly 65 percent of the country's total retail market, the food and grocery sector increasingly contributes to national GDP, rural–urban employment and food security. With rising urbanisation, growing liquid cash availability, rapid digital deepening and financialinclusion, consumption patterns are increasingly shifting toward processed, packaged and convenience-foods, supported by the proliferation of e-commerce and technology-driven retail innovations. Artificial intelligence, data analytics and integrated supply-chain management are revolutionising the food marketing and delivery patterns, efficiently linking farmers directly to consumers. However, the sector continues to face challenges such as post-harvest losses, infrastructural bottlenecks and lack of proper integration of supply chains. The evolving food retail ecosystem symbolises a unique fusion of tradition and modernity: where local and global elements converge. As India moves toward a digitally integrated and consumer-centric economy, its food retail market not only drives economic modernisation but also reshapes national dietary habits, employment structures and food security frameworks. The food retail market underscores its trajectory both as an engine of inclusive growth and a reflection of India's sociol-economic transformation.

Retailing is the terminal stage of the Marketing continuum, through which commodities ultimately reach consumers (Acharya and Agarwal, 2017). The food retail market is the critical interface between food items and the consumers, encompassing an extensive spectrum of outlets: from local 'kirana' stores, street vendors to fast-food corners, open market kiosks to modern supermarkets, hypermarkets, food malls, cloud kitchen or the rapidly expanding e-commerce platforms. It remains the final and most indispensable link in the agri-food supply and value chain, connecting and integrating farmers, processors, distributors and customers within a vast interconnected web of economic transactions and social exchanges.

Importance of Food Retail Market

The food retail market hasan immense impacton India's economic as well as social fabric.

- It is a crucial link between the agricultural sector, food processing industries and grocery markets with their established consumer base. From being produced at the farm to reaching consumers after proper processing and post-harvesting, there is a long supply chain.
- It acts as a major driver of rural and urban employment, providing livelihoods to millions of people across the supply chains, from small farmers, middlemen, transporters, weighmen to vendors, supermarket workers and retail-shoppers.
- The sector ensures a continuous availability of food items and easy accessibility of food, thereby playing an undeniable role in maintaining national food security and price stability. Mosts of the farm products are highly demanded to prepare these retail foods, such as potatoes, onion, garlic etc.
- Beyond its economic significance, the food retail market influences consumer preferences, dietary diversity and nutritional outcomes, shaping the way India eats and lives. Its growing formalisation through e-commerce sectors and digital integration makes them easy to get connected and ordered, in a transparent and low-cost manner.
- Easy availability and affordable pricing strengthen the continuity of food supply chain. From a tired workman to a fatigued spouse, busy housewife to bookworm student all find it very comfortable to order fast food to consume at a cozy couch or get the product hand-delivered within a couple of minutes, visiting nowhere.

By connecting production systems with consumers, being digitally integrated and aided by modern trade with traditional systems, the food retail industry has evolved to be a part of India's mobile economy.

Economic Significance of Food Retail Market in India

The economic size of the Food retail market is continuously increasing and rapidly growing, along with serving a broader customer base.

- The food and grocery segment is very dominant in India, making up roughly 65 percent of the total retail market size. This figure is more or less the same in all economies, being 63 percent in the United States. So it is the underrated backbone of the domestic trade framework of India.
- The Indian food processing industry, a technological backbone of the food retail market, accounts for 32 percent of the country's total food market (Nangare, 2018). It is the 5th largest industry in India and noted for its sizeable production, consumption and expected further growth (Nangare, 2018).
- It contributes around 8.80 and 8.39 percent of Gross Value Added (GVA) in Manufacturing and Agriculture respectively, 13 percent of India's exports and 6 percent of total industrial investment in the country (Nangare, 2018). The Indian gourmet food market is currently valued at 1.3 billionUS$ and is growing at a Compound Annual Growth Rate (CAGR) of 20 percent (Nangare, 2018). The contribution of the Food Processing Industry in the Gross Domestic Product generated from the manufacturing sector was 16 percent in 2016 (Ministry of Food Processing Industry Report, 2016).
- It generates extensive employment opportunities, directly and indirectly supporting millions of livelihoods across

both rural, urban and rurban regions. In the period 2011-2017, employment in the registered food processing sector increased at an average annual growth rate of 4.22 percent (Nangare, 2018). It is a rising sector in encouraging labour movement from agriculture to manufacturing sector.

- Thirdly, the food retail system ensures food security and price stability, balancing the flow of commodities from surplus to deficit regions while shaping the nation's consumption patterns.
- What makes India's food retail market particularly attractive is its scale, diversity, and growth potential. With a population exceeding 1.4 billion, rising disposable incomes, increasing urbanisation and changing dietary habits, the demand for packaged, processed and convenience foods is soaring. The growing presence of organised retail chains, multinational brands, and digital grocery platforms has further transformed consumer experience-emphasising quality, convenience and innovation.

In addition, India's young consumer base, rapid digital penetration and expanding middle class offer a promising landscape for investors, entrepreneurs and policy planners alike. Whether it's traditional 'kirana' stores adopting digital payment systems or tech-driven startups offering 10-minute deliveries, the sector's evolution reflects a unique blend of heritage and modernity making the Indian food retail market one of the most dynamic and resilient in the world.

Organised vs. Unorganised Retail

With smooth progress in food retail market, this segment shows properly arrayed patterns in many aspects.

- Major constituents of organised food retail sector are-
  - Supermarkets (e.g., Reliance-Bharti Walmart tie-up, ITC, Godrej, Aditya Birla Groups, Food Bazar)
  - Hypermarkets (e.g., Metro, Big Bazar)
  - Discount Chains
  - Convenience Stores
  - Cooperatives
- They require higher fixed costs and high investment for establishment.
- A major part of the cost is on construction, building the supply chain and proper arrangements for conducting the business.
- Low marketing cost
- Efficient supply chain
- Complete elimination of middlemen.

However, the unorganised food retail sectors are highly abundant across the country. They are characterised by-

- They are mainly composed of Grocery stores (56 percent), Small Kiosks (17 percent), general provision stores (14 percent) and others (13 percent)
- Floor space is between 100 to 500 sq. ft.
- Variable cost is low
- Low margin per article (bulk sale)
- Personal rapport with customers
- Open for a long
- Fragile supply chain
- There are almost 12 million 'Kirana stores' in India, which account for 90 percent of total retail business (Acharya and Agarwal, 2017).

Drivers of Growth: The New Indian Consumer

The modern Indian consumers are is health conscious, brand-philic and digitally aware. Rising income level, spread of smartphones cum digital technologies and exposure to global cuisines have gradually changed consumption habits.

- **Health and Wellness Foods:** The Modern generation, including the Gen. Z pupils, show an increasing trend to attend a gym for maintaining physical fitness and body stability. They are highly aware of the intake of healthy, sugar-free, low-carbohydrate foods.
- **Convenience Foods:** Ready-to-cook and

ready-to-eat segments are booming due to urban lifestyles and dual-income households, where there is a lack of time.

- **E-commerce Expansion:** Online grocery platforms witnessed exponential growth in the post-pandemic times, with express delivery and subscription-based services becoming the neo-normal. Unavailability of time for cooking and bringing food materials has encouraged online order-based e-commerce platforms.

Together, these shifts reflect a consumer base that values quality, value of money and convenience simultaneously.

Role of Technology and Innovation

Technology is the invisible backbone of India's food retail revolution. From AI-driven demand forecasting and warehouse automation to digital payments and QR-based billing, the sector is becoming smarter and more efficient.

- **Supply Chain Digitisation:** Companies are integrating farmers, wholesalers and retailers into unified digital platforms to ensure transparency and to make the system easier.
- **Smart and Digitised Retailing:** Artificial intelligence and data analytics help big retailers and large industries to manage their inventory, optimise the pricing and personalise attractive offers for consumers.
- **E-grocery Platforms:** Companies like Zepto, Blinkit and Swiggy Instamart have made the food delivery process rapid and more convenient. Popularisation of '10-minute delivery' models has blended technology with urban convenience.

This digital transformation not only provides a positive customer experience but also supports small farmers and food processors by providing direct market linkages and fairer prices.

Challenges Ahead

Despite its rapid growth, the food retail sector faces a few persistent challenges:

- High supply chain fragmentation and post-harvest losses, particularly for perishable commodities.
- Regulatory complexities regarding food safety, packaging and labelling.
- Infrastructure gaps, especially in cold storage and last-mile logistics.
- Balancing modernisation within clusivity, ensuring that traditional retailers are not left behind in the digital shift.

Addressing these issues requires sustained collaboration between the government, private sector and cooperatives to ensure equitable and sustainable retail growth.

Conclusion

India's food retail market is no longer just about selling food, it is all about a culture of redefining the entire eco-system of food production, distribution and consumption. From the farmer's field to the consumer's table, every link in the chain is being rewired with technology, transparency and trust. As the world's most populous democracy embraces digital retail and evolving tastes, the Indian food market stands as a global example of how tradition and innovation can thrive together: serving both economic progress and cultural continuity. Hybrid retail formats, where offline stores partner with online delivery platforms, are set to dominate urban markets. The sector's evolution will not only redefine how India eats but also how it creates livelihoods, manages resources and connects producers to consumers.

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Diversity and Classification of Temperate Nut Species

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Introduction

Nuts are one of the oldest sources of food for living being and their history is very rich. Ancient fossils prove their presence on earth, long before man arrived. In botany, the word "Nut" is very ambiguous, as per scientific community nut is a simple dry fruit with one seed, in which the ovary wall becomes increasingly hard as it matures. The diversity of temperate nut includes Almond, Walnut, Pecan nut, Pistachio nut, Chestnut, Hazelnut, Macadamia nut, which are mostly grown in Himalayan region. Presently, robust challenges within nut crop breeding are their perennial woody character, long juvenile period and presence of Dichogamous nature in flowering. Future nuts require variability among population for breeding programme, although the size of the breeding population can be unlimited, the management, phenotyping and selection of these seedlings are major limiting factors. In any breeding programme, genetic diversity is crucial for selecting parents for the continuous development of novel cultivars to fulfil expanding needs and international standards. Different molecular markers (RAPDs, RFLPs, SSRs, ISSRs, AFLPs etc.) enable direct selection of genomic regions governing the trait of interest such as high quality, yield, and resistance to abiotic and biotic stresses advancements in gene editing, such as CRISPER-cas9 mediated genome editing and genomics-assisted breeding offer new opportunities to hasten the development of climate-resilient crops.

In botany, Word "Nut" is very ambiguous term. As per American Heritage Dictionary of English Language, 5th Edition, 2011, "a nut is an indehiscent fruit having single seed enclosed in a hard shell, such as Acorn or Hazelnut", or "any of various other usually seeds enclosed in hard covering such as seed coat or stone of drupe, as in Pine nut, Almond, or walnut". Finally, it seems that a definition accepted by scientific community in which nut is a simple dried fruit with one seed in which ovary wall become increasingly hard as it matures, and where the seed remains unattached with in the ovary wall (Woodroof, 1967; Jaynes, 1969). However, in culinary context, a wide variety of dried seeds are also called as "nuts" by extension because of their shell (Jaquenet and Monerete-Vautrin, 2007) shown in Fig. 1.

Among the nut that we are having, Walnut Pecan nut and Almond are the seeds of drupe. While as Hazelnut and Chestnut are botanically as well as culinary purpose

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described as nut. Brazil nut is not botanically nut but rather than seed of capsule. A botanical classification of species producing nut proposed by Jacquenet and Moneret- Vautrin (2007) given in (Fig.2 and Fig.3). In Temperate Nut include, Almond, Walnut, Pistachio, Pecan nut, Chestnut, Hazelnut and Pine nut respectively.

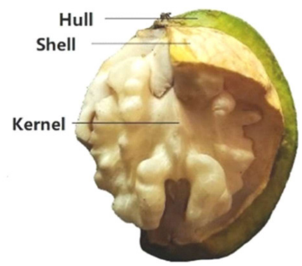

Fig. 1 Anatomy of Nut

According Nuts and Dried Fruits Statistical Yearbook 2022/23 published by International Nuts and Dried Fruit Council (INC), World tree Nut production has followed rising trend over the past decade. Total production amount of 5.3 million metric tons in the year of 2022/23. Global tree nut production grew at average rate of about 250,600 MT per year (except pistachios, which are reported on in shell basis, tree nut production amount expressed on kernel basis throughout this report). In year 2022/23, Almond and Walnut accounted for 27% and 22% of global production, respectively, followed by Cashews (20%), Pistachios (14%), and Hazel nut (11%). Whereas, Pacan nut, Macadamia nut, Pine nuts and Brazil nut together accounted for the remaining (6%) of global nut production.

Fig. 2 Diversity of Temperate Nut Fruits

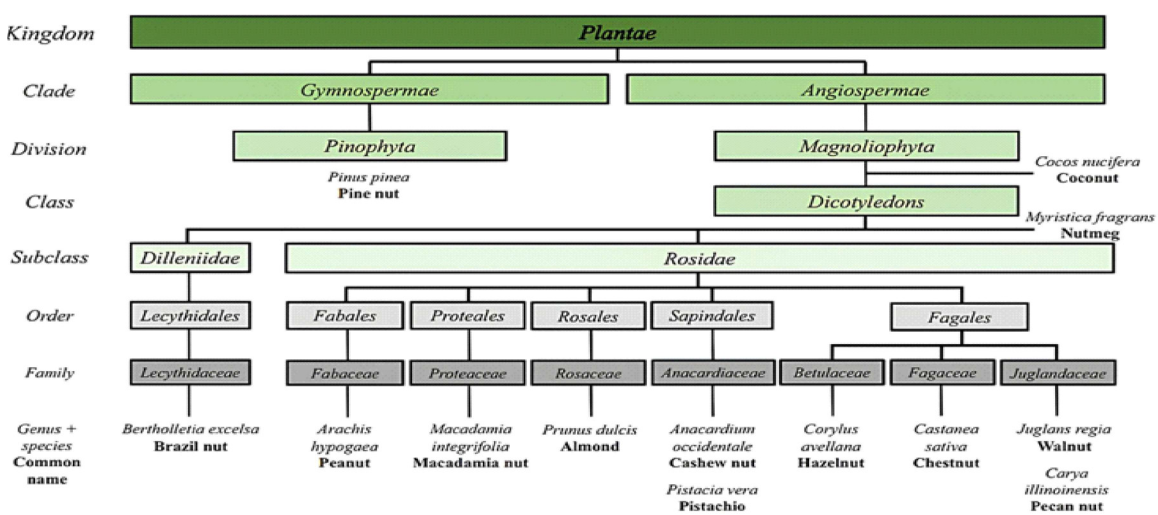

Fig.3 Botanical classification of nuts adapted from Jacquenet and Moneret-Vautrin (2007) and according to the Angiosperm Phylogeny Group (APG III 2009)

The highest annual growth rates over last ten years were observed for Walnut and Macadamia nut (9%), followed by Cashews (7%). Pistachio and Pecan crop grew at an average of 5% per year while, Almond and hazelnuts, grew at an annual rate of 3%. On average, the USA led global tree nut production over the past five seasons (2018/19-2022/23), with an average share of 40%. Almonds, pistachios and walnuts were the most widely grown crops, accounting for 59%, 22% and 15% of USA tree nut production, respectively. Turkey came in second with 11% of global production, with hazelnuts and pistachios accounting for 63% and 30% of Turkish output, respectively.

The intensifying threat of climate change is a major challenge to global food security. One of the ways to mitigate its impact is by developing crops that can withstand environmental stresses such as drought, heat, and salinity. Plant breeders have been using conventional and modern approaches to achieve climate-resilient crops. Climate-resilient crops refer to both crop and crop varieties that exhibit improved tolerance towards biotic and abiotic stresses. These crops possess the capacity to maintain or even increase their yields when exposed to various stress conditions, such as drought, flood, heat, chilling, freezing and salinity. Conventional breeding entails selecting and crossing plants with desirable traits, while modern breeding deploys molecular techniques to identify and transfer specific genes associated with stress tolerance. However, the effectiveness of both methods is contingent on the crop species and the targeted stress. Advancements in gene editing, such as CRISPER-cas9 and genomics-assisted breeding, offer new opportunities to hasten the development of climate-resilient crops. These new technologies include Marker Assisted Selection, Genome-Wide Association Studies, Mutation breeding, Transcriptomics, Genomics, Speed breeding and more. However, breeding for quality improvement in perennial fruit & Nut crops is affected by a number of limitations like, long juvenile phase, large size of the plant, and environmental problems e.g., flower & fruit drops (Karanjalker and Begane, 2015). A balanced approach that combines traditional and non-conventional breeding approaches could assist to solve this problem. Biotechnological approaches give precision and dependability, and they are thought to shorten the breeding cycle in long juvenility crops.

Breeding Objectives

Walnut: Yield trait: Synchronisation of flowering, High no. of fruitful laterals, Precocity, Late leafing, Early harvesting. Nut trait: Smooth shell texture, Light colour, Round to oblong shape, Paper shell, Strong shell seal. Kernel trait: High kernel shell ration, Plump, Bold, Easy to remove kernel halves, Light in colour, Sweet in taste, Well filled. Biotic & Abiotic trait: Resistance to anthracnose, Tolerant to PFA, Heat tolerant, Winter hardiness. Rootstock-Scion trait: Easy to propagate, Compatibility, Tolerant to blackline and Phytophthora rot.

Almond: Yield trait: Late bloom, Hardy buds and wood, Self- fertility autogamy, Regular bearing. Nut and kernel trait: Sweet kernels, well-sealed nut, High shelling percentage. Biotic & Abiotic trait: Low chilling requirements, Drought tolerance. Rootstock trait: Easy to propagate, Compatibility.

Pistachios Nut quality, size and appearance, Reduction in percentage of blank or unfilled nuts, Increasing the percentage of split nuts, Increasing the green color of kernel at maturity, Alternate bearing, Higher pollen viability and overlap bloom period. Biotic stress (soil borne fungal disease, Verticillium spp., Phytophthora spp. and Rhodococcus spp. [causing pistachio bushy top syndrome], etc.) resistance.

Pecanut: Dichogamy, Alternate bearing, Cluster size, Shelling %, Nut weight, nut size, Kernel weight.

Chestnut: Kernels uniform in size and round shape, Long storage life (oil less prone to rancidity), High nutritional and nutraceutical value, Little or no fiber on the pellicle of the kernel.

Hazelnut: Reduced sucker emission, Self-compatibility, Early nut maturity, Well-sealed nut shell (lack of split sutures), Little or no fiber on the pellicle of the kernel, Resistance to bud mites.

Major Problems in Nut Fruit Breeding

I. Tree nut Fruits having long generation cycle of 2-10 years depending upon species and cultivars and hence more recombinations are not possible.

II. Nut crops have long Juvenile period and making it difficult for early assessment of strain.

III. Nut crops are highly heterozygous nature require large population for effective selection.

IV. Presence of sexual incompatibility is the major limitation factor for breeding as well as in yield perspective eg. In Hazelnut we found sporophytic sexual incompatibility.

V. Presence of Dichogamy in nut crop, protandry and protogyny condition for male and female anthesis found in nut crops. Thus, non-synchronisation of male and female flowering results in low yield.

VI. In India minor nut like, Pistachio, Hazelnut, Pecan nut, Macadamia nut, chest nut and Pine nut there are lack of germplasm and variation can restrict the breeding programme. So far, there is no such breeding work done in minor crop in India although, they were cultivated in most of Northern state and eastern states of nation.

Conclusion

Temperate nut species play a vital role in global horticulture due to their nutritional, economic, and ecological importance. Rich genetic diversity among genera like Juglans, Prunus, Corylus, Castanea, Carya, and Pistacia offers great potential for crop improvement. However, breeding progress is limited by long juvenile periods, heterozygosity, dichogamy, and lack of germplasm, especially in India. Integrating conventional breeding with modern genomic tools such as marker-assisted selection, QTL mapping, CRISPR-Cas9, and speed breeding can accelerate the development of superior, climate-resilient cultivars. Strengthening germplasm collection and evaluation, particularly for minor nut crops, along with global collaborative efforts, is essential to enhance productivity and sustainability under changing climatic conditions.

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Agrinofy: AI Driven Precision for Smarter, Sustainable Agriculture

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Introduction

Agrinofy is an international agri tech company leveraging artificial intelligence, big data, IoT, and remote sensing to modernize agriculture and empower stakeholders with intelligent insights. Its overarching vision is to build a future of smarter, climate resilient, and profitable farming, driven by data and precision technologies.

Agrinofy serves a broad audience-including smallholder and large scale farmers, agri entrepreneurs, cooperatives, NGOs, government agencies, researchers, and agritech developers. Its core mission emphasizes democratizing access to agricultural intelligence, optimizing resource use, and promoting food security through sustainable innovation.

Agrinofy's Tech Ecosystem

Agrinofy delivers several AI powered platforms serving different agricultural needs:

a) Digital Agriculture Advisory Services (DAS)

A comprehensive, AI powered advisory ecosystem providing personalized guidance -from crop selection and irrigation to pest alerts and market intelligence. It supports these services via mobile app, voice, and SMS, even in offline settings.

Key features include

i. Tailored crop advisory based on soil, crop stage, and real time weather
ii. Early pest and disease alerts via satellite or sensor data
iii. Hyperlocal weather and climate risk information
iv. Live market price intelligence
v. Multilingual voice and SMS support and 24/7 digital support (AI agents & human experts)
vi. Farmers register via mobile or field agents, provide location and crop data, and receive ongoing, real time guidance, all with a feedback loop for continual improvement.

b) Pest & Disease Detection Platform (the focus section)

The flagship module for diagnosing and managing crop health threats through AI.

c) AgriAI SaaS Platform

A cloud based service offering tools such as crop suitability analysis, pest & disease detection APIs, seed/input recommendations, task alerts, irrigation intelligence, analytics dashboards, and chatbot advisors.

d) AI Powered Precision Farming

This solution incorporates sensor and satellite data to forecast yields, monitor soil health, optimize inputs, and provide mobile accessible dashboards with tangible benefits like water savings (~30%) and yield increases (15–40%).

e) AI Agri Drone Services

On demand aerial imagery, crop health mapping, precision spraying, reseeding, and field analytics-powered by drones, AI, and cloud infrastructure.

Deep Dive: Pest & Disease Detection Platform

Purpose & Value

Designed for early detection and management of crop threats, this platform equips farmers with speedy AI diagnostics, preventive advice, and regional threat mapping to reduce losses and boost yields.

Key Features

- **AI-Based Image Diagnosis:** Farmers upload photos; the system identifies pests/ diseases instantly.
- **Symptom-Based Search:** Text based input of symptoms yields probable diagnoses.
- **Treatment & Prevention Recommendations:** The platform delivers tailored guidance for managing identified threats.
- **Geo Tagged Disease Alert Map:** Users see real time regional outbreak visualizations.
- **AI Chatbot "AgriMedic":** Delivers instant support through an intelligent assistant.
- **Crop Wise Pest Calendar:** Seasonal data helps plan proactive measures.
- **Typical User Flow**
- **Login** → Upload image or describe symptoms → AI diagnosis → Treatment advice → Option to purchase recommended inputs → Further support via AgriMedic or human agents
- **Impact for Farmers**
- **Rapid, accessible diagnostics:** Image based AI during early outbreak stages empowers faster response, even in isolated areas.
- **Localized outbreak awareness:** Geo mapping helps farmers circumvent hotspots and adjust strategies proactively.
- **Guided response:** Tailored treatment advice ensures more accurate and effective interventions.
- **Layered support:** From AI chatbot to human assistance, farmers aren't left at a diagnostic dead end.
- **Proactive planning:** Pest calendars and early alerts let farmers pre empt threats before escalation.

Limitations & User Responsibility

Agrinofy's AI models are advisory only, not infallible. Diagnoses and recommendations are probabilistic and users are encouraged to validate advice in the field. Agrinofy Models are retrained regularly (monthly or quarterly) using diverse data sources-feedback loops, research partners, satellite/IoT data-to maintain relevance and accuracy.

Integration in Agrinofy's Broader Suite

The Pest & Disease module is woven into Agrinofy's multi layered ecosystem:

- **Within DAS:** Loss detection triggers early alerts and prevention guidance.
- **Across SaaS:** Its capabilities can be embedded in dashboards, external apps, or enterprise platforms.
- **Sensor & Drone synergy:** The AI detection capabilities can authenticate and enrich data from drones and field sensors, improving model reliability and diagnostic reach.

Benefits for Stakeholders

- **Smallholder Farmers:** Affordable, easy-to-use diagnostics help reduce crop damage, limit unnecessary pesticide use, and boost profitability.
- **Institutional Users:** NGOs and governments gain dashboard grade situational awareness for tracking disease outbreaks, planning responses, and coordinating extension services.
- **Agri Businesses:** Input suppliers and service providers can connect with affected farmers, offer solutions, and deploy marketing or support more strategically.
- **Agritech Developers:** The SaaS API lets others integrate Agrinofy's AI models and analytics into their tools.

Ethical, Operational, and Regional Considerations

- **Ethical AI & Privacy Compliance:** Agrinofy strictly adheres to ethical AI standards-ensuring data privacy (e.g., GDPR/ CCPA compliant), transparency, bias mitigation, and explainability. Versions are managed, and major updates are communicated to users.

- **Technology Access & Inclusivity:** Agrinofy supports multiple access modes-mobile app, voice, SMS, agent-mediated input-making it inclusive for those without advanced devices. Plus, multilingual interfaces and offline support reduce literacy and infrastructure barriers.
- **Continuous Learning & Adaptation:** The platform refines its models through retraining based on real user interactions, expert feedback, and shifting agricultural trends-making it adaptable across regions, seasons, and crops.

Comparative Perspective: Agrinofy vs. Other Tools

While several pest/disease apps exist-such as Agrio or Plantix-Agrinofy distinguishes itself by offering:

Multimodal input (image + symptoms + voice/SMS)

Geo visualization of threats

Integrated support ecosystem (AI + human agents)

Embedded in broader advisory, analytics, and drone-enabled intelligence platform

This holistic integration, especially with SaaS and advisory capacities, positions Agrinofy as more than a diagnosis tool—a comprehensive agri digital ecosystem.

Challenges & Future Potential

Challenges

- **Accuracy in complex settings:** Diagnosing pests or diseases under suboptimal image quality or symptom similarity remains a technical hurdle.
- **Connectivity:** Though Agrinofy offers offline inputs, delivering image-based AI in low-bandwidth zones presents UX challenges.
- **Scalability and training:** Keeping the AI updated across multiple geographies, crops, and conditions demands robust data collection and retraining.
- **Adoption and trust:** Farmers often depend on legacy methods; building confidence in AI tools requires training, success stories, and validation.

Future Directions

- **Expand the knowledge base:** Incorporating more crop types, pest/disease profiles, and region-specific threats.
- **Real-time sensor/drone fusion:** Automated aerial or sensor-derived inputs could further accelerate detection pipelines.
- **Predictive outbreak modeling:** Enabling forecasting-from weather, soil, or trend indicators-to guide anticipatory interventions
- **Marketplace coupling:** Offering verified input procurement directly linked to diagnosis and advisory results.
- **Institutional deployment:** Embedding the platform into public agricultural extensions, research networks or cooperative systems.

Conclusion

Agrinofy's Pest & Disease Detection Platform is a powerful, AI-driven tool aimed at transforming how farmers identify and respond to crop threats. Through instant AI diagnostics, tailored treatment advice, regional outbreak maps, and layered chat support, it equips stakeholders to respond swiftly and effectively. What sets Agrinofy apart is it's positioning within a broader ecosystem-spanning advisory services, AI SaaS modules, precision farming tools, and aerial drone support—making it a central pillar in a modern digital agriculture framework. With strong adherence to ethical AI principles, inclusive access methods, and relentless model improvements, Agrinofy demonstrates how integrated agricultural intelligence can be made accessible, trustworthy, and impactful.

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Containerized Culture for Year Round Vegetable Production

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Introduction

Rapid global urbanization exacerbates the demand for locally produced, fresh vegetables while simultaneously diminishing the availability of traditional farmland. Contemporary cities face challenges such as limited cultivable land, escalating food costs, and concerns about food safety and sustainability. Within this context, containerized culture emerges as a pragmatic and scientifically sound method for producing vegetables in confined spaces such as balconies, rooftops, patios, and windowsills. By confining growth media to containers and optimizing root-zone parameters such as moisture, aeration, and nutrient availability, container gardening facilitates precise agronomic control. This precision minimizes the risks of soil-borne diseases and environmental stress, which commonly affect open-ground farming systems. The technique is recognized for its contribution towards urban food sovereignty and environmental sustainability, through reduced pesticide use, water conservation, and resource recycling.

Advantages

Container gardening provides a broad spectrum of advantages, addressing technical, environmental, and social needs, including:

- **Versatile:** container garden can be growing on a balcony, patio, courtyard, indoors on windowsills or rooms with adequate light.
- **More variety:** You can grow plants that may not be suitable to grow in your garden soil and grow plants next to each other even though they may have different soil needs.
- **Accessibility:** Growing plants in containers makes gardening accessible to almost anyone including children, those with limited mobility and the elderly.
- **Mobility:** Plants in pots can easily be moved to suit your needs or to a more suitable sunny or shady location during the day.
- **Change your look:** Easily vary your colour scheme. As each plant finishes flowering or fruiting, it can be replaced with another.
- **Flexibility**: Rearrange plants to suit the season or your personal taste.
- **Control space invaders:** Vigorous growers like mints and bamboo that are too invasive if let loose in the garden do well in containers, but will take over an in-ground garden.
- Easier to control weeds, diseases, insect and pests.
- **Time and labour saving:** Less time is spent weeding, walking and watering when

plants are grouped all in one place.

- **Water Efficiency:** Targeted irrigation through drip or self-watering systems minimizes water wastage, conserving this critical resource amid rising urban demand.
- **Environmental Benefits:** Incorporating recycling of organic waste as substrates and using repurposed containers reduce environmental footprints, aligning with principles of circular economy.

Crop Selection for Container Cultivation

The success of container gardening hinges on appropriate selection of vegetable crops suited to container limitations, particularly concerning root depth and space requirements. Empirical studies and extension guidelines categorize crops as follows:

Crop Category	Example Crops	Recommended Container Depth
Leafy Greens	Spinach (*Spinacia oleracea*), Lettuce (*Lactuca sativa*)	15–20 cm
Root Vegetables	Radish (*Raphanus sativus*), Carrot (*Daucus carota*), Beetroot (*Beta vulgaris*)	25–30 cm
Fruiting Vegetables	Tomato (*Solanum lycopersicum*), Brinjal (*Solanum melongena*), Okra (*Abelmoschus esculentus*)	30–45 cm
Climbing Crops	Beans (*Phaseolus vulgaris*), Peas (*Pisum sativum*), Cucumber (*Cucumis sativus*)	25–30 cm + vertical support

Cultivation of these crops in containers requires adaptation of planting densities, container dimensions, and cultural practices to optimize growth parameters.

Container Size Requirements for Major Vegetable Crops

The selection of container size affects crop yield and health. Recommended minimum container volumes, depths, and spacing per crop are as follows:

Vegetable	Min. Volume (gallons)	Depth (inches)	Plants per Container	Spacing (inches)
Tomato	5	18-24	1	18-24
Eggplant	5	12-18	1	18-24
Pepper	3	12-18	1	12
Cucumbers	5	12-18	1	12-16
Lettuce	2	6-8	1	4
Beans (bush)	2	8-10	3	6-8
Carrot	5	12-18	12	2-3
Radish	2	6-8	12	1-2
Squash	5–7	18-24	1	24-6

Container Selection and Management

Choosing appropriate containers is critical for ensuring adequate root aeration, drainage, and thermal regulation. Containers can be fabricated from materials such as plastic, clay, terracotta, cement, or repurposed items like recycled bottles and grow bags. Key considerations include:

- **Drainage:** Containers must possess sufficient holes or outlets for excess water to escape, preventing root rot.
- **Material Properties:** Porous materials (e.g., clay) provide better aeration but may dry out quickly; plastic retains moisture but

can lead to overheating if dark-colored.

- **Sustainability:** Utilizing recycled or upcycled materials reduce environmental footprints.
- **Color:** Light-colored containers minimize heat absorption, stabilizing root zone temperatures.

Potting Media Composition and Nutrient Management

The substrate is pivotal for providing adequate water retention, nutrient availability, oxygen diffusion, and microbial symbioses. Scientific consensus recommends potting mixes comprising:

- One part mineral-rich garden soil for essential nutrients and soil biota.
- One part well-decomposed compost or vermicompost to provide organic matter, beneficial microbial communities, and nutrient reservoirs.
- One part inert materials such as cocopeat, perlite, or sand for improved drainage and aeration.

Seedling transplanting

- Vegetables that can be easily transplanted are best suited for container culture.
- Seedlings may be purchased from local nurseries or can be grown at home.
- Seeds can also be germinated in a baking pan, plastic tray, pot, or even a cardboard milk carton.
- Most vegetables should be transplanted into containers when they develop their first two to three true leaves. Transplant the seedlings carefully to avoid injuring the young root system.

Fertilizers for Container Plants

- Add slow-release fertilizer at planting such as Osmocote with a formulation of 14-14-14.
- Initially, half-strength, water-soluble fertilizer used when plants begin to grow actively.
- Peters® 20-20-20 or Miracle Gro® 15-30-15 are two examples sold in most garden centers.
- Increase fertilizer to recommended rate as plants mature

Application of fertilizer

- Easiest way of fertilizer application in containers is to prepare a nutrient solution and then pour it over the soil mix.
- You can buy commercial fertilizer mixes, otherwise make nutrient solution himself by dissolving 2 cups of a complete fertilizer such as 10-20-10, 12-24-12, or 8-16-8 in 1 gallon of warm tap water.
- This mixture is highly concentrated and must be diluted before it can be used to fertilize the plants.
- To make the final fertilizing solution, mix 2 tablespoons of the concentrated solution in 1 gallon of water.

Environmental Management: Water, Light and Temperature

- **Light**

Light is a key factor affecting photosynthesis and growth rates. Leafy greens, such as lettuce and spinach, generally require about 5 to 6 hours of direct sunlight daily to maintain robust growth and nutrient density. In contrast, fruiting vegetables like tomatoes, peppers, and eggplants need longer exposure, typically 6 to 8 hours to optimize photosynthetic activity, fruit development, and yield.

- **Water Management**

Maintaining soil moisture within an optimal range is crucial. Both overwatering and under watering can broadly impair physiological processes leading to poor growth or mortality. Container media with high retention yet prompt drainage capabilities assist irrigation management. Drip irrigation systems combined with mulching can significantly reduce water requirements and enhance moisture stability.

- **Temperature**

Because containers are more susceptible to rapid temperature fluctuations, shade provision or reflective coatings may be necessary to prevent excessive root-zone heating. Conversely, during cooler months, containers can be moved indoors or to sheltered locations to protect crops from low temperatures.

Crop Management Practices

- **Pruning**: Removal of dead or diseased tissues and selective thinning improve air-flow and direct energy towards productive growth.
- **Training:** Climbers require adequate supports such as trellises or stakes to optimize space vertically and facilitate air circulation.
- **Harvesting:** Timely harvesting of leafy greens and fruits prolongs productivity. Regular picking also encourages new growth, enhancing overall yield.

Pest and Disease Management

Pest and disease control relies predominantly on organic and preventive measures to minimize chemical residues and environmental impact. Application of organic pesticides such as neem oil, garlic extracts, and insecticidal soaps effectively suppresses common pests.

Challenges and Mitigation Strategies

Problem	Cause	Suggested Mitigation
Leggy plants, poor yield	Insufficient light	Move to sunnier location
Yellowing leaves, stunting	Excess water, poor drain	Improve drainage; water less frequently
Poor growth, purple color	Low temperature, P deficit	Move to warmer area; supplement phosphate
Leaf burn/margin browning	High salt build-up	Leach container with fresh water
Holes in leaves or spots	Pests or diseases	Manual removal, organic sprays, improve hygiene

Economic and Social Implications

Container gardening aligns with the dual goals of environmental stewardship and food sovereignty. High upfront costs for containers and substrates are offset by continuous harvests and reduced dependency on commercial produce. Urban dwellers especially low-income and elderly populations can economize while accessing fresher, safer vegetables.

Socially, container gardening promotes community engagement, mental well-being, and nutritional education. It embodies sustainable urban development models supporting circular waste manage-ment and climate adaptation.

Conclusion

Containerized vegetable cultivation offers a viable and eco-friendly means to achieve fresh, nutritious, and pesticide-free produce within limited urban spaces. This approach addresses the challenges posed by urbanization and food security, empowering gardeners to produce year-round crops with controlled inputs. Successful container gardening necessitates informed decisions regarding container sizes, growing media, nutrient management, and environmental conditions. With proper management, containerized culture can yield high-quality vegetables, enhancing self-sufficiency and contributing to sustainable urban agriculture.

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Synergistic Effect of Liquid Biofertilizer and Phospho Compost on Capsicum Growth at 30 days

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Introduction

Soil health is the key to agricultural production. Soils are natural habitat for billions of diverse micro organisms which serve as the ecological engineers to make soil as a "living" system. Healthy soils generally have balanced nutrient levels and sufficient biological activity especially of micro organisms. However intensive cultivation with modern practices including application of agrochemicals have led to increased nutrient from the soil and disturbed the soil biological equilibrium leading to deteriorated soil health (Praveen *et al.*, 2025). This has eventually made our soils "Sick" which will ultimately lead to reduce fertility (Nhu *et al.*, 2018).

Application of microorganisms in agriculture is well known. The micro organisms like *Rhizobium, Azotobacter, Azospirillum*, PSB, KMB and arbuscular mycorrhizae have significant impacts in crop production and protection. Changing climate scenario (Mohammed *et al.*, 2021). The liquid micr-obial consortium (Parasmoni NPK) was developed by Parasmoni Research team using three inoculants- *Azotobacter chroococcum, Bacillus polymyxa* and *Frateuria aurantia* and Parasmoni VAM comprising *Arbuscular mycorrhizal* spores. Compost and phospho compost were also prepared by Parasmoni Organic & Agri Product Private Limited.

An experiment was conducted by Parasmoni Research team in 2024- 2025 to evaluate the effect of different liquid formulation of Azotobacter, Phosphate solubilizing bacteria (*Bacillus polymixa*) and Potash mobilizing bacteria KMB (*Frateuria aurantia*) as individual or as in combination with Arbuscular mycorrhizae (Parasmoni VAM) (soil base) and compost(organic manure) and phospho compost in varieties (Hangarian yellow). The combination showed the better results when compared to the control. In growth parameters, Parasmoni KMB with Parasmoni VAM and Parasmoni Samriddhi and phospho compost prepared by Parasmoni team showed the highest results next to all the Biofertilizers applied.

Methods

The use of microbial consortium combined with NPK fertilizer in long term sustainable nutrient management that can be beneficial for improving the quality of soil fertility. Research on the response on capsicum plants to the use of Parasmoni Azoto L, Parasmoni NPK L (Product name), Parasmoni KMB L, Parasmoni PSB L and the addition of Parasmoni VAM (Product name) and Parasmoni Samriddhi has been done to determine the effect of the use of those on the growth & production of capsicum.

Dosage: Liquid Biofertilizer 360ml/ acra compost 180kg/acra, phospho compost 120kg/acra

Microbial inoculums: All microbial inoculums viz Azotobacter chrooccum, Phosphate solubilizing bacteria, Bacillus polymyxa and potash mobilizing bacteria *Frateuria aurantia* the strains were collected from MTCC Chandigarh. Mycorrhizal spores were collected from Vivekananda Institute of Biotechnology Nimpith W.B. All are maintained in Parasmoni Research laboratory and formulations were done the basis of need.

Table 1: Effect of liquid Bio-fertilizers along with compost in capsicum in 30 days

Treatment	Length (m)		Dry weight(g)		No. of branches	No. of flowers	No. of fruits
	Shoot	Root	Shoot	Root			
Control	20	31	0.6	0.3	3	2	0
Compost	27	33	2.3	0.6	4	3	2
Compost + Azotobacter	29	34.5	2.5	0.6	4	3	2
Compost + PSB	32	35	3.2	0.8	4	3	0
Compost + AM fungi	31	41.6	2.2	0.8	3	3	2
Compost + KMB	35	45	2.8	0.8	4	4	3
Compost + NPK consortia + AM fungi	37.5	47.1	2.8	1.2	5	3	2

Compost –Parasmoni Samriddhi prepared by Parasmoni

Azotobacter-Liquid *Azotobacter chrooccum* - Parasmoni Azoto L

PSB- *Liquid Bacillus polymyxa*-Parasmoni PSB L

KMB- Liquid *Frateuria aurantia* -Parasmoni KMB L

AM fungi- Endomycorrhizal spores- Parasmoni VAM

NPK consortia- Azotobacter + PSB + KMB

Phospho compost- Prepared by Parasmoni.

Table 2: Effect of liquid Bio-fertilizers along with phosphorous compost in capsicum on 30th day.

Treatment	Length (m)		Dry weight(g)		No. of branches	No. of flowers	No. of fruits
	Shoot	Root	Shoot	Root			
Control	20	31	0.6	0.3	3	2	0
Control	21	32	0.6	0.3	3	2	0
Phospho compost	27.8	34.7	2.7	0.6	4	4	2
Phospho compost + Azotobacter	30.5	35.9	2.8	0.7	4	4	3
Phospho compost + PSB	33.1	38	3.7	0.8	4	4	2
Phospho compost + AM fungi	33.8	43.3	4	0.9	3	3	4
Phospho compost + KMB	36	50.1	3.2	0.9	4	4	4
Phospho compost +	41.7	54	3.9	1.4	5	6	4

Treatment	Length (m)		Dry weight(g)		No. of branches	No. of flowers	No. of fruits
	Shoot	Root	Shoot	Root			
NPK consortia + AM fungi							

Azotobacter- Liquid *Azotobacter chrooccum* - Parasmoni Azoto L

PSB- Liquid *Bacillus polymyxa*-Parasmoni PSB L

KMB- Liquid *Frateuria aurantia*–Parasmoni KMB L

AM fungi- Endomycorrhizal spores- Parasmoni VAM

NPK consortia- Azotobacter + PSB + KMB

From the above study conducted by Parasmoni Research team to evaluated the effect of different liquid biofertilizers *Azotobacter*, PSB, KMB and AM fungi (Soil base). Arbuscular mycorrhizae (soil base) (Parasmoni VAM) and potassium mobilizing bacteria (Parasmoni KMB) as individual as well as in combination along with compost (Parasmoni Samriddhi) and phospho compost (prepared by Parasmoni) in capsicum varieties (Hangerian yellow), showed the better results when compared to the control. Further the phospho compost applied field showed pronouncing results when compared to compost applied field showed pronouncing results in all the parameters studied. In growth parameters potassium mobilizing bacteria (*Frateuria aurentia*) enriched phospho compost showed the highest results next to all the Biofertilizers applied together. This may be due to the mobilization of K as well as release of growth hormones by the K mobilizer and increased the uptake of potassium by the plants (Table 1-2)

Conclusion

It is very necessary to understand that, liquid biofertilizers are not merely usual broth cultures from fermenters and are specially prepared with desired agriculturally important micro organisms along with proper nutritional base to facilitate protection of organisms from adverse conditions and resting spore formation or cysts etc (Berruti *et al.*, 2016). Many researchers still have doubts about the liquid formulations even through all bacterial inoculums are commercially being well accepted by the farmers. It is proved in laboratory test that all the liquid biofertilizers have more than 2 years of shelf life. Very much easy to use by the farmer. Dosages is 10 times less than carrier based powder biofertilizers very high enzymatic activity since contamination is nil. The maximum benefit can be harnessed by use of liquid biofertilizer with compost or phospho compost.

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Medicinal Benefits of *Curcuma amada* (Mango Ginger)

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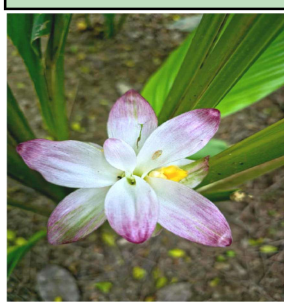
Introduction

Curcuma amada, commonly known as mango ginger, belongs to the Zingiberaceae (ginger) family and is renowned for its strong aromatic fragrance. Native to India and Southeast Asia, it is widely cultivated in states like Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, and Odisha, often alongside turmeric and ginger. For centuries, mango ginger has held an important place in Indian kitchens and traditional medicine. While it is popularly used in pickles, chutneys, and curries for its distinctive flavour, its true significance lies in its remarkable medicinal and therapeutic properties, making it valuable in both the food industry and alternative medicine.



Inflorescence of *Curcuma amada*

Fully grown plant of *Curcuma amada*

Botanical Description

Mango Ginger (*Curcuma amada* Roxb.) is a perennial herb with underground rhizomes resembling common ginger but paleyellow inside and exuding a pleasant raw mango fragrance when crushed. The plant grows 60-100 cm tall with long, lance-shaped leaves-smooth above and slightly rough beneath-and bears cone-shaped inflorescences with pale green bracts tipped with purplish or pink sterile bracts. The rhizomes are thick, buff-colored outside, and used mainly for culinary and medicinal purposes. Mango ginger thrives in warm climates (15–30°C), with 20°C as the ideal temperature for seed germination. It prefers well-drained soil with a pH of 6–8 and benefits from nitrogen-rich fertilizers, though excess water can hinder its growth.

Chemical Composition

Mango ginger is a well-known aromatic plant valued for its distinctive raw mango-like flavor, which comes from compounds such as a-3-carene and cis-ocimene. Its rhizomes contain curcumin, demethoxyc-urcumin, and bis-demethoxycurcumin. The essential oil extracted from its leaves is rich in furanosesquiterpenoids, including epi-curzerenone, curzerenone, curzerene, and furanogermenone. Additionally, the root essential oil contains isosorbide and n-hexadecanoic acid.

Medicinal Uses

1. Digestive problems

Mango Ginger is widely used in Ayurveda as a digestive stimulant. It aids in the secretion of digestive enzymes, improving appetite and reducing indigestion, bloating, and flatulence.

2. Anti-inflammatory and Pain Reliever

Mango Ginger has strong anti-inflammatory properties. The active compounds help in reducing swelling and joint pain caused by arthritis and muscle strain. In traditional medicine, the paste of the rhizome is applied externally to bruises, sprains, and rheumatic pains for quick relief.

3. Antimicrobial and Antifungal Effects

The extracts of *Curcuma amada* possess antibacterial and antifungal activities, effective against pathogens like *Bacillus cereus, B. subtilis, Micrococcus luteus, Staphylococcus aureus, Enterobacter fecalis* and *Salmonella typhi* (anti-bacterial) and against *Aspergillus niger, A. terreus, Fusarium monoliforme* and *F. falcatum* (anti-fungal). This makes it useful in treating skin infections, minor wounds, and acne.

4. Respiratory Ailments

Mango Ginger acts as a natural expectorant. In traditional medicine, its decoction is used to relieve cough, cold, and sore throat. It helps in loosening mucus and clearing the respiratory tract, offering comfort during seasonal flu or bronchitis.

5. Skin and Hair Health

Due to its antioxidant and antimicrobial nature, Mango ginger is often used in herbal beauty care. Regular use of its extract in face masks or hair oils helps in maintaining clear skin, preventing dandruff, and promoting scalp health.

6. Anti-nausea and Anti-ulcer Properties

Mango Ginger is a traditional home remedy for vomiting, stomach upset, and ulcers. The essential oils soothe the stomach lining and regulate gastric acid secretion. It is particularly effective for people who suffer from travel sickness or morning nausea.

Culinary Uses

Apart from its medicinal values, Mango Ginger is commonly used in pickles, chutneys, and salads, offering a tangy and spicy mango-like flavor. In some regions, it is added to buttermilk or herbal teas to enhance digestion and cool the body during summer. The rhizomes can be stored in brine or dried and powdered for year-round use.

Conclusion

Curcuma amada, is more than just a spice, it is a natural healer wrapped in fragrance. Its blend of taste, aroma, and medicinal uses makes it one of the most versatile herbs in traditional Indian medicine.

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Kashilalima: A Glimpse of Modern Agriculture

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Introduction

In the face of increasing population pressure, climate change, and the need for sustainable food production, the role of scientifically improved crop varieties has become more critical than ever. Okra (*Abelmoschus esculentus*), a widely cultivated vegetable crop in India, is not only important for its nutritional value but also for its economic relevance to small and medium-scale farmers. Among the newer and more promising cultivars, the variety Kashilalima stands out as a significant development in the field of horticultural science. This variety represents a successful blend of traditional crop knowledge and modern breeding techniques, designed to address key agricultural challenges such as low yield, pest susceptibility, and poor market adaptability. The objective of this article is to explore the background, development, and agronomic advantages of Kashilalima, while also reflecting on its role as a symbol of innovation in Indian agriculture.

History of Okra Cultivation in India

Okra has been cultivated in India for centuries. It is believed to have originated in Africa and was brought to India through trade routes. Over time, Indian farmers and scientists have developed several local and hybrid varieties of okra suited to different regions and seasons.

Traditional varieties were known for their taste and adaptability but had issues with disease resistance and lower yields. As agriculture advanced, scientists focused on developing improved varieties to meet the growing food demand and enhance productivity. One such improved variety is Kashilalima, which is now being promoted in certain parts of India.

Development of Kashilalima Variety

The Kashilalima variety of okra was developed through selective breeding and research to improve certain qualities like pod length, color, yield, and resistance to pests and diseases. It was developed by agricultural scientists and field researchers who identified the need for a high-performing variety suited to local conditions.

The name Kashilalima comes from two parts – "Kashi", which refers to the region around Varanasi (a region known for agricultural research), and "Lalima", which means redness or a reddish shade. This name likely refers to the slightly reddish tint on the pods or stems of this variety, though it remains green overall.

This variety has been promoted in farmer field trials, agricultural exhibitions, and government seed programs. It is becoming increasingly popular due to its favourable characteristics.

Characteristics of Kashilalima Okra

The Kashilalima variety shows several desirable traits that make it a good choice for cultivation. Some of the main features are:

- **Pod Length:** Medium to long pods, which are straight and uniform.
- **Colour:** Bright green pods with slight red tint near the tip in some cases.
- **Plant Growth:** Medium tall plants with strong stems and good branching.
- **Flowering Time:** Early flowering, usually within 35-40 days of sowing.
- **Fruit Bearing:** High fruit setting and frequent harvesting possible.
- **Pest Resistance:** Good resistance to common pests like fruit borers and leaf hoppers.

Yield: High yield potential per acre under proper management.

Advantages of Growing Kashilalima

There are many reasons why farmers may choose to grow Kashilalima over other traditional varieties. Some of the main advantages include:

1. High Yield

The variety has shown higher productivity compared to older types of okra. This means more profit for farmers.

2. Early Maturity

The early maturity helps in early harvesting and also fits well in crop rotation systems.

3. Better Market Demand

The attractive appearance and uniform size of the pods make it suitable for market sale and exports.

4. Pest and Disease Resistance

It requires fewer chemical sprays, which reduces input costs and makes it safer for the environment.

5. Suitable for Different Soils

This variety adapts well to various soil types and weather conditions, especially in North Indian states.

6. Good Taste and Shelf Life

The pods are tender, tasty, and remain fresh for longer, which helps in transportation and storage.

Challenges and Considerations

- **Agronomic Precision Required**

Although Kashilalima performs well, it demands careful adherence to agronomic practices such as proper spacing, nutrient management, and irrigation scheduling to achieve optimal yields.

- **Limited Accessibility to Quality Seeds**

In some rural or remote regions, the availability of certified Kashilalima seeds is still restricted, which hampers widespread adoption.

- **Awareness Deficiency Among Farmers**

Many smallholder farmers remain unaware of this improved variety due to insufficient agricultural extension services and outreach programs.

- **Susceptibility Under Stress Conditions**

While the variety is generally resistant to pests, extreme climatic stress such as drought or unseasonal rains can still affect its productivity.

- **Post-Harvest Handling Sensitivity**

The pods, though tender and market-friendly, require careful handling and timely transportation to preserve freshness and reduce spoilage.

- **Initial Input Costs**

Adoption of improved practices often involves slightly higher initial investment in inputs like quality seeds and fertilizers, which may discourage economically weaker farmers.

Conclusion

The Kashilalima variety of okra is not just a better-yielding and disease-resistant crop — it is also a reflection of how modern agricultural research and techniques are changing the way we grow food. Through selective breeding, scientific trials, and farmer feedback, this variety has been developed to meet the demands of today's farming – where efficiency, sustainability, and quality all matter. It shows how agriculture in India is moving from traditional practices toward more technology-driven and research-based methods. By using improved seeds like Kashilalima, farmers are able to increase production, reduce chemical usage, and earn better incomes. This variety is a small but clear example of how modern science is helping to shape the future of farming and food security in our country.

In conclusion, Kashilalima is not just a vegetable crop it is a symbol of agricultural progress.

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Hi-Tech Farming –How Iot Is Revolutionizing Agriculture

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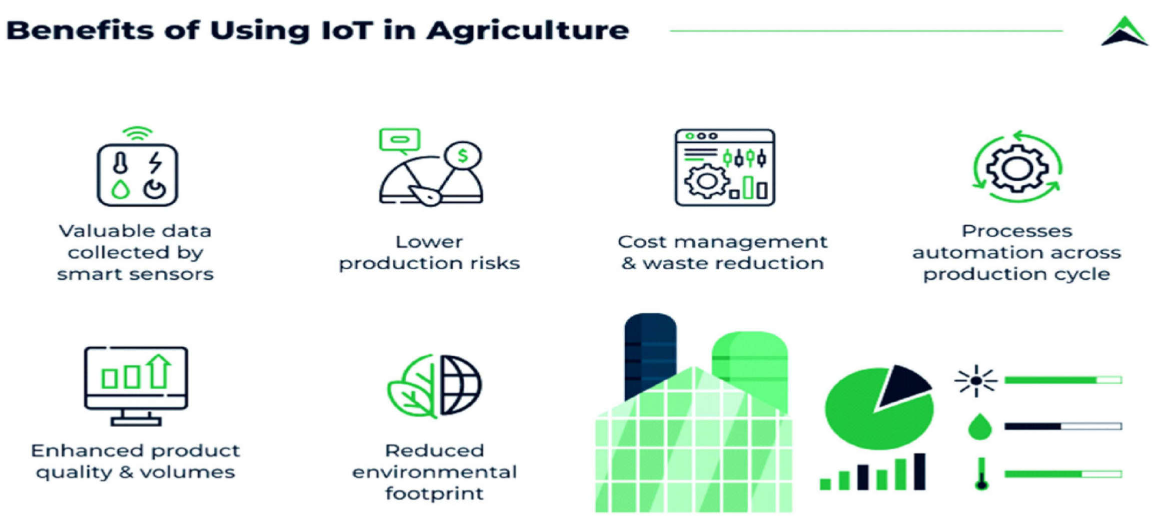
Introduction

Hi-tech agriculture refers to practice agriculture using modern techniques & practices hi- tech farming also known as modern or smart farming includes the use of advanced technologies to improve agricultural productivity, efficiency& sustainability.

The concept aims to use modern technology to increase the quantity and quality of agricultural products. With technological advancement and reach, farmers have access to gps, soil scanning, data management, and internet of things technologies. By precisely measuring variations within a field and adapting the strategy accordingly, farmers can greatly increase the effectiveness of pesticides and fertilizers, and use them more selectively. Similarly, under animal husbandry, using high tech agriculture for smart farming, farmers can better monitor the needs of individual animals and adjust their nutrition correspondingly, thereby preventing disease and enhancing herd health. The hi-tech farming systems have its application in fisheries sector also.



Key aspect of hi-tech farming include

- **Precision Agriculture:** Uses GPS, sensors & data analytics to optimize planting, irrigation & fertilization. Drones and satellites monitor crop health.
- **Hydroponics & Aeroponics:** Soilless farming methods that use nutrient-rich water or mist.

- **Vertical farming:** reduces land use and increases yield. It is growing crops in staked, laid indoor with controlled lighting, temperature, and humidity.
- **Automation & Robotics:** autonomous tractor, robotic and AI-driven monitoring system, reduces labor costs, and improves efficiency.
- **IOT & smart sensor:** sensor tracks soil moisture, weather conditions, and plant growth. Data helps farmers make real-time decisions.
- **Artificial intelligence & big data:** AI predicts weather patterns, pests,& diseases. Machine learning helps optimize farm management.
- **Solar-powered & sustainable farming:** solar panels for irrigation and energy needs, sustainable water management, and eco-friendly techniques.
- **Biotechnology & Gmos:** Genetically modified crops for higher yield, pest resistance & climate adaptability.
- **IOT (Internet of Things):** A network of physical devices embedded with sensors, software, and connectivity to collect and exchange data. These devices communicate with each other over the internet without direct human intervention.

Need for Hi-Tech Agriculture

The world's population predicted to exceed 10 billion people by 2050, high-tech agriculture is crucial to supplying the rising need for food. Because traditional farming is severely hampered by climate change, unpredictable weather, and resource shortages, sophisticated technology is essential to sustainability. Drones, GPS, IOT, and AI are used in precision farming to maximize resource utilization, cut waste, and boost yields. Productivity and resilience are increased by methods like hydroponics, vertical farming, and genetically engineered crops. While smart farming reduces chemical use and incorporates renewable energy, automation through robotics and AI-driven machinery solves the labour crisis. Data analytics aid in risk prediction, guaranteeing improved management, while block chain and artificial intelligence enhance market access and supply chain transparency. All things considered, high-tech agriculture is essential to sustainability, economic stability, and food security.

Benefits of Hi-tech farming

1. **Increased Yield:** Data Driven insights improve crop production.
2. **Resource Efficiency:** Reduces eater, Fertilizer & pesticide waste.
3. **Lower labour Costs:** Automation minimize manual labour.
4. **Sustainability:** Reduces environmental impact and conserves resources.
5. **Climate Resilience:** Smart monitoring helps adapt to changing weather conditions.

Challenges & considerations

- **High initial investment:** Costly tech adoption.
- **Technical knowledge:** Farmer need training to use smart system
- **Data Privacy & Security:** Protecting farm data from cyber threats.
- **Infrastructure Dependency:** Reliable internet supply are necessary.

Future Trends in Hi-Tech Horticulture

A: Smart Greenhouses and Controlled Environment Agriculture (CEA)

- **AI-powered climate control:** Automated regulation of temperature, humidity & light.
- **LED-based precision lighting:** Energy-efficient growth lighting tailored to plant needs.
- **Co2 enrichment:** Optimized carbon dioxide levels for faster plant growth.

B. IOT-Enabled Precision Farming

- **Soil & plant health sensor:** Real-time monitoring of nutrient levels, moisture & disease risk.

- **Automated irrigation:** AI-driven water management to reduce.
- **Smart pest control:** IOT-based detection and biological pest management system.

C. Robotics & Automation

- **Autonomous harvesting robots:** AI-driven machines for picking fruits & vegetables.
- **Automated planting & transplanting:** Drones and robotic arms for precision planting.
- **AI-powered weeding machines:** Eliminating the need for herbicides.

D. Vertical Farming & Hydroponics Expansion

- **Urban Farming:** High-tech indoor farm in cities using vertical stacking
- **Hydroponics, aeroponics & aquaponics:** Soilless farming techniques for higher yield and sustainability.
- **AI-based nutrient optimization:** Automated delivery of customized nutrients

E. Biotechnology & Genetics

- **Microbial Solution:** Smart bio-fertilizer to enhance soil health
- **Artificial Pollination:** Robotic bees & drones assisting in pollination

F. Block Chain & Agri-Tech Data Integration

- **Supply Chain Transparency:** Ensuring food traceability from farm to consumer.
- **Smart Contacts:** AI-based automated transactions between farmers, supplies & market.
- **Predictive analytics:** AI-driven demand forecasting to minimize food waste.

Advantages

- Increased yield high productivity per unit area
- Resource efficiency & sustainability
- Reduced labour dependency
- Climate resilience
- Improved food security & supply chain

Disadvantages

- High initial investment & maintenance costs
- Job losses in traditional farming
- Data privacy & cyber security risks
- Dependence on technology & infrastructure
- Environmental risks

Conclusion

Traditional agriculture is becoming a more profitable, sustainable, and efficient industry thanks to hi-tech farming. Farmers may improve their decision-making, save expenses, and boost productivity by utilising cutting-edge technologies like automation, sensors, drones, and data analytics. It guarantees food security for the expanding population in addition to aiding in the preservation of natural resources. The secret to creating a smart and contemporary agricultural future is to embrace high-tech farming.

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Pioneer Women Agripreneurs of Kolar District of Karnataka

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Introduction

Agriculture is the lifeblood of the economy in most developing countries, and food processing accelerates agricultural produc-tion and promotes sustainable agriculture. Emphasis is laid on the women agri-preneurship by Krishi Vigyan Kendra (KVK) and other government or non- government organisations. Women entre-preneurship has gained momentum in the last three decades with the increase in the number of women enterprises and their substantive contribution to economic growth. Here such example of various agripreneurs of Kolar district in Karnataka state.

Grama Vikas NGO, started processing of tomatoes in Mulbagil taluk of Kolar district, Trained women from 49 families to make dried flakes and pickles of tomatoes. During lockdown farmers could not export their harvest therefore MVN Rao thought of tomato processing in a traditional way. His ideas turned to train farm women to have economic stability during glut peiods. Around 50 farm women were given a skill development training programme on use of solar dryers and other tomato processing equipments and these farm women processed 250 tonnes of tomatoes in the Gram Vikas training unit. They have produced various value added tomato products such as tomato pickles and flakes, powder. These tomato products were purchased by Domino's and McDonald's companies which demanded for tomato flakes and powder. The project hopes that farmwomen up skill themselves and take up this processing as an entrepreneurial activity in upcoming years to increase the shelf life of tomatoes in Kolar district.

Rathnamma, a visionary farm woman from Gundamanttha village in Srnivasa-pura taluk of Kolar district of Karnataka State has established a venture called "Vedik Foods" in a remarkable tale of women empowerment. Her journey from a farm woman to a successful agripreneur is inspiring. She established herself as a pioneer in the field of agripreneurship.

Rathnamma manages a diverse range of farm activities in her two-acre Mango orchard, one-acre millet field, one-acre sericulture plantation, and one acre of curry leaf plantation. The turning point in her success story came when she participated in a five-day vocational on-campus training program on "Women Empowerment through Value Addition, Marketing, and Health Benefits of Minor Millets" at ICAR-KVK, Kolar, during July, 2017 which comes under the jurisdiction of University of Horticultural Sciences, Bagalkot. This vocational training equipped her skills in value addition, product development and market strategies that served as foundation for agripreneurship journey.

Rathnamma adopted the technologies from ICAR-IIHR, Bengaluru and UHS, Bagalkot and started value addition and processing, specialized in pickles of Aonla, Mango, lemon and Tomato, millet processing and masala powder products. She is marketing organic jaggery, chia seeds, and processed products of finger millet like Ragi chakkli, Ragi malt and various kinds of Ready to serve beverages.

She adopted the technology called low-cost ripening chamber technology to ripen mangoes naturally not only from her field but also procure raw Mangoes from FPOs and SHGs, ripens them and sells them in 3kg boxes with a brand name to nearby urban cities and Home delivery service is provided through online marketing.

With financial assistance from ATMA, Department of Agriculture, and Pradhan Mantri Formalization of Micro Food Processing Enterprises (PMFME) under the Ministry of Food Processing Industries (MOFPI), New Delhi, she set up millet processing unit in 2019-20 and a pickle unit in 2022-23.

Presently, she is involved in millet-based value-added products like cleaning and packing of millets, millet malt, millet upma mix, millet dosa mix, Aonla pickle, Mango pickle, lemon sweet pickle, masala powder products, all marketed under brand name, "Vedik foods".

Conclusion

"Women are builders, moulders of nation's destiny."- Rabindra Nath Tagore. Empow-ering women particularly rural women for the task are a challenge. Women in rural sector can play a crucial role to give a boost in the processing of perishable products at small sector. There is an urgent need to support women managed rural production and marketing ventures in horticulture, and post-harvest processing and to provide technology training and input support to women to take advantage of emerging high-value agribusiness sector.

In the words of **APJ Abdul Kalam** "empowering women is a prerequisite for creating a good nation, when women are empowered, society with stability is assured. Empowerment of women is essential as their thoughts and their value systems lead to the development of a good family, good society and ultimately a good nation."

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Speed Breeding- Powerful Tool to Accelerate Crop Research and Breeding

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Introduction

Speed breeding has revolutionized agriculture by accelerating breeding cycles, enhancing precision and contributing to the development of more productive, resilient and sustainable crop varieties. The speed breeding reduces the time required to develop new cutivars of the crop. Rapid generation advancement will open up a wide range of possibilities to assess the phenological responses of genotypes and modify them in favour of human needs. When combined with biotechnological tools like genomic selection and plant tissue culture techniques, it will enable the breeders to produce superior genotypes keeping pace with changing environment and ever-increasing human population.

Speed breeding

It is a controlled-environment crop improvement method that accelerates the plant breeding cycle by manipulating light, temperature, humidity and photoperiod to produce multiple generations per year.

- **2001:** Dr. Lee Hickey and his team at the University of Queensland start developing speed breeding protocols for various crops.
- **2007:** First published results demonstrating the successful application of speed breeding in wheat.
- **2010-2015:** Development of optimized light spectra and intensities for different crop species.
- **2017:** Publication of a landmark paper in Nature Plants, detailing a standardized speed breeding protocol.
- **2018-present:** Integration with other breeding technologies like genomic selection and CRISPR gene editing.

Principles

- **Controlled environment:** Plants are grown in growth chambers or greenhouses with optimized conditions.
- **Light manipulation:** High-intensity, full-spectrum LED lights with enhanced red and blue wavelengths are used.
- **Photoperiod adjustment:** Extended light cycles (e.g., 22 hours light/2 hours dark) are employed to accelerate development.
- **Temperature control:** Temperatures are maintained within optimal ranges to promote rapid growth.
- **Humidity regimes:** Controlled humidity levels support healthy plant development.

Benefits and Applications

Benefits

- **Faster generation advancement**

Produces multiple generations of crops

each year (up to six for wheat and barley), significantly speeding up the breeding process.

- **Accelerated genetic gain**

By shortening the development time, speed breeding enables faster progress toward developing improved varieties.

- **Trait introgression**

Allows for rapid introduction of desirable traits, such as disease resistance and grain quality, into new varieties through backcrossing.

- **Gene bank exploration**

Facilitates rapid evaluation and incorporation of new genetic diversity from gene banks.

- **Integration with modern technologies**

Can be combined with advanced tools like genomic selection, high-throughput phenotyping, and CRISPR-based gene editing.

Applications

- **Wheat and barley research**

A powerful tool for accelerating research and breeding of these important cereal crops.

- **Broad crop improvement:**

Adopted globally for diverse applications, including chickpea, lentil, and oat breeding.

- **Developing climate-resilient crops:**

Helps in developing robust, climate-resilient varieties by evaluating them in simulated future climate conditions.

Today, speed breeding is recognized as a valuable tool in addressing global food security challenges, especially in the face of climate change. Its ability to accelerate crop development cycles has made it an integral part of many breeding programs worldwide.

As we move forward, the technique continues to evolve, with ongoing research focusing on:

- Optimizing protocols for a wider range of crop species
- Reducing energy costs and improving sustainability
- Integrating artificial intelligence for more efficient breeding decisions

The historical journey of speed breeding from a space-focused experiment to a widely adopted agricultural technique underscores its importance in modern plant science and its potential to revolutionize crop improvement strategies for years to come.

Detailed methodology of speed breeding

This chapter provides a comprehensive, step-by-step guide to implementing speed breeding protocols.

Environmental control setup

A. Growth chamber specifications

- **Temperature range:** 22°C ± 3°C
- **Relative humidity:** 60-70%
- **CO_2 concentration:** 400-450 ppm

B. Lighting system

- **Light intensity:** 400-600 μmol m^{-2} s^{-1} (PAR)
- **Photoperiod:** 22 hrs light / 2 hrs dark
- **Light spectrum:** Full spectrum LED with enhanced blue and red wavelengths

C. Plant growth media and nutrition

1 Soil mixture

- 70% peat moss, 20% vermiculite, 10% perlite
- pH adjusted to 6.0-6.5

2 Nutrient solution

- Modified Hoagland's solution
- **EC (Electrical Conductivity):** 1.5-2.0 mS/cm
- **Application:** Daily fertigation or automated drip system

D. Speed breeding protocol

1 Seed preparation

- Surface sterilization with 1% sodium hypochlorite solution
- Pre-germination on moist filter paper for 24-48 hours

2 Planting

- Transfer pre-germinated seeds to growth media
- Maintain plant density at 100-150 plants/ m^2

3 Growth phases management

- Vegetative phase
- Reproductive phase
- Seed maturation

4 Pollination techniques

- **Self-pollinating crops:** Gentle shaking of plants to promote pollen dispersal
- **Cross-pollinating crops:** Manual cross-pollination is needed

5 Seed harvesting

- Monitor seed moisture content (target: 15-20%)
- Hand-harvest mature seeds
- Rapid drying at 35°C for 24-48 hours

E. Data collection and monitoring

Growth parameters

- **Plant height:** Measure every 7 days of crop growth
- **Leaf area:** Use portable leaf area meter at 30, 60 and 90days after sowing
- **Biomass:** Fresh and dry weight at 30, 60 and 90days after sowing
- Days to flowering/ Days to 50% flowering
- Number of fruits
- Number of seeds per fruit
- Total yield per plant/unit area

F. Quality control measures

1 Genetic purity

- Molecular marker analysis should be done for key traits
- Phenotypic screening for off-types

2 Seed quality assessment

- **Germination tests:** Standard and accelerated aging
- **Vigor tests:** Electrical conductivity and tetrazolium chloride test

G. Safety considerations

1 Personal protective equipment

- Eye protection for high-intensity lighting
- Respiratory protection when handling fine soil particles or chemicals

2 Electrical safety

- Regular inspection of electrical components
- Proper grounding of all equipment

3 Chemical safety

- Proper storage and handling of fertilizers and pesticides
- Adherence to local regulations for chemical use and disposal of waste

Conclusion

Speed breeding approaches can double the annual genetic gains as compared to the winter nurseries. It is highly convenient for crossing studies, gene transformation, plant phenotyping, and mutation studies when combined with speed breeding.

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Red Rot of Sugarcane

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Introduction

Sugarcane (*Saccharum* spp.) is a tall, perennial grass grown mainly in tropical and subtropical regions for its high sucrose content stored in stalks. It is crucial to the global sugar industry and used for ethanol, jaggery, and bioenergy. Originating in Southeast Asia and New Guinea, sugarcane is a vital crop in agriculture and culture, with India and Brazil as top producers. It's by-products like bagasse, molasses, and press mud support industries such as paper, alcohol, and fertilizer, promoting sustainability.

Origin and domestication of sugarcane

Sugarcane's origin and domestication trace back to around 8000 BC in the region of New Guinea, where *Saccharum officinarum* was first domesticated by Papuans. From New Guinea, it spread westward to Maritime Southeast Asia and later hybridized with native species like *Saccharum spontaneum*. Another domestication center existed in southern China and Taiwan, where Saccharum sinense was cultivated by Austronesia's.

In India first reported in1901 in Andhra Pradesh and it occurs in most of the sugarcane growing states particularly Bihar, Uttar Pradesh, Madhya Pradesh, Haryana and Punjab.

Human selection improved sugarcane's sucrose content, developing the modern "noble cane." Present-day sugarcane varieties are mainly complex hybrids originating from *S. officinarum*, *S. spontaneum*, and some contribution from *S. sinense* and *S. barberi* (cultivated in India). The crop spread further to India, China, Persia, and eventually the Mediterranean by the early medieval period through trade and conquest.

***Saccharum officinarum*:** The "noble cane," with thick stalks and high sugar, primarily used for commercial sugar.

***Saccharum spontaneum*:** A wild species valued for disease resistance, used in breeding.

***Saccharum robustum*:** Native to Papua New Guinea, with tall, strong stalks, used in hybridization.

***Saccharum barberi*:** Found in northern India, early-maturing and suited to subtropical climates.

Symptoms of Red Rot Disease

- Appear after rainy season when plant growth stop & sugar formation start
- The earliest symptoms are the yellowing and drooping of the upper leaves (near the tip).
- Later the infected stems shrivel.
- The rind looses the bright colour and become wrinkled.
- Cane becomes light weight and can be easily broken.

Effect of Disease

- Induces conversion of sucrose into glucose and alcohol in mature cane sugar plant, due to enzymatic action of pathogen.

- Loss in sucrose content may be as high as 33%.
- Juice of bad odour & not set well on boiling due to conversion of sucrose into glucose.
- Low quality sugar as well as reduction in production.
- Even threatens to destruct the entire crop of the field leading to enormous loss.

Mycelium of Red Rot Disease

- The fungus mycelium is found within and in the intercellular spaces between the pith cells of the host.
- The hyphae constituting the mycelium are thus both inter- and intracellular.
- They are slender, colourless, branched and septate.
- The hyphae produce a large number of chlamydospores in the pith parenchyma.

Disease Cycle

- The inoculum lives from one growing season to the next on the debris of the diseased plants.
- The conidia are short-lived and thus play no role in the perennation of the pathogen.
- The thick-walled chlamydospores and perithecia are considered as probable means of survival.
- Acervuli survive in the active stage for 3 or 4 months in the soil.
- The survival of the mycelium for this limited period is sufficient to provide easy catching of the succeeding crop because sugarcane practically has no dead season.
- The disease is borne in the seed sets which serve as chief means of survival and spread of the disease.
- The diseased sets sown in the soil, sprout into infected shoots which soon produce conidia in the acervuli.
- The conidia serve as a secondary means of infection and spread of the disease.
- They get detached and are dispersed through the agency of wind, water and insects.
- On reaching the surface of the healthy sugarcane plants, they germinate immediately in the moisture retained in the enclosing sheaths.

Control Measures/Disease control

- Field sanitation is an important measure to prevent the build source of primary inoculum.
- It consists in the collection and burning of sugarcane trash in the field.
- Plantation of resistant cultivars, like, Co. 846, Co. 951, Co. 1148, Co. 561, B.0.3, 8.0. 7 and B.O. 32 is most effective method.
- The use of sound and healthy seed sets.
- Long rotation of crops minimizes soil borne infection, Crop rotation 2-3 yrs.
- Setts treatment - Carbendazim @2.5 gm/ lit. of water for 30 minutes.
- Hot water treatment-52° C for 8 hrs., 54° C for 2 hrs.
- Hot air treatment - 54° C for 6 hrs.
- Removal of infected stool.
- Plant the crop when conditions are optimal for rapid germination and maintain proper soil moisture.
- Harvest susceptible cultivars before they have passed the peak of maturity.
- Practice crop rotation, with an alternate crop at the end of the planting and rotooning cycles.

Conclusion

Red rot disease of sugarcane continues to be a serious threat to production of sugarcane all around the globe. Integrated disease management strategy is the best possible option in controlling this disease, rather than relying upon a single method. An understanding of the pathogen is a prerequisite for disease management, which could be accomplished by molecular diagnostic tools for a rapid and precise detection of the pathogen in seed cane. Though limited information is available regarding the true basis of disease resistance, molecular tools are now available to identify suitable markers that can be relied upon for supporting the conventional breeding approaches.

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Next-Gen. GST Reforms: A Boon for Food and Agricultural Sectors

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Introduction

Goods and Services Tax (GST), enacted in 2011 through constitutional amendment, has transformed the Indian economy by unifying existing indirect taxes into an integrated and single indirect tax system. The effect has also positively influenced Indian Agricultural system, having its effects being percolated in the agrarian economy, food market, supply chain management, agricultural input and processing market. The cascading effect is eliminated, stepping towards an 'One Nation-One Tax-One Market' framework. It has reduced multiple tax burdens, unnecessary red-tapism and complex formality and simplified the agribusiness and entrepreneurial environment. The new reformation, known as Next Gen. GST, has put 99 percents of all the products under 5 and 12 percent tax rate and a substantial range of daily commodities are untaxed. The revised framework has rationalised the rate, favoured the consumers, empowered the federal balances, thereby stimulating the growth and augmenting the demand. Mosts of the agricultural inputs like fertilisers, farm machinery, packaging materials and other products like dairy products attract 5 percent GST rate. This would pave the pathway for a stronger micro-economy, sustainable farming, climate-resilient agriculture and robust ground for an inclusive economy.

The agriculture and allied sector, the long-serving backbone of the Indian economy, is once again at the cusp of transformation. This time the dynamo is not driven by seeds, soil or any other farm output, but by the reformation and revision of the country's taxation system. The Government of India has reduced the tax slab and rate on agricultural and food items, which will minimise the farming costs and reduce the economic burden on farmers' shoulders. The new reformation of the Goods and Services Tax (GST) has put 99 percents of all the products under 5 and 12 percent tax (rate) and a substantial range of commodities are untaxed, lying in zero percent tax slab. The recent wave of Next-Generation Goods and Services Tax (Next-Gen. GST) reforms aims to simplify, rationalize and digitize the indirect tax structure, offering a much-needed boost to the food and agricultural value chains.

What is GST

The inauguration of Goods and Services Tax (GST) is one of the most significant fiscal reforms in the country's post-independence history, introduced on 1st July, 2017. It is a comprehensive indirect taxation system that aims to integrate all pre-existing indirect taxes (except few state taxes) to encompass under one single umbrella, avoiding multiple taxes and eliminating the cascading effect, to conglomerate all under a single tax. It replaced a labyrinth of central and state-level taxes, such as Excise duty, Service tax, Value Added Tax (VAT), Entertainment tax, Octroi tax, Entry tax etc., under a unified taxation framework: an 'One Nation-One Tax-One Market' system.

Historic Roadmap towards GST

The idea of Goods and Services Tax (GST) first emerged in India in 2000, when the then central government, under the Prime Minister Atal Bihari Vajpayee, set up an empowered committee to draft its road-map. The committee was headed by Dr. Asim Dasgupta, the reputed, MIT-doctorated economist and the then Finance Minister of West Bengal. In 2002, a committee was constituted to recommend necessary tax reforms under Vijay Kelkar, the then Advisor of Finance Minister and former Executive Director of the IMF. Although mosts of the political parties and governments agreed on this unified taxation system, due to changes in political regimes in center and states, the initiation of GST got delayed.

After years of deliberation, intergovernmental negotiation among the states and centre, legal consultations and constitutional interventions (since such fiscal revision necessitates constitutional amendment), the 122nd Constitution Amendment Bill was tabled in the august parliament in 2014 and passed in 2016. It paved the enactment of 101st Constitution Amendment Act, inserting a new sub-article in the Indian Constitution: Article 279 (A). Assam was the first state to approve the bill (2016) and eventually all states ratified by 2017.

Over the years, it has evolved through several reforms, digital innovations and legal revisions, revising it a dynamic instrument and simplified platform for economic integration and seamless growth. It had been urgently required for a long, especially in sectors like food and agriculture, where value chains span multiple states and the stakeholders were vulnerable to the systemic fragility of the taxation system for multiple payments and obstacles.

7 Pillars from GST Reforms

There are the 7 pillars of the Next-Generation GST Reforms, these are the core areas that the government aims to prioritise for household benefits, and also making the GST system simpler, fairer and more inclusive. They are scripted in a growth-oriented manner to pave the way forbetter financial governance and smooth administration.

Structural Strengthening	♦ Correction of inverted duty structures ♦ Clarification of classifications ♦ Ensuring long-term tax stability for businesses
Rate Rationalisation	♦ Simplifying the tax framework ♦ Two slabs, primarily 5% and 18% ♦ Phasing out the compensation cess
Ease of Compliance	♦ Introduction of the Pre-Filled Returns ♦ Faster Refunds ♦ Simplified Registration Procedure ♦ Reduction of Burdens for Small Taxpayers
Consumer-Centric Approach	♦ Keeping essential and daily-use goods in lower tax brackets ♦ Higher household affordability

Empowering MSMEs & Manufacturing	♦ Reduction of Tax Inefficiencies ♦ Encouraging Local Production ♦ Improved Cash Flow for Small Manufacturers.
Strengthening Federal Governance	♦ Ensuring Stable Revenue Growth for States ♦ Cooperative Decision Making in GST Governance
Stimulating Growth & Demand	♦ Lowering Taxes ♦ Increased Consumer Spending ♦ Boosted Industry Output ♦ Overall Economic Momentum.

Impact on Food Sectors

The major impacts on food sectors are enumerated below:

Impact on Food Processing Machinery

- GST on food processing, packaging and preservation machinery reduced from 18% to 5%.
- This significantly cuts capital costs for small and medium food processors, enhancing technology adoption and productivity.

Encouragement to Processed and Packaged Food Industries

- Certain ready-to-eat and semi-processed foods, including cereals, flour mixes and dehydrated products, have been placed in lower tax brackets (12% to 5%).
- The move is expected to increase affordability and expand the domestically processed food market, under the broader agricultural market.

Boost to Cold Chain and Storage Infrastructure

- Refrigeration units, cold storage systems and related equipment now attract 5% GST, down from 12-18%.
- This facilitates the development of integrated cold chains, reducing post-harvest losses, integrated supply chain management and improved food quality and enhanced shelf life.

Dairy-Related Equipment (Milk Cans and Containers)

- GST on milk cans made of iron, steel or aluminium reduced from 12% to 5%.
- Processing equipment, chilling units, milking machines and testing instruments are now taxed at 5% instead of 12–18%.
- GST on products like ghee, paneer, curd and butter remains moderate (mostly 5%), ensuring affordability and stable consumer demand.
- Simplified compliance and faster refunds under the Next-Gen GST platform improve liquidity for cooperatives like AMUL, MILMA and Mother Dairy.

Support for MSMEs and Start-ups in Food Processing

- Simplified compliance procedures and faster input tax refunds improve working capital flow for micro and small enterprises, along with higher profit margin and simplified formalities.
- These changes enhance the viability of start-ups and rural food processing units, especially under various extension schemes like Prime Minister's Formalisation of Micro Food Processing Enterprises (PMFME) etc.

Consumer-Centric Price Stability

- Lower tax rates on essential food items will reduce the prices, assisting to maintain price stability, particularly in staples like pulses, cereals and edible oils.
- This benefits both consumers and retailers, ensuring steady demand, smooth supply and stronger market balance.

Impact on Agricultural Input Sectors

The agricultural input sector, encompassing fertilizers, seeds, pesticides, farm machinery, electricity and irrigation instruments, forms the backbone of India's farm productivity and rural livelihoods. So the price of these inputs and tools would reduce the production cost in farming, which not only increases farmers' profit margin but also benefits consumers household, reducing their daily expenditure in food items. The 56th GST Council Meeting introduced a series of rate rationalisations and structural corrections to ease the cost pressures on farmers, along to promote indigenous manufacturing.

Fertiliser Raw Materials (Sulphuric Acid, Nitric Acid, Ammonia)

- Fertiliser is the most important input, covering almost 20% of the value of total purchased inputs.
- 53% of the total incremental foodgrain production in 70s was due to fertilisers.
- Fertiliser can increase labour productivity and mitigate the land constraints.
- GST rate reduced from 18% to 5%.
- This significantly lowers input costs for fertiliser manufacturers and ensures more affordable fertiliser prices for farmers.

Bio-pesticides and Micronutrients

- Farm produces worth 2.5 trillion rupees is annually lost for pathogens and weed attacks.
- India's plant protection chemical production is lower than its requirement, so the gap is abridged by imports. 90% of the production is from private sectors.
- GST on bio-pesticides and plant micronutrients reduced from 12% to 5%.
- The revision promotes the use of ecofriendly practices paving the way of organic farming and sustainable agriculture.

Farm Machinery

- Farm Machinery broadly replaced organic labour requirement. Human and animal labour provided 61% of the total farm labour in 1970-1, which has been reduced to 5 to 10% range, underscoring a rapid progress in farm mechanisation, its adoption, financial affordability and credit availability.
- Agricultural and horticultural machinery (tillage, harvesting, threshing, irrigation etc.) is now taxed at 5%, down from 12 and 18%.
- Tractor parts, such as tyres, tubes, hydraulic pumps and gearboxes also shifted to 5% GST.
- Small diesel engines (up to 15 HP), widely used for irrigation and small-scale opera-tions, also now attract 5% GST.
- GST rate on irrigation instruments like drip irrigation nozzles, sprinklers and hand pumps reduced from 12% and 18 % to 5%.
- These changes are expected to collectively make mechanization more affordable and adoptable for small and marginal farmers, eventually increasing the efficiency and augmenting the profit margin. Application of water-efficient technologies will support climate-resilient agriculture.
- Machines used for composting and soil preparation moved from 12% to 5% GST rate.

Structural Simplification and Implementation

- The GST framework is being simplified, with most goods now classified under two main slabs-5% and 18%-to ensure clarity and consistency.
- These reforms collectively aim to reduce input costs, enhance supply chain efficie-ncy, and promote local manufacturing in the agricultural sector.

Conclusion

The next generation of GST reforms is more than a fiscal adjustment; it represents a strategic push toward a smarter, digital, balanced and inclusive agricultural economy. By bridging the gap between policy interventions and on-ground implementation, these reforms can transform the food and farm sectors into engines of growth. So it is an important stepping stone for making India's agricultural landscape future-ready and catalysing rural growth, employment generation and consumer affordability. Encouragement of innovation, supporting the agri-businesses and platformisation of Indian Agriculture for boosting commerce will enable India to compete more effectively in international markets. By integrating digital platforms, cooperative governance and equitable taxation and fiscal revisions, the Next-Gen. GST reforms have the ability to transform India's food and agricultural sectors into resilient engines of economic development and making the country's agricultural landscape globally competitive.

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Water Lilies in Landscaping: How These Elegant Flowers Shape Aquatic Ecosystems

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Introduction

The *Nymphaea* genus, commonly known as water lilies, is universally recognized as the "aristocrat of the water garden pool," highly sought after for its ornamental appeal, characterized by showy, fragrant flowers and expansive, lush foliage. However, the integration of these plants into managed aquatic environments, ranging from small container gardens to extensive wetlands, moves beyond mere aesthetics, positioning water lilies as crucial components of freshwater ecosystems. Many of these species are not only important economic crops but have also held significant cultural symbolism for thousands of years, particularly in Buddhism and Hinduism. This order represents an early branch of angiosperms and plays a crucial role in evolutionary biology, offering valuable insights into the development and diversification of flowering plants. (Zhang *et al*., 2020).

Water Lilies in Landscaping

Water lilies are not only iconic for their beauty but also play a significant role in landscaping, particularly in the design of water features such as ponds, lakes, and fountains. These stunning aquatic plants bring a touch of serenity, vibrancy, and natural elegance to outdoor spaces, while offering a variety of environmental benefits. Whether incorporated into formal gardens, backyard ponds, or natural water gardens, water lilies can transform an ordinary landscape into a tranquil oasis. Here's how water lilies can enhance landscaping projects.

1. Aesthetic appeal and visual impact

One of the primary reasons water lilies are used in landscaping is their breathtaking beauty. Their large, floating leaves and colorful flowers make them a striking focal point in any water feature. Water lilies bloom in a variety of colors, including white, pink, yellow, purple, and blue, allowing for a wide range of design possibilities. Their gentle, floating nature adds a sense of calm and elegance, creating a serene atmosphere that enhances the overall aesthetic of the landscape.

2. Creating a relaxing, tranquil environment

Water features themselves are known for their soothing effects, and when paired with water lilies, they amplify the calming atmosphere. The soft movement of lily pads on the water's surface and the delicate blooms swaying in the breeze create a peaceful, natural sanctuary.

In addition to the visual beauty, the reflective nature of water lilies often seen in their mirrored images on the pond's surface, adds a spiritual and almost mystical quality to the space. Whether you're designing a Zen garden or a tranquil backyard pond, water lilies can become an essential element of your landscape's calming ambiance.

3. Enhancing ecological balance

Beyond their beauty, water lilies contribute significantly to the ecological health of a pond or water garden. They play an important role in maintaining the balance of the aquatic ecosystem in landscaping by:

- **Providing shade:** The large, broad leaves of water lilies create shade on the water's surface, which helps regulate water temperature and prevents the excessive growth of algae. This contributes to maintaining clean and healthy water, which is crucial for sustaining fish, amphibians, and other aquatic organisms.
- **Oxygenation:** Water lilies engage in photosynthesis, absorbing carbon dioxide and releasing oxygen into the water, which is essential for the survival of aquatic life.
- **Preventing erosion:** The roots of water lilies anchor the soil, helping to reduce erosion around the edges of ponds and water gardens, thus stabilizing the aquatic environment.
- **Encouraging biodiversity:** The flowers attract pollinators such as bees and beetles, while the leaves and roots provide shelter for fish, insects, and small amphibians. This helps to create a rich and diverse ecosystem within the landscape.

4. Low-maintenance landscaping option

Water lilies are relatively low-maintenance compared to many other plants. Once established, they require minimal care and can thrive in a variety of water conditions. Here are a few reasons why water lilies are a practical landscaping choice:

- **Resilient growth:** Water lilies are adaptable and can tolerate a range of water conditions, from clear, fresh water to slightly murky ponds. They can also handle a range of climates, though tropical varieties do require warmer temperatures.
- **Seasonal beauty:** Many water lilies bloom from late spring to early fall, providing long-lasting color and beauty throughout the growing season. They go dormant in winter, which makes them a manageable feature that doesn't require year-round attention.
- **Minimal pruning:** Water lilies don't need constant pruning. Occasionally trimming back dead or damaged leaves is all that's necessary to keep them looking their best. Additionally, water lilies self-propagate, so new plants will naturally grow if they are allowed to spread.

5. Types of water lilies for landscaping

When selecting water lilies for landscaping, it's important to consider the specific requirements of your space. There are two main types of water lilies that are commonly used in landscaping:

- **Hardy water lilies:** These are ideal for temperate climates and can survive colder temperatures. They bloom from late spring to early fall and are known for their ability to withstand frost. Hardy water lilies come in a wide range of colors, including white, pink, and red.
- **Tropical water lilies:** Native to warmer climates, tropical water lilies require warmer water temperatures but offer more vibrant colors, including shades of blue, purple, and yellow. These lilies bloom throughout the summer and have a more dramatic, exotic appearance.

6. Water Lily Arrangement and Design Tips

Incorporating water lilies into a landscape design can be done in various ways. Here are some creative ways to integrate water lilies into your garden:

- **Pond design:** Place water lilies in the center of a pond or along the edges to create a natural, organic look. Grouping them with other aquatic plants such as reeds or grasses can enhance their beauty and create a more balanced ecosystem.
- **Container gardens:** For smaller spaces or more controlled environments, water lilies can be grown in containers placed in fountains or decorative water basins. This allows for easier maintenance and positioning while still enjoying the beauty of the lilies.
- **Floating islands:** For a more dramatic effect, consider creating floating islands using water lilies and other aquatic plants. These can be placed in larger ponds or lakes, creating a striking visual element in your landscape.
- **Accent for waterfalls:** Water lilies can also be used as an accent around waterfalls or streams. Their beauty contrasts wonderfully with the moving water, providing a peaceful and visually stunning atmosphere.

7. Considerations when adding water lilies to your landscape

While water lilies are relatively easy to care for, there are a few things to consider when incorporating them into your landscape:

- **Water depth:** Water lilies need a minimum depth of 18 inches to thrive, so ensure your pond or water feature is deep enough for their roots to anchor properly.
- **Sunlight:** Water lilies require full sun for optimal growth, so choose a location that gets at least 6 hours of sunlight each day.
- **Space for growth:** Make sure to allow sufficient space for the lilies to spread, as they will expand over time and may require thinning if overcrowded.

8. Water lily varieties suitable for lily pool

There are over 50 species of water lilies, with the most common ones being *Nymphaea alba* (white water lily), *Nymphaea odorata* (fragrant water lily), and *Nymphaea lotus* (Egyptian blue water lily). These species vary in size, color, and shape but share common characteristics such as floating leaves and large, showy flowers.

Yellow	Nymphaea Chromatella, Nymphaea Helvola, Nymphaea St Louis Gold, Nymphaea Sunrise
White	Nymphaea Gonnere Double White, Nymphaea tetragona Alba
Pink	Nymphaea Fabiola, Nymphaea Firecrest, Nymphaea H.C. Haarstick, Nymphaea Indiana, Nymphaea James Brydon, Nymphaea Joanne Pring, Nymphaea Paul Harriot, Nymphaea Rose Arey
Blue	Nymphaea Tina, Nymphaea Somptuosa, Nymphaea nouchali – cyanea, Nymphaea Daubeniana

Floral development

1. Flowering time

Bloom in the morning and close their flowers in the afternoon. Only a few species bloom at night and close their flowers before the morning. The bloom of *Nymphaea* flowers usually last three to four days, which largely shortens the shelf life of cut flowers.

2. Floral fragrance

Most *Nymphaea* flowers emit fragrant molecules, volatile organic compounds, to attract various kinds of pollinators. A wide variety of small molecules or metabolites are responsible for the diverse floral colors and scents. The *N. colorata* flower releases 11 different volatile molecules, mainly terpenoids, fatty acids, and benzenoids as fragrant molecules, among which methyl decanoate is the major fragrance molecule.

3. Floral colors

Nymphaea species display a variety of floral petal colors, including white, red, purple, yellow, blue, etc. A few *Nymphaea* water lilies, such as *N. colorata, N. caerulea, N. 'King of Siam'*, etc., exhibit beautiful blue petals. Flavonoids are the key elements of floral color. *Nymphaea* species contain a wide variety of flavonoids. For example, a broad sampling of 35 tropical *Nymphaea* cultivars identified 34 flavonoids (Zhu *et al.,* 2012)

The Role of Water Lilies in Aquatic Ecosystems

Water lilies (*Nymphaea*) are well-adapted to life in calm, shallow waters, where they grow from the muddy bottoms and float gracefully on the surface. With their broad, round leaves and colorful blooms, water lilies create unique and vital habitats for various organisms. But beyond their aesthetic value, water lilies contribute to the health of aquatic ecosystems in several important ways:

1. **Providing shade and cooling effects:** The large, floating leaves of water lilies form a natural canopy over the water. This helps regulate water temperature by blocking direct sunlight, keeping the water cooler, and preventing overheating. The shade they provide is crucial for many aquatic creatures, including fish, amphibians, and invertebrates, offering them refuge from predators and creating a stable environment for survival.
2. **Preventing algal blooms:** Water lilies play a key role in maintaining water quality by reducing the growth of algae. Water lilies provide a critical ecological service by suppressing water temperatures by up to 2°C and controlling algae through solar attenuation. Their leaves absorb excess sunlight and reduce the amount of light that reaches the water's surface, which in turn prevents the rapid proliferation of algae. This helps maintain clearer water, which is beneficial for all aquatic life. (Wallace *et al*., 1885)
3. **Oxygenating the water:** While water lilies are primarily rooted in the mud at the bottom of the water, their stems and leaves have the ability to exchange gases with the atmosphere. The process of photosynthesis performed by the leaves not only generates oxygen but also contributes to stabilizing the oxygen levels in the water, which is essential for the health of aquatic organisms like fish and bacteria.
4. **Nutrient cycling:** The roots of water lilies extend deep into the sediment, helping to anchor the plants and reduce sedimentation. As the plants decompose, they release nutrients back into the water, which can be used by other plants and microorganisms. This nutrient cycling process is vital for maintaining the ecological balance of freshwater systems. (Santra *et al.,* 2024)
5. **Biogeochemical Liability:** The aggressive expansion of species such as Nymphaea odorata in organic-rich wetlands poses a direct ecological trade-off, acting as an efficient atmospheric conduit for methane ($CH4$) emissions, thereby linking localized landscape design choices to global climate impact.
6. **The 30–40% Management Threshold:** Effective, sustainable management requires the surface coverage of water lilies to be maintained strictly below 30-40%. This threshold is critical because it simultaneously preserves open water habitat necessary for waterbirds, prevents the plant from activating its competitive heterophylly mechanism, and sustains the light levels required for optimal plant health.

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Scientific Pig Farming

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Introduction

The challenges faced by our country in securing food and nutritional security for the fast-growing population require an integrated approach to livestock farming. Among the various livestock species, piggery is one of the most promising sources of meat production, and pigs are highly efficient feed converters after broilers. Apart from providing meat, pigs also serve as a source of bristles and manure.

Pig farming provides employment opportunities to seasonally employed rural farmers and supplementary income to improve their living standards. The major advantages of pig farming are as follows:

- Pigs have the highest feed conversion efficiency, meaning they produce more live-weight gain from a given quantity of feed than most other meat-producing animals.
- Pigs can utilize a wide variety of feedstuffs such as grains, forages, agricultural by-products and certain household waste materials, converting them into nutritious meat. However, feeding spoiled or unbalanced rations may reduce feed efficiency.
- Pigs are prolific breeders with a short generation interval. A sow can be bred at 8–9 months of age and can farrow twice a year, producing 6–12 piglets per litter.
- Pig farming requires relatively small investment in buildings and equipment.
- Pigs produce a high meat yield, with dressing percentages ranging from 65–80%, which is higher than many other livestock species.
- Pork is nutritious and rich in energy and vitamins such as thiamine, niacin and riboflavin.
- Pig manure is widely used as fertilizer in agricultural fields and fish ponds.
- Pigs store fat efficiently, which is used in industries such as soap, paint and chemical manufacturing.
- Pig farming provides quick returns, as marketable weight can be achieved within 6–8 months.
- There is considerable domestic and export demand for pig products such as pork, bacon, ham, sausages and lard.

Scope for Pig Farming and Its Contribution to the National Economy

According to the Animal Husbandry Department Annual Report (2012–13), the pig population of the country is around 11.1 million. Pork production in India contributes only about 7% of the total animal protein supply and is mainly concentrated in the northeastern region, where pig farming is dominated by backyard and informal-sector farmers.

The 18th Livestock Census (2007) recorded a marginal decline in the total swine population. India's domestic market for processed pork products is small and largely dependent on imports. Although a few companies produce sausages, bacon and ham, the overall pork processing industry remains small.

India has about 3,600 slaughterhouses, but most do not export, and only a few meet international standards. Even these do not typically process pork.

Pig farming continues to support rural poor communities, especially those with limited land and resources who cannot afford improved breeds or scientific housing and feeding. Therefore, there is a strong need for schemes that promote scientific pig breeding and rearing with financial support.

Recognizing this potential, the Government of India established 115 pig-breeding farms across the country to ensure the availability of good-quality foundation stock.

Financial Assistance from Banks / NABARD

Large piggery development projects require detailed project reports. Components such as land development, construction of pig sheds, purchase of breeding stock, procurement of equipment and feed costs up to the point of income generation are considered for bank loans. Additional items may be supported depending on justification and need.

Housing

The normal requirements of covered floor area, open yard area, air space and water for different classes of pigs are:

Class of Animal	Covered floor area per animal (m^2)	Open yard area per animal (m^2)	Air Space (m^2)	Water required for drinking (Liters)
Boar	6.25-7.50	8.8-12.0	11.5	45.5
Farrowing	7.50-9.00	9.8-12.0	11.5	18.22
Weaner	0.96-1.80	8.8-12.0	8.5	3.5-4
Dry Sow	1.80-2.70	1.4-1.8	8.5	4.5-5

Under village conditions, pigs are often housed in simple pens measuring 3 m × 2.4 m or 3 m × 3 m, with an open yard of similar size. Pen walls should be 1.2–1.5 m high and provide protection from wind and rain.

Management

Good management refers to the skillful application of updated knowledge across all farm operations.

Care of the Boar

- Boars reach sexual maturity at 5–8 months. Exotic boars may take slightly longer under Indian conditions.
- Young boars should be used cautiously and introduced through hand-mating in a separate mating pen.
- A yearling boar can manage 10–15 females and mate 7–8 gilts per week.
- Hand-mating is preferred over field-mating or pen-mating.
- New boars must undergo a minimum 30-day isolation period.
- Boars unfamiliar with each other should not be kept together.
- Provide 1.5–2.0 m^2 of dry, draft-free sleeping area.
- Feed 2.0–2.5 kg of a 14% protein ration daily. Avoid overfeeding to prevent obesity and poor libido.
- Increase ration to 2.5 kg/day about 6–8 weeks before the breeding season.

- Conduct fertility checks at least 30 days before use.

Management of Breeding

- Proper feeding of sows and gilts before breeding is essential.
- Flushing (extra feeding) for 7–10 days before mating improves conception.
- After mating, keep animals on limited feed until the last six weeks of pregnancy, after which full feeding should resume.

Fertility of the Herd

- A sow or gilt that fails to show heat, conceive or maintain pregnancy is considered infertile.
- Producing only 1–2 piglets indicate subfertility.
- Embryonic mortality in sows and gilts is around 30%.

Record Maintenance

Maintain accurate, up-to-date breeding records, including heat dates, service dates, litter size and any abnormalities. All pigs must have proper identification tags or markings.

Feeding and Management Practices

- Breeding stock should receive balanced diets containing essential proteins, minerals and vitamins.
- A 16% protein ration is generally adequate for breeding animals.
- Temperature significantly influences feed intake, behaviour and reproduction.
- Embryo survival is higher at 15.6°C (60°F) compared to 32°C (90°F).
- Heat stress reduces fertility and must be avoided.

Age of Breeding Stock

- Gilts should be bred at 12–14 months of age and at a minimum weight of 100 kg.
- Ovulation increases with successive cycles up to the fifth cycle; therefore, breeding should begin around the second or third heat.

Detection of Heat

Successful Swine breeding and high conception rate depends on the ability to identify sow and gilts in heat. The average length of oestrous cycle in pigs is 21 days (range 16-25 days). The oestrous symptoms last for 5 to 7 days beginning with vulvar swelling and vaginal discharge. In true oestrous there is frequent urination, reduced appetite, mounting and standing for service detected by the erection of ears and immobility when normal pressure is applied to the back (Lumbo-Sacral region) or when someone sits on the back.

Time to Breed

- Age at breeding: 8 months
- **Weight:** 100–120 kg
- **Heat duration:** 2–3 days
- Best time to breed: first day of heat for gilts, second day for sows
- **Services:** two matings, 12–14 hours apart
- **Gestation period:** 114 days (range: 109–120 days)

Care of Pregnant Animals

The gestation period of a sow varies from 109 to 120 days, with an average of 114 days. Pregnant animal should be housed in groups in separate enclosures and should not be mixed with new animals to avoid fighting.

About 3m2of dry draft-free housing should be available for each sow. The pregnant animals should be allowed to move about every day in the morning on a free range or a pasture.

Common Diseases of Pigs

A. Bacterial Diseases

- Caused by bacteria found in animals and the environment.
- Examples include anthrax, black quarter and tuberculosis.
- Wounds should be treated promptly to prevent bacterial infection.

B. Viral Diseases

- Viruses must live inside host cells to reproduce.
- They cause around 60% of disease outbreaks.
- Examples: rabies, Newcastle disease, three-day stiff sickness (ephemeral fever).
- Viral diseases are difficult to treat because antivirals may damage host cells.

C. Parasitic Diseases

Common parasites include Ascaris, lice, coccidia, ringworm, mange, hookworm, whipworm and Trichuris.

- Cleanliness reduces parasite load.
- Deworm pregnant sows 10–14 days before farrowing.

D. Nutritional Diseases

- **Protein deficiency:** poor growth
- **Fatty acid deficiency (linoleic acid):** hair loss, scaly dermatitis
- **Calcium/phosphorus deficiency:** rickets, osteomalacia, bone deformities
- **Salt deficiency (NaCl):** reduced growth, abnormal behaviour
- **Iron/Copper deficiency:** anaemia
- **Zinc deficiency:** parakeratosis
- **Vitamin A deficiency:** eye problems
- **Vitamin D deficiency:** rickets, weak bones
- **Vitamin E deficiency:** prolonged clotting time, hemorrhages

Conclusion

Pig farming is a practical and promising component of India's livestock sector when supported with scientific practices. With proper housing, balanced nutrition, planned breeding and timely health care, pigs can achieve high productivity even under modest rural conditions. Their efficient feed conversion, rapid growth and ability to utilize diverse feed resources make them valuable for improving rural livelihoods. Strengthening scientific management practices and improving farmer access to quality breeding stock and technical guidance can transform pig rearing into a sustainable and profitable enterprise that supports household income and contributes to national nutritional security.

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ABOUT THE SOCIETY

Father of Nation Mahatma Gandhi's concept of rural development meant self-reliance, and least dependence on outsiders. India is an agrarian country and about 65% of our population lives in rural areas. But unfortunately, most of us do not have any idea about the extent of poverty and the real conditions of rural India.

With the purpose of serving the agricultural fraternity and farming community the Society for Advancement in Agriculture, Horticulture and Allied Sectors (SAAHAS) was founded in 2020 (under Society Registration Act, 1860). Among multifarious ways of serving farming community we are involved in training of the farmers by organising technology dissemination programmes in villages, guiding them to adopt good agricultural practices involving planned crop management. It helps in reducing farm base losses and motivating them to become farmer level entrepreneur rather than a simple producer. It involves initiating skill based knowledge to the student of agriculture, horticulture and allied sectors to encourage them to serve the farmers in the best possible ways.

SAAHAS calls us to look into the genuine problems of farmers and address those issues for their betterment in the arena of Agriculture, horticulture and allied sectors. Besides agriculture, horticultural crop production has been given a major focus by Govt. of India in future crop diversification, improving livelihood through doubling farmers' income, economic opportunities through export and job opportunities. While good beginning is made, much is to be achieved in different areas in agro-horticulture sector.

Apart from that, SAAHAS helps developing the culture to involve more number of women in farming, processing of crops and value addition thereof for higher returns in terms of total income. SAAHAS eagerly involves with the farmers and agriculture entrepreneur to motivate them for introducing hi-tech farming, which includes growing of high value horticultural crops in hydroponics, aeroponics, polyhouse, net house and greenhouse. The society has geared up its activities to take up the challenges of biotic and abiotic stresses, emerging needs of quality seeds and planting material and reducing cost of production.

There are several government and non-government organisations intended of farmer's welfare; still there is dire need for more involvement and attachment with the farmers. Our society's noble initiative can ensure diminishing of the persistent gap between agro-technocrats, scientists with the needy farmers. We not only ensure that the farmers choose right variety of right crop, better nutrient management through diagnosis recommended system and pest diagnosis but we also help them to sale their produce at premium rates. There is a major issue of chemical residues in food, soil and ecology which is also a big concern of the century. The Society also aims to motivate the farmers either for minimal use of chemical inputs or total adoption of organic farming. Consultancy, training, awareness programs, national and international seminars and symposia and technical services are the prime activities of the SAAHAS.

Society for advancement in Agriculture, Horticulture and Allied Sectors publishes peer reviewed scientific journal, 'Journal of Applied Agriculture and Life Sciences (JAALS)', biannually since January 2020 focusing on articles, research papers and short communications of both basic and applied aspect of original research in all branches of Agriculture, horticulture and other allied sciences. To apprise the scientists and all those who are working in the field of Agriculture, horticulture and allied sectors about recent scientific advancement is the aim of the Journal.