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AGRI-Life

Transfarming agriculture in Bundelkhand through rainbow revolution...

Horticultural innovation for sustainable development and nutritional security

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From Vice Chancellor's Desk...

Horticulture is a ray of hope in a time when the global population is growing at an unprecedented rate and straining our food systems. It provides creative answers to some of the most important problems of our day, such as meeting the nutritional demands of billions of people and maintaining environmental sustainability.

With its diverse crops and cutting-edge technologies, Horticulture is pivotal in driving sustainable development. From vertical farming and precision agriculture to climate-resilient crops and smart irrigation systems, the innovations in this field are transforming how we produce and consume food. By optimizing resource use and minimizing waste, these advancements enhance productivity and contribute to environmental conservation.

Horticulture also contributes significantly to the advancement of nutritional security. Human health depends on the abundance of vitamins, minerals, and antioxidants found in fruits, vegetables, and other horticultural crops. Increasing these products' accessibility and availability can greatly lower malnutrition and enhance community well-being, especially in areas that are already at risk.

Integrating technology, research, and community involvement is at the core of these initiatives. Our universities and research centres must keep acting as hubs for innovation, encouraging collaborations between researchers, decision-makers, and business executives. We may hasten the adoption of sustainable horticultural practices and guarantee that their advantages reach the most marginalized groups by bridging the gap between research and real-world application.

I invite all stakeholders to collaborate, innovate, and invest in the transformative potential of horticulture. Together, we can build a resilient and nutritionally secure world that leaves no one behind.

I extend my heartfelt appreciation to Dr. Anil Kumar, Editor-in-Chief, Dr. Manish Srivastav, Special Editor, and all the contributing authors for their efforts in curating this special issue. I am confident that this edition of Agri-Life will provide readers with valuable insights and foster a deeper understanding of the critical role horticulture plays in our nation's development.

(A. K. Singh)
Vice Chancellor

Editorial

Horticulture innovation for sustainable development and nutritional security

The horticulture sector is moving towards a logarithmic phase and will strive to have immense potential to contribute to the 5-billion-dollar economy of the country. There is a big scope to improve nutrition and well-being, raising income-generating employment opportunities and earning foreign exchange.

Welcome to this edition of Agri Life magazine, where we delve into the transformative world of horticultural innovation and its pivotal role in shaping a sustainable and nutritionally secure future. As we confront the dual challenges of climate change and a rapidly growing global population, horticulture emerges as a beacon of hope, offering innovative solutions that align economic growth with environmental stewardship. There is an urgent need for widened adaptation of modern technologies to sustain horticultural production.

The intersection of technology and traditional horticultural practices is fostering breakthroughs that are revolutionizing the way we grow, harvest, and consume food. From precision agriculture and vertical farming to genome editing and biofortification, the advancements in horticulture are not merely about increasing farm productivity, and mitigating the issues of climate change and stresses but about doing so in ways that conserve resources and enhance the nutritional value of produce. These innovations are paving the way for resilient agricultural systems that can withstand the uncertainties of a changing climate.

Equally significant is the role of horticulture in addressing nutritional security and mitigating malnutrition in the growing population of India. Fruits, vegetables, and other horticultural crops are indispensable for a balanced diet, providing essential vitamins, minerals, and phytonutrients. By integrating innovative practices, we can ensure that these nutrient-rich foods are accessible, affordable, and sustainable for communities worldwide, particularly in regions where malnutrition remains a pressing issue.

In this issue, we bring you compelling stories of researchers, farmers, and entrepreneurs who are at the forefront of this green revolution. From smallholder farmers adopting climate-smart practices to startups leveraging artificial intelligence to optimize crop yields, these narratives showcase the power of collaboration and innovation in transforming challenges into opportunities.

As custodians of the planet, we all have a role to play in promoting sustainable horticulture. It is possible through policy advocacy, supporting local farmers, or adopting sustainable consumption habits, our collective actions can create a ripple effect that ensures the prosperity of both people and the planet.

Let us celebrate the ingenuity and resilience of the horticultural sector while continuing to push the boundaries of what is possible. Together, we can cultivate a world where sustainable development and nutritional security go hand in hand. All the authors and editorial team especially special editor **Dr. Manish Srivastav,** Dean, CoHF Assistant editor and **Dr. Govind Vishwakarma** for their sincere and dedicated effort to bring this important issue revolving around an innovative and sustainable horticulture production system.

(Anil Kumar)
Editor in Chief

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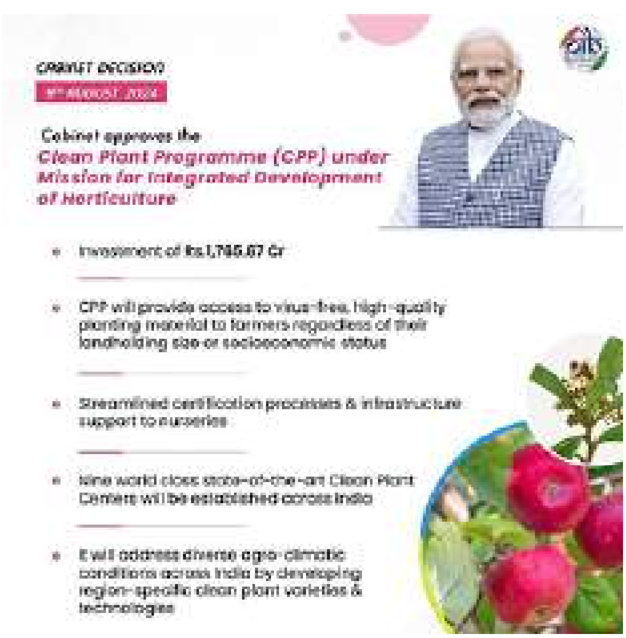
Transforming Horticulture through Clean Plant Programme

Rajiv Kumar[1], Saransh Kumar Gautam[2], Aman Kumar Maurya[2] Ranjit Pal[2] and Govind Vishwakarma[2]

In addition to being the world's second-largest producer of fruits and vegetables, India is also the world's largest producer of Bananas, Mangoes, Papayas, Pomegranates, and other fruits, but it is unable to meet the demands and quality standards of the global market. To address these issues, increase the yield and export of our produce, and obtain virus-free planting material, the Union Cabinet approved the Clean Plant Programme (CPP) under the Mission for Integrated Development of Horticulture (MIDH) in the Entrim budget, 2023. The National Horticulture Board (NHB) is implementing the CPP and MIDH in collaboration with the Indian Council of Agricultural Research (ICAR), with a significant investment of Rs. 1,765.67 crore, and is led by the Ministry of Agriculture and Farmers Welfare (GOI).

Aim of the project

The project intends to increase the availability of certified disease-free planting supplies for horticultural crop farmers throughout India. Long-term, this will boost India's horticultural crops' yields, crop quality, and climate resistance. Almond, Apple, Avocado, Berries, Citrus, Grapes, Guava, Litchi, Mango, Pomegranate, and Walnut are the project's initial target crops. By accrediting private nurseries and testing and certifying their planting materials, the project will increase the propagation of disease-free planting materials under the certification scheme, develop clean plant centers that maintain disease-free foundation materials that will subsequently be propagated by accredited nurseries, and enhance institutional and regulatory frameworks to operationalize the clean plant program for horticulture.



Source: Research Unit, Press Information Bureau, GOI

Components of CPP:

1. **Development of Clean Plant Centers (CPCs):** To serve as hubs for illness diagnosis and treatment, 9 CPCs have been created. These will manage the quarantine of both imported and domestic planting materials and raise mother plants for nurseries. By ensuring that all planting materials marketed in the nation are disease-free, CPCs will enhance the overall well-being and excellence of horticulture crops.

2. **Enhancement of Infrastructure:** There will be the development of large nurseries where clean planting materials may be multiplied. After obtaining the mother plants from CPCs, they would be propagated in nurseries and ultimately given to farmers. Therefore, this will make it official for farmers to get high-quality planting supplies, ensuring that all farmers have access to the greatest resources for crop production.

3. **Regulatory and Certification Processes:** A strong certification system will be put under the Seeds Act of 1966, in place to guarantee accountability and traceability in the manufacturing and distribution of planting material. This will guarantee that high standards are maintained and provide farmers confidence in the caliber of the planting materials they utilize.

Key Benefits of the Clean Plant Programme (CPP)

- **Farmers**
  - **Increased Crop Yields:** By providing virus-free, superior planting material, the CPP aims to boost crop yields.

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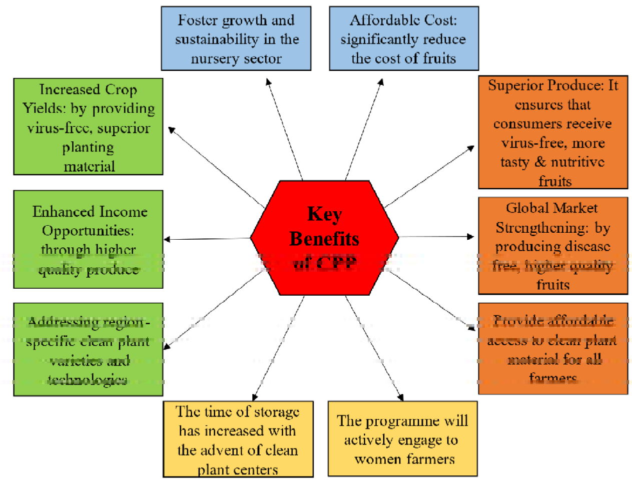
- **Enhanced Income Opportunities:** Higher quality produce will lead to better market prices and income for farmers.

- **Nurseries**
  - **Propagation:** Streamlined certification processes and infrastructure support will help nurseries in efficiently producing clean planting material.
  - **Sustainability:** Improved facilities will foster growth and sustainability in the nursery sector.
- **Consumers**
  - **Superior Produce:** The initiative ensures that consumers receive fruits that are not only virus-free but also enhanced in taste, appearance, and nutritional value.
- **Exports**
  - **Global Market Strengthening:** With higher-quality, disease-free fruits, India will enhance its position as a leading global exporter, thereby expanding market opportunities and increasing its share in the international fruit trade.

Clean Plant Centers (CPCs): Nine Clean Plant Centers have been established for various horticultural crops and linked with the collaboration of different ICAR's institutes.



Source: Research Unit, Press Information Bureau, GOI

Inclusion and Sustainability

Sustainability and inclusion are highly valued in the CPP. It seeks to give all farmers, irrespective of their landholding size or socioeconomic standing, inexpensive access to clean plant material. Additionally, the initiative will aggressively involve women farmers, guaranteeing their involvement in decision-making, training, resource access, and planning. Additionally, by creating clean plant types and technologies adapted to each area, the CPP will handle the various agroclimatic conditions found throughout India.

Sr. no.	CPC Location	Crops covered	Linked ICAR Institute
1.	Pune, Maharashtra	Grapes	National Research Center for Grapes, Pune
2.	Bikaner, Rajasthan	Citrus fruits	Central Institute of Arid Horticulture (CIAH), Bikaner.
3.	Nagpur, Maharashtra	Citrus fruits	Central Citrus Research Institute, Nagpur
4.	Solapur, Maharashtra	Pomegranate	National Research Center on Pomegranate – Solapur
5.	Bengaluru, Karnataka	Mango, Guava, Dragon fruit and Avocado	Indian Institute of Horticultural Research (IIHR), Bengaluru
6.	Srinagar, Jammu and Kashmir	Temperate Fruits Apple, Almond, Walnuts, etc.	Central Institute of Temperate Horticulture (CITH), Srinagar
7.	Mukteshwar, Uttarakhand	Temperate Fruits Apple, Almond, Walnuts, etc.	Regional Station of CITH, Mukteshwar.
8.	East India	Tropical and Subtropical Plant	East India Horticulture Center in West Bengal and Jharkhand
9.	Lucknow	Mango, Guava, Litchi	Central Institute for Subtropical Horticulture (CISH), Lucknow

(Source: PIB, GOI, 2024)

Relevance to Broader Initiatives

Broader programs like Mission LiFE (Lifestyle for Environment) and the One Health philosophy are aligns with the Clean Plant Program. A key step in becoming India a worldwide leader in fruit production and export is the CPP, which encourages sustainable methods and lessens reliance on imported planting materials.

About Mission for Integrated Development of Horticulture (MIDH)

The Mission for Integrated growth of Horticulture (MIDH) was initiated in 2014-15 and will be implemented throughout the 12th five-year plan with the aim of overall growth in the horticulture sector covering fruits, vegetables, root & tuber crops, mushrooms, spices, flowers, medicinal & aromatic plants, coconut, cashew, cocoa and bamboo in the country. MIDH is enforced under Green Revolution - Krishonnati Yojana.

Ongoing Sub-schemes of MIDH:

- 3 Centrally Sponsored Schemes:
  - National Horticulture Mission (NHM)
  - Horticulture Mission for North East & Himalayan States (HMNEH)
  - National Bamboo Mission (NBM)
- 3 Central Sector Schemes:
  - National Horticulture Board (NHB)
  - Coconut Development Board (CDB), Cochin
  - Central Institute for Horticulture (CIH), Nagaland

Major roles of MIDH:

- **Plantation Infrastructure Development:** Producing high-quality seed and planting material by setting up nurseries and tissue culture facilities.
- **Area Expansion:** Establishment of new orchards and gardens for various crops.
- **Rejuvenation:** Rejuvenation of infected, old and unproductive orchard.
- **Promotion of Organic Farming:** Encouraging organic practices, certification and creating vermi-compost facilities.
- **Establishing of Water Resources:** Developing community tanks, on-farm ponds and rain-water harvesting systems.
- **Protected Cultivation:** Setting up poly-houses, greenhouses, shade net houses, and walk-in tunnels, along with micro irrigation facilities.
- **Horticulture Mechanization:** Make availability of power tillers, tractors, and plant protection equipment.
- **Human Resource Development (HRD):** carrying out study tours, exposure visits, farmer training, and awareness campaigns.
- **Post-Harvest Management (PHM) Infrastructure:** Setting up cold storage, pack houses, ripening chambers, refrigerated vehicles, processing units, and food processing facilities in North Eastern States.
- **Marketing Infrastructure:** Creating retail stores, wholesale marketplaces, direct market platforms, rural markets, and stationary and mobile vending carts.

Nutri-Gardens: A Sustainable Model for Food and Nutritional Security

Etalesh Goutam[1*], Bharti[1], Vishal Tripathi[1] and Adesh Kumar[2]

Abstract

In recent years, nutri-gardens, or nutritional gardens, have gained significant attention as a sustainable solution to address food and nutritional security, especially in developing countries like India. These gardens serve as household-level agricultural systems, providing year-round access to a variety of nutritious fruits, vegetables, and medicinal plants, contributing to better health and livelihoods. Nutri-gardens support biodiversity conservation, reduce food miles, and empower women and marginalized communities by fostering self-reliance. As India strives towards self-sufficiency in agriculture, these small-scale yet efficient models play a pivotal role in promoting food security and combatting malnutrition. This article explores the potential of nutri-gardens, focusing on their role in achieving food security, enhancing dietary diversity, and their alignment with India's broader goals under the Clean Plant Program. It also emphasizes the challenges and solutions in implementing nutri-gardens and highlights successful case studies. By adopting nutri-gardens, India can strengthen its horticulture sector, contributing to a healthier, more resilient population.

Keywords: Nutri-Gardens; Food Security; Nutritional Diversity; Sustainable Agriculture; Clean Plant Programme

Introduction

Nutri-gardens, or nutritional gardens, are small-scale agricultural systems designed to provide families with access to fresh, nutritious food while promoting sustainability. The concept of nutri-gardens revolves around growing a diverse range of nutrient-rich crops in small household or community-managed spaces. A typical nutri-garden may consist of vegetables, fruits, herbs, and medicinal plants cultivated within household compounds or community spaces. These gardens are designed to supplement the nutritional needs of families and communities, particularly those in rural or semi-urban areas. Nutri-gardens align with sustainable agriculture principles, offering a way to enhance food security at the grassroots level. These gardens can be essential in addressing food insecurity, improving dietary diversity, and reducing malnutrition, particularly in rural and tribal areas. Food security is not just about producing enough food but ensuring access to nutritious food. In India, the challenge is twofold: producing sufficient quantities of food while improving the quality of diets to combat malnutrition. Nutri-gardens can be an integral solution, enhancing dietary diversity, improving micronutrient intake, and fostering food resilience.

Nutri-Gardens: The Need for a Sustainable Approach

In India, a significant portion of the population suffers from malnutrition, particularly micronutrient deficiencies, which can lead to serious health issues such as anaemia, stunted growth, and weakened immunity. With rising urbanization and shifting dietary patterns, there is a growing reliance on processed foods, leading to poor nutritional outcomes. Nutri-gardens present a sustainable way to counter this, offering households direct access to fresh, organic produce. Several studies have demonstrated the benefits of home gardens in improving dietary diversity. According to the Food and Agriculture Organization (FAO), home gardens can meet up to 30% of a household's food needs, providing

Figure 1: A well-designed nutri-garden promoting food diversity

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essential vitamins, minerals, and fiber. By incorporating indigenous crops, which are often more nutritious and resilient to local conditions, nutri-gardens also contribute to preserving biodiversity .

Key Components of Nutri-Gardens

Crop Diversity: Nutri-gardens are designed to maximize biodiversity, growing a range of nutrient-dense crops such as leafy greens, legumes, and fruits. This diversity ensures year-round availability of essential vitamins and minerals. A balanced nutri-garden includes a mix of leafy greens, root vegetables, legumes, fruits,

Figure 2: A variety of nutrient-dense crops in an established nutri-garden

and medicinal herbs, ensuring that families get a variety of nutrients. For instance, spinach and amaranth are rich in iron, while citrus fruits provide vitamin C. Including legumes like beans enhances protein intake.

Seasonality: Nutri-gardens are designed to produce year-round. Crop planning based on local agro-

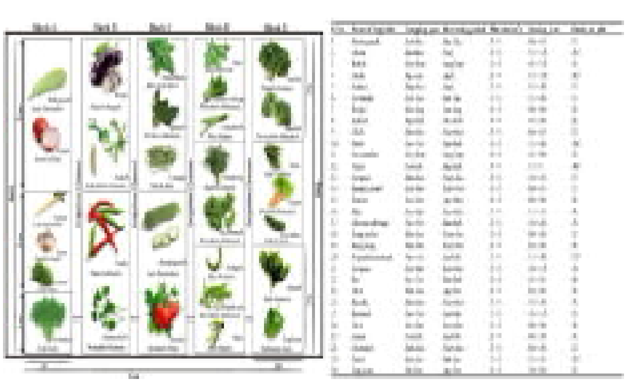

Figure 3: Design and layout of a 6 x 6 square meter vegetable nutrition garden (Jindal & Dhaliwal, 2017)

climatic conditions ensures continuous harvests and nutritional supply. This is especially important in regions that face seasonal food scarcity.

Water and Soil Management: Effective use of resources is central to nutri-gardens. Rainwater harvesting, composting, and organic farming practices help maintain soil fertility and water conservation, reducing the environmental footprint.

Women Empowerment: Nutri-gardens empower women, who often manage household food production. By engaging in small-scale agriculture, women can supplement family incomes and contribute to better health outcomes for their families.

Figure 4: Women cultivating nutri gardens symbolizing empowerment and food security

Case Studies: Success Stories in India

One successful model is found in the state of Chhattisgarh, where the government has promoted kitchen gardens as a means to combat malnutrition in tribal areas. The introduction of indigenous crops such as millets, alongside traditional vegetables, has helped improve dietary diversity (Chhattisgarh State Government Report, 2022). Similarly, in Kerala, the Kudumbashree program encourages women to cultivate nutri-gardens in urban and semi-urban settings, contributing to better nutritional outcomes and economic empowerment. The role of educational institutions and NGOs in promoting nutri-gardens is also noteworthy. Many schools have introduced nutrition gardens as part of their mid-day meal programs, ensuring that children receive balanced diets while also learning sustainable farming practices.

Nutri-Gardens and the Clean Plant Program

The Clean Plant Program (CPP) is a significant initiative by the Indian government aimed at improving the quality and availability of disease-free planting material for horticultural crops. It was implemented by National Horticulture Board (NHB) in association with Indian Council of Agricultural Research (ICAR) and approved in 2024 with a substantial budget of ₹ 1,765.67 crore. This program focuses on enhancing the productivity and quality of fruits such as mangoes, apples, citrus, and more. It involves the establishment of nine Clean Plant Centers (CPCs) across India in the ICAR institutes, equipped with state-of-the-art diagnostic and therapeutic labs. These centers will provide virus-free, high-quality plant material to farmers, which will help increase yields and boost exports. The program is aligned with broader sustainability goals under Mission LiFE (Lifestyle for Environment) and the One Health initiative, promoting eco-friendly agricultural practices. It also focuses on inclusivity, particularly by engaging women farmers in planning and resource management The Clean Plant Program, with its emphasis on horticultural advancements, can further support the nutri-garden initiative by ensuring access to disease-free, high-yielding planting material. By integrating clean planting materials into nutri-gardens, it is possible to improve productivity, reduce crop losses, and ensure the availability of nutrient-dense crops. This will also help safeguard against pest and disease outbreaks, which are a significant challenge in small-scale farming.

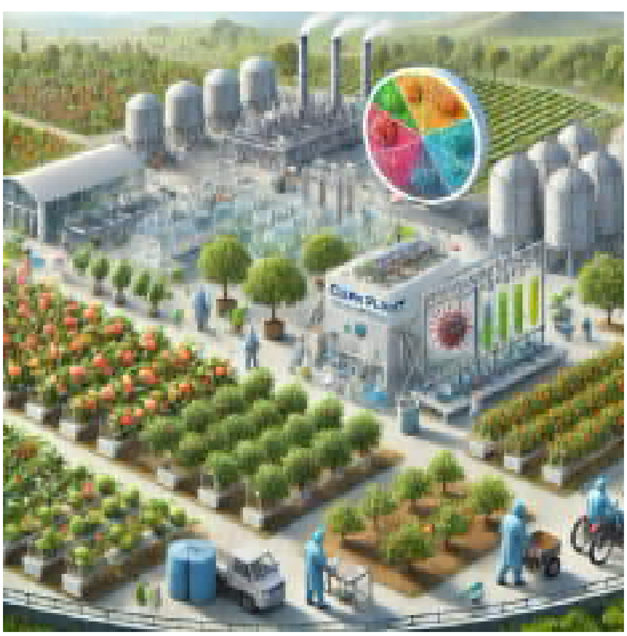

Figure 5: An idealized version of a clean plant program center

Challenges in Implementing Nutri-Gardens

While nutri-gardens present a viable model for food security, they are not without challenges. Limited access to quality seeds, inadequate knowledge of sustainable farming practices, and resource constraints like water availability are key hurdles that need to be addressed. Extension services and government support programs can play a pivotal role in overcoming these challenges by providing training and resources to communities. Moreover, scaling up nutri-gardens requires effective policy interventions. By integrating nutri-gardens into broader agricultural and nutritional policies, India can ensure that this model reaches a larger segment of the population, particularly in underdeveloped regions.

Conclusion

Nutri-gardens offer a practical, sustainable solution to the twin challenges of food and nutritional security. By promoting biodiversity, empowering women, and ensuring a continuous supply of fresh, nutritious produce, these gardens have the potential to transform rural and urban food systems. With the support of the Clean Plant Program and targeted interventions, nutri-gardens can help India move closer to its goal of self-reliance in agriculture. For communities, they represent a powerful tool for improving health and resilience, especially in the face of climate change and resource constraints. The time is ripe to scale up the adoption of nutri-gardens and integrate them into national food security strategies.

Mycorrhizal Associations for Horticultural Crops: Benefits Under Salt Stress Conditions

Priyanka Chandra, Nirmalendu Basak, Parul Sundha, Amresh Chaudhary and Arvind Kumar Rai

Abstract

Nearly all the terrestrial plants have symbiotic associations with arbuscular mycorrhizal fungi (AMF) that increase growth and productivity, particularly in abiotic stress. By enhancing nutrient absorption, including phosphorus, water, and nutrient uptake, AMF enhances plant development. AMF increases plant's ability to withstand abiotic stresses such salt, drought, and heavy metal toxicity. AMF also affects the osmotic adjustment, hormone control, and antioxidant defence mechanisms of plants and enhance photosynthetic efficiency, and plant performance. AMF helps to maintain resilient ecosystems because of its beneficial effects on carbon sequestration, nitrogen cycling, and soil structure. Due to their many functions in enhancing plant health and productivity along with soil health, AMF, have become a convenient option for sustainable agriculture.

Keywords: Symbiotic Associations, Arbuscular Mycorrhizal Fungi, Sustainable Agriculture, Horticultural Crops

Introduction:

One of the main causes of the decline in cultivated soil productivity is soil salinization. The area of salinized soils is surging; however, this trend is hard to pinpoint precisely. In irrigated soils, the issue is particularly pronounced. An estimated 20% (45 million hectares) of arable land contributing almost one-third of the total food grain, can be damaged by salt. An estimated 10 million hectares of agricultural land are lost annually due to salt accumulation worldwide. Climate change, excessive groundwater consumption (particularly near the sea), growing use of low-quality water for irrigation, and widespread irrigation linked to intensive farming and inadequate drainage can all hasten this rate . According to estimates, salinity would impact 50% of the world's arable land by 2050. Many agricultural crops, including the majority of horticultural crops, which have a low tolerance to soil salinity, are less productive when the soil is salinized. Yet, a major global objective is to significantly boost the production and consumption of horticulture crops which are the main source of vegetables, dietary fiber, vitamins, minerals, and folic acid, and play a significant role in human nutrition and health. Salt stress reduces plant nutrition and impact on plant growth. The water-deficit/ osmotic effect under salinity reduces plant water uptake caused by a high concentration of salt in the soil. When the concentration is high enough to damage and reduces crop development. The osmotic effect of salinity causes little genotype variations and causes metabolic changes in the plant that are equivalent to those brought on by water stress-induced "wilting." Furthermore, because of nutritional imbalances and specific-ion toxicities, salt stress inhibits plant growth.

Most terrestrial plants associate with arbuscular mycorrhizal fungus (AMF) in a mutualistic relationship. AMF colonization in roots may increase a plant's resistance to salt stress, and AMF uses a number of strategies to mitigate salinity stress. To mitigate the detrimental consequences of salts, AMF enhances water and nutrient uptake, regulates osmotic balance, modulate antioxidant enzymes to guard against reactive oxygen species (ROS), improves photosynthetic rate, and maintain hormone levels leading to improved plant growth and productivity. Under salt stress, AMF maintains ionic equilibrium and increases the assimilation of plant nutrients including nitrogen, phosphorus, potassium, zinc and copper. Another process linked to AMF-mediated plant salt tolerance is proline buildup. AMF's contribution to proline accumulation in plants, however, some studies found that plants colonized by AMF under stress had higher proline contents, while other studies found reduced proline contents. Reducing salt stress in plants requires an effective reactive oxygen species (ROS) scavenging system. AMF colonization improves the oxidation scavenging system by increasing the synthesis of antioxidant molecules and boosting enzyme activity. Numerous studies have shown that AMF-colonized plants exhibit higher levels of antioxidant enzymes under salt stress than non-colonized plants. Photosynthetic activity is restricted by salinity stress alters stomatal conductance, interferes with photosynthetic machinery,

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and lowers the activity of photosynthetic pigments. To counteract the impacts of salts and boost photosynthesis for growth and development, AMF helps plants maintain their water status, improve photosynthetic pigments, and raise stomatal conductance.

Effect of Salinity on Crop Growth and Nutrition

The assemblage of Na^+ and Cl^- creates obstruction in the uptake of vital components like K^+, Ca^{2+}, and NO_3^-, salt accumulation in the root zone develops osmotic stress and disturbs cell ion homeostasis. Certain ion toxicities result from harmful concentrations of Na^+ and Cl^- and/or boron building up in transpiring leaf tissue. Due to accumulation of toxic ions, damage to chloroplasts and other organelles, inactivation of enzymes, and inhibition of photosynthesis and protein synthesis occurs in plant cell.

The increased concentration of Na^+ and Cl^- in the soil solution due to ion competition (i.e., Na^+/Ca^{2+}, Na^+/K^+, Ca^{2+}/Mg^{2+}, and Cl^-/NO_3^- in plant tissues) may result in nutritional imbalances and deficiencies of several nutrients in plants. When the Na^+/Ca^2 ratio in soil solution is high, calcium deficit conditions are frequently observed. Nevertheless, rather than competitive effects with Na^+, reduced transpiration rate which is linked with lower Ca^{2+} uptake by tomato plants. Salt stress reduces commercial yield of horticultural crops, due to lower productivity and commercially worthless fruits, roots, tubers, and leaves.

Types of Mycorrhizae

AMF are a group of beneficial fungi that forms symbiotic relationship with the roots of most plants. These relationships enhance nutrient and water uptake, providing numerous benefits to both the fungi and the host plants. The main types of mycorrhizae include:

1. **Arbuscular Mycorrhizae:** They penetrate the root cells, forming structures called arbuscules which aids nutrient exchange. They are especially common in agricultural crops.
2. **Ectomycorrhizae:** These fungi envelop the root surface and do not penetrate the root cells. They are often found in woody plants and forest ecosystems.
3. **Ericoid Mycorrhizae:** Associated primarily with Ericaceous plants (like blueberries), these fungi help in nutrient uptake in acidic soils.
4. **Orchid Mycorrhizae:** Critical for the germination and growth of orchids, these fungi form specialized relationships that aid in nutrient absorption during the early life stages of the plant.

Significance in Plant Health and Growth

Mycorrhizal fungi play a crucial role in promoting plant health and growth. Their benefits include:

1. **Enhanced Nutrient Uptake and Plant Growth Yield:** By extending the root system, mycorrhizae increase the surface area available for absorbing nutrients, especially micronutrients, phosphorus, and nitrogen. AMF have been shown in numerous studies to enhance biomass, root development, and crop output in general. AMF inoculation significantly improves the growth of crops like tomatoes, peppers, and cucumbers. Numerous crops have been the subject of extensive research on the impact of AMF on physiological components and plant growth. Under stressful conditions, AMF enhanced plant growth and the uptake of nutrients, including phosphorus and nitrogen. The reason for this growth stimulation is that AMF makes a greater volume of soil accessible by extending the absorbing network beyond of the rhizosphere's nutrient depletion zones. Fungal hyphae can also absorb more nutrients since they are much thinner than roots and can fit through smaller pores. AMF improves plant access to nutrients, especially those whose ionic forms have a low mobility rate or those that are present in low concentration in the soil solution, by increasing the total absorption surface of infected plants through the extension of the root absorbing area. The water transfer rate from exterior hyphae to the root is estimated to be between 0.1 and 0.76 ìL H_2O h^{-1} per hyphal infection point. Additionally, almost 20% of all plant water intake is attributed to AMF, underscoring the significance of the symbiosis in host plant water status. When compared to the control treatment, AMF markedly enhanced *Cucurbita maxima* growth and metabolism, as evidenced by the concentrations of fat, crude protein, crude fiber, and carbohydrates in the inoculated plants' shoot and root systems. Both plant growth and phytochemical components like sugar, protein, phenol, tannin, and flavonoid content were markedly enhanced by inoculation with AMF. Mycorrhizal colonization has been shown to enhance the quality of the fruits as well as plant yield and water usage efficiency in watermelon. Similar outcomes were seen in mycorrhizal

inoculated tomato plants, where fruit sugar, organic acid, and vitamin C concentrations increased. The performance of peach seedlings in potted conditions was shown to be enhanced by AMF, which also markedly increased the concentrations of K, Mg, Fe, and Zn in the leaves and roots, as well as the concentrations of Ca in the leaves and Cu and Mn in the roots.

2. **Improved Water Relations:**

By improving plant nutrition, AMF increases the capacity of plants to osmoregulate through the synthesis of nontoxic compatible solutes, as well as improving plant health, which increases the plants' resistance to environmental stressors. Additionally, by enhancing soil water retention and regulating root hydraulic conductivity, AMF can assist roots absorb more water and lessen oxidative stress brought on by dehydration in their host plants because their mycelia enhance soil structure and moisture properties. Plants colonized by AMF also tend to have higher root hydraulic conductivity and symplastic flow, maybe as a result of increased expression of root aquaporins, which enable plants to absorb more water.

3. **Stress Tolerance:**

Abiotic stressors like drought, salt, and temperature changes are common for horticultural crops. By enhancing water and nutrient intake, mycorrhizal fungi help plants better withstand these challenges, which makes them essential for sustaining productivity under harsh conditions. It is widely acknowledged that AMF, either alone or in combination, can lessen the effects of environmental stresses such as heavy metals, nutrients, temperature, salinity, and drought. For example, plants exposed to both salinity and drought produce more reactive oxygen species, which can be detrimental to plants. Reactive oxygen species (ROS) are detoxified by enzymes such catalase, peroxidase, glutathione reductase, and superoxide dismutase.

Through mechanisms like increased photosynthetic rate, mineral nutrient intake and accumulation, osmoprotectant accumulation, modulation of antioxidant enzyme activity, and modifications to the rhizosphere ecology, AMF symbiosis shields plants from a range of abiotic stressors. It is suggested that various stresses induce similar mechanisms via which AMF-mediated changes in the phytohormone profile, mineral uptake and assimilation, accumulation of suitable osmolytes and secondary metabolites, and up-regulation of the antioxidant system occur.

Application Methods

Mycorrhizas can be applied through several methods:

1. **Soil Inoculation:** Introducing mycorrhizal spores or fungal propagules directly into the soil at planting can establish beneficial associations early in the crop's life.
2. **Seed Coating:** Coating seeds with mycorrhizal inoculants ensures that the fungi are present in the root zone from germination, promoting early root development.
3. **Root Drench:** For established plants, applying a liquid formulation of mycorrhizal fungi directly to the soil or onto the roots can stimulate new mycorrhizal associations.
4. **Compost or Organic Amendments:** Incorporating mycorrhizal fungi into compost or organic matter allows for gradual release and establishment in the soil, promoting long-term benefits.

Conclusion

With numerous advantages AMF significantly improve the yield and health of horticultural crops. These symbiotic connections between fungi and plant roots improve the uptake of nutrients, especially micronutrients, phosphorus, and nitrogen. Mycorrhizae enhance the effectiveness of water and nutrient absorption by expanding the surface area of the root system, which results in healthier plants that are more resilient to environmental challenges. Mycorrhizal fungi also help to improve the aeration and structure of the soil. These fungi improve drainage and water retention by forming soil aggregates, which lowers the chance of erosion and creates an improved growth environment for horticultural crops. Moreover, the use of AMF in horticulture is consistent with the expanding organic and sustainable farming trends. They are a useful ally for growers looking for eco-friendly solutions because of their capacity to enhance soil health and lessen reliance on chemical inputs. In conclusion, AMF have significant and varied positive benefits on horticultural crops. Mycorrhizae provide disease resistance, enhance soil structure, increase nutrient and water absorption, and improve crop health and productivity. Adopting these symbiotic relationships helps to ensure food security and environmental health. Horticulturists can utilize these advantages to develop more robust and fruitful agricultural systems as studies on the intricacies of mycorrhizal interactions continue to advance.

Crop Regulation in Guava

*Thrombo Tayu[1], Dheeraj Patidar and Sukanya Misra

Abstract

Guava Psidium guajava L. is a tropical fruit. However, in India, it is grown in tropical and subtropical regions. Guava bears fruit throughout the year but winter fruit (Mirg Bahar) is most desirable as it is better in all aspects as compared to rainy season fruit (Ambe Bahar). Guava bears fruit on current season lateral shoots. To regulate flowering and fruiting in guava we use various crop regulation methods such as bending of shoots, root pruning and root exposure to sunlight, shoots pruning, water stress and chemicals like NAA, 2,4-D and Urea are used at different concentrations to regulate and deblossoming of flower to obtain fruiting at desirable season. This method puts stress on the guava plant as a result it sheds its leaves and undergoes the temporal dormant stage. New flushes appear in the next season where we can see flowering and fruiting on current season lateral branches.

Keyword: Crop regulation, guava, winter fruit, pruning, deblossoming.

Introduction

Guava is one of the promising tropical fruits of India. The scientific name is *Psidium guajava* L. It belongs to the family myrtaceae and the origin of guava is Tropical America. It is a good source of Vitamin C and has high pectin content which is good for jelly making. It is known as the poor man apple because its nutrient content is like that of an apple. It is a hardy crop grown in a wide range of agro-climate conditions. The optimum temperature ranges from 23-28°C and can tolerate a pH of 4.5 to 8.5. Guava can grow in both tropical and subtropical economically. Guava flowers and fruiting throughout the year Ambe bahar (flowering February-March and fruit ripe in July-August), Mirg Bahar (flowering June-July and fruit ripe in October to December) and Hasth Bahar (Flowering October-November and fruit ripe in February to April). However, in north India rainy season fruit (Ambe Bahar) are low in quality due to insipid taste and high incidence of pests and diseases, rough in nature and low in nutrients while Winter crops fetch higher prices in the market and better in quality than rainy crop. It is recommended that only one crop should be taken annually because bearing throughout the year reduces the quality and quantity of the fruits. Continuous fruiting leads to small-sized berries, a smaller number of fruits per plant and poor nutritive content in the fruit. So, it is advised to have a single crop in a year. To regulate a single crop in a year we go for crop regulation by providing stress to the plant. Stressed plant defoliates their leaves and flowers and a new flush appears.

Crop Regulation

Guava flowers emerge in the newly emerged flush irrespective of season in a year. New flush appears after getting certain stress; hence we observe maximum flowering in summer (rainy season crop) after crop expose to winter in north India. Most of the stored and reserved food material are consume by rainy season crop so we get less and poor fruit quality in winter season if we take three crops in a year. Taking three crops in year is a exhaustive process for the plant, all the nutrients and reserve food from the plant will be exhausted which eventually lead to poor yield and quality of the fruit. Rainy season fruit are poor in quality and during rainy season there is a glut in the market, hence we go for winter season fruit in guava which give good quality and fetch higher price in the market. To get winter season fruit we need to regulate the flowering of guava, stress is provided for few months just before onset of flowering in spring or summer season (Ambe Bahar) guava. Various methods are applied to control and regulation of flowering in guava, this regulation process is known as crop regulation. Crop regulation reduce the consumptive use of pesticides by avoiding fruiting at the peak incidence time of pest and diseases, thus it is a sustainable practice and maintain the environment.

Treatment or Bahar for crop regulation in guava

1. Ambe bahar/rainy crop: Flowering occur in February to March and fruit ripe on July to august month.
2. Mirg Bahar/winter crop: Flowering in plant occur at the month of June to July and fruits ripe in October – December

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3. Hast Bahar/spring crop: flowering in plant occur at the month of October to November and fruit ripe in February to April.

Criteria for selecting bahar in different location are:

1. Availability of irrigation water.
2. Market demand.
3. Incidence and extend of pest and diseases.
4. Climate of the area.
5. Market value of the fruit.
6. Increase the production and quality of fruit.

Method of crop regulation

There is various method for regulation of crop in guava. Regulation of crop for bumper production of lateral bud and new flush to increase the yield and income of the farmer.

Crop Regulation by bending of guava shoots.

Crop bending of guava is common practice in west Bengal for flowering and fruiting in guava. West Bengal prefer winter crops which gives superior quality fruit as compared to rainy crops. Execution of bending is done by defoliation of shoots and these defoliated branches are forced to bend with help of rope tied to the pegs on the soil till the new flushes appear. First bending practice should be done after two years of transplanting. Bending of branches increases the wood tension of branch and decrease the formation of phloem as result it reduce the transportation of food material from branch to other parts of plant and maintain better C:N ratio which result in profuse flowering and fruit setting. Bending treatment influenced the amount of free amino acid, tryptophan, peroxidase, catalase and phenol oxidase activity in bark and leaves. Profuse flowering and fruiting due to stimulation of proline biosynthesis which result due to stress condition created by bending. However, bending in month of July to September promote more vegetative growth rather than reproductive growth due to abundance of moisture of soil, temperature, relative humidity and availability of rainfall. Thus, failed to produce flowering bud and promote vegetative growth. Bending in the month of winter season (October to February) shows high percentage of flowering, fruit setting and good quality of fruit.

Crop regulation by water stress.

Mirg Bahar is commonly practice in northern plains of India where plant is exposed to stress conditions to obtain fruit in winter. To create stress in plant withholding of irrigation from month of February to May is practice. During these months frequency of irrigation is reduce, less frequent irrigation is given to keep plant alive and avoid complete wilting of the plant. The tree starts shedding their leaves during summer (April-May), thus conserving food material reserve for winter crops. Withholding of irrigation in addition to root pruning show better result than withholding water alone in heavier soil, while in lighter soil withholding irrigation is enough for crop regulation. Withholding of irrigation along with root pruning is successful practice in Maharashtra region. After withholding and root exposure of guava plant for few months, manure is applied around the basin and irrigated frequently to restart the normal growth of the plant. Mirg bahar plant start their vegetive growth and new flushes appears on rainy season which gives fruit in winter season.

Crop regulation by root pruning and root exposure.

The feeder roots of guava trees lie at the depth of 15-25cm. The main root is deep rooted but the small root hairs which act as feeder roots present at shallow depth. To create stress in plant we should remove this root hair along with withholding of irrigation. To remove the root hair from root we need to dig up at the depth of 10 -15cm around 50-60cm radius (drip line) from the tree trunk and remove the soil to expose it to sunlight. Exposure of root and pruning of root can suppress rainy season fruit to get good quality winter fruit. While removing feeder root we should be careful and should not damage the main root of the tree. Root pruning is not suggested in light texture and shallow soil where withholding of water is enough for crop regulation. This practice is commonly followed in heavy texture soil along with withholding of water. One month before commencement of flowering, the pruned and expose root are covered with soil mix with FYM and immediate irrigation is given. Root pruning causes shedding of leaves and forced plant to undergo dormant. Root pruning is not recommended for Uttar Pradesh region as it impose moisture stress and cessation of growth of the plant.

Crop regulation by shoot pruning

Fruiting of guava occur on current season lateral shoots as a result it is highly irregular in bearing fruit in a year or season. Bearing of fruits depend on the shoot's growth and these shoots depend on environment factor that affect new flush development. Pruning is necessary to maintain good ratio between vegetative and reproductive parts and effect the physiology of the plant. Pruning regulates the sink preference for allocation of photosynthates and maintain proper density of the plant. Light pruning increases the productive branches and number of fruits per branch. To encourage winter season fruit, we need to prune the current season flush growth of spring season to avoid rainy season fruit. The intensity of pruning range between 25%-75%. However, optimum pruning percent for maximum quality and quantity production is 50%. The length of pruning varies from 10-60cm from the tips.

Crop regulation by chemical method.

Crop regulation by physically and manually is very tedious job, time consuming and less cost-effective method. Chemical deblossoming is an easy method. To regulate flowering and obtaining winter fruit in guava we can use certain chemicals like NAA, 2 4-D carbaryl, ethrel, potassium iodide and urea found effective in deblossoming in guava. These treatment does not affect the tree and quality of fruit found that spray of urea 10% or 15% at the time of flowering in spring show effective deblossoming in rainy season guava crop and promote fruiting in winter season. Spray of 15% urea at 10 days interval found effective in deblossoming in 'Sardar' and 'Allahabad Safeda' guava. 0.5% of potassium iodide followed 20% of urea found effective. Application of Naphthalene Acetic Acid (NAA) at 250 ppm as a spray result in deblossoming of flower of rainy season fruit and increasing the yield and quality of winter crop. 60ppm of 2,4-D was found most effective in increasing the yield and quality of winter fruit in Allahabad Safeda as compared to urea and NAA.

Conclusion

Guava is an important fruit crop in India due to it nutritional quality and cheap price as compared to other fruit crops. Guava can fruit throughout the year. However, winter fruit is preferred in most of the northern plains because winter crop is superior in quality, less prone to disease and fetch higher price in the market. Guava plants produce a greater number of flower and fruit in rainy season fruit, however, the quality is low and insipid in taste. To obtain fruit in winter we need to regulate flowering. Regulation of crop can be done by various method such as water stress, root pruning and root exposure, shoot pruning, bending and chemical method. Except chemical method, all methods are tedious, time-consuming and labour-intensive methods. Chemicals like NAA, 2,4-D and Urea show better result in the deblossoming of flowers to encourage fruiting at desirable time.

Nutri-Garden: A sustainable model for food and nutritional security

Nida Manzoor, Sumati Narayan, Ajaz Ahmed Malik and Nindiya Bharti

Abstract

There is widespread poverty, food insecurity and under-nutrition in India. The household-level data on calorie intake indicates that the average calorie consumption among the population in India has been declining over the last twenty years. Considering the parameters of economic and social development, the undernourished population of India is continually on the rise and the situation has worsened with the spiralling inflation witnessed with regard to food prices. The nexus between food security and climate change is further aggravated by poverty, which needs to be challenged by enhancing the resilience of the food production system. To promote family farming. Nutri gardens not only improve the nutritional status of rural households, but they also provide a small and consistent source of income. The main objective of Nutri-gardens is to promote dietary diversification to improve the nutritional status of the farm families to make available vegetables and fruits throughout the year. Nutri-gardens are an advanced form of kitchen garden and it act as an easy and effective tool to combat malnutrition and nutritional disorders in both rural and urban families. Nutri gardens also promote employment opportunities for the youths and women.

Keywords: Nutri-gardens, undernourished population, food security, malnutrition

Introduction

With a future world population of 9.6 billion by 2050, rising urbanization, decreasing arable land, and weather extremes due to climate change, global agriculture is under pressure. As a result, the quality of life has suffered due to various economic, social and cultural causes and also lack of dietary diversification for example micronutrient deficiency is common and causes impaired physical and cognitive development. India's undernourished population is continually on the rise and the situation has worsened with the spiralling inflation witnessed with regard to food prices. Therefore, achieving food and nutritional security has been one of the prime focuses for developing nations like India. The adequate intake of vegetables can help combat malnutrition by providing essential vitamins and minerals required for children's development and overall good health. India's present vegetable production level permits per capita consumption of only 120 g, against the recommended daily intake 300 g per day. A well-planned Nutri-garden can fulfil a family's fruit and vegetable needs throughout the year. This sustainable, low-cost approach plays a crucial role in reducing malnutrition, raises awareness about vegetable cultivation, increasing productive work hours and achieving food, nutritional and economic security. Incorporating nutrient-dense plants, including at least one perennial tree and three types of leafy greens, provides an ideal source for enhancing green vegetable consumption in the diet. Additionally, roots, tubers and other vegetables can also be cultivated in such nutrient gardens

Though India is the second largest producer of fruits and vegetables, their consumption is insufficient. Now-a-days people are more health conscious and good food shall be our medicine. Increased consumption of fruits and vegetables is one of the easiest and cheapest ways of enhancing health. Asia with diverse climatic condition and an array of fruits and vegetables are cultivated in different parts of the continents. Many underutilized fruits and vegetables, which are rich sources of phytochemicals are to be cultivated in Nutri-gardens. There is an increasing demand for indigenous, location specific underutilized vegetables and fruits throughout the world.

The concept of home and kitchen garden is one of the oldest forms of gardening when human first mastered the art of cultivating land. They lived in the tribes of colonies and were nomadic, a tribe would cultivate a piece of land until it was no longer fertile, then move on to some other area. But today, the Nutri-garden is an advanced form of Kitchen Garden, where vegetables are grown alongside fruits, herbs, spices and other beneficial plants such as medicinal herbs, providing a supplemental source of food and income. For small and marginal farmers, produce from Nutri-garden can make a significant contribution to the family diet and offer numerous other benefits especially for women, including

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the economic self-sufficiency. Consequently, Nutri-gardens have been introduced as they offer a more direct pass from food production to improve nutritional outcomes. Nutri-garden has not only improved the consumption percentage of different food groups but also the diversification of vegetables and fruits has improved the nutrient consumption status of the family. Thus, Nutri gardens could help in achieving sustainable development goals in food and nutritional security.

Selection criteria for vegetable crops:

1. Choose vegetables that are favoured by family members, especially Women and children.
2. Variety of vegetables should be chosen to ensure wide range of vegetables each offering unique benefits
3. Select varieties that are resistant to common pest and diseases.
4. Ensure that high quality planting material like seed cutting, seedlings and tubers of selected vegetables are readily available and accessible locally.
5. Also incorporate both improved and traditional varieties to prevent agro-biodiversity and cultural heritage.
6. Introduce and test new nutritious crop species or varieties to gauge their accessibility acceptability, which can also generate enthusiasm for gardening

Perennial plant should be placed on one side of garden to prevent them from shedding other crops, competing for nutrients with annual vegetables or interfering with proper crop rotation. Once established, these perineal vegetables require a minimal care and steady supply of produce year after year, with little additional cost or effort. Vegetables which lose their quality and freshness rapidly after harvest, such as spinach, amaranth, fenugreek, mint, and radish, should be given priority in the garden. The garden should be located on the eastern or southern side of the house to have maximum sunlight and near a water source if possible

Table 2: Components of a nutrition garden

S.No.	Components	Characteristics
1.	Perennial crops	Perennial fruits and vegetables are located at one end of the Nutri-garden so that they will not interfere with the intercultural operations of other crops and will not shade them, since grafts or dwarf varieties occupy lesser space, those are preferred in a nutrition garden.
2.	Annual plants plots	Then the remaining area must be divided into equal plots for raising annual vegetables. For continuous and steady availability of vegetables throughout theyear, crop rotation has to be followed in each plot to prevent pest and disease incidence.
3.	Borders	Dwarf and bushy vegetables are grown on the borders of garden plots.
4.	Fences	Fences can be made up of barbed wire to protect the crop from stray animals. Live fence is made up of plants like chekkurmanis or other tailing vegetables like coccinea, winged bean and dolichos bean.
5.	Beehive	A bee hive is essential to ensure pollination in cross -pollinated vegetables, especially in cucurbits. The farmer will ge t honey as an additional income.

Implementation of Nutri-Garden

Site Selection: Refers to a situation in which there is no obstruction to the flow of sunlight, water and no hindrance created by poor soils. Small-sized spaces including balconies or rooftops can also be utilized and engaged in container gardening.

Crop Selection: The crop which is to be selected must be enriched with protein or other nutrients such as leafy vegetables, tomatoes, beans, carrots, herbs, etc. The local landraces or varieties may be more preferable than improved ones since they are easier and more resilient to grow.

Table 1: The following lists of vegetables are grown in distinct seasons in northern parts of India.

Winter (October-February)	Summer (March-June)	Rainy season (July-October)
Potato, cauliflower, cabbage, knol -khol, broccoli, carrots, Brussels sprouts, kale, radish, turnip, carrot, beetroot, onion, garlic, leek, broad bean, lettuce, parsley, celery, peas, spinach, fenugreek, mustard, coriander, fennel	Okra, cowpea, cluster bean, tomato, eggplant, chilli, capsicum, garden bean, pumpkin, bitter gourd, bottle gourd, luffa, cucumber, melons, amaranth, Colocasia, asparagus	Okra, cowpea, cluster bean, chill), eggplant, tomato, capsicum, cucurbit vegetables (except melons), radish, turnip, carrots, sweet potato, Colocasia.

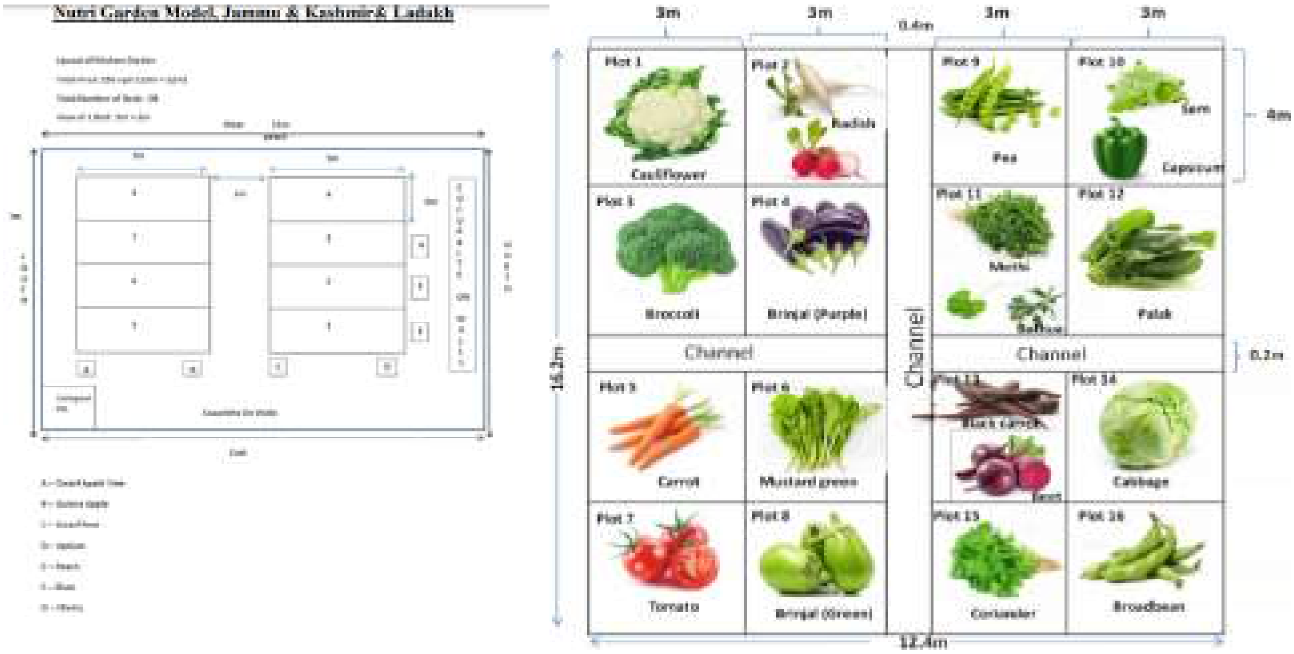

Fig a, b: Layout of Nutri-Garden

Soil Management: Such additions may include compost, organic manure like FYM, vermicompost etc and other soil improving materials in order to maintain the health of the soil. Crop rotation and intercropping systems are also some of the steps that can be followed to avoid soil depletion.

Water Management: water saving irrigation methods including the drip irrigation or even clay pot irrigation practices that are in need of little moisture must be utilized.

Community Involvement: Involving the community by letting them be part of the planning, planting and maintenance of the Nutri-Gardens will also make them adopt them.

Conclusion

Eating more vegetables improves health, reduces obesity and cuts down on the risk of chronic diseases such as diabetes and cancer. Having a Nutri-garden helps save on grocery bills when economic times are tough. Gardening with vegetables can be fun and provide delicious and highly nutritious fresh food. Nutri gardens represent an especially useful strategy for promoting sustainable livelihood objectives of the poor, including secure access to land and water, improved financial security, improved leverage in wage bargaining, improved nutrition, and improved social status as well. Nutrition gardens can help in the diversification of agriculture and food security of the people the easy availability of vegetables and pulses increases its consumption, enriches the soil and helps in the reduction of pesticide use. Marketing is also not a problem here as produce from a 1500m2 area can be consumed within a family of 8 members. So, in the present scenario of agriculture, the nutrition garden concept needs more attention of policymakers, researchers, extension workers and farmers.

Plant Quarantine Strategies to Sustain Horticulture Production

Diksha Banal[1], Astha[2] and Nindiya Bharti[1]

Abstract

The term "quarantine," derived from the Latin word "Quarantum" (meaning forty days), holds immense significance in the context of global trade. As import and export of plant commodities escalate, so does the risk of moving insect pests and diseases across borders. India, recognizing this challenge, enacted the Plant Quarantine Order (PQ Order) in 2003, harmonizing its regulations with international standards set by the International Plant Protection Convention (IPPC) and the World Trade Organization (WTO). The PQ Order underscores the pivotal role of **plant quarantine** in preventing the introduction and spread of harmful pests, diseases, and weeds. By enforcing strict measures at national and international levels, quarantine agencies aim to protect domestic agriculture and native flora while ensuring safe global trade. The goal: sustain horticulture production and secure our food supply.

Keywords: plant quarantine, global trade, pest prevention, horticulture production

Introduction

In an interconnected world of global trade, the movement of plant commodities has surged, offering immense opportunities but also carrying risks. Exotic pests and diseases, once confined to their native habitats, now pose threats to crops worldwide. India, recognizing this challenge, enacted the Plant Quarantine Order (PQ Order) in 2003, aligning its regulatory framework with internationa standards. The PQ Order underscores the pivotal role of **plant quarantine** in preventing the introduction and spread of harmful pests, diseases, and weeds. As horticulture plays a vital role in food production, economic growth, and environmental sustainability, safeguarding horticultural crops becomes paramount. Effective plant quarantine strategies are essential for maintaining healthy plant populations, ensuring food security, and supporting international trade. In this context, let's explore the key strategies and significance of plant quarantine in sustaining horticulture production. The term "quarantine," derived from the French word meaning "40-day period," refers to a legal restriction aimed at preventing the introduction and establishment of plant diseases or insect pests in areas where they do not currently exist. In India, plant quarantine is regulated under the Destructive Insects and Pests Act of 1914. Internationally, Pest Risk Analysis (PRA) serves as a crucial defensive method in managing the risk associated with the movement of pests and diseases.

Objectives of Plant Quarantite

1. **Tracing and Identification of Quarantine Pests**:
   - Detect and identify pests that pose a risk to plant health.
   - Implement control measures to prevent their spread.
2. **Pest Risk Analysis and Quarantine Conditions**:
   - Evaluate the risk associated with imported and transit plant shipments.
   - Determine appropriate quarantine conditions to mitigate risks.
3. **Inspection, Sampling, and Testing**:
   - Rigorous inspections at borders and ports.
   - Collect samples for testing to ensure compliance with phytosanitary standards.
4. **Post-Entry Quarantine Regulations**:
   - Supervise and enforce regulations on plants after entry.
   - Monitor and manage potential risks.
5. **Phytosanitary Certification for Export**:
   - Issue certificates confirming compliance with export requirements.
   - Ensure safe movement of plant consignments across borders.

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History of Plant Quarantite in India

Plant quarantine measures in India have evolved over time to address the challenges posed by global trade and the need to safeguard agriculture. Here are key milestones:

1. **Early Initiatives**:
   - In 1906, the Indian government ordered compulsory fumigation of imported cotton bales to prevent the introduction of the Mexican cotton boll weevil (Antonymous grandis).
   - The Destructive Insects and Pests Act (DIP Act) was established on February 3, 1914, laying the foundation for plant quarantine regulations.
2. **Growth and Adaptation**:
   - Over the years, the DIP Act underwent revisions and amendments to meet changing requirements, especially in the context of liberalized trade under the World Trade Organization (WTO).
   - The Directorate of Plant Protection, Quarantine, and Storage (DPPQS) was established in 1946, with plant quarantine activities commencing at Bombay seaport.
3. **Key Developments**:
   - India's first plant quarantine and fumigation station was formally inaugurated on December 25, 1951.
   - The National Bureau of Plant Genetic Resources (NBPGR) was created in August 1976.
   - The Division of Plant Quarantine, with sections for Entomology, Plant Pathology, and Nematology, was established in 1978.
   - In October 1988, the Plants, Fruits, and Seeds (Regulation of Import into India) Order, 1989 (popularly known as the PFS order) came into force.
4. **Ongoing Review and Adaptation**:
   - Regular review and amendments are essential to align plant quarantine practices with global trade dynamics and emerging challenges.

Plant Quarantite: Safeguarding Agriculture

Over time, introduced pests and pathogens have wreaked havoc on crops worldwide, leading to famines and economic losses. Here are some historical examples:

1. **Ireland's Potato Blight (1845)**:
   - The late blight pathogen (*Phytophthora infestans*) was inadvertently introduced to Ireland from Central America.
   - This devastating event caused almost total failure of the potato crop, resulting in the infamous Irish famine.
2. **Grapevine Industry in France**:
   - Powdery mildew (*Uncinula necator*), phylloxera, and downy mildew (*Plasmopara viticola*) were introduced from America.
   - These pests virtually annihilated the grapevine industry in France during the mid-19th century.
3. **American Chestnut Blight**:
   - Chestnut blight (*Endothia parasitica*) arrived in the U.S. around 1906.
   - Within 25 years, American chestnut trees were almost exterminated, causing immense economic losses.
4. **Sri Lanka's Coffee Leaf Rust (1868)**:
   - Coffee leaf rust (*Hemileia vastatrix*) devastated coffee plantations, leading to the replacement of coffee with tea.

5. Coconut Leaf Miner in India (Late 1960s):

Pests and diseases which have been introduced worldwide

S. No.	Pests	Introduced in	Introduced from	Year
1	Late blight of potato (*Phytophthora infestans*)	Europe	S. America	1830
2	Powdery mildew of grape (*Uncinula necator*)	England	USA	1845
3	Grape Phylloxera (*Phylloxera vitifoliae*)	France	USA	1845
4	Downy mildew of grape (*Plasmopara viticola*)	France	USA	1878
5	Golden nematode of potato (*Heterodera rostochinensis*)	USA, Mexico	Europe	1881
6	Mexican boll weevil (*Anthonomus grandis*)	USA	Mexico & C-America	1892
7	Chestnut blight (*Cryphonectria parasitica*)	USA	Asia	1904
8	Citrus canker (*X. citri*)	USA	Asia	1907
9	Blister rust of pine (*Cronartium ribicola*)	USA	Europe	1910
10	Fire blight of apple (*Erwinia amylovora*)	New Zealand	N-America	1919
11	Onion smut (*Urocystis cepulae*)	Switzerland	France	1924
12	Dutuch elm (*Ceratostomella ulmi*)	USA	Holland	1928-30
13	Bacterial canker of tomato (*Cornebacterium michiganense*)	UK	USA	1942
14	Coffee rust (*Hemilia vastatrix*)	Brazil	Africa and Asia	1970

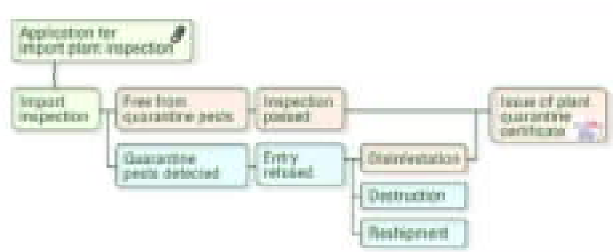
The introduced coconut leaf miner (*Promecotheca cumingi*) caused widespread damage to coconut plantations.

Pests and diseases introduced in India from other countries

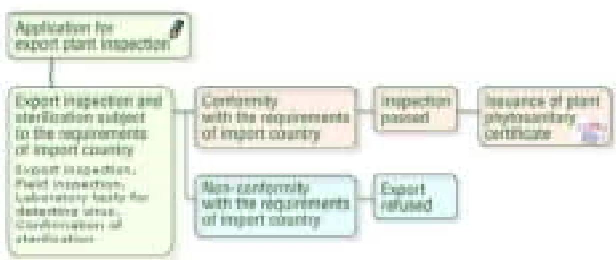
S. No.	Pests	Native Place	Year of Introduction
1	Coffee rust (*Hemileia vastatrix*)	Srilanka	1879
2	Late blight of potato (*Phytophthora infestans*)	England	1883
3	Rust of chrysanthemum (*Puccinia carthami*)	Japan/Europe	1904
4	Flag smut of wheat (*Urocystis tritici*)	Australia	1906
5	Downy mildew of grape (*Plasmopara viticola*)	Europe	1910
6	Downy mildew of maize (*Sclerophthora*)	Java	1912
7	Downy mildew of cucurbits (*P. cubensis*)	Srilanka	1918
8	Black rot of crucifers (*Xanthomonas compestris*)	Java	1929
9	Foot rot of Rice (*Fusarium moniliforme*)	South East Asia	1930
10	Leaf spot of sorghum	South Africa	1934
11	Powdery mildew of rubber (*Oidium heveae*)	Malaya	1938
12	Blank Shank of Tobacco	Holland	1938
13	Fire blight of pear	England	1940
14	Crown gall of Aple/pear (*A. tumefaciens*)	England	1940
15	Bunchy top virus	Srilanka	1940
16	Canker of apple (*Sphaeropsis* spp.)	Australia	1943
17	Wart of potato (*Synchytrium endobioticum*)	Netherlands	1953
18	Bacterial blight of paddy (*X. oryzae*)	Philippine	1959
19	Golden Nematode of potato	Europe	1961
20	San Jose scale of apple	Italy	1900
21	Wooly aphid of apple	Australia	1928
22	Sunflower downy mildew (*Plasmopara halstedii*)	Australia	1985

India's robust plant quarantine system serves as a vital defense against the inadvertent introduction of pests and diseases. Key features include the requirement for an "Import Permit" before any seed or planting material can enter the country. Additionally, all imported consignments must be accompanied by a "Phytosanitary Certificate" issued by the official Plant Quarantine Service of the source country. Rigorous inspections occur at specified entry points (such as land customs stations, seaports, and airports), where authorized plant quarantine officials assess consignments and apply necessary fumigation or disinfection measures. Seeds or planting materials needing isolation are cultivated in post-entry quarantine facilities, adhering to guidelines set by the Plant Protection Adviser. Importantly, packing materials of plant origin are strictly prohibited, with soil import for research purposes requiring a special permit. Under the DIP Act, both the Central Government and State Governments have authority to create rules governing the import and movement of seeds and planting materials within India. The Directorate of Plant Protection, Quarantine & Storage, led by the Plant Protection Adviser to the Government of India, is responsible for enforcing quarantine regulations nationwide. To achieve this, plant quarantine and fumigation stations operate at international airports, seaports, and land customs stations. These stations meticulously inspect, fumigate, and disinfect incoming consignments before releasing them to recipients. Notably, consignments intended for sowing, planting, or propagation purposes can only be imported through specific quarantine stations—Amritsar, Bombay, Calcutta, Delhi, and Madras. These stations are equipped with well-established laboratories, quarantine greenhouses, and skilled scientific personnel to effectively address quarantine requirements. Additionally, these facilities handle bulk imports for both commercial purposes and planting.

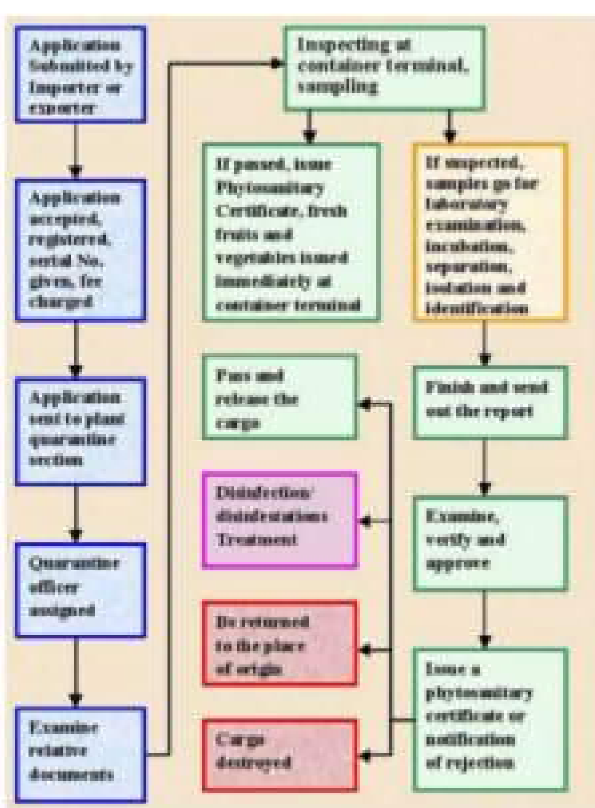
Import flow chart



Export flow chart



Procedures of plant quarantine



Key Approaches in Plant Quarantine

1. **Integrated Pest Management (IPM)**: IPM combines various techniques to manage pests effectively while minimizing reliance on synthetic pesticides. It involves monitoring, biological control (using natural enemies), cultural practices, and judicious use of chemical treatments. By implementing IPM, farmers can reduce the need for chemical interventions and promote sustainable crop health[1].

2. **Natural Substances and Biocontrol Agents**: Researchers are exploring natural substances (such as plant extracts or molecules) and biocontrol agents (beneficial organisms like predators, parasitoids, or antagonistic microorganisms) to combat plant pathogens. These alternatives can reduce reliance on synthetic pesticides and contribute to sustainable disease management in horticulture[2].

3. **Plant-Induced Gene Silencing (PGIS)**: PGIS is an innovative approach where specific genes in the pathogen are silenced using RNA interference. By targeting pathogen-specific genes, PGIS can enhance plant resistance to diseases without harming beneficial organisms or the environment[3].

4. **Soil Health Management**: Healthy soil supports robust plant growth and resilience. Practices like adding organic matter (such as compost), practicing crop rotation, and maintaining balanced soil nutrients contribute to sustainable horticulture. Healthy plants are less susceptible to diseases and pests[4].

5. **Strict Quarantine Protocols**: Quarantine measures play a critical role in preventing the introduction and spread of invasive pests and diseases. By enforcing strict protocols at entry points (such as airports, seaports, and land customs stations), we can safeguard our crops and ecosystems. Regular monitoring ensures early detection and control of potential risk

Effective Plant Quarantine Treatments

1. **Fumigation**:

   - Methyl bromide is commonly used for fumigation under atmospheric or reduced pressure. It targets fruits, vegetables, plants, nuts, railroad cars, ships, and wood products.

- Other fumigants like hydrogen cyanide (HCN), phosphine, and EDCT (a mixture of ethylene dichloride and carbon tetrachloride) are also employed.

2. **Heat Treatment**:

   - Hot water or hot air treatments eradicate insects, mites, nematodes, fungi, bacteria, and viruses.
   - The treatment temperature must be high enough to kill pests and pathogens without harming the host plant.
   - Examples: Flower buds (44°C for 240 min), chrysanthemum (48°C for 25 min), and potato tubers (45°C for 5 min) against nematodes; strawberry runners (46°C for 10 min) against insects and mites.

3. **Cold Treatment**:

   - Atmospheric cold plasma jets effectively disinfect fungus-infected plant leaves and control infection spread.

4. **Chemical Treatment**:

   - Chemicals can be applied as dust, slurry, spray, or dips.
   - Dosages should eliminate pathogens without harming the host.
   - Safety for personnel handling treated seeds is crucial.

5. **Tissue Culture**:

   - Tissue culture reduces the risk of introducing pests and pathogens:Introductions involve meristem tips, excised buds, or embryos, minimizing infection size.Aseptic plantlet systems inherently detect pests and pathogens.

Importance of Plant Quarantite

Historical Context:

In the early twentieth century, inadequate quarantine control allowed several foreign pests toenter the subcontinent. This experience highlighted the need for robust quarantine practices.

Globalization and Trade:

With globalization and liberalization in international trade, the Sanitary and Phytosanitary (SPS) Agreement under the World Trade Organization (WTO) has amplified the significance of plant quarantine.By regulating and restricting the import of plants and plant products, quarantine processes prevent the introduction and spread of destructive exotic pests.

Safe Global Trade:

Plant quarantine facilitates safe agricultural trade by providing technically competent andreliable phytosanitary certificates.These certificates meet the requirements of trading partners, ensuring smooth commerce while safeguarding against pests.

Pathogen Management:

Even pathogens seemingly minor in their native environments can wreak havoc in new surroundings.Isolating plants for a specific period allows for the production of fresh, disease-free plants.

Preventing Non-Indigenous Threats:

Plant quarantine is essential to prevent the introduction of non-indigenous pests and diseases into a country.Intercepting and eradicating these threats before they become widespread and well-established is crucial.

Conclusion

Effective implementation of quarantine processes is highly recommended for managing pests and diseases, ultimately contributing to sustainable horticulture and global food security.

Protected Cultivation of High-Value Horticultural Crops

Astha[1], Raj Narayan[2] and Nindiya Bharti[3]

Abstract

Protected cultivation has revolutionized the horticultural industry by offering controlled environments that maximize productivity, enhance quality, and extend growing seasons for high-value crops. This review paper discusses the various methodologies and technologies involved in protected cultivation, explores their benefits and limitations, and examines their impact on the production of high-value horticultural crops such as tomatoes, cucumbers, peppers, and orchids. The paper also considers future trends and research directions to further advance this field. Protected cultivation has significantly advanced the production of high-value horticultural crops by creating optimal growing conditions through controlled environments. This approach includes various systems such as greenhouses, polyhouses, and high tunnels, which mitigate adverse weather, pests, and diseases, thus enhancing crop quality and yield. By regulating factors like temperature, humidity, and light, protected cultivation extends growing seasons, leading to year-round production and consistent market supply. However, challenges such as high initial costs, technical expertise requirements, and energy consumption persist. Innovations in automation, AI, and sustainability are addressing these issues, promising further improvements in efficiency and environmental impact. Overall, protected cultivation offers a strategic advantage in producing premium horticultural crops, catering to increasing global demand and enabling more sustainable agricultural practices.

Introduction

The global demand for high-value horticultural crops has driven innovations in cultivation practices to ensure consistent quality and yield. Protected cultivation, encompassing greenhouses, playhouses, and high tunnels, has emerged as a vital technique for achieving these objectives. By shielding crops from adverse weather conditions and pests, these systems create an optimal environment for growth, which is crucial for high-value crops that require precise conditions to reach their full potential. Protected cultivation is a modern horticultural technique that optimizes the growing environment for high-value crops by using structures like greenhouses, polytunnels, and shade houses. These controlled environments shield plants from harsh weather, pests, and diseases, creating ideal conditions for their growth. By regulating factors such as temperature, humidity, and light, protected cultivation extends growing seasons, enhances crop quality, and boosts yields. It also promotes efficient use of resources like water and nutrients.

Greenhouses are fully enclosed with transparent materials, allowing light while controlling temperature and humidity. Polytunnels, covered with plastic sheeting, are cost-effective and suitable for seasonal crops. Shade houses filter sunlight, reducing heat stress. This technique is particularly beneficial for sensitive crops such as tomatoes, strawberries, and ornamental flowers.

While protected cultivation offers significant benefits, including higher quality produce and increased yields, it requires substantial initial investment and technical expertise. Energy consumption for environmental control can also be high. Future advancements in technology and sustainable practices are expected to further enhance the efficiency and viability of protected cultivation, making it an increasingly important method for growing high-value horticultural crops.

Types of Protected Cultivation Systems

2.1 Greenhouses

Greenhouses are the most common form of protected cultivation, offering a controlled environment with adjustable temperature, humidity, and light levels. Modern greenhouses are equipped with advanced systems such as automated ventilation, shading, and irrigation, which help maintain optimal conditions for plant growth. The use of high-quality materials for greenhouse construction, such as polycarbonate panels or advanced plastics, enhances light transmission and thermal insulation.

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2.2 Polyhouses

Polyhouses, or plastic-covered tunnels, are a cost-effective alternative to traditional greenhouses. They provide protection from harsh weather and pests while allowing for easier temperature management through ventilation and shading. Polyhouses are typically used for crops like tomatoes, cucumbers, and peppers, which benefit from a controlled environment but do not require the sophisticated systems found in greenhouses.

2.3 High Tunnels

High tunnels, also known as hoop houses, are semi-permanent structures covered with plastic. They offer less control over environmental conditions compared to greenhouses but are effective in extending the growing season and protecting crops from wind and rain. High tunnels are particularly useful for growing crops in regions with extreme weather conditions and are often used for early-season and late-season crops.

3. Advantages of Protected Cultivation

3.1 Enhanced Crop Quality and Yield

Protected cultivation provides an environment where factors such as temperature, humidity, and light can be precisely controlled, leading to higher quality produce. For high-value crops like tomatoes and cucumbers, which are sensitive to environmental changes, these systems can result in increased fruit size, better colour, and improved taste.

3.2 Extended Growing Seasons

By mitigating the effects of seasonal changes, protected cultivation systems allow for year-round production. This is particularly beneficial for high-value crops with a limited natural growing season, enabling producers to supply markets consistently and command premium prices.

3.3 Reduced Pest and Disease Pressure

Protected environments limit the entry of pests and diseases, reducing the need for chemical pesticides and enhancing crop health. Integrated pest management (IPM) strategies can be more effectively implemented in these controlled settings, leading to more sustainable production practices.

3.4 Resource Efficiency

Protected cultivation systems can optimize resource use, including water and fertilizers. Automated irrigation and fertigation systems deliver precise amounts of water and nutrients, reducing waste and promoting efficient use of resources.

4. Limitations and Challenges

4.1 High Initial Investment

The cost of establishing protected cultivation systems can be significant, particularly for high-tech greenhouses. This initial investment may be a barrier for small-scale producers, although long-term benefits often outweigh the costs.

4.2 Technical Expertise

Operating advanced protected cultivation systems requires technical knowledge and expertise. Farmers must be trained in managing environmental controls, pest management, and crop nutrition to fully benefit from these systems.

4.3 Energy Consumption

Maintaining optimal conditions within greenhouses can lead to high energy consumption, particularly for heating and cooling. This can result in increased operational costs and environmental impact, necessitating the adoption of energy-efficient technologies and renewable energy sources.

Here's a table listing various high-value crops that are well-suited to protected cultivation, along with a brief description of each crop's suitability and benefits from using protected environments:

Crop Type	Examples	Description	Benefits from Protected Cultivation
Vegetables	Tomatoes, Cucumbers, Bell Peppers	These vegetables are highly sensitive to climate fluctuations and pests.	**Consistent Quality:** Protection from pests and diseases. **Extended Season:** Longer growing periods and multiple harvests.
Fruits	Strawberries, Melons, Tomatoes	High-value fruits often require specific conditions for optimal growth and fruiting.	**Enhanced Yield:** Improved fruit size and quality. **Earlier Harvests:** Protected environments can lead to earlier fruit production.

Herbs	Basil, Cilantro, Mint	Herbs benefit from controlled temperatures and reduced pest pressures, which can enhance their flavour and growth.	**Improved Flavour:** Optimal growth conditions lead to better flavourprofiles. **Extended Harvest Periods:** Protection from seasonal weather changes.
Flowers/ Ornamentals	Roses, Orchids, Gerbera Daisies	These crops often require precise environmental conditions to ensure high-quality blooms and extend blooming periods.	**Better Bloom Quality:** Controlled environment enhances colour and longevity. **Increased Production:** Year-round availability and reduced disease risk.
Leafy Greens	Lettuce, Spinach, Kale	Leafy greens grow well in protected environments where temperature and humidity can be managed to avoid bolting and disease.	**Increased Yield:** Consistent production and higher quality leaves. **Extended Growing Season:** Ability to grow year-round.
Specialty Crops	Exotic Mushrooms, Microgreens	Specialty crops like mushrooms and microgreens benefit from stable, controlled conditions for optimal growth.	**Enhanced Growth Rates:** Controlled environments can accelerate growth. **High Market Value:** Often have premium prices and demand.

This table summarizes the types of high-value crops that thrive under protected cultivation systems, highlighting their specific needs and the advantages they gain from such environments.

5. Case Studies

5.1 Tomatoes in High-Tech Greenhouses

High-tech greenhouses for tomato cultivation in regions like the Netherlands have demonstrated significant improvements in yield and quality. Automated systems for climate control and fertigation have enabled producers to achieve year-round production with consistently high-quality fruit.

5.2 Orchids in Polyhouses

In regions with high humidity, polyhouses have proven effective for orchid cultivation. The controlled environment helps prevent fungal diseases and promotes optimal growth conditions, resulting in vibrant and healthy flowers.

6. Future Trends and Research Directions

6.1 Automation and AI: The integration of automation and artificial intelligence (AI) in protected cultivation is expected to enhance operational efficiency and precision. AI-driven systems can optimize environmental controls, predict pest outbreaks, and analyze crop performance in real-time.

6.2 Sustainability: Future research will likely focus on improving the sustainability of protected cultivation systems. This includes developing energy-efficient technologies, reducing resource use, and exploring alternative materials for construction.

6.3 Vertical Farming: Vertical farming, which involves growing crops in stacked layers within controlled environments, offers a promising direction for high-value horticultural crops. This approach maximizes space utilization and can be integrated with protected cultivation systems for enhanced productivity.

Here's a table summarizing key aspects of protected cultivation of high-value horticultural crops, with examples based on typical practices and research findings:

Aspect	Description	Examples
Types of Structures	Various structures used to protect crops and control the environment.	**Greenhouses:** Enclosed with transparent materials (e.g., glass or polycarbonate). **Polytunnels:** Tunnels covered with plastic sheeting. **Shade Houses:** Structures with mesh or shade cloth.
Benefits	Advantages of using protected cultivation methods.	**Extended Growing Seasons:** Allows for multiple harvests per year. **Enhanced Crop Quality:** Reduces diseases and pests. **Increased Yields:** Promotes vigorous plant growth. **Resource Efficiency:** Optimizes water and nutrient use.

Crops	Types of high-value crops suited to protected cultivation.	**Vegetables:** Tomatoes, cucumbers, bell peppers. **Fruits:** Strawberries, melons. **Flowers/Ornamentals:** Roses, orchids.
Challenges	Potential issues and considerations when implementing protected cultivation.	**Initial Costs:** High setup expenses for infrastructure. **Technical Expertise:** Requires knowledge of environmental control and crop management. **Energy Use:** Significant energy required for heating/cooling.
Technological Advances	Innovations improving protected cultivation efficiency and sustainability.	**Automated Systems:** Advanced climate control. **Sustainable Practices:** Use of renewable energy sources and efficient materials. **Improved Materials:** Better insulation and durability of structures.
Research Findings	Insights from studies on the effectiveness and impact of protected cultivation.	**Study Example:** Research shows greenhouses can increase tomato yields by 20-30% compared to open fields (*Journal of Agricultural* Science, 2022). **Field Study:** Polytunnels boost strawberry production by enhancing early fruiting (*Horticulture Research*, 2021).

This table provides an overview of protected cultivation methods, highlighting their benefits, challenges, and examples of high-value crops and research findings related to these techniques.

Conclusion

Protected cultivation has proven to be a transformative approach for the production of high-value horticultural crops. By offering controlled environments that optimize growth conditions, these systems enable higher quality, increased yields, and extended growing seasons. Despite challenges such as high initial costs and energy consumption, ongoing advancements in technology and sustainability will continue to drive the evolution of protected cultivation. As the global demand for high-value horticultural products grows, the role of protected cultivation in meeting these demands will become increasingly significant.

Vegetable Grafting for Combating Stresses and Increasing Productivity

Khushboo Sharma, Sumati Narayan and Nindiya Bharti

Abstract

Vegetable grafting, involving the union of a rootstock and scion, is increasingly valued for enhancing crop resilience and productivity. By combining the strengths of different plant parts, grafting optimizes nutrient uptake through extensive root systems with higher root hair density and beneficial mycorrhizal associations. This leads to improved water and nutrient absorption, better photosynthesis, and more efficient resource allocation, resulting in increased flower and fruit production, superior fruit quality, and extended shelf life. Grafting effectively manages both biotic stresses, such as soil-borne diseases like Fusarium wilt, and abiotic stresses, including salinity, drought, and temperature extremes. In controlled environments like greenhouses, it addresses challenges related to high-density planting and nutrient competition. Future advancements, driven by biotechnological innovations like CRISPR/Cas9 and marker-assisted selection, promise to enhance rootstocks with broader resistance. Integrating grafting with sustainable practices will further boost crop efficiency and contribute to future food security.

Introduction

Vegetable grafting is an increasingly vital technique in modern agriculture, known for its ability to address both biotic and abiotic stresses while boosting crop productivity. This method involves the union of two distinct plant parts: the rootstock, which provides the root system, and the scion, which produces the economic fruit. By combining the advantageous traits of these parts, grafting enhances plant resilience and performance. Rootstocks are specially selected for their robust root systems, which feature enhanced root hair density and beneficial mycorrhizal associations, improving water and nutrient uptake. This leads to superior plant vigor, increased yields, and better fruit quality. Vegetable crops, whether grown in open fields or advanced greenhouses, often face significant stressors such as salinity, drought, and temperature extremes, which can severely impact productivity and yield. Grafting offers a sustainable solution by improving plant tolerance to these stresses and enhancing overall growth. Despite its benefits, challenges remain in selecting the optimal rootstock-scion combinations and understanding the underlying mechanisms of stress tolerance. Currently, grafting is widely recognized in cucurbitaceous and solanaceous crops worldwide. However, two key challenges persist when using watermelon grafted plants to enhance abiotic stress tolerance. First, selecting the optimal rootstock-scion combination that aligns with the actual or anticipated stress factors. Second, advancing our understanding of the underlying tolerance mechanisms. Addressing these challenges could pave the way for breeding rootstocks that enhance the stress resilience and productivity of vegetable crops.

Biotic Stresses:

Soil-Borne Fungi: In India, vegetables such as brinjal, tomato, bitter gourd, and cucumber are cultivated extensively due to their nutritional benefits. However, their continuous cultivation, both in open fields and protected environments like greenhouses, is often disrupted by soil-borne diseases, notably Fusarium wilt caused by Fusarium species. This disease is prevalent in countries including China and Southeast Asia, thriving in light, sandy soils with poor drainage and high temperatures (35-40ºC). Vegetable grafting is a common global practice to combat these soil-borne diseases, with research showing that rootstocks like *Solanum torvum* can effectively resist Fusarium wilt, Verticillium wilt, bacterial wilt, and root-knot nematodes. In particular, brinjal, which faces numerous diseases including Fusarium wilt and dry root rot caused by *Macrophomina phaseolina*, benefits significantly from grafting. Dry root rot, exacerbated by high temperatures (30-35°C) and low moisture, can severely reduce brinjal yields, causing up to 70.5% loss in late-harvest crops. Recent studies by Sherly (2010) demonstrated that grafting brinjal onto *S. torvum* rootstock significantly mitigates dry root rot, maintaining plant health and productivity. This finding, confirmed through biochemical and enzyme activity analyses, marks a significant advancement in sustainable brinjal production in India.

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Bacteria: Bacterial wilt is another significant threat to vegetable crops. Bacterial wilt is caused by the bacterium *Ralstonia solanacearum*. It affects various crops, including tomatoes, potatoes, and eggplants. rafting susceptible tomato scions onto resistant rootstocks (such as wild tomato species or other resistant varieties) helps prevent bacterial wilt transmission from soil to the scion. The rootstock provides a barrier, limiting the bacterium's movement through the plant. Grafting can provide resistance against bacterial pathogens, ensuring healthier plants and improved yields.

Root Knot Nematodes (RKN): *Meloidogyne incognita*, *M. javanica*, and *M. arenaria* are common root-knot nematode species. These nematodes induce characteristic galls (swellings) on plant roots, disrupting nutrient uptake and water flow, Solanaceous (e.g., tomatoes, peppers, eggplants) and cucurbitaceous (e.g., cucumbers, melons) vegetables are particularly susceptible. Grafting involves joining a resistant rootstock (the lower portion) with a susceptible scion (the upper portion). Alterations in plant metabolism and nutrient mobility contribute to nematode resistance. Changes in plant vigor and physiological attributes enhance overall resilience.The rhizosphere microbial community may also play a role in nematode suppression.Grafting onto RKN-resistant rootstocks (e.g., resistant watermelon rootstocks) helps manage nematode infestations.

Abiotic Stresses:

Salinity: Approximately 7% of the world's land area and nearly 20% of arable irrigated land are affected by soil salinity. Climate change exacerbates salinization, leading to predictions that the extent of saline land will increase under future climate scenarios. Soil salinity adversely impacts plant growth and production. To mitigate the effects of salinity and utilize saline soils for vegetable crop production, various strategies have been proposed. One effective and straightforward approach is using salt-resistant genotypes as rootstocks to enhance crop tolerance to salt stress. High soil salinity disrupts water uptake and nutrient balance in plants. Grafted plants, particularly those with salt-tolerant rootstocks, are better equipped to withstand saline conditions.

Drought: Drought is a significant water stress issue that threatens sustainable vegetable production worldwide, stemming from water deficits in water-limited conditions. While advances in breeding and biotechnology have produced some drought-tolerant crop varieties, these improvements have primarily benefited cereal crops. Climate change significantly impacts water availability, affecting vegetable crop productivity and often leading to total crop failures. Decreased precipitation and rising mean air temperatures contribute to reduced irrigation water availability, while increased

Table 1: Diseases reported to be controlled by grafting in different vegetable crops

Disease and pest	Pathogen	Crops
Fusarium wilt	*Fusarium oxysporum*	Tomato, pepper, Cucumber, melon, watermelon,
Fusarium crown and root rot	*Fusarium oxysporum Fusarium solani*	Tomato, pepper, watermelon,
Verticillium wilt	*Verticillium dahlia*	Tomato, eggplant Cucumber, melon, watermelon,
Monosporascus sudden wilt	*Monosporascus cannonballus*	melon, watermelon
Phytophthora blight	*Phytophthora capsici*	Tomato, pepper, watermelon, Cucumber
Target leaf spot	*Corynespora cassiicola*	Cucumber
Gummy stem blight	*Didymella bryoniae*	Melon
Southern blight	*Sclerotium rolfsii*	Tomato
Brown root rot	*Colletotrichum coccodes*	Tomato, eggplant
Rhizoctonia damping off	*Rhizoctonia solani*	Tomato
Powdery mildew	*Podosphaera xanthii*	Cucumber
Downy mildew	*Pseudopernospora cubensis*	Cucumber
Bacterial diseases		
Bacterial wilt	*Ralstonia solanacearum*	Tomato, pepper, eggplant
Nematodes		
Root-knot	*Meloidogvne spp.*	Cucumber, melon, watermelon, tomato, eggplant, pepper
Viral diseases		
Melon necrotic spot virus	Melon necrotic spot virus (MNSV)	Watermelon
Tomato yellow leaf curl	Tomato yellow Leaf curl virus (TYLCV)	Tomato
Tomato spotted wilt	Tomato spotted wilt virus (TSWV)	Tomato

evapotranspiration is expected under drought conditions, as vegetables are composed of approximately 90% water. Grafting can enhance water-use efficiency by improving root systems. For instance, drought-tolerant rootstocks can help sustain crop productivity during periods of water scarcity.

Temperature Extremes: Extreme temperatures can lead to significant vegetable production losses by causing wilt and necrosis, slowing truss formation, and affecting fruit ripening. Grafting can help mitigate these issues by protecting plants from thermal stress and enhancing yield due to the physiological benefits associated with grafted plants. Vegetable crops are highly sensitive to both high and low temperatures. In tropical environments, high temperatures are common during the growing season, while in temperate and subtropical regions, chilling or low temperatures can pose serious problems for crops like tomatoes, squash, cucumbers, and watermelons during winter, spring, and autumn. Abiotic stress from extreme temperatures, whether hot or cold, affects crop growth, but grafted plants often demonstrate improved temperature tolerance, enabling them to thrive in challenging climates.

Flooding: Unpredictable heavy rainfall leading to excessive moisture can significantly impact the production of many vegetable crops due to their high sensitivity to flooding. Some vegetables cannot tolerate flooded soil conditions throughout their growth and development. Excess moisture reduces the oxygen available to plant roots, disrupting photosynthesis and altering water potential. Research has shown that grafting can enhance flooding tolerance in various vegetable crops. For instance, tomatoes, which are sensitive to flooding, have benefited from interspecific grafting to improve their tolerance. Grafting can enhance root aeration and help prevent oxygen deprivation during flooding events.

Table 2: Examples of top-performing rootstock and scion combinations in vegetable crops under different stress

Drought stress		
	Rootstock	**Scion**
1	PS1313 (*C. maxima* Duchesne X *C. moschata* Duchesne)	Watermelon (*C. lanatus* (thunb.) Matsum and Nakai) cv. Ingrid
2	Tomato (*S. lycopersicum*) cv. Beaufort	Tomato (*S. lycopersicum*) cv.M28
3	Pepper (*Capsicum annum* L.) cv. Verset	Pepper (*C. annum* L.) cv. Atlante, PI -15225 and ECU-973
Salinity stress		
1	(a) Macis (X *L. Siceraria* Standl., Nunhems Zaden, The Netherlands) (b) Ercole (X *C. Maxima* Duchesne X *C. moschata* Duchesne, Nunhems Zaden, The Netherlands)	Watermelon (*C. lanatus*) cv. Tex
2	Black-seeded Fig leaf gourd (X *C. ficifolia* Bouché) Chaofeng Kang sheng wang (*L. siararia* Standl.)	Cucumber plant (*Cucumis sativus* L) Jinchun No. 2
3	Cucurbita hybrid root stocks (*C. maxima* Duch. X *C. moschata* Duch.) 'P360' and PS13132	(a) Melon (*Cucumis melo* L) cv. Cyrano (b) Cucumber (*Cucumis sativus* L) Akito
Thermal stress		
	Rootstock	**Scion**
1	Tomato (*Solanum lycopersicum*) RX-335	Tomato (*Solanum lycopersicum*) Tmknvf2
2	Tomato (*Solanum lycopersicum*) cv. LA1778	Tomato (*Solanum lycopersicum*) cv- T5
3	Figleaf Guard (*Cucurbita ficifolia* bouche)	Cucumber (*Cucumis sativus*) cv Jinyang No. 4
Flooding stress		
	Rootstock	**Scion**
1	Luffa (*Luffa cylindria* Roem) cv. Cylinder #2	Bitter melon (*Momordia charanthia*) cv. New Known You #3
2	*Lagnaria siceraria* (Landrace)	Watermelon (*Citrullus lanatus* (thunb.) Matsum and Nakai) cv. Crimson Tide
3	Eggplant (X *Solanum melongena*) cv. Arka Neelkanth, Mattu Gulla, BPLH 1 and Arka Keshav	Tomato (*Solanum lycopersicum*) cv. Arka Rakshak
4	Eggplant (X *Solanum melongena* X) cv. IC -354557, 10111056. IC-374873, CHBR-2	Tomato (*Solanum lycopersicum*) Hybrid line cv. Arka Rakshak, Arka Samrat

Grafting onto special rootstocks significantly enhances nutrient uptake, resulting in improved growth and yield of grafted plants. This improvenutrient acquisition, support superior plant vigor, leading to higher yields and better fruit quality. The robust root systems bolster photosynthesis and resource allocation, which translates to greater flower and fruit set, enhanced fruit size, uniformity, and extended shelf life.

In controlled agricultural environments like greenhouses, grafting provides enhanced adaptability. This adaptability results in increased plant resilience and productivity. Specifically, in the production of tomatoes, cucumbers, melons, and watermelons, grafting onto disease-resistant rootstocks reduces crop losses from soil-borne pathogens and improves resilience to environmental stresses, including cold soils. Future advancements in vegetable grafting, driven by biotechnological innovations such as CRISPR/Cas9 and marker-assisted selection, promise to further enhance rootstock traits, expanding resistance to a wider range of pathogens and environmental conditions, and offer substantial benefits to modern agriculture.

Vertical farming: a futuristic approach

Nida Manzoor, Sumati Narayan, Khursheed Hussain, F.A Khan and Nindiya Bharti

Abstract

Vertical farming is emerging as a promising innovative solution to address global food security challenges. With its high land use efficiency, adaptability to urban environments as well, and integration of advanced technology, vertical farming can solve several major problems in food production, especially amidst rapid global population growth and current climate change scenario. Vertical Farming is an innovative agricultural method where crops are grown in vertically stacked layers, often integrated into controlled environments such as skyscrapers, warehouses, or shipping containers. This approach leverages advanced technologies like LED lighting, hydroponics, and climate control systems to optimize plant growth and maximize space efficiency. Vertical farming allows for year-round production, reduces the need for land, conserves water, and minimises the carbon footprint associated with traditional agriculture. It has a potential to become a major force in achieving sustainable global food security. In this context, vertical farming is not only an alternative but also a significant step forward towards positive transformation in the global agricultural sector.

Keywords: Vertical farming, hydroponics, food security, climate change.

Introduction

Climate change has contributed to the decrease of arable land. Through flooding, hurricane, storms, and drought, valuable agricultural land has been decreased drastically, thereby damaging the world economy. Scientists predict that climate change and the adverse weather conditions it brings will continue to happen at an increasing rate. These events will lead to the despoliation of large tracts of arable land, rendering them useless for farming. On contrary, traditional farming requires substantial quantities of fossil fuels to carry out agricultural activities like ploughing, applying fertilizers, seeding, weeding, and harvesting.

The technology of vertical farming depicts it all, instead of preparing a large area of land for more space for crop production, stack new farms on top of each other or farm vertically using pipes. The main focus of this technology is to be able to produce crops with higher or same quality as the locally produced crops, but using only a small portion of land. Also, another solution for the gradual decrease of agricultural land is the construction of vertical farm facilities inside the already constructed or abandoned buildings rather than developing new lands. If this technology is fully implemented and adopted, there is high possibility that vertical farms can sustain the needs of communities and produce more crops than traditional farms with larger area of production. With this result, the use of traditional farms is less needed, thus these lands are replenished and will be more fertile. As growing population places increasing demand on food availability. As farmers struggle with bridging the gap between demand and supply of crops using traditional farming methods, more innovative and efficient cultivation techniques continue to surface. One of these methods is vertical farming.

Fig 1: Example of some Vegetable vertical farms

Vertical farming makes a tremendous contribution for food sustainability in our current situation. Vertical farming is the practice of producing crops in vertically stacked layers of trays, and vertically surfaces in a fully controlled environment agricultural technology. The crops grown are artificially grown using light as source of energy in their development. Vertical farms can be built in abandoned and old buildings or using shipping containers. Also, this technology can produce more crops than traditional farming or greenhouse farming despite it uses only small area of production. Vertical farming could enable food production in an efficient and sustainable manner, save water and energy, enhance the economy, reduce pollution, provide new employment opportunities, restore ecosystems, and provide access

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to healthy food. In a controlled environment, crops will be less subject to the vagaries of climate, infestation, the nutrient cycle, crop rotation, polluted water runoff, pesticides, and dust.

Vertical Farming systems can be broadly divided into two categories– those comprising multiple levels of traditional horizontal growing platforms, and those where the crop is grown on a vertical surface. Stacked horizontal systems include multiple levels of traditional horizontal growing platforms sometimes with level rotation incorporated, or controlled environment (CE) facilities. A variation of this approach is that of multi-floor towers where each level is isolated from the surrounding levels. The use of balconies for crop production is another example of VF using stacked horizontal growing surface. Vertical growing surface include green walls which can be positioned on the side of buildings and other vertical surfaces and cylindrical growth units with vertical arrangements of plants. Many horticultural crops, such as leafy vegetables including lettuce (*Lactuca sativa*) and herbs, tomato (*Solanum lycopersicum*) and pepper (*Capsicum* spp.) are grown

Table 1: Vertical farming Systems & their Key Characteristics

Vertical Farming system	Key Characteristics	Major benefits
Hydroponics	Water as growing medium for soilless cultivation	Reduces, even eliminates, soil-related cultivation issues; Significantly reduces the need for fertilisers or pesticides.
Aeroponics	A hydroponics replica in which plants' roots are sprayed with nutrient solutions or mist.	Additionally, aeroponics uses less water than other methods of growing plants.
Aquaponics	Aquaponics and hydroponics are combined in this system.	Creates mutually beneficial relationships among plants and fish by using fish tank refuse to "fertigate" hydroponics production beds, as well as a hydroponic bed also serves to safe water for the fish's pond.

Table 2: Crop specification of Vertical Farming systems

Vertical Farming system	Commonly Grown Vegetables	Vegetables Not Ideal for the system
Hydroponics	**Leafy Greens:** Lettuce, spinach, kale, arugula. **Herbs:** Basil, mint, cilantro, parsley. **Fruiting Vegetables:** Tomatoes, cucumbers, peppers, strawberries. **Root Vegetables:** Radishes, beets, carrots (with specific systems like deep water culture or nutrient film technique).	**Large Root Crops:** Potatoes, sweet potatoes, and other large tuberous crops are challenging to grow in hydroponic systems due to their extensive root structures. **Grain Crops:** Wheat, rice, and other cereals are generally not suitable for hydroponics because they require large fields and extensive growing periods.
Aeroponics	**Leafy Greens:** Lettuce, spinach, kale. **Herbs:** Basil, oregano, thyme. **Fruiting Vegetables:** Tomatoes, cucumbers, bell peppers. **Root Vegetables:** Aeroponics is particularly effective for growing root vegetables like radishes and potatoes because the roots are suspended and exposed to nutrient-rich mist.	**Heavy Fruiting Vegetables:** Large, heavy fruits like pumpkins and watermelons are not well-suited to aeroponics because they require substantial support and space. **Grain Crops:** Similar to hydroponics, grains like wheat and corn are not typically grown in aeroponics due to space and structural constraints.
Aquaponics	**Leafy Greens:** Lettuce, chard, spinach, bok choy. **Herbs:** Basil, mint, watercress. **Fruiting Vegetables:** Tomatoes, cucumbers, peppers. **Legumes:** Peas, beans (particularly dwarf varieties).	**Root Vegetables:** Potatoes, carrots, and other root crops are challenging to grow in aquaponics because the growing medium (often gravel or clay pellets) may not provide the necessary environment for proper root development. **Heavy Fruiting Vegetables:** Large fruits like melons and pumpkins are also difficult to cultivate in aquaponics systems due to their extensive space and support requirements.

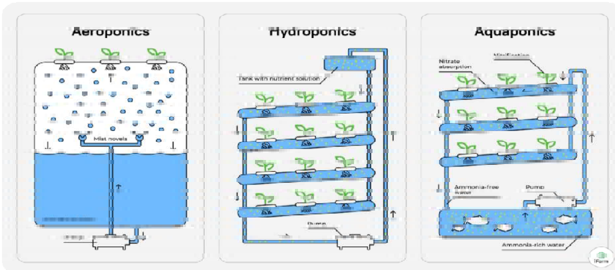

Fig 2: Different Vertical farming Systems

in large-scale glasshouses using hydroponic systems. These can include substrate blocks formed of rock-wool or similar materials which provide a matrix for plant roots and are drip-fed with a precisely controlled mixture of water and nutrients. Therefore, such horizontal growing systems have the potential to be stacked on top of each other within taller structures to form a vertical farm. Crop choice in Stacked Horizontal Systems can be dictated by the space available between each level, with shorter crops allowing for a higher number of levels and so potentially greater yield per unit height of the growth system.

- Lettuce is a highly versatile crop that can be successfully grown in hydroponics, aeroponics, and aquaponics. Its shallow root system, rapid growth rate, and tolerance to varying nutrient levels make it ideal for all three systems. Lettuce thrives in nutrient-rich water environments and does not require much support, making it one of the most commonly cultivated crops in controlled-environment agriculture

Media Used in Vertical Farming

1. Perlite

Expanded crystal specks produced from volcanic rock after already being superheated are known as perlite. Depending on the application, it can be used either loosely or in plastic sleeves submerged in water for a short period of time. It is also used in potting soil mixes to reduce the density of the soil and improve drainage. In general, perlite has a higher air-to water ratio. It can float if flood and drain feeding is being used if it's not contained. Several different types of rock have been combined to create it.

2. Vermiculite

It is a member of smectite group of minerals, having abundant amount of potassium and magnesium. It retains a lot of water as well as helps in improving drainage and aeration of the soil, even if it's not as durable as other mediums like sand and perlite.

3. Coconut Coir

Ultra peat, Cocopeat, and Coco-Tek are just a few of the trade names for this product. Vermiculite and perlite work together to keep water and air separate. Because it's made from coconut husks, it is an organic product and is completely renewable resource.

4. Peat Moss

Peat moss is an excellent medium for retaining water. Peat moss is commonly included in pre-packaged potting soil for use in potted plants that need extra moisture. Peat moss is a great way to keep soil moist. To thrive, tropical plants necessitate an abundance of humidity as well as warmth.

5. Sand

The use of sand as a growing medium for plants that need a dry as well as loose soil conditions is advantageous. Carrots and potatoes, two common root crops, do better in sand because it is porous, light, and don't retain quite much moisture as other crops.

6. Rock Wool

Hydroponically, rock wool, also known as mineral wool, is the most commonly used medium. In both free drainage and recirculation systems, this inert substrate is used. As a result of aerosolizing molten mineral compounds, a fibrous medium is formed, making it capillary-accessible and impervious to microbiological degradation.

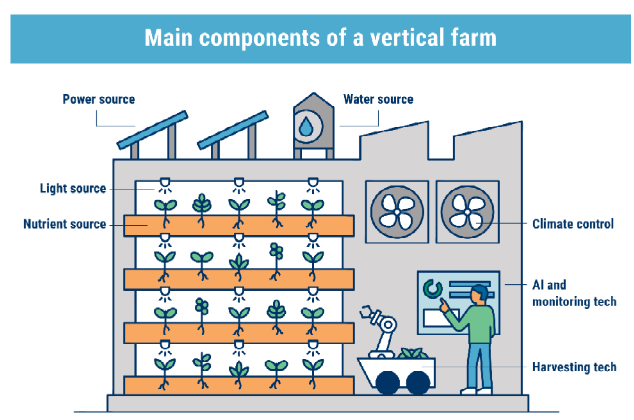

Fig 3 Main Components of a vertical Farm

Working principles of vertical farming

a) **Plant Selection**: Selecting the right type of plant is critical to the success of vertical farming. The plants selected must be suitable for their growing environment and have a life cycle that is compatible with the tiered system.

b) **Nutrition**: Vertical farms often use hydroponic or aeroponic systems that allow nutrients to be delivered directly to plant roots. This ensures the plants get proper and optimal nutrition.

c) **Light**: Because vertical farming is often done indoors or in enclosed buildings, providing light is a key factor. Special LED lights are used to provide the right light spectrum for plant growth.

d) **Environmental Controller**: Environmental temperature and humidity must be maintained to suit the needs of the plant. The use of automated technology helps maintain an optimal environment without the need for manual intervention.

Advantages of Vertical farming

Vertical farming has several benefits and advantages of its own. Some of these benefits include:

- **Increasing Land Efficiency**: By planting vertically, this farming allows more plants to grow on a limited land area. For example, one vertical plant column can accommodate dozens of plants, effectively increasing land productivity.
- **Reducing Water Use**: The hydroponic system in vertical farming uses water more efficiently than conventional farming. The water used in this system can be recycled, thereby reducing overall water consumption.
- **Easier Pest Control**: Indoor vertical farming or enclosed buildings provide better pest control. This reduces the use of pesticides and maintains the quality of agricultural products.
- **Increasing Local Food Availability**: With vertical farming, food can be produced in urban areas themselves. This means reducing dependence on food imported from rural areas or abroad. The use of vertical farming innovations can open up new business opportunities for farmers and contribute to increasing their income.

Factors that cause an increase in farmer income through vertical farming:

1. **Increased Productivity**: By increasing land efficiency, vertical farming allows farmers to grow more crops on limited land. As a result, agricultural production increases, and farmers can sell more of their crops
2. **Added Value of Agricultural Products**: Vertical farming often produces crops that are high quality and different from those available in traditional markets. This provides added value to their agricultural products, so the selling price is higher
3. **Stable and Guaranteed Market**: By utilizing advanced technology, vertical farming can guarantee a stable food supply throughout the year. This means farmers can sell their crops regularly, without being too dependent on seasons and weather conditions.
4. **Diversification of Agricultural Products**: With vertical farming, farmers can grow various types of crops in one system. This diversification of agricultural products allows farmers to reach a wider market and face lower risks in the agricultural business.

Limitation of implementation of vertical farming

- **High Initial Investment**: Establishing a vertical farming system requires significant initial investment, primarily to purchase the necessary equipment and infrastructure, such as LED lights, irrigation systems, and environmental control technology. This can be an obstacle for farmers with limited capital
- **Limitations of Technology and Knowledge**: Not all farmers in urban areas have sufficient access to and knowledge regarding vertical farming technology. Training and technical assistance are needed so that farmers can operate the system effectively and successfully
- **Availability of Raw Materials**: Vertical farming uses certain planting media or substrates. The availability and price of raw materials such as hydrogel which can influence sustainability and production costs
- **Licensing and Regulations**: Implementing vertical farming in urban areas often involves complex licensing and regulatory aspects. Complicated bureaucratic procedures can be a challenge for farmers who want to start a vertical farming business
- **Changes in Consumer Behaviour**: Introducing vertical farming products to consumers requires appropriate education and promotion. Changing consumer behaviour to switch and trust vertical farming products can sometimes be a challenge.

Conclusion

Since the need for soil-based farming is largely being challenged by new high-tech cultivation techniques such as hydroponics, aeroponics, and aquaponics. When it comes to growing crop production, vertical farming is becoming increasingly popular. Food sustainable development could benefit greatly from the use of vertical farms. In terms of environmental, social, and economic sustainability, vertical farming has a myriad of benefits. VF therefore necessitates a combined technical approach to factors including lighting, growing system, crop nutrition, energy efficiency, construction and site selection. Whilst Vertical farming has been shown to have potential for the production of a wide range of crops, the technical and economic optimisation of Vertical farming requires further attention with additional research into maximising productivity and reducing system costs being required.

A Nutrient-Dense Drumstick to Improve Human Health

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Introduction

Drumstick is also known as Sahjan in the Bundelkhand region and his botanically Moringa oleifera, which is an Angiospermae, a fast-growing, drought-resistant tree belonging to the family Moringaceace. It is also known as horseradish, benzoline tree, kelor, Marango, mlonge, moonga, mulangay, saijhan, sajna and Ben oil tree. It originated in southwest India and is properly grown in the South Indian states. The tropical and subtropical areas are suitable for cultivation. Moringa is a deciduous tree that can reach a height of 10 to 12 m (32 - 40 feet) and a trunk of diameter 45 CM. They have a corky grey bark, branching and fern-like leaves. The flowers are fragrant and hermaphrodite surrounded by 5 unequal thinly veined, yellowish White Petals. The fruit is hanging a-sided capsule of 20 to 45 CM in size with seeds of a diameter of 1 cm. The drumstick tree is insect-pollinated by a large number of insects.

Medicinal importance:

Drumstick is also called the medical tree due to its high nutritional use and medicinal properties. All parts of the plant have renewable sources of Tocopherols (alpha and gamma) phenolic compounds, beta carotene, Vitamin C and total proteins containing essential amino acids. They are the richest source of vitamin A, B, C, D, E, and K minerals present are K, Mg, Ca, Mn, Zn, Cu and Fe. The leaves, gums and bark help to overcome vitamin deficiency support the cardiovascular system normal blood glucose levels excellent body anti-inflammatory action, enrich anaemic blood and support the immune system against HIV. Moringa leaves help to overcome malnutrition due to the high source of protein and fibre. Moringa seat cake obtained as a product by pressing seeds are used to filter water using flocculation to produce Portable water for animal or human consumption.

Use and By-product

1. Nutrition:

a) **Leaves:** Rich in vitamins (A, C, E), minerals (calcium, potassium), and protein. They can be eaten fresh, cooked, or dried and powdered to add to foods.

b) **Seeds:** High in protein and healthy fats, the seeds can be eaten fresh, roasted, or processed to extract oil.

c) **Pods (Drumsticks):** Commonly used in curries and soups, especially in South Asian cuisines.

d) **Flowers:** Edible and often used in teas or added to foods for nutritional benefits.

2. Medicinal Uses:

Anti-inflammatory and antioxidant: Moringa is used traditionally to help with arthritis, asthma, heart disease, and diabetes. Antibacterial and antifungal properties: Used in traditional medicine to treat infections, including skin and urinary tract infections. Supports liver and kidney health: Moringa has been used to help detoxify and support these organs.

3. Agricultural use:

a) **Animal Feed:** Moringa leaves are rich in nutrients and can be used as a nutritious feed supplement for livestock.

b) **Natural Fertilizer:** The plant's leaves can be composted or processed to produce bio-fertilizer, boosting crop growth.

c) **Soil Improvement:** Moringa helps to fix nitrogen in the soil, improving soil fertility when cultivated as part of an intercropping system.

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4. **Water Purification:**

Seed Powder: Moringa seeds contain natural coagulants that can purify water by binding to impurities, making it safer for drinking.

5. **Cosmetics and Personal Care:**

Moringa Oil: Extracted from seeds, it's rich in oleic acid and used in skincare for its moisturizing and anti-aging properties. Moringa oil is also used in hair care products for hydration and scalp health.

6. **Biofuel:**

Seed Oil: Moringa seed oil can be processed to produce biofuel, serving as a renewable energy source.

By-Products of Moringa

1) **Moringa Powder:** Made from dried leaves, it's used as a supplement or added to smoothies, juices, and foods for a nutrient boost.
2) **Moringa Oil (Ben Oil):** Extracted from seeds, it is used in skincare products, perfumes, and as a cooking oil.
3) **Moringa Seed Cake:** The residue left after oil extraction, which can be used as a fertilizer or in water purification.
4) **Moringa Capsules/Tablets:** Made from powdered leaves or seeds and marketed as dietary supplements for easy consumption.
5) **Animal Feed:** By-products from moringa processing can be repurposed as nutritious feed for animals.

Climatic Requirements and Soil

Drumstick are drought resistant plant which preferably suits the soil and climatic conditions of the Bundelkhand region. The climatic conditions of plants are normally at pH 6 to 7.5, and clear loam soil is required for commercial cultivation. The high clay soil is not preferred which causes water stagnation during the rainy season and causes severe loss of vegetative part. It withstands under the rainfed hot semi-arid zones of Bundelkhand having soil depth of 0.5-0.7 m and maximum and minimum temperature range of 46.5 degrees centigrade and 12.7 degree centigrade simultaneously with a minimum rainfall of 941.25 mm and RH level 27.5 to 92.5 0%.

Varieties

Bundelkhand region is a semi-arid zone and the best variety suited for commercial cultivation of PKM1 and PKM2.

1. **PKM 1(Periyakulam 1):** It is grown for its heavy biomass and tenderly it provides highest yield in shortest period as well as taste better than other varieties. Length of each pod is 45 to 75 cm and each plant yield300 to 400 sticks. PKM-1 is particularly high in vitamins A, C, and E, calcium, iron, and essential amino acids, which are crucial for bone health, immune support, and energy production. Contains a substantial amount of protein (up to 30% in dried leaves), which is beneficial for people in regions with limited access to animal protein sources. High in antioxidants such as flavonoids, polyphenols, and ascorbic acid, which combat oxidative stress, protect against cellular damage, and may lower inflammation.

2. **PKM 2 (Periyakulam 2):** It is a hybrid between MP 31 and MP 28 plants that are quickly growing. Each plant has 12 branches and bears flowers in clusters of 3 to 4 pods per cluster harvested in 170 -180 days. Length of the pod 125 cm. It has less number and more flesh and gives and yield of 98 ton/ha. The upcoming future these two varieties can be grown in Bundelkhand region is a large scale which will provide high source of income in a smaller span of time. PKM-2 has a similar nutritional profile to PKM-1 but with slightly higher concentrations of certain minerals like calcium and magnesium. These nutrients are vital for muscle and nerve function, bone health, and overall energy production. PKM-2 leaves have high protein content and are also rich in dietary fiber, supporting digestive health and providing a feeling of satiety, which can be helpful for weight management. PKM-2 is also rich in antioxidants and phytochemicals such as quercetin and chlorogenic acid, which are known for anti-inflammatory and anti-carcinogenic properties.

Flowering and Fruiting

The flowers emerge from the current season growth either terminally or new shoots or on the leaf axes. The length and colour of the inflorescence depend on the genotype. The flowers of white to Purple scented, small flowers with linear bracts. Flower has five calyx which is pointed and green, petals of 5 narrow veined and white in colour. Ovary superior and three carpal one locule and many ovules and three placentae. 5 fertile stamens alternately arranged. Fruits are cylindrical and elongated 13 to 15 valved, unilocular capsule and seeds are winged. Drumstick flowers within 5 to 6 months of sowing. In South India the plant flowers in July September and again in April May, in Central Kerala the peak flowering in December and Jan. They usually ready for harvesting in 7 to 8 months after sowing.

Nutritional Requirement

No nutritional disorder observed usually in drumstick exceptionally chlorosis is some leaves of the plant is observed. To have a commercial yield the tree is supplied with 20 kg FYM per plant and basal dose of 100 kg urea, er tree f SSP, MOP per tree for higher yield. The half those of Nitrogen and potassium are applied in top dressing at the end of august for better growth and development, in organic production 10 kg per tree as compost as Basal application of sowing + 20 kg poetry at the time of pruning

Irrigation

Drumstick are hardy plant no need of irrigation in rainfed condition, considering flowering and fruiting, the first phase of fruiting is in rainy season August and September in which ample amount of water is present but during the summer months the plants are to be irrigated in every 15 days interval to have better fruiting

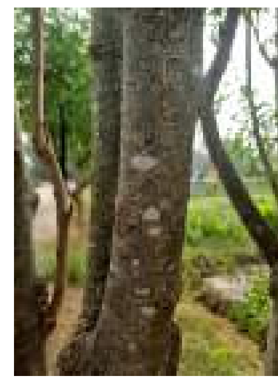
Cultural Practices

Weeding

Moringa is a slow growing crop and faces are acute competition with the weeds. weed problem depends on the climatic condition. Application of Pendamethalin @ 1.25 kg a. i. per hectare after showing as per emergence herbicide with hand weeding or hoeing in every 25 to 30 days help us to control weed

Pruning

Pruning is an important practice which is to be followed in drumstick. The emergence of overcrowded vegetative shoots on the main the ground level is to be removed with dead wood to be cut. As flowering and fruiting arises from the current season shoot it is an important practice which is to be followed. After them last harvest the tree should be pruned 1.5 m from ground level and paste with Bordeaux mixture to control the for the infection. The new should grows 10 to 15 days after pruning healthy shoots are allowed to grow at 20 to 30 cm distance and unhealthy are removed by thinning.



Plant protection

The major pest is leaf eating Caterpillar, jassid, aphid which can be controlled by dimethonate spray @ 0.2%. The root rot can be controlled by drenching soil water with copper oxide chloride at @ 0.2% leave fitting Caterpillar (Noorda blitialis WLK) which the foliates the whole crop if not managed properly. Spray on @ 2 ML per litre water from top to trunk of the tree that death of all and larva from the tree after the stray indicate effectiveness, fruit fly eggs should be collected and destruction of fruit fly pots by Spinosad 45 SC @ 56-gram a. i.per hectare is found to be the best for minimising pod damage

Yield

The first yield is to be obtained in the month of November and second in Feb, generally fruits at after the Feb do not get marketable size due to the shortage of moisture for pod development .The optimum time for harvesting is plumbing appearance with shallow ridges on pods .The average yield of both the varieties in Bundelkhand region is 22 quintal per hec with 42.50 kg pods per tree which the good source of income for the poor people hence define as the Miracle Plant in nutritional and income wise.

Papaya and Cucumber: An Ideal Intercrop Model for Sustainable Agriculture

Anushka Mehta, Manju, Chetna, Shikhar Kumar and Govind Vishwakarma

Introduction

Intercropping, the practice of growing multiple crops together on the same land, has gained significant attention in recent years due to its potential to enhance crop yields, promote sustainable agriculture and mitigate climate change. Among various intercrop combinations, papaya (*Carica papaya*) and cucumber (*Cucumis sativus*) have emerged as an ideal pairing, leveraging their complementary growth habits and requirements.

Carica papaya, commonly known as papaya, is a tropical plant native to Central America and southern Mexico and member of the Caricaceae family and is widely cultivated in tropical and subtropical regions and rich source of vitamins A and C, potassium, and an enzyme called papain, which aids digestion. It is a fast-growing, herbaceous plant that can grow up to 10-15 meters tall. It bears two types of flowers: male and female. Male flowers are slender and tubular, while female flowers are shorter and more robust.

Cucumis sativus, commonly known as cucumber, is one of the most widely cultivated and consumed vegetables globally, originated from Ancient Asia, belonging to the gourd family, Cucurbitaceae, this versatile plant has been a staple in various cuisines for over 3,000 years. The plant has a sprawling habit, with flexible stems that can spread up to 5 meters and also a good source of vitamins C and K, potassium, and antioxidants.

This article explores the benefits, advantages and guidelines for cultivating papaya and cucumber as an intercrop.

Advantages of Papaya and Cucumber Intercropping

1. ' **Space Optimization:** Papaya plants provide shade for cucumber which requires partial shade and cucumber vines spread around the base, maximizing space usage and reducing land requirements. Papaya is a tall plant that can grow up to 10-15 meters, while cucumber is a vining crop that spreads along the ground. By planting cucumber between papaya plants, the vertical space is optimized. Papaya and Cucumber Intercropping allows for more plants to be grown in the same area, increasing plant density and optimizing space use.

2. **'Soil Conservation:** Cucumber's spreading habit helps retain soil moisture, reduce erosion and maintain soil health. Papaya's extensive root system and cucumber's spreading vines hold the soil in place, preventing erosion and soil loss. Papaya and cucumber have different nutrient requirements, reducing competition and promoting nutrient cycling, which benefits both plants and the soil.

3. **'Pest Management:** Papaya's tall stature and cucumber's dense foliage deter pests, minimizing pesticide use and promoting integrated pest management. The diversity of plants in intercropping makes it harder for pest to locate their target plants. In Papaya and Cucumber intercropping, Papaya act as a trap crop for pests like aphids, whiteflies, and mealybugs, which are attracted to its leaves and stems, reducing pressure on cucumber. Cucumber's proximity to papaya can reduce aphid populations, as cucumber's sap can repel aphids. Papaya's strong scent can repel Cucumber Beetles (*Acalymma vittatum*) which target cucumber.

4. **'Nutrient Sharing:** Papaya benefits from cucumber's nitrogen-fixing ability, while cucumber utilizes papaya's nutrient-rich shade. Cucumber's roots are more efficient at absorbing phosphorus from the soil. Papaya benefits from the excess phosphorus absorbed by cucumber. Both plants have different micronutrient requirements. Papaya provides copper and zinc to cucumber, while cucumber provides boron and manganese to papaya.

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5. **‘Diversified Income:** Growing both crops ensures a steady income stream throughout the year, enhancing economic stability for farmers. Papaya and cucumber have different maturity periods, allowing for an extended harvest season and continuous income.

6. **‘Microclimate Creation:** The combination creates a favorable microclimate, regulating temperature and humidity levels. Papaya plants provide shade for cucumber plants, creating a cooler microclimate. Cucumber plants spread on the soil, regulating soil temperature and retaining moisture.

Advantages of Papaya and Cucumber cultivation for Arid regions

Advantages of Papaya

1. **Drought tolerance:** Papaya is highly resistant to drought, as it has a deep root system that allows it to access water deep in the soil, it’s stem and leaves can store water, allowing the plant to survive for longer periods without rain ,making it an ideal crop for arid regions.

2. **Low water requirement:** Papaya requires less water compared to other fruits, making it a water-conserving crop. Papaya’s small leaves reduce water loss through transpiration, helping the plant conserve water and it’s waxy leaves prevent water loss by creating a barrier that reduces moisture loss.

3. **High yield:** Papaya is a high-yielding crop, providing farmers with a significant income source. Papaya has a high fruit set rate and fruit grows rapidly, allowing for multiple harvests per year. Papaya plants can produce fruit for up to 10 months, extending the harvest season.

4. **Nutritional benefits:** Papaya is rich in vitamins A and C, potassium, and other essential nutrients, addressing malnutrition in arid regions. Papaya is an excellent source of vitamin C, with a single medium-sized fruit providing over 100% of the recommended daily intake. It is also a rich source of potassium, an essential mineral that helps maintain healthy blood pressure, promotes bone health, and supports muscle function. Papaya contains an enzyme called papain, which aids digestion, reduces symptoms of irritable bowel syndrome (IBS), and supports gut health.

5. **Soil adaptability:** Papaya can grow on poor soil, reducing the need for fertilizers and other chemicals. It can grow in a wide range of soil pH levels, from 5.5 to 7.5. Papaya forms myccorhizal associations with fungi, which help absorb nutrients from poor soil.

Advantages of Cucumber

1. **Heat tolerance**: Cucumber is highly tolerant of heat, making it suitable for arid regions with extreme temperatures. Cucumbers have a high water content (about 96%), which helps to regulate their temperature and maintain cell turgor pressure. They have a waxy coating on their skin that helps to prevent water loss and reduce transpiration. Cucumbers produce heat shock proteins that help protect against heat stress.

2. **Water efficiency:** Cucumber requires moderate water, making it a water-efficient crop for arid regions. Cucumbers have a deep root system that allows them to access water deep in the soil, reducing the need for frequent watering.

3. **Short gestation period:** Cucumber has a short maturation period, allowing farmers to harvest within 50-60 days. They produce fruit early in their growth cycle, allowing for multiple harvests in a short period. They can quickly regenerate after harvesting, allowing for continuous production.

4. **Market demand:** Cucumber has high market demand, providing farmers with a lucrative income source and they can be grown year round , ensuring consistent supply to meet market demand. Cucumbers are easy to store, transport, and use in various products, making them a convenient option for suppliers and buyers.

5. **Soil versatility:** Cucumber can grow on a range of soils, including sandy and loamy soils found in arid regions**.** They are tolerant of poor soil conditions, such as salinity, drought, and waterlogging and hence can be grown on wide ranges of soil .

Cultivation Guidelines

1. **‘Choose Compatible Varieties:** Select papaya varieties like ‘Sunrise’ or ‘Sunset’ and cucumber varieties like ‘Poinsett’ or ‘Slicing’, considering factors like climate, soil and market demand. While choosing the varieties, choose cucumber varieties

with a bush or compact growth habit to avoid shading out papaya plants and papaya varieties with a dwarf or compact growth habit to fit between cucumber rows.

Some popular intercropping combinations:

- 'Straight Eight' cucumber + 'Solo' papaya
- 'English' cucumber + 'Dwarf Hawaiian' papaya
- 'Bush Pickle' cucumber + 'Red Lady' papaya

2. **'Plant Spacing:** Plant papaya 2-3 meters apart, with cucumber seeds sown around the base to optimize space usage. When intercropping papaya and cucumber, consider the following spacing combinations:
   - Papaya (dwarf/compact): 1.5-2.5 meters apart, with cucumber (bush/compact) planted in between at 30-60 cm apart
   - Papaya (semidwarf): 2.5-3.5 meters apart, with cucumber (vining) planted in between at 60-90 cm apart

3. **'Irrigation:** Maintain consistent moisture levels, taking care not to overwater, which can lead to disease and root rot. Papaya requires more water than cucumber, especially when fruiting. Water every 2-3 days for papaya and every 3-4 days for cucumber. Papaya needs about 600-800 mm (24-32 in) of water per growing season, while cucumber requires about 400-600 mm (16-24 in). Use drip irrigation for efficient water use and reduced evaporation. Place drippers near the base of each plant.

4. **' Fertilization:** Apply organic fertilizers to promote healthy growth, improve soil fertility and reduce chemical use. Consider using organic fertilizers like compost, manure, or green manure to promote soil health and nutrient cycling. Papaya requires more potassium (K) for fruiting, so add additional K-rich fertilizer (e.g., potassium sulfate) during fruiting stage while Cucumber requires more nitrogen (N) for leaf growth, so add additional N-rich fertilizer (e.g., ammonium nitrate) during vegetative growth stage. Fertilize papaya at planting, fruiting, and post-harvest, while fertilize cucumber at planting, vegetative growth, and fruiting stages.

5. **'Pruning and Training:** Prune papaya regularly to maintain shape and promote fruiting, and train cucumber vines to a trellis or a fence to optimize space and promote vertical growth. Train papaya plants to a single stem or a central leader to promote vertical growth and fruiting and remove lower branches to promote fruiting on upper branches .

Challenges and Future Directions

While papaya and cucumber intercropping offers numerous benefits, challenges persist:

1. **'Crop Competition:** Monitor for competition and adjust planting densities to ensure optimal growth. Papaya plants can grow quite large and may shade out cucumber plants, reducing their growth and productivity. Cucumbers require consistent moisture, while papayas have a higher water requirement during fruiting. To manage these competition , prune papaya plants to maintain a smaller size and reduce shading , use drip irrigation to deliver water directly to the roots of each plant, reducing competition for water.

2. **'Disease Transmission:** Both crops are susceptible to similar insect vectors and similar diseases and Intercropping increases the proximity and contact between the two crops, making it easier for diseases to spread. Cucumber and papaya share similar soilborne pathogens like fusarium and phytophthora, which can be transmitted through contaminated soil and water. Overhead irrigation can splash water and transmit diseases like anthracnose and phytophthora between the two crops. To manage disease transmission between cucumber and papaya during intercropping use disease-resistant varieties of both crops, implement good sanitation practices, such as removing weeds and debris, and disinfecting tools and equipment use physical barriers, such as row covers, to prevent insect vectors from transmitting diseases.

3. **'Market Demand:** Assess local market demand before cultivating to ensure economic viability as demand for papaya and cucumber can fluctuate, making it challenging to ensure consistent market supply. Limited market channels and buyers may limit the sale of intercropped papaya and cucumber.

To address these challenges, further research is needed:

1. **'Optimizing Planting Ratios:** Investigate ideal papaya-to-cucumber ratios for maximum yields. A common ratio is 1:2 or 1:3 (one papaya plant for every two or three cucumber plants). Plant papaya

at a density of 1,500-2,000 plants/ha and cucumber at 3,000-4,000 plants/ha can be planted.

2. **'Exploring Other Combinations:** Investigate intercropping papaya with additional crops to diversify income streams. There are various other intercropping combinations so that farmer can enhance their income and every farmer can do it easily like combination of Papaya and Pineapple is beneficial and popular combination in tropical regions, pineapple and papaya have similar growing requirements and can benefit from each other's shading. Chillies and Papaya is another beneficial intercropping combination as Chilies and papaya have a symbiotic relationship and can help repel pests and improve growth. Some other combinations are Papaya + Tomato, Papaya + Peppers, Papaya + Beans, Papaya + Radish, etc.

3. **'Economic Viability:** Conduct comprehensive cost-benefit analyses to ensure the economic feasibility of this intercrop model. Intercropping can lead to higher total yields per acre, as both crops can be harvested simultaneously. Growing two crops together can provide multiple income streams, reducing dependence on a single crop.

Conclusion

Papaya and cucumber intercropping is a viable, sustainable agricultural practice promoting resource efficiency, biodiversity and economic stability. By adopting this model, farmers can increase yields, reduce chemical use and enhance economic stability. As the global focus shifts toward sustainable agriculture, this intercrop combination offers a promising solution for environmentally conscious farming practices.

Recommendations

1. **'Farmers:** Adopt papaya-cucumber intercropping to enhance economic stability and reduce environmental impact.

2. **'Researchers:** Investigate optimal planting ratios, explore additional intercrop combinations and conduct economic viability studies.

3. **'Policy Makers:** Promote sustainable agricultural practices through incentives, training programs and policy support.

By embracing papaya-cucumber intercropping, we can contribute to a more resilient, productive and sustainable agricultural future.

Kokoda: The Hidden Superfood for a Healthier Future

Anjali Sharma[1], Brij Bihari Sharma[2], Akanksha Singh[3], Arjun Lal Ola and R.K. Singh

Abstract

Kakoda (*Momordica dioica*), commonly known as spiny gourd, is an underutilized vegetable with the potential to become a significant superfood. Native to the Indo-Malayan region and widely grown across South Asia, Kakoda is a dioecious climbing creeper from the Cucurbitaceae family, thriving in tropical and subtropical climates. The fruit, rich in essential nutrients, contains high levels of vitamin A, vitamin C, dietary fibre, and vital minerals like calcium and iron. Its bioactive compounds, such as flavonoids, phenolics, and saponins, provide powerful antioxidant, anti-inflammatory, and anti-diabetic properties, contributing to the prevention of chronic diseases such as diabetes and cardiovascular conditions. Despite these benefits, Kakoda remains largely underutilized due to insufficient awareness and research. This abstract explores its potential to enhance food security and nutritional diversity in the face of climate change, highlighting its adaptability to diverse agro-climatic conditions, including areas prone to abiotic stress. Promoting the cultivation and consumption of Kakoda could lead to healthier diets and sustainable agricultural practices, positioning it as a hidden superfood for a healthier future. Further research is needed to fully understand its therapeutic potential and optimize its use in modern agriculture.

What is Kakoda?

Kakoda is a nutritionally rich summer, dioecious and perennial crop. It is commonly known as kakrol, kantola or parora, is a dioecious climbing creeper from the Cucurbitaceae family the same plant family that includes cucumbers, melons, and pumpkins. It flowering between July and august, with fruiting from September to November. The fruit is shortly beaked, obtuse, densely covered with soft spines, and changes from green to yellow as it matures, containing an inner red kernel. The seeds are rounded, broadly ellipsoid, slightly compressed, and irregularly corrugated, encased in red pulp. This plant is widely distributed across India, Pakistan, Bangladesh, and the Himalayas, extending to Sri Lanka. It has been reported at altitudes up to 1,500 meters in Assam and the Garo Hills of Meghalaya. Native to the Indo-Malayan region, Kakrol is an underutilized Cucurbitaceous crop with potential significance. The vegetable has been traditionally grown and consumed in rural areas but has yet to make its mark in global food markets.

In many ways, Kakoda is a perfect example of an underutilized crop. It has been largely neglected by modern agriculture despite its resilience to adverse environmental conditions and its rich nutritional profile. So, what makes this spiny gourd so special?

Nutritional Powerhouse: What Makes Kakoda a Superfood?

Kakoda is a highly nutritious vegetable that offers a wide range of health benefits. Despite being low in calories, it is packed with essential vitamins and minerals that contribute to overall well-being.one of its key nutritional features is its richness in vitamins A and C. Vitamin A plays a vital role in maintaining healthy vision and supporting immune function, while vitamin C acts as a powerful antioxidant, enhancing immune health and promoting radiant skin. In addition to its vitamin content, Kakoda is also an excellent source of dietary fiber. This high fiber content aids digestion, supports healthy bowel movements, and helps regulate blood sugar levels, making it a great choice for those aiming to manage their weight or improve digestive health. Moreover, Kakoda is abundant in bioactive compounds such as flavonoids and phenolics, which exhibit strong antioxidant properties. These compounds help protect the body against oxidative stress, reducing the risk of chronic conditions like heart disease and cancer. Incorporating Kakoda into your diet is a simple and effective way to boost your nutrient intake. Its subtle, slightly bitter flavor pairs well with a variety of cooking methods, whether stir-fried, curried, or added to soups, making it a versatile addition to many dishes.

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Climate-Resilient and Sustainable: Farmer's Dream

As climate change continues to threaten global food security, the need for crops that can thrive in tough environments is greater than ever. Here's where Kakoda shines.

Kakoda is a hardy plant that grows well in both tropical and subtropical climates. It requires minimal water and can tolerate poor soils, making it ideal for regions where more delicate crops would struggle to survive. Its deep root system allows it to access water and nutrients from deeper layers of soil, making it more drought-tolerant than many other vegetables. Furthermore, Kakoda is naturally resistant to several pests and diseases that commonly affect other crops in the cucurbit family. This reduces the need for chemical pesticides, making Kakoda an excellent candidate for organic and low-input farming systems. Farmers looking to diversify their crops and improve resilience against the unpredictability of climate change could benefit significantly from cultivating Kakoda. With its low input requirements and strong resistance to environmental stressors, Kakoda offers a sustainable option for agriculture in vulnerable regions.

***Kakoda* diversity in Yamuna- Chambal ravines tracts of U.P. M.P. and Rajasthan Boarder**

Health Benefits Beyond Nutrition

Beyond its impressive nutritional profile, Kakoda also holds promise for its medicinal properties. In traditional medicine, Kakoda has been used for centuries to treat various ailments. Recent studies are beginning to back up some of these claims, highlighting its potential in modern medicine.

The fruits of kakoda, commonly used as a vegetable, possess a wide range of medicinal properties. They are known for their diuretic, stomachic, laxative, hepatoprotective, and antivenom properties. Traditionally, the fruit has been used to treat asthma, leprosy, excessive salivation, and inflammation caused by lizard and snake bites. Fresh fruit juice is often prescribed to manage hypertension, while fruits cooked in a small amount of oil are consumed for the treatment of diabetes. Additionally, tender fruits are rubbed on the skin to alleviate pimples and acne, and roasted seeds are taken to address eczema and other skin disorders. The dried fruit, when powdered or made into an infusion and introduced into the nostrils, produces a powerful errhine effect, provoking a significant discharge from the nasal mucous membrane. The leaves of kakoda also hold significant medicinal value. They exhibit antihelminthic and aphrodisiac properties and are used to treat a variety of conditions, including fever, jaundice, asthma, bronchitis, piles, hepatic damage, mental disorders, digestive disorders, and urinary complaints. The root juice acts as a stimulant, astringent, and antiseptic. They are commonly used in cases of bleeding piles, bowel infections, and urinary disorders. Root powder is applied to soften the skin and reduce perspiration. Mucilaginous tubers from female plants are specifically used to treat bleeding piles and bowel infections. In the Konkan region, root juice is a traditional remedy for inflammation caused by contact with house lizard urine, and roots from the male creeper are used to treat ulcers, particularly those caused by snake bites.

Why Is Kakoda Still Underutilized?

Despite its numerous benefits, Kakoda remains a minor crop, underutilized in both agricultural and consumer markets. Several factors contribute to this:

Lack of Awareness: One of the biggest challenges is simply a lack of awareness among consumers and farmers alike. While Kakoda is known in some regions, it hasn't been widely promoted or included in global food systems.

Poor seed germination: Seed dormancy is a significant limiting factor hindering the commercial cultivation of spine gourd. Additionally, low temperatures and seed hardness contribute to the slow and poor germination observed in Kakoda.

Limited Research: There has been little scientific research or breeding work done on Kakoda compared to other crops. This means there are fewer high-yielding or improved cultivars available to farmers, limiting its adoption.

Market Challenges: Without strong consumer demand, there is little incentive for farmers to grow Kakoda. Additionally, the lack of established supply chains makes it difficult for farmers to sell their produce in broader markets.

Addressing these challenges will require coordinated efforts from governments, researchers, and agricultural organizations to promote the cultivation and consumption of Kakoda.

Unlocking Kakoda's Potential: The Way Forward

To fully harness the potential of Kakoda, several key actions must be undertaken across different sectors. First and foremost, raising public awareness is essential to promote its nutritional and environmental benefits. Public campaigns that focus on educating consumers about Kakoda's health advantages could drive demand for this underutilized vegetable. At the same time, efforts should be made to inform farmers about Kakoda's low-input requirements and its resilience to changing climate conditions. This knowledge could encourage broader cultivation, especially in regions where crops are affected by abiotic stress. In addition to raising awareness, investment in research and development is crucial. More research is needed to develop improved Kakoda varieties that are adaptable to various agro-climatic conditions. This would not only expand the regions where Kakoda can be grown but also enhance its yield and quality. Furthermore, studies into the vegetable's nutritional and medicinal properties could underscore its value as a functional food, attracting more interest from both the agricultural and health sectors. Finally, market development is critical for Kakoda's widespread adoption. Creating strong market linkages and establishing value chains are essential steps in ensuring the crop's success. Processing techniques, such as drying or freezing, could extend Kakoda's shelf life and availability throughout the year, further increasing its marketability. With the right strategies in place, Kakoda has the potential to become a valuable crop that contributes to both human health and sustainable agriculture.

Conclusion

Kakoda (*Momordica dioica*) emerges as a hidden superfood with significant potential to contribute to global health and sustainability. Its impressive nutritional profile, rich in vitamins, minerals, and bioactive compounds, positions it as a valuable addition to diets, especially in regions where malnutrition and lifestyle-related diseases are prevalent. The fruit's unique medicinal properties, which include anti-diabetic and antioxidant effects, further enhance its appeal as a natural remedy for chronic health issues. Moreover, Kakoda's resilience to abiotic stress makes it a viable crop for cultivation in diverse agro-climatic conditions, offering a sustainable solution to food security challenges in the face of climate change. By promoting the cultivation and consumption of Kakoda, we can diversify agricultural practices and improve nutritional options in local diets. To realize Kakoda's full potential, increased research and awareness initiatives are essential to educate farmers and consumers about its benefits. As we strive for a healthier future, integrating Kakoda into modern agricultural systems and diets can pave the way for a more sustainable and nutritionally rich world, highlighting the importance of preserving and promoting underutilized crops in our food systems.

AGRI-INNOVATION

1. IoT in Agriculture

In agriculture, the Internet of Things (IoT) is a smart farming solution to monitor crop fields from anywhere. This involves using sensors to monitor soil moisture, crop health, livestock conditions, temperature, etc. With the help of IoT technology, automated irrigation systems efficiently manage water resources. By gathering data on factors like moisture and temperature, IoT assists in determining the precise amount of water required for crops each season.

2. Real-Time Kinematic (RTK) Technology

Robert Salmon, a farmer from the UK, discovered that limiting the paths of farming machinery to specific lanes significantly reduced harm to the soil. When machines roam freely across the land, it can lead to almost all of the land being driven over. This, in turn, harms the land's drainage and its ability to crumble properly. RTK technology, on the other hand, offers accuracy down to the centimetre. This level of precision allows farmers to create accurate maps of their fields and ensure that their vehicles always stick to the same lane. It sends the correct positioning data to tractors via radio signals, keeping them on the right path as they move. This new technology in agriculture in India improves soil health and productivity, resulting in higher yields with less resource input.

3. AI/ML and Data Science in Agricultural Technology:

Farmers find agricultural forecasting much more accessible when they harness the power of AI/ML (Artificial Intelligence/Machine Learning) and data science technology. Technologies like 3D laser scanning and spectral imaging/analysis enable farmers to predict weather conditions and optimise resource usage for irrigation, fertilisation, and pest control. Through AI/ML and data science, farmers can analyse their fields to identify the best locations for planting seeds. They can even employ computer vision to determine the ideal height, width, and spacing for plants. This data is then used to enhance their farming methods.

4. *Tricholime* by Dr V Srinivasan, Dr R Praveena Dr R Dinesh and Dr S J Eapen

A New Granular Lime-based Trichoderma Formulation ICAR-Indian Institute of Spices Research (ICAR-IISR), Kozhikode have successfully developed a new granular lime-based Trichoderma formulation. The formulation named '*Tricholime*', integrates Trichoderma and Lime into a single product, making the application easier for the farmers.

5. Soymilk Powder, an Alternative to Dairy Products: collaboration with M/s Bio-Nutrients (India) Pvt. Ltd., Bhopal and ICAR-CIAE, Bhopal

Soymilk, an aqueous extract of soybean, is becoming more and more popular as consumers become more health conscious and seek out alternatives to dairy products. Soymilk is treated as a healthy food because it is cholesterol and lactose-free, and contains phytochemicals. Consumption of soymilk is primarily increasing among those consumers who are lactose intolerant, vegetarian and seeking healthier diets. Furthermore, there is a real interest among. consumers in soymilk in the form of dried powder. A dry powder product is highly desirable since it not only possesses long shelf-life but also requires relatively low transportation cost and storage capacity and the product can be distributed over a wide area. At present the firm is producing around 100 tons of soymilk powder per year and marketing at an average price of ₹ 225/ kg of soymilk powder.

6. Frieswal Female Calf Born through OPU-IVF-ET:

In a landmark achievement, the ICAR-Central Institute for Research on Cattle (ICAR-CIRC) in collaboration with Uttarakhand Livestock Development Board (ULDB), Kalsi, Dehradun, have successfully produced a healthy Frieswal female calf using the cutting-edge technique of Ovum Pick-Up In Vitro Fertilization-Embryo Transfer (OPU-IVF-ET) from a recipient Sahiwal cow. This milestone accomplishment was made possible through a collaborative effort between Dr Suresh Kumar, Head of Cattle Physiology and Reproduction, and his team, along with the team of experts of Animal Breeding Farm, Kalsi, Dehradun led by Dr A P S Aswal, Project Coordinator of ET NDP I.

***7. Raj-Himani*: India's First Horse Foal through Frozen Semen and Embryo Transfer Technologies**

Continuing the success in producing foal through Embryo transfer, scientists at Equine Production Campus, Regional Station, ICAR-National Research Centre on Equines, Bikaner, Rajasthan for the first time in the country have produced a horse foal using admixture of two technologies viz. frozen semen technology and Embryo transfer technology. During the process for producing the viable embryos, frozen semen from a stallion was used for artificial insemination and the embryo was recovered from the inseminated mare on 7.5 day after ovulation. The recovered embryo after flushing was transferred to the estrus synchronised surrogate mare. The mare delivered a healthy female foal at 3:40 AM (IST) on 4 October 2023.

8. CTRI Naveena (FCJ-11): A high-yielding FCV tobacco variety

Flue-cured Virginia (FCV) tobacco, grown in Northern Light Soils (NLS) of Andhra Pradesh is known as semi-flavourful to flavourful tobacco. About 75% of the tobacco produced here is being exported to other countries. ICAR- Central Tobacco Research Institute (CTRI), Rajahmundry has released an FCV high-yielding somaclonal, FCJ-11 in the name of CTRI Naveena for cultivation under irrigated conditions of NLS through AP SVRC. CTRI Naveena has a yield potential of more than 3,300 kg/ ha and can even yield up to 3,900 kg/ha under favourable conditions. It can withstand rain damage to a certain extent during crop growth compared to other varieties grown in this region. CTRI Naveena shows lower incidence of Spodoptera, budworms and aphids under field conditions. Produces more number of leaves (33) with higher bright grades (80%). A cured leaf is bright lemon to orange in colour with a good aroma. The cured leaf has an acceptable range of physical, chemical and smoke parameters. Found to be remunerative (B:C cured leaf has acceptable range of physical, chemical ratio and smoke parameters. Found to be remunerative (B:C ratio 1.57) to farmers with an additional revenue of '50,000/ha than existing varieties. 1.57) to farmers with an additional revenue of %50,000/ ha than existing varieties.

9. DOGR-RGP-3, an onion variety released from DOGR, Rajgurunagar, Pune Maharashtra

Attractive dark red globe-shaped bulb free from doubles and bolters. Bulb storage is 2-3 months. The average marketable yield is 207q /ha. Harvested in 100-105 days after transplanting. Suitable for Kharif season. Recommended for zone IV (Jabalpur, Raipur, Chiplima, Akola, Jhalawar).

10. Controlled Environment Agriculture (CEA)

Controlled Environment Agriculture (CEA) is a method of cultivating plants in a fully regulated environment. It is also known as 'vertical farming or indoor farming.' In this type of cultivation, all the plant's needs are met by artificially providing them with water, nutrients, and light using hydroponic, aquaponic, and aeroponic techniques.

11. **Kisan Samridhhi online market portal: revolutionizing Indian Agriculture through Digital Vyapar Network (DIVYAN)** developed by ICAR-ATARI, Bengaluru, and managed by KVK, Pathanamthitta

Direct online sales portal for seeds, planting materials, bio-products, value-added products and technological products produced by KVKs, FPOs, entrepreneurs, and SHGs. Promotes wider reach, transparency, market access and fair pricing. Operational in Karnataka, Kerala and Lakshadweep, connecting KVKs, farmers, agri-entrepreneurs and consumers to foster entrepreneurship and market access. The portal aims to establish a Digital Vyapar Network (DIVYAN) for efficient agricultural marketing.

Compiled by: Dr. Govind Vishwakarma
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Swachh Bharat Abhiyan

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