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An overview on production constraints, strategies and innovative production technologies of fruit crops

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Abstract
India ranks second in the world fruit production rankings, producing 13% of total fruit production. It is a leading producer of mango, banana, papaya, Sapota, and acid lime. Fruits are essential for human diets and are being researched under ICAR, leading to over 108 million tons of fruit production. The plant improvement programme has developed various fruit crops, including mango, banana, citrus, pineapple, papaya, guava, Sapota, jackfruit, litchi, grape, apple, peach, pear, plum, apricot, almond, walnut, Aonla, Ber, pomegranate, Annona, Phalsa, regular bearing mango hybrids, and export quality grape varieties. Improved propagation techniques have increased production and standardized agro-techniques for large-scale adoption. India has made significant progress in producing lesser-known fruits like Aonla, Ber, bael, Sapota, and pomegranate. The corporate sector is showing interest in fruit crops, and there has been a shift in consumption patterns. Recent fruit production techniques are expensive but profitable for large commercial growers, but most are still in the experimentation stage. Fruit crop management is crucial for producing high-quality fruits, with innovative techniques reducing time and labour requirements, increasing yield, and achieving sustainability goals. This review describes various production methods of fresh fruit. Modern technology related equipment is very expensive but very useful for growers who have a large business. Many of the technologies that benefit the fruit industry are still in the experimental phase. Management of fruit crops is an important factor affecting the time it takes to produce quality fruit for the market. New technologies for different processes in fruit production machines can help growers reduce time and labour, thereby increasing yields by achieving precise targets.

Keywords: Constraints, strategies, innovative production technologies, advance techniques, fruit crops

Introduction
India ranks second globally in terms of fruit and vegetable production due to its diversified agro-climatic areas. In 2022-23, India produced 108.34 million tonnes of fruits and over 212.91 million tonnes of vegetables, accounting for nearly 10% of global production in each category (FAO statistics, 2023) [7]. With 170 million hectares of agricultural land, 10% is used for horticulture, accounting for 33% of the agricultural value (Table 1). Major fruits grown in India include bananas, mangoes, oranges, apples, grapes, pineapples, papayas, and melons. The review paper aims to identify research on advanced and innovative fruit production techniques, including soilless culture, aeroponics, meadow orcharding systems, high density plantation, and advanced intelligent information techniques.

Global scenario in fruit production
Bananas and the four primary tropical fruits of papaya, avocado, pineapple, and mango are crucial for world agricultural production, supporting smallholders' livelihoods and nutrition. The global commerce of these goods has grown rapidly due to rising incomes, changing customer tastes, and improved supply chain and transportation management. The major tropical fruit export sectors and the worldwide banana industry produce around USD 10 billion and USD 11 billion annually, respectively. Revenue from production and trade can significantly impact agricultural GDP of exporting countries, with banana exports accounting for over half of agricultural export revenue in Ecuador and 40% in Costa Rica. Exporting these tropical fruits has the potential to generate substantial income for producing nations. Future market development of these agricultural commodities is crucial.

The amount of fresh fruit produced worldwide increased from 576.65 million metric tons in 2000 to around 933.1 million metric tons in 2022. (OECD-FAO, 2023) [25]. India is the world's top producer of bananas and mangoes, with the domestic market being the primary destination for most of its fruit and vegetable production. Over three-quarters of consumption comes from the domestic market. Only 1% of fruits and vegetables are exported, and 2% are further processed. Waste or value loss accounts for over 20% of production, with estimated losses of 12 and 21 million tons, resulting in a total food value loss and waste output of 10.6 billion USD. (National Academy of Agricultural Sciences, 2019) [24].

Indian scenario in fruit production

India's 2022-23 fruit production is dominated by Andhra Pradesh with a production of 19 million tonnes, followed by Maharashtra with a production of over 12.4 million tonnes. The country's export market is dominated by low-value fruits and vegetables such as onions, mango pulp, fresh mangoes, dried walnuts and berries. India exported 674,291.70 tonnes of fresh fruits worth US$ 339 million to the world in 2022-23, with major exporters like United Arab Emirates, Bangladesh, Iran, Iraq and Nepal. (APEDA, 2023) [2].

Table 1: Worldwide production of fruits

Country	Million Tons
China	313.00
India	108.34
Brazil	41.00

***Source*:** FAO STAT (2023)

Production limitation in fruit crops in India

Studies have shown that the productivity and quality of crop s are below their potential due to various factors such as:

1. Crop production is poor due to low quality of plant material, low genetic quality, poor management, lack of evaluation mechanism, risk of infection, need for renewal of old vineyard, small area, lack of rain, high diseases. Lack of technology awareness and investment capacity, insufficient financing, infrastructure problems and lack of knowledge on seasonal products for export needs.
2. Poor postharvest management, lack of infrastructure, poor marketing, poor workforce, poor standards and high capital investment affect the utilization of equipme nt, deteriorating the raw product.
3. Due to the initial cost of planting or orchards, it is very difficult to plant new orchards and improve old orchard s for a variety of garden crops,
4. In the absence of proper and improved storage space, lo ngterm planning for horticultural development will be d ifficult and impossible.
5. Major diseases such as mango whorls, spongy tissue an d deformations, guava blight, citrus blight and Phytopht hora blight create longterm production problems in man y crops, and there are still many pests and diseases that remain unresolved.
6. There is no technology to improve the land and landsca pe, which is a promising area for future expansion. Ther e is no better way to grow poor crops on a large scale, a nd this method works best on barren lands and poor or i mpoverished soils.

Future planning for fruit crop production in India

1. Priority should be given to research activities across pro duct needs and disciplines, and strong institutional linka ges should be established with Bhabha Atomic Research Centre, Department of Biotechnology, Scientific and Ind ustrial Research Council and National Agricultural Univ ersities. Modernization of fruit growing as a business req uires cooperation between the private sector in research, seed production, value addition, diversification and expo rt promotion. Nursing organization development requires project-based funding and one time grants. Emphasis should be placed on creating a fle xible database for fruit crops, collecting business intellig ence, forecasting and developing research and developm ent programs.
2. It is important to protect intellectual property, including various disclosures, registrations, transfer agreements an d disease variations. Quality guidelines and Codex stand ards for the export of local fruits and vegetables should b e established, and health regulations regarding vegetative ly produced products should be strictly followed and con trolled. Genetic libraries for fruit crops such as guava, pa paya, citrus and mango have been expanded to include hi ghyielding crops and crops resistant to various environm ental conditions techniques.
3. Fruit development involves genetic modification of com mercial varieties and development of dwarf rootstock/spr out varieties to facilitate highspeed cultivation and expor t of fruits such as mango, sapopo, mandarin and Berber. Scint types and rootstocks are designed for fruits that are resistant to important stress factors such as blight, frost, PRV, Phytophthora and deformations.
4. The aim is to create a cropping system in various agroec ological areas by creating a common crop base for major crops (such as guava, guava, passion fruit, mango) and s upplementing nutrients using the health system of the lea f. Increase fruit yield.
5. Standardize water management technologies such as irri gation, fertilization and microirrigation for tropical, subtr opical and temperate fruit crops, develop innovative orga nic farming methods for export crops, and standardize pr oduction technologies for high-quality export commodities.
6. This article discusses strategies to increase crop yields in both the public and private sectors through the use of qu ality, diseasefree crops. He also discussed rehabilitation of old cropsby replacing old crops with more profitable c rops like cashew and mango. The use of plant growth inh ibitors, rootstock dwarfing and highdensity planting in ci trus and mango cropsare also discussed. The importance of biomass/unit time production for poverty alleviation a nd food security in areas such as papaya, pineapple and b anana is also discussed. The use of pesticides and plant g rowth regulators is also discussed.
7. This study aims to use postharvest technology to extend t he shelf life of perishable horticultural products and redu ce costs during harvesting, storage and transportation. It also aims to improve the village, harvest grapes cheaply, preserve fruit pulp and improve raisin drying technology . Pomegranate, banana, mango, lychee, sapota, kinnow, plantain etc. Large fruits require many handling procedu res for tropical fruits, suchas precooling, storage in a con trolled climate, and postharvest sea transportation. Dryin g techniques, such as room temperature processing and e

xtending shelf life, can help promote exports and prevent drying.

Innovative production technologies of fruit crops

Advance techniques for propagation in fruit production

Fruit planting is crucial for the growth of the fruit sector, but choosing the right planting material and technologies for mass replication is essential. Mistakes in early stages can lead to significant financial losses. Commercial fruit production relies on high-quality, true-to-type planting material. Fruit plants often produce non-identical offspring due to cross-pollination, so they are propagated vegetatively through methods like grafting, cutting, budding, and special vegetative structures. Before planting, plants are kept in a nursery until they reach a mature stage for orchard planting. Increasing the amount of healthy planting material for new, high-yielding cultivars will significantly boost India's fruit production. Induction of roots in cuttings and layers has been successful with mist propagation, fogging method, bottom heat, growth regulators, etiolation, and invigoration. The banana micro propagation protocol has been standardized.

Table 2: Propagation methods used in fruit industry for multiplication of different fruit crops

Fruit crop	Propagation method	Fruit crop	Propagation method
Mango	Soft wood, wedge and veneer grafting	Pecan nut	Patch budding and wedge grafting
Grape	Hard wood cutting and wedge grafting	Pineapple	Slip/sucker
Guava	Wedge grafting	Plum	T-budding, tongue and wedge grafting
Gooseberry	Hardwood/semi-hard wood cutting	Pomegranate	Wedge grafting/air layering, Hard wood cutting
Jackfruit	Patch budding and soft wood grafting	Raspberry, Blackberry	Sucker
Jamun	Soft wood grafting	Sapota	Wedge grafting
Kiwi fruit	Hard/semi hard wood cutting	Strawberry	Runner
Lemon/lime	Cutting and budding	Sweet Orange	T-budding/wedge grafting
Litchi	Air layering and wedge	Walnut	Patch budding and wedge grafting
Mandarin	T-budding and wedge grafting	Fig	Hard wood/semi-hard wood cutting
Peach	T-budding, wedge and tongue grafting	Almond	T-budding and wedge grafting
Pear	T-budding, wedge and tongue grafting	Aonla	Patch budding and wedge grafting
Apricot/ Avocado	T-budding and wedge grafting	Apple	T-budding/tongue and wedge grafting
Bael	Wedge grafting	Cherry	Tongue and wedge grafting
Banana	Suckers/corm	Custard apple	Wedge grafting
Cashew	Soft wood grafting	Date palm	Sucker/off shoot

Source: Robinson (2004)

Vegetative propagation is a crucial agricultural method for developing high-quality and quantity fruit crops and strengthening a country's economy. However, it also increases the susceptibility of some plant species to viruses that could destroy all crops. In India, most fruit trees were budded or grafted onto seedlings from various sources. Recently, clonal rootstocks with specific characteristics are being used to overcome adaptation-related problems. These rootstocks have advantageous traits such as tolerance to pests and diseases, tolerance to heavy clay or saline soils, winter cold or high temperatures, and poorly drained soils. There is no genetic difference between parent rootstock clones. (Choudhary *et al*., 2015) [6].

Advance techniques for Soilless culture in fruit production

In today's agriculture, aeroponics is a method of growing crops without soil. Lakkireddy *et al*., (2018) [17] define aeroponics as a modern soilless growing method used in the food industry. In the 21st century, soilless culture technology plays an important role in aeroponic food production. In this innovation, plants are grown using natural environments. The most important change to ensure the delivery of products to the roots is the use of sprays, atomizers and atomizers to create small bubbles (Christie and Nichols, 2003) [5]. By promoting growth and preventing diseases, the use of misters in aeroponics helps increase productivity by improving plant nutrition. Aeroponics can produce high plant yields because it properly supplies oxygen and water, two factors traditionally used to determine the limits of plant growth. Jun *et al.* (2008) [8] conducted an experiment to examine the effect of reduced root zone temperature on root and shoot growth in aeroponics. For the purpose of the experiment, strawberries were grown by aeroponic method in the cold season. They found that loss of root zone temperature caused a reduction in root growth, especially strawberry roots. The greatest principle elongation occurs in the central region of 18^0C, while the lowest number and length of lateral origins occur in the central region of 8^0C. Strawberry leaf area, length, width, and leaves all decrease with temperature. roots and the weight of roots and shoots. Kanechi *et al.* (2015) [13] developed a new aeroponic mechanism using water spray and fertilization to grow strawberries in late spring using the dry air method. Using this technique, the solution is sprayed from a very fine point at a distance of approximately 10 µm to the root area. Researchers use dry air aeroponics to grow strawberry plants to compare flower growth, fruit quality, photosynthesis rate, chlorophyll content, and solvent content in leaves of plants fertilized with drip irrigation, using palm bark media as a control. In dry air aeroponics, the number of inflorescences and fruit Brix increased significantly compared to the control, while the number and growth of stolon decreased. Based on their research, they concluded that strawberries can be produced using modern methods without the need for soil. Treftz, (2015) [39] evaluated the perception and nutrition of raspberries and strawberries grown in soil and soilless systems. Hydroponics seems to be a solution for sustainable food production because the food produced is both delicious and healthy. Results from hydroponics show greater value, better or equal to similar nutrients, and preference or better compared to soil-grown raspberries and strawberries. According to a study by Lee *et al.* (2015) 19] stated that differences in nutrients affect the growth and yield of summer strawberry varieties grown in soilless systems. Mattner *et al.* (2017) [23] examined and analyzed the use of soilless systems in strawberry cultivation and found that although these systems are more expensive than mature systems, there is no need to use pesticides in the soil to control pests. In addition, these improvements are often used in the early stages of a runner's appearance, helping to reduce the number of generations required to be able to run.

Advance techniques for orchard management in fruit production

Orchard soil management includes many ways to keep soil healthy and protect it from wind and rain. These include tall planting, mulching, crop rotation, turf culture, mixed cropping, cover crops, and seeding. Intercrops are recommended in orchards with drained or eroded soil because they provide organic matter, improve the biological complexity of the soil, and reduce erosion. Cover crops such as beans are better at fixing nitrogen and reducing weeds during the rainy season. Good agricultural practices, including tillage and weed management, help maintain plant range and prevent pests and diseases. However, it also has disadvantages such as increased nutrient leaching, soil erosion and loss of organic matter. Mulching is another technique used by orchards to improve growth and retain soil moisture. Common materials include hay, straw, crop residue, leaves, sawdust and plastic. Biological mulch materials such as dry leaves, straw and coconut leaves can control plant growth, reduce evaporative loss and create a microclimate. Loose straw acts as a barrier, inhibiting plant growth and reducing competition for nutrients. Plastic sheeting is used as mulch due to its cost and ability to control soil moisture, keep soil warm, reduce plant growth, and improve moisture. In general, mulching can improve the quality and yield of horticultural crops, improve plant health and insect resistance, and promote soil microbial activity and aeration. On top of the mulch strips it is necessary to put sawdust, coconut coir dust, straw or rice husk; However, to avoid disease, mulch should be 20-30 cm away from the trunk of the tree. Sapota cv. Kalipatti's greatest yield under 200 gauge black polythene film was reported by Singh *et al*., (2015) [30]. Tiwari *et al.* (2014) [40] investigated the effects of drainage and plastic mulching on Sapota fruit tree yield. They found that soil treated with plastic mulch increased organic carbon, organic matter, humic acid, microbial community, potassium, phosphorus, total nitrogen content, and carbon/nitrogen ratio. However, soil covered with plastic mulch has lower pH and less nitrogen. Biometric data shows that plastic mulch treatment and irrigation had a positive effect on saporta plants, with results increasing from 7.62% to 41%. Weed control is crucial to maintaining a healthy vineyard and includes mulch, hand weeding, and chemicals. Mulching the body reduces weeds and improves the soil around the body. Spraying glyphosate is recommended for weed control. Intermediate tillage is recommended for improved aeration and good plant management. Young orchards need a strong wind to protect them from frost, drought and extreme heat. Guo *et al.* (2015) [11] used hyperspectral imaging technique to distinguish disease-affected and healthy leaves, including citrus tristeza. Leaves were photographed in the visible and near-infrared spectrum. Surface enhanced Raman spectroscopy analysis was used. Liu *et al.* (2015) [20] found imidephosphorus residues on the surface of orange peel. In their search for the insecticide imidophos, they used materials such as Clarite and colloidal silver. The results of the study show that the Raman signal of imide phosphorus increases in a constant range from 5 to 30 mg/L. To determine the nitrogen content of plantation jujube tree, Wu *et al.* (2015) [42] developed a spectroscopy-based nitrogen parameter detector. A control unit and several measuring instruments are mounted on the instrument panel. The sensor core was used to measure the effects of the jujube plant at different wavelengths, ensuring that nitrogen elements in the orchards were not damaged. The partial least squares model best fits the data of Wang *et al.* (2015) [41] for the determination of chlorophyll content in unripe fruits using hyperspectral methods. Zhang *et al.* (2015) [43] proposed an optical method for rapid measurement of nitrogen and chlorophyll concentrations in fruit juice. They found that four wavelength groups (550 nm, 640 nm, 680 nm, and 780 nm) were responsible for the nitrogen and chlorophyll content of the leaves during photoreaction. Liu *et al*. (2015) [20] developed a method using spectroscopy to estimate the soluble content in Newhall oranges from seven sources. They used the true recurrence model (PLS) halfway through and found that the predictive model based on the initial analysis was valid. Sun *et al*. (2015) [35] developed a machine vision using time-flight 3D imaging technology and image processing techniques using interference and adaptive filters. The system achieved 81.8% detection, with only one operation yielding erroneous results.

Advance techniques for HPD and Meadow orcharding planting in fruit production

High-density planting is a soil management strategy that maximizes land use and fruit yield. It is used successfully in many fruits such as apple, pear, banana, pineapple, mango, guava, tangerine, tangerine and pomegranate. Traits such as dwarf genotypes, rootstocks, pruning, training, inhibitors, plant geometry modification and disease control can be used to achieve high yields. HDP also increases the value of hot weather and dried fruits. Recent experiments at the Central Institute of Subtropical Horticulture in Lucknow have shown that guava can be grown closer together according to HDP. Singh, 2008 [32]. The average yield of guava grown in prairie orchard systems is reported to be 40-60 tonnes/ha compared to traditional systems. The first reports of weeds for fruit crops can be traced back to many scientists. Modern improvements in this way have been made thanks to the widespread use of fertilization and advances in machine-assisted pruning and training methods. Robinson (2004) [28] suggested that the development of quality management techniques has led to an increase in the cultivation of plums, apples, peaches, peaches, cherries, apricots and apricot trees. Creating four trees, improving branching methods and reducing pruning techniques are important developments that enable more trees to be obtained Singh (2010) [29] in 1.0 m x 2.0 m spacing. This results in a density of 5000 trees per hectare. The system is designed to bear fruit from the first year and is managed to create a simple framework. Kaushik *et al*. (2013) [15] found effective fertilizer use, nutrition, yield and quality in guava varieties. 'Shweta' in lawn garden requires 75% irrigation of water system and application of 75% water soluble fertilizer through drip irrigation technology. Choudary *et al*., (2015) [6] Claims to produce new fruit, replacement of trees and best driving work. Singh *et al*., (2015) [15] conducted a study on the production and characteristics of guavas grown in grassland using drip irrigation and polyethylene mulching. Allahabad Safeda was grown and tested at four irrigation levels with tray evaporation supplement. When the evaporation table is less than 80%, fruit weight (107.3 g), yield (16.92 kg·m3) and number of fruits (27.3) are higher. Hariom and Shant (2015) [12] studied the effects of branch pruning on guava flowering, fruit growth and yield in prairie orchards and found that when the limb was halved, the reduced vegetative growth produced new branches in 50% of cases to be new. branches. April buds bear fruit better throughout the winter.

Canopy management practices for flower induction in HDP: Advanced planting techniques include training and pruning techniques, which are important components. Pruning a guava tree when plant density is high can increase yields. Guava responds well to pruning as it controls shoot growth and prominence by limiting content expansion and restoring the balance between the shoots and the root system. Many studies have shown that pruning will inevitably increase the number of flowers, demonstrating the importance of this strategy in high cultivation. Singh *et al.* (2001) [31] reported higher yields for five consecutive years in Sardar and Allahabad Safeda guava varieties when pruned between April and June. According to Jadhav *et al.* (2002) [9], 60% of guava trees produced more flowers than control and lightly pruned (30%) plants. (2002) [9]. Mohammed *et al*. (2006) [21] found the maximum number of flowers per flower when pruned to 60 cm during winter. Mehta *et al.* (2012) [22] found that pruning 3 times per year produced the highest number of flowers per plant (20.13), but pruning 80% of October in the winter of October 2009 was most productive. minimum number of flowers per plant (7.72). An experiment by Kumar and Rattanpal (2010) [14] showed that pruning 1/2 of the plant's growth yielded a maximum of 544 fruits per tree and 55.1 kg per tree, with an estimated yield of 54.4 tonnes/ha. 6m x 4m.

Water management and root treatment

When trees are not watered from February to mid-May, they lose their flowers and enter a dormant state because nutrients are stored in their branches (Sachin *et al.,* 2015) [33]. The tree enters the dormant phase by carefully removing the top 40-60 cm of soil around the trunk, exposing the roots to the sun and reducing moisture upwards. That's why leaves started falling from the trees. In order to achieve harvest Sachin *et al.,* 2015 [33], Suresh *et al.,* 2016) [36]), after the first three to four weeks, the roots need to be covered again with a mixture of soil and fertilizer (Jun *et al.,* 2008) [8].

Fertilizer management in HDP

Fertigation is a method of applying fertilizers in a way that aligns with crop needs, maximizing their nutrient content, and ensuring precise timing and distribution of water and nutrients, thereby reducing fertilizer costs and reducing leaching losses. (Kumar *et al.,* 2007) [16]. As with regular watering, optimal split fertilizer treatments will enhance crop output both in terms of quantity and quality compared to the traditional approach. Sharma *et al.,* (2011) [34] found that drip irrigation at 100% ETc yielded the highest guava fruit yield (18.7 t/ha), while the lowest yield (11.0 t/ha) was achieved at 60% ETc. The maximum fruit yield and water productivity were achieved under drip irrigation at 100% ETc with 120% of the recommended N dose. The Lucknow-49 guava cultivar produced an average of 4.60 kg fruits per plant, with the highest estimated yield of 10.22 tonnes/ha at a 50% RDF fertigation dose during HDP fertilization schedule, compared to 6.73 tonnes/ha in the control (Auxcilia *et al.,* 2019) [3]. In comparison to basin irrigation, Sharma *et al.,* (2011) [34] found that fertigation produces a better yield in guava. According to Kaushik *et al.,* (2013) [15] study on guava development and yield in a meadow orchard system found that when 100% water soluble fertilizers were combined with water irrigation and cumulative pan evaporation, the maximum fruit diameter and weight were measured. However, the optimal treatment achieved a maximum benefit:cost ratio of 2.91 by irrigating 75% of cumulative pan evaporation and 75% of water soluble fertilizers, making this treatment the optimal choice. Jeyabal *et al.,* (2000) [34] obderved fertigation at 75% recommended NK level with urea and multi-K produced a 12.3% greater yield than soil treatment at 100% NK level, suggesting a 25% reduction in NK in addition to an increase in productivity in a three-year-old guava plantation.

Application of growth regulators and chemicals on fruit production under HDP

Chemicals such as maleic acid hydrazide can affect the structure of plants by inhibiting bud growth, maintaining the same number of internodes and leaves, and improving green leaf pigmentation. They also control or slightly encourage root growth with a root-to-shoot ratio that supports the roots. A study comparing three male acid hydrazide (MH) herbicides to a control group found that application of 2-chloroethyltrimethylammonium chloride (CCC) did not shorten the shoot length of Thompson seedless male fruits but was more effective at increasing sugar diameter. Lichev *et al.,* (2001) [18] found that paclobutrazol application significantly inhibited annual bud growth and increased photosynthetic activity, potentially increasing cherry yield. Application of paclobutrazol in mango reduces tree height, volume and shoot length due to the inhibitory effect of paclobutrazol. According to the research conducted by Albuquerque *et al.,* (2000) [1] an increase in grape buds was observed after the application of 1500 ppm CCC. Cont. “Autumn Blessings” of Red Raspberries Ghora *et al.,* [10] investigated the effects of growth inhibitors (CCC, butyrohydrazine and paclobutrazol) on growth and development in plastic greenhouses. They found that application of 500 ppm CCC accelerated flowering and fruit ripening by approximately 10 days. Brahmachari *et al.* (1995) [4] by treating ethylene at 25 or 50 ppm, the fruit yield, weight and quality of guava increased, while the seed quantity and weight decreased. Absorption of Ethephon in pineapple and the reason for failure to form flowers. They also found that ethylene-releasing chemicals such as ethephon are often used to promote bromeliad flowering Turn bull *et al.* (1999) [38]. According to Ramburn (2001) [27] foliar spraying of 0.5 g PBZ + 0.4 g ethephon/litre increased the flowering of irregularly flowering lychees. Onaha *et al.* (2001) [26] found that bromeliad flower induction rate was higher. Because growth inhibitors reduce tree height, canopy size and spread, they can have a significant impact on fruit production by allowing more trees to grow in land area.

Conclusion

The review paper discusses the importance of efficient utilization of inputs in fruit crop production, focusing on innovative technologies that enhance the effectiveness and targeted delivery of these inputs. Fertilization methods like fustigation, foliar fertilization, and nano fertilizer have been identified as effective in improving nutrient availability, reducing wastage, and enhancing plant absorption efficiency. Water-efficient technologies like drip irrigation, micro sprinklers, and partial root zone drying have been developed to minimize water loss and optimize plant water uptake. Plant bio regulators and growth enhancers have shown promise in improving fruit quality, yield, and post-harvest characteristics. Integrated pest management approaches, biological control agents, and pheromone-based monitoring systems have been implemented to promote natural pest suppression, minimize pesticide usage, and protect beneficial organisms. The integration of these innovative approaches in fruit crop production systems offers opportunities to enhance input utilization efficiency, reduce production costs, and minimize environmental impact.

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