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RECENT INNOVATIONS AND ADVANCED TECHNIQUES FOR ENHANCING GUAVA (*PSIDIUM GUAJAVA* L.) PRODUCTIVITY: A REVIEW

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ABSTRACT

India is blessed with diverse agro-climatic conditions, ranging from arid and semi-arid to tropical, sub-tropical, and temperate regions, making it suitable for cultivating a wide variety of fruit crops. Currently, India is the world's second-largest fruit producer, trailing only China. To meet the growing demand for nutritious food in a sustainable, secure, and affordable manner, it is crucial to adopt advanced agricultural practices that enhance both the quantity and quality of produce. Despite India's significant fruit production, there remains considerable potential to improve productivity. This review highlights several innovative high-tech practices in guava cultivation aimed at boosting productivity. Key techniques include mulching, meadow orcharding, high-density planting, pruning, flower induction, fruiting management, fertilization, fertigation, crop regulation, foliar nutrition, and the use of salinity-tolerant rootstocks. These methods have shown promise in improving production, productivity, and fruit quality. By integrating these advanced practices into guava cultivation, farmers can achieve higher yields and better-quality produce, contributing to sustainable agricultural development.
Keywords **:** Guava, Advanced techniques, productivity, fruit quality.

Introduction

Guava (*Psidium guajava* L.) is a widely cultivated fruit valued for its rich flavor, pleasant aroma, and high nutritional content. Native to tropical regions of the Americas, spanning from Mexico to Peru, guava thrives in both tropical and subtropical climates. In India, it ranks as the fourth most cultivated fruit. The fruit is known for its delightful fragrance (Moona *et al.*, 2018) and is low in carbohydrates, fats, and proteins while being a rich source of vitamin C, pectin, and phytochemicals (Fernandesa *et al.*, 2014), including polyphenols and carotenoids. Additionally, guava contains essential minerals such as calcium, phosphorus, and iron. It is commonly consumed fresh and is also processed into various products such as jam, jelly, nectar, marmalade, paste, cakes, and biscuits (Patra *et al.*, 2004). Beyond its culinary uses, different parts of the guava tree, including the leaves, roots, bark and immature fruits, has medicinal applications. They are traditionally used to treat ailments such as gastroenteritis, diarrhea, and dysentery. In India, guava is cultivated over approximately 2.65 million hectares, yielding around 4.054 million tonnes of fruit. Bihar leads in guava production, followed by Andhra Pradesh and Uttar Pradesh. In Tamil Nadu, guava is grown on 9,691 hectares, with an annual production of 155,058 metric tonnes and an average productivity of 16 metric tonnes per hectare (Santhi *et al.*, 2022).

In recent years, guava cultivation has shifted from subsistence farming to commercial production. One key strategy for optimizing land use and profitability is tree spacing, which aims to maximize resource utilization such as light, water, and nutrients within a confined area to achieve higher yields. With rising land costs and the need for quicker returns on investment, there is a global trend toward high-density planting systems, such as meadow orcharding or ultra-high-density planting.

Despite the increase in the area and production of guava over the past decade, productivity has not seen significant improvement. Traditional planting systems, which are still widely used, make it challenging to achieve desirable production levels. Additionally, in these systems, guava trees take 4-5 years to reach commercial bearing, increasing the overall cost of production per unit area. As a result, the shift toward high-density planting systems is gaining momentum worldwide to address these challenges and improve efficiency. Several studies have been conducted in India to enhance guava yield and fruit quality using various technological advancements (Boora *et al*., 2016; Lal *et al*., 2017). Therefore, the adoption of modern and innovative techniques is crucial to further improving both the quality and productivity of guava.

High density planting

High-density planting (HDP) has emerged as a transformative approach in guava cultivation, shifting the paradigm from traditional extensive farming to intensive, precision horticulture. This innovative system, while well-established in temperate fruit crops like apples, has demonstrated remarkable success in tropical fruits, particularly guava, through extensive research across India.

Breakthroughs in High-Density Configurations

Recent trials by the Central Institute of Subtropical Horticulture (CISH), Lucknow, have validated ultra-high-density planting at 2 m × 1 m spacing (5,000 plants/ha), achieving unprecedented yields of 40-60 tons/ha through meticulous canopy management. The meadow orchard system, incorporating regular topping and hedging, has proven particularly effective in maintaining optimal light interception and air circulation while maximizing land use efficiency (Nautiyal *et al*., 2023). Notably, the Lucknow-49 cultivar has shown exceptional adaptability to challenging sodic-alkaline soils (ESP >15%) at 3 m × 1.5 m spacing (2,222 plants/ha), demonstrating the system's versatility across soil conditions (Auxcilia *et al*., 2019).

Precision Management for Optimal Results

The success of HDP systems hinges on several critical factors:

1. Canopy architecture control: Implementing modified leader system training
2. Precision nutrition: Drip fertigation with balanced NPK + micronutrients
3. Growth regulation: Strategic use of paclobutrazol for controlled vegetative growth
4. Mechanized operations: Enabling efficient pruning and harvesting

Comparative Performance Analysis

Research reveals an inverse relationship between planting density and individual plant productivity, yet demonstrates clear advantages at the hectare level:

- Traditional systems (6×5 m; 333 plants/ha): 35.15 kg/plant (rainy season)
- High-density systems (6×2 m; 833 plants/ha): 15.07 kg/plant but 3× higher total yield (Brar *et al*., 2009)

The optimal moderate-density configuration of 6×4 m (416 plants/ha) balances microclimate optimization with increased plant numbers, yielding 20% higher productivity without compromising fruit quality (Lal *et al*., 2000; Bal and Dhaliwal, 2003).

Economic and Sustainability Benefits

1. Early bearing: Commercial production commencing in 2nd year vs 4th year in traditional systems
2. Resource efficiency: 30-40% water savings through drip irrigation integration
3. Labor optimization: 25% reduction in harvesting costs due to smaller tree size
4. Quality enhancement: Improved fruit color and sugar content from better light exposure

Crop regulation

Guava cultivation in India follows distinct seasonal flowering patterns, with three major flushes annually: Ambe Bahar (February-March flowering with rainy season harvest), Mrig Bahar (June-July flowering with winter harvest), and Hasth Bahar (October-November flowering with spring harvest) (Boora *et al*., 2016; Lal *et al*., 2017). However, these natural cycles often lead to uneven fruit production, causing market fluctuations between oversupply and shortages. Effective crop regulation has become essential to align production with market demand while optimizing fruit quality and yield. Farmers strategically select specific bahar periods based on multiple factors including irrigation availability (Mrig Bahar being preferred in irrigated areas for superior fruit quality), market prices (winter crops typically commanding premium rates), pest pressure (rainy season being more susceptible to fruit flies), and climatic conditions (avoiding extreme temperatures during fruit set). Modern regulation techniques combine traditional knowledge with scientific interventions, employing controlled water stress (30-45 days irrigation withholding), root zone management (surface root scraping), chemical treatments (Ethephon 200ppm for uniform flowering), and canopy manipulation (30-50% pruning intensity). These practices offer significant benefits, potentially increasing premium-grade yields by 35-40%, reducing pesticide use by 25% through avoided pest-prone seasons, extending market availability, and boosting farmer incomes by 50-60% through seasonal price advantages. Current research continues to refine these methods, including trials with growth retardants like paclobutrazol for precision flowering control in high-density plantations, demonstrating how targeted crop regulation can transform guava cultivation into a more profitable and sustainable enterprise (Lal *et al.*, 2017; Maji *et al.*, 2015).

Crop regulation is done through different methods like

Withholding irrigation

Withholding irrigation from February to mid-May induces flower shedding in guava trees, allowing them to enter a rest period. During this phase, carbohydrate reserves accumulate in the branches, promoting stronger vegetative growth and improved fruiting in the subsequent season (Sachin *et al.*, 2015). This technique is particularly effective in heavy clay soils, which retain moisture for longer periods, ensuring gradual stress induction. However, in sandy soils, where water drains rapidly, this method is less effective, as the trees may experience excessive stress, leading to stunted growth or reduced yield (Tiwari and Lal, 2000).

To optimize results, growers should consider soil type, climate, and cultivar sensitivity when implementing water stress techniques. In regions with high temperatures and low humidity, partial irrigation may be necessary to prevent excessive tree stress. Additionally, combining pruning with controlled water stress can further enhance flowering synchronization and yield consistency.

Root exposure and root pruning

In guava cultivation, the root exposure technique is an effective method for growth regulation that involves carefully removing the upper 7–10 cm soil layer within a 40–60 cm radius around the tree trunk. This practice exposes the surface roots to sunlight, temporarily reducing moisture supply to the canopy and inducing leaf shedding, which forces the tree into a rest period. After 3–4 weeks, the exposed roots are covered with a nutrient-rich soil-manure mixture and irrigated, promoting vigorous new growth and improved flowering in the following season. Studies have demonstrated that this method enhances fruit yield and quality by synchronizing the tree's growth cycle (Lal *et al.*, 2017; Sachin *et al.*, 2015; Suresh *et al.*, 2016). The technique offers several advantages, including breaking alternate bearing patterns, improving soil aeration in heavy soils, enhancing nutrient uptake when manure is incorporated, and serving as an organic alternative to chemical growth regulators. For optimal results, the practice should be performed during dry seasons with careful execution to avoid damaging major roots, and should be followed by proper irrigation and fertilization. This eco-friendly approach is particularly valuable for small-scale growers seeking sustainable yield enhancement methods.

Shoot pruning

Shoot pruning is a vital practice in guava cultivation, as it stimulates the growth of new vegetative shoots, which are essential for flower and fruit development. This technique not only helps in managing the tree size but also enhances fruit quality and yield by promoting better light penetration and air circulation within the canopy. Studies have demonstrated that proper pruning improves nutrient allocation, reduces pest and disease incidence, and encourages uniform fruit production.

Research by Thakre *et al.* (2016) highlights the importance of pruning in maintaining tree vigor and productivity. Additionally, studies on guava cv. Paluma (Sarrano *et al.*, 2008a; Sarrano *et al.*, 2008b) emphasize that well-timed pruning enhances sprouting and fruiting efficiency. Similar findings were reported in Nepal (Adhikari and Kandel, 2015) and Cairo, Egypt (Sahar and Hameed, 2014), where the timing and intensity of pruning were found to significantly influence shoot regeneration and overall yield. Optimal pruning practices vary depending on climatic conditions, cultivar, and desired harvest time, making it essential for growers to adopt region-specific strategies.

Debloosming

Deblossoming is a critical management practice in guava cultivation that significantly improves fruit yield and quality. Various chemical and mechanical methods have been developed for effective flower thinning:

1. Chemical Methods

- Urea sprays have shown effectiveness in deblossoming (Singh *et al*., 2002)
- Ethephon application provides reliable flower thinning (Singh *et al*., 2000)
- Potassium Iodide (Sachin *et al*., 2015) and 2,4-D (Das *et al*., 2007) demonstrate good results
- Naphthalene Acetamide (NAD) has proven successful (Maji *et al*., 2015)
- 100 ppm NAA application works particularly well for guava cv. L-49 in rainfed conditions of Eastern India (Das *et al*., 2007)

2. Economic Considerations

- Partial removal (50%) of rainy season flowers has shown economic benefits (Das *et al*., 2007)
- Manual deblossoming remains economically unfeasible for large-scale operations (Singh *et al*., 2002)

3. Physiological Benefits

- Removal of rainy season flowers enhance winter crop yield and quality (Lal *et al*., 2017)
- Proper deblossoming improves resource allocation within the tree.
- Results in larger, higher-quality fruits in the target season.

Flower thinning and shoot bending

Guava productivity and fruit quality can be significantly enhanced through strategic flower thinning and shoot bending techniques. Thinning flowers during summer months improves winter crop yields by 20-30% while producing larger, higher-quality fruits with better market value, as it reduces competition among developing fruits and allows for optimal resource allocation (Lal *et al*., 2020). Shoot bending, an innovative canopy management practice, offers multiple benefits including delayed flowering for off-season production, improved light penetration, enhanced bud break, and reduced excessive vegetative growth (Sarkar *et al*., 2005). These techniques achieve maximum effectiveness when integrated with balanced nutrient management featuring proper NPK and micronutrient application, precision irrigation that includes controlled water stress during critical growth phases, and comprehensive pest management to minimize energy diversion from fruit production (Sharma *et al*., 2018). Additional benefits include improved canopy structure through regular pruning, which enhances light distribution and reduces disease incidence. Field implementations have demonstrated 30-40% increases in overall productivity, with farmers reporting higher profitability due to premium pricing for superior off-season fruits. The combined application of these scientifically-validated methods provide a holistic approach to guava cultivation that optimizes both yield and fruit quality while maintaining tree health across seasons.

Table 1: Suitable Methods for Crop Regulation in Guava

Method	Description	Effects on Crop Regulation	References
Pruning	Selective removal of branches to balance vegetative and reproductive growth.	Enhances flowering, promotes off-season fruiting, improves fruit quality	Thakre *et al*., 2016; Sarkar *et al*. (2017)
Chemical Regulation (Paclobutrazol, Ethephon, NAA, GA_3)	Application of growth regulators to synchronize flowering and fruiting. |	Paclobutrazol delays vegetative growth; Ethephon induces flowering; NAA and GA_3 regulate fruit set.	Singh *et al*., 2000, Das *et al*., 2007
Nutrient Management	Adjusting NPK and micronutrient supply at critical growth stages.	Enhances flowering, prevents excessive vegetative growth, improves yield.	Sharma et al., 2013
Water Stress Management	Controlled irrigation or drought stress at specific stages.	Induces flowering by restricting vegetative growth.	Sachin *et al*., 2015
Deblossoming	Manual removal of excess flowers and fruits.	Prevents overbearing, improves fruit size and quality.	Lal *et al*., 2017

Use of mulching	Organic/inorganic mulches to regulate soil moisture and temperature.	Promotes uniform flowering, enhances nutrient uptake.	Das *et al.*, 2010
Girdling	Partial removal of bark from the main stem or branches.	Alters carbohydrate partitioning, induces flowering.	Sarkar *et al.* (2017)

Root stock

Guava rootstocks play a crucial role in determining tree vigor, yield potential, and stress tolerance, particularly under challenging soil conditions such as saline-sodic environments. Recent research has identified several promising guava accessions with desirable rootstock characteristics that can enhance productivity in marginal soils.

A comprehensive study conducted at the Horticultural College and Research Institute for Women in Trichy (2014–2018) evaluated 31 guava accessions for their physiological and biochemical responses to sodicity stress. Among these,"Surka Chitti Natputani" exhibited vigorous growth habit, making it a potential candidate for rootstock development in stress-prone areas, while "Cheeni guava" displayed dwarf and erect growth characteristics suitable for high-density planting systems. The accession "Nasik" recorded the highest fruit yield (26.285 kg $tree^{-1}$), followed by "Mirzapur Seedling" (24.277 kg $tree^{-1}$), indicating their superior performance under sodicity stress. Additionally, "Allahabad Safed" was identified for its excellent dessert-quality attributes, including favorable rind thickness, soft seeds, and high total soluble solids (Santhi *et al.*, 2022).

Table 2 : Suitable species for guava rootstocks

Rootstock	Features	References
Psidium guajava	Commonly used, vigorous growth, adaptable, but susceptible to wilt & nematodes	Satpal *et al.* (2011)
Psidium cattleianum	Dwarfing effect, cold tolerance, resistant to root diseases; lower yield	
Psidium friedrichsthalianum	Tolerant to Phytophthora, nematodes, and alkaline soils; slow initial growth	
Psidium guineense	Drought tolerance, moderate vigor, nematode resistance, suitable for sandy soils	
Psidium molle	High resistance to nematodes, good graft compatibility, but slow growth	
Psidium longipetiolatum	Resistant to guava wilt and root-knot nematodes, moderate vigor	

Mulching

Mulching has emerged as a critical agronomic practice in guava cultivation, significantly influencing plant growth, fruit yield, and quality parameters. A comprehensive study conducted in West Bengal's new alluvial zone evaluated various organic and inorganic mulching materials, revealing important insights for modern guava orchards (Das *et al.*, 2010).

Key findings from mulching research:

The study compared seven distinct mulching treatments:

1. Black polythene (250 gauge) - Superior performance with 347.95 fruits/plant and 47.05 kg yield/plant
2. White polythene (250 gauge) - Effective alternative to black polythene
3. Organic mulch:
   - Cowpea cover crop (living mulch)
   - Sugarcane trash (0 cm thickness)
   - Dry guava leaves (10 cm thickness)
   - Sawdust (5 cm thickness)
   - Paddy straw (10 cm thickness)

Benefits of mulching in Guava cultivation:

1. Yield Enhancement:
   - Increased fruit number and individual fruit weight

- Higher yield per plant and per hectare
- More uniform fruit development

2. Soil Improvement:

- Moisture conservation (reducing irrigation needs by 30-40%)
- Temperature moderation in root zone
- Organic matter addition (for organic mulches)
- Weed suppression (85-90% reduction)

3. Fruit Quality Improvement:

- Enhanced sugar content
- Better fruit size and color development
- Reduced fruit cracking
- Improved shelf life

Practical Recommendations

- Commercial orchards: Black polythene mulch proves most effective for maximum yield
- Organic production: Paddy straw or dry guava leaves (10 cm thickness) offer excellent alternatives
- Sustainability focus: Cowpea as cover crop provides dual benefits of soil cover and green manure
- Cost-effectiveness: Locally available materials like sugarcane trash or sawdust can be utilized

Mechanisms of Action:

The superior performance of black polythene mulch can be attributed to:

- Optimal soil temperature regulation
- Complete weed suppression
- Maximum moisture retention
- Enhanced nutrient availability
- Reduced soil compaction from rain impact

Fertigation

Fertigation has revolutionized nutrient management in guava cultivation by synergistically combining irrigation and fertilization into a single, highly efficient system. This precision agriculture technique delivers water-soluble nutrients directly to the root zone in alignment with the crop's physiological growth stages, ensuring optimal nutrient uptake while minimizing wastage. Studies demonstrate that fertigation enhances nutrient use efficiency by 30-40% compared to conventional broadcast methods, while simultaneously reducing fertilizer requirements by up to 50% and virtually eliminating leaching losses (Kumar *et al*., 2007).

The superiority of fertigation is particularly evident in high-density guava orchards. Research on 'Lucknow-49' guava under HDP systems revealed remarkable results - fertigation with just 50% of the recommended fertilizer dose (300:150:150 g NPK/plant/year) produced 4.60 kg fruit/plant, translating to 10.22 tonnes/hectare. This outperformed traditional soil application of 100% RDF, which yielded only 6.73 tonnes/hectare (Auxcilia *et al*., 2019).

Conclusion

This review underscores how science-based interventions can transform guava cultivation by optimizing productivity and resource efficiency. High-density planting, when paired with precision canopy management, enhances yield per unit area, while crop regulation techniques like strategic pruning, root exposure, and controlled irrigation synchronize fruiting with market demands. Fertigation and tailored nutrient management mitigate interplant competition in dense orchards, improving nutrient use efficiency by 30-40% while reducing input costs. The integration of stress-tolerant rootstocks and growth regulators further elevates fruit quality and yield stability. Critically, drip irrigation and foliar micronutrient applications ensure optimal resource delivery. For sustained impact, farmer adoption of these integrated practices through demonstrations and knowledge sharing is imperative. By harmonizing these innovations, guava cultivation can achieve 20–25% higher productivity with improved sustainability, meeting both economic and environmental goals.

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