# Examining the impact of Integrated Fertility Management in Fruit Crops: A Review


## Abstract

Efficient nutrient management is crucial for maximising fruit production, enhancing quality and ensuring long-term sustainability in agricultural systems. This study examines the contributions of macronutrients, micronutrients and organic manures to improving soil fertility and promoting the establishment of high-quality fruit harvests. In addition, the study investigates the impact of chemical fertilisers and plant growth regulators on the physiological processes crucial for optimising fruit yield. The study highlights the significance of utilising integrated nutrient management strategies, which involve the combination of organic and inorganic inputs, to attain a harmonious equilibrium between maximising fruit harvests and ensuring the soil's long-term health. The results suggest that this strategy improves the quantity and quality of fruit produced and promotes sustainable farming by reducing its environmental impact. These findings provide significant information for fruit growers and agronomists who want to maximise fruit output by implementing balanced and sustainable nutrient management strategies. This approach ensures both immediate agricultural success and the long-term preservation of soil and environmental resources for future generations.



**Keywords:** *Integrated Nutrient Management, Soil Fertility, Fruit Yield Optimization, Fruit Quality Enhancement, Horticultural Sustainability*




## Introduction

Efficient nutrient management is crucial for maximising fruit production, improving quality and ensuring sustainability in agriculture. The use of chemical fertilisers has been prevalent for meeting the nutrient demands of crops; however, their excessive use has led to soil degradation, environmental pollution and potential harm to fruit quality. In light of these challenges, there is an increasing emphasis on adopting Integrated Nutrient Management (INM) strategies.

INM aims to optimise soil conditions, encompassing physical, chemical, biological and hydrological properties, by combining organic and inorganic nutrient sources. This approach balances the use of artificial fertilisers, organic manures, crop residues and biofertilisers, ensuring enhanced crop productivity while maintaining long-term soil health. According to Mahajan *et al.* (2009), INM promotes a synergistic effect between various nutrient sources, improving soil fertility and reducing the dependency on chemical inputs.

### Nutrient status of Indian soils

- Indian soils have been found to have low levels of nitrogen (N) and phosphorus (P), with 89 and 80 per cent of soil samples falling into the low to medium category. However, the situation is relatively better regarding potassium (K), with only 50 per cent of samples falling into the low to medium range.

- The elements S, Zn, B, Mo, Fe, Mn and Cu are deficient by 41%, 49%, 33%, 22%, 12%, 5% and 3%, respectively.

**Table 1. Nutrient deficiencies status in different states of the Indian Subcontinent (ppm)**

| States | N | P | K | S | Zn | Fe | Cu | Mn | B |
|---|---|---|---|---|---|---|---|---|---|
| Andhra Pradesh | 100 | 100 | 58.00 | 28.90 | 22.30 | 16.80 | 1.00 | 1.70 | 2.80 |
| Assam | 100 | 100 | 82.00 | 16.70 | 25.60 | 00.00 | 3.80 | 00 | 11.90 |
| Bihar | 94.00 | 97.00 | 96.00 | 42.80 | 37.90 | 9.90 | 1.90 | 7.40 | 36.30 |
| Chhattisgarh | 100 | 100 | 59.00 | - | 20.10 | 6.80 | 3.20 | 14.10 | - |
| Gujarat | 89.00 | 100 | 37.00 | 42.00 | 23.10 | 23.90 | 0.40 | 6.30 | 17.90 |
| Haryana | 100 | 100 | 39.00 | 35.80 | 15.30 | 21.60 | 5.20 | 6.10 | 3.30 |
| Himachal Pradesh | 24.00 | 88.00 | 100.0 | 00.00 | 11.10 | 0.80 | 2.10 | 3.50 | 32.00 |
| Jharkhand | 100 | 98.00 | 79.00 | - | 20.30 | 0.00 | 0.50 | 0.0 | 56.00 |
| Karnataka | 81.00 | 96.00 | 22.00 | - | 13.50 | 3.50 | 2.70 | - | - |
| Kerala | 94.00 | 76.00 | 82.00 | - | 1.20 | 1.30 | 11.40 | - | 24.70 |
| Madhya Pradesh | 90.00 | 87.00 | 46.00 | 27.70 | 66.90 | 10.20 | 0.60 | 1.80 | 1.70 |
| Maharashtra | 100 | 100 | 21.00 | 26.50 | 54.00 | 21.50 | 0.20 | 3.80 | 54.70 |
| Orissa | 100 | 100 | 69.00 | 31.10 | 22.70 | 1.80 | 0.30 | 1.10 | 52.50 |
| Punjab | 100 | 47.00 | 11.00 | 53.30 | 16.60 | 6.20 | 3.60 | 15.2 | 17.50 |
| Rajasthan | 100 | 100.00 | 24.00 | - | 85.50 | 35.50 | 63.70 | - | - |
| Tamil Nadu | 98.00 | 62.00 | 32.00 | 14.30 | 65.50 | 10.60 | 13.00 | 7.9 | 19.90 |
| Telangana | - | - | - | 31.80 | 26.90 | 17.00 | 1.40 | 3.80 | 16.10 |
| Uttar Pradesh | 100 | 100 | 61.00 | 32.50 | 33.10 | 7.60 | 6.30 | 6.50 | 16.20 |
| Uttarakhand | 80.00 | 100 | 67.00 | 11.20 | 9.90 | 1.40 | 1.40 | 4.70 | 7.00 |
| West Bengal | 100 | 90.00 | 19.00 | 37.40 | 11.90 | 0.00 | 1.20 | 0.90 | 46.90 |
| All India | 95.00 | 95.00 | 48.00 | 24.70 | 43.30 | 14.40 | 6.10 | 7.90 | 20.60 |

**Source**: Katyal *et al.* (2016)



Integrated Nutrient Management started in the late 1980s and it is important to solve the issues related to micronutrient deficiencies and deterioration of soil health (Baskar *et al.*, 2022). INM has gained significant importance in fruit production. These benefits include maintaining health, reducing the reliance on chemical fertilisers and minimising environmental pollution of the soil. In addition, it offers plants the necessary nutrients at an affordable price. According to Gaur (2001), this approach effectively prevents nutrient loss and controls the spread of insect pests and diseases.

The INM method is an excellent solution for farmers seeking an alternative to expensive chemical fertilisation to nourish their crops. Furthermore, the objective is to improve the condition of the land by enhancing its biological, mechanical, hydrological and physical properties. According to Saikia *et al.* (2015), this practice aims to improve agricultural productivity and reduce soil depletion. It is increasingly acknowledged that implementing integrated nutrient management practices can improve crop yields while maintaining soil health. The study discusses various activities to enhance soil quality and water management. These activities include using different methods and materials, including FYM, farm waste, composts, green manures, fertilisers, intercropping, cover crops, tillage maintenance and drainage systems (Wu and Ma, 2015). This approach utilises state-of-the-art methods, including precise placement of fertilisers and the application of urea coatings. These methods have been carefully designed to improve plant uptake and reduce nutrient losses. (Saikia *et al.*, 2015). These activities allow producers to prioritise sustainable planning and carefully consider environmental implications rather than solely focusing on returns. If you want to achieve integrated nutrient management, there are several practices you can adopt. These include incorporating organic manures like FYM, vermicompost, bio-fertilisers and inorganic fertilisers.

Farmyard manure, or FYM, is a precious source of nutrients. It contains essential micronutrients and is abundant in organic matter. Rai (2014) highlights the numerous advantages of manure for soil. It can enhance the organic matter content, improve soil structure and drainage in clay soil and boost the water-holding capacity. In addition, manure has multiple benefits for soil health and fertility. It is a valuable source of nutrients released slowly over time, helping nourish plants. Furthermore, it plays a crucial role in preventing erosion caused by water or wind. Manure also promotes the growth of earthworms and other beneficial microorganisms in the soil, contributing to its overall health.

Vermicompost is a crucial component of integrated nutrient management, showcasing remarkable levels of organic carbon. This product is vital for preserving soil fertility and offers a complete range of essential nutrients in just the right proportions, making it a top-notch option for nourishing plants. This product significantly improves soil fertility and quality by enhancing its chemical, biological and physical properties. This product also encourages the development of beneficial substances and microorganisms while preventing the growth of harmful microbes. This has numerous benefits for soil health. Applying vermicompost has significantly boosted crop yield, enhanced nutrient status and improved nutrient uptake. Several studies have demonstrated the beneficial impact of vermicompost on a range of fruit crops. For instance, Singh *et al.* (2008) and Chaurasia *et al.* (2022) found positive effects on strawberry crops, while Acevedo and Pire (2004) observed similar results in papaya crops. Athani and Hulamani (2000) reported positive outcomes in banana crops, while Athani *et al.* (2005) found that vermicompost benefits the guava crop. Mahmoud and Gad (2020) also observed positive effects on bean plants and Mahmud *et al.* (2019) reported similar findings in pineapple crops.

Bio-fertilisers are essential to integrated nutrient management, as they consist of living organisms that enhance the supply of primary nutrients to the main crop. These organisms can be applied to seeds, plants, or the soil, providing a valuable boost to agricultural productivity (Kumar *et al.,* 2018). This type of fertiliser is distinct from chemical or organic fertilisers because it does not directly provide plant nutrients. Instead, it promotes the growth of specific fungi and bacteria. It is a relatively simple and cost-effective installation option. Bio-fertiliser has positively impacted various aspects of plant growth and development. Studies have shown that it can lead to higher growth rates, increased stem girth and improved yield development by 10-40% (Stewart and Roberts*,* 2012).

Additionally, bio-fertilisers have been found to enhance fruit quality, increase fruit weight and improve the fruit's Total Soluble Solids (TSS) content. Furthermore, it has the added benefit of reducing acidity compared to chemical fertilisers (Alam and Seth., 2014). Hazarika, mango (Poonia *et al.,* 2018) and many more scientists, horticulturists and other pomologists.

**Component of INM**

The INM system includes a range of organic fertilisers, including FYM, compost, green manure, vermicompost, bio-fertilisers and crop residues. In addition, it requires choosing the right crop varieties, implementing effective cultural management practices and making the most of soil and water resources to achieve successful and suitable crop production.

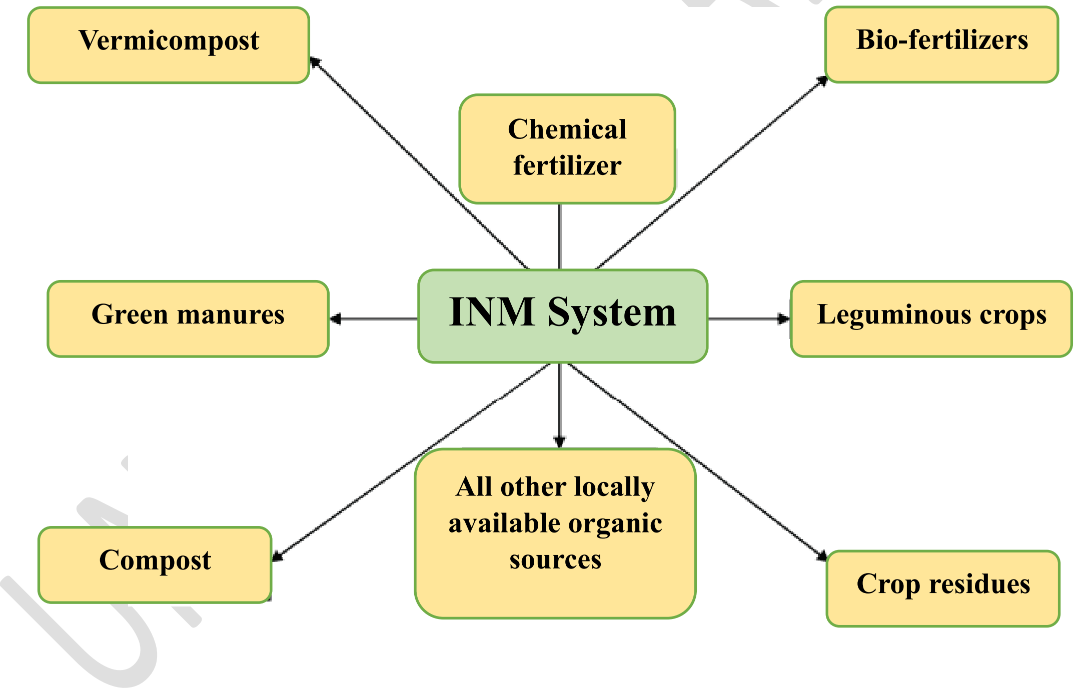


**Fig:1. The INM system's component**

Therefore, the INM system can potentially enhance crop productivity and improve soil conditions through synergistic effects. The critical components of the INM system include:

1. Including soil fertility and maintaining crops like legumes and green manures can be valuable to your gardening practices.
2. Recycling the crop residues can be a beneficial practice.

3. They are utilising a variety of organic manures such as vermicompost, FYM, biogas, compost, poultry manure, Phosphate-compost, slurry and press mud cakes.
4. Efficient genotypes.
5. Using fertiliser nutrients is carefully balanced to meet the crop's specific needs and maximise yields.
6. The use of biological substances has been explored in a study by Jat *et al.* (2015).
7. The impact of INM on fruit crop yield, growth and quality.

**Aonla(*Emblica officinalis*)**

Tripathi *et al.*(2015a) experimented on ten-year-old plants of aonlacvNA-7 and found the yielded result with the highest values recorded fruit set at 40.56% ($T_9$), fruit retention at 34.64% ($T_9$), fruit drop at 65.35% ($T_9$), fruit length at 3.70 cm ($T_9$), fruit width at 4.60 cm ($T_9$), fruit weight at 50.32 g ($T_9$) and fruit volume at 42.89 cc ($T_9$). For chemical traits, seed weight was 2.38 g (T1), total soluble solids (TSS) were 11.40 °Brix ($T_5$), total sugar content was 6.86% ($T_5$), ascorbic acid was 542.22 mg ($T_5$), titratable acidity was 2.37% ($T_4$). TSS to acid ratio was 4.85 ($T_5$) under the northern plains of India.

Tripathi *et al.* (2015b) study mimic that a combination of 75% NPK, 4 kg Vermicompost, 100.00g *Azotobacter* and 100.00 g PSB significantly improved fruit set, retention and yield. The treatment also enhanced fruit quality, achieving the highest values for total sugars, ascorbic acid and TSS: acid ratio while decreasing titratable acidity. This suggests that an integrated nutrient management strategy optimises aonla crops in northern India.

Kumar *et al.* (2023), the researchers explored the impact of integrated nutrient management on the growth, yield and quality of Aonla (cv. NA-7) to assess the effects of this management approach on the plant's overall performance. Significant improvements in various aspects of fruit production. These improvements included increased fruit set, retention, yield and quality attributes such as size, weight and TSS. The treatment yielded the highest ascorbic acid content of 559.27 mg/100.00g pulp and the highest TSS: acid ratio of 9.28. Additionally, it had the lowest titratable acidity of 1.39 %. Based on the research, adopting this integrated nutrient management approach can significantly enhance the yield and quality of Aonla fruit in the Northern plains of the Indian subcontinent.

**Ber (*Ziziphus mauritiana*)**

In a study, Katiyar *et al.* (2012) investigated the impact of integrated nutrient management on regenerated Ber trees' growth, flowering, fruiting, yield and quality. The 35-year-old trees underwent pruning in 2009 and were subjected to six different NPK treatments, with all treatments supplemented with 50 kg of FYM. The results showed that T5 stimulated plant growth, while T4 improved flowering, fruit formation and fruit quality, resulting in the highest yield of 30.08 kg per tree.

**Banana (*Musa* spp.)**

Shukla *et al.* (2022) conducted an experiment to evaluate the effect of Integrated Nutrient Management (INM) using a combination of organic and inorganic nutrients and bio-fertilisers on tissue-cultured banana cv's growth, yield and quality. Grand Naine. The results revealed that the application of T7 (75% RDF of P + 100% RDF of NK + 25% FYM + 25%

vermicompost + 50g *Azospirillum* + 50g PSB) significantly improved yield parameters, including maximum bunch weight (19.99 kg), number of hands per bunch (11.71), number of fingers per hand (19.29), total fingers per bunch (223.44), finger weight (139.12 g), fruit yield plant$^{-1}$ (31.10 kg), fruit yield (95.79 t/ha), finger length (21.67 cm) and finger girth (17.79 cm).

Shukla *et al.* (2022) experimented to see the integrated approach on the growth of ratooned banana and was revealed that T7 (75% RDF of P + 100% RDF of NK + 25% FYM + 25% vermicompost + 50g *Azospirillum* + 50g PSB) resulted in the maximum plant height (60.25 cm at 60 days to 221.22 cm at 240 days), pseudo stem girth (23.74 cm at 60 days to 67.40 cm at 240 days), number of leaves (9.38 at 60 days to 26.97 at 240 days) and suckers (8.37 at shooting stage). It also recorded the highest leaf area (10.43 $m^2$), inflorescence length (122.23 cm) and the shortest duration for flowering (282.81 days) and fruit harvest (85.83 days).

Tripathi *et al.* (2017) demonstrated the importance of biofertilisers and evaluated the effects of bio-fertilisers on tissue-cultured banana cv. Grand Naine. The combination of *Azotobacter*, *Azospirillum*, PSB and *Trichoderma harzianum* (50 g each per plant) yielded the most favourable results regarding plant growth and fruit quality. Plants showed the most significant pseudo stem height (146.16 cm), girth (65.33 cm), total leaves (34.33), functional leaves at inflorescence (17.33) and inflorescence length (112.83 cm). Additionally, they achieved the highest bunch weight (22.25 kg), number of fingers per hand and per bunch (16.66 and 143.00) and number of hands per bunch (8.33). Enhanced fruit quality, with the highest finger weight (135.83 g), length (19.16 cm), diameter (15.33 cm), TSS (19.00° Brix), total sugars (18.68%), pulp content (80.86%) and favourable pulp-to-peel ratio (4.22), with minimised peel content (19.14%) and acidity (0.47%).

In a study conducted by Patil and Shinde (2013), it was procured that the application of T3, which included 50% RDF, farmyard manure, PSB, *Azotobacter* and VAM, resulted in the highest leaf number (32.30), maximum leaf area (17.93 $m^2$), girth (81.34 cm) and height (190.84 cm) in banana cv. Ardhapuri. In addition, the factors contributing to yield, such as yield (85.80 t/ha) and bunch weight (19.31 kg), were higher in $T_3$. Based on the findings, it was observed that using a combination of RDF 50%, Farmyard manure, PSB 50 g, *Azotobacter* 50 g and 250g VAM per plant positively impacted the yield and growth of banana.

The findings of Tripathi (2020) from the study on the ratoon banana crop indicate that the treatment involving 100% RDF of NPK, along with 50g of *Azospirillum*, 50g of PSB and 50g of *Trichoderma harzianum* per plant, resulted in the tallest plants (145.45 cm) with the largest circumference of pseudo stem (64.00 cm). These plants also had the highest number of leaves (30.60) per plant, longest inflorescence (105.80 cm), most significant number of fingers per hand (17.66) and per bunch (140.00), most extended finger length (19.33 cm), heaviest finger weight (138.00 g), widest finger diameter (15.10 cm), highest levels of total soluble solids (17.98 ° Brix) and total sugars (17.20%) and the highest pulp content (80.36%) and pulp-to-peel ratio (4.58). Additionally, this treatment required the shortest duration (232.33 days) from planting to flowering or the emergence of the bunch and resulted in the lowest levels of titratable acidity (0.42%) and peel content (17.36%). My suggestion isto become the most economical and eco-friendly for the livelihood farmers of the North Plains of the Indian subcontinent.

Kuttimani *et al.* (2013) charted that the application of RDF 100% + Wellgro soil 40% resulted in higher corm diameter (79.17 and 79.17 cm), root numbers (242.57 and 233.00) and corm volumes (4.10 and 4.73 lit plant$^{-1}$). There has been a significant rise in RDF by 100% when using either 40% Wellgro soil or 10 kg FYM plant$^{-1}$ over the course of both experimental years. This increase has been observed in various growth parameters, including the leaf area index, crop growth, net assimilation rate, relative rate of growth and absolute rate of growth, as well as in physiological parameters such as nitrate reductase activity, soluble protein and total chlorophyll content. Therefore, integrated nutrient management approaches are the most suitable option for maximising banana growth and physiological parameters.

A study conducted by Bhalerao *et al.* (2009) discerned that the treatment consisting of a 100% recommended dose of fertiliser (RDF) along with 10 kg of farmyard manure (FYM), 25 g of phosphate solubilising bacteria (PSB) and 25 g of *Azospirillum*had a positive impact on the yield of banana. This treatment showed similar results to the treatment that combined 50% of the NPK nutrients from inorganic and bio-fertilisers with 50% from organic sources such as green manure and FYM. In addition, it has been noted that relying solely on organic manure is insufficient for achieving maximum production compared to integrated nutrient management.

Nayyer *et al.* (2014) found that Banana cv. Grand Naine plants treated with RDF 100% + *Azospirillum* 50 g + *T.harzianum* 50g + 50 g PSB /plant exhibited higher pseudo girth (67.98cm), stem height (150.27 cm), inflorescence length (118.50 cm) and leaf numbers (34.66). These plants also showed early flowering (253.33 days) and a shorter time from flowering to bunch harvesting (110.00 days) than other treatments. Similar treatment also resulted in significant improvements in the following parameters: finger numbers per hand (19.33), finger numbers per bunch (160.00), bunch weight (24.50 kg), finger weight (140.00 g), diameter (15.20 cm), length (20.33 cm), pulp percentage (82.17%), total sugars (18.66%), TSS (19.26 °B) and pulp to peel ratio (4.60). Additionally, the treatment led to a decrease in titratable acidity to a minimum of 0.40 %.

**Mango (*Mangifera indica*)**

In their study conducted at the Khagrachari site, Zonayet *et al.* (2020) found that the $T_4$ treatment (150% of $T_2$) resulted in the highest mango yield of 22.30 kg/plant. At the Bandarban site, the $T_3$ treatment produced the highest mango yield of 48.25 kg per plant, 125% higher than the $T_2$ treatment. At the Rangamati site, the $T_4$ treatment produced the highest mango yield of 23.10 kg per plant, which is 150% of the $T_2$ treatment.

Vala *et al.* (2020) provided a thorough analysis of the findings. Based on my analysis of the data from the past four years, treatment $T_7$ showed impressive results. It had the highest plant height of 5.33 m, maximum plant spread (E-W) of 4.34 m, plant spread (N-S) of 3.97 m, fruit circumference of 9.53 cm, fruit length of 8.76 cm, fruit weight of 185.50 g, fruit yield of 18.40 kg/plant and 3271 kg/ha, total sugar content of 14.78 % and TSS of 26.81 %. The treatment that combined 50% nitrogen from RDF and 50% nitrogen from Castor Cake per kilogram per year demonstrated superior results compared to other treatments.

Nehete and Jadav (2019) found impressive results regarding the Mango cv. Amrapali. The application of ($T_{13}$) N 70% + $P_2O_5$ 85% + PSB + *Azotobacter* led to the highest TSS (21.43 %), Total sugar (18.82 %), maximum Ascorbic acid (42.76 mg) and Reducing sugars (8.80 %) compared to the other treatments. It was observed that the highest yield of 54.00 kg/tree was achieved with the application of N 85% + $P_2O_5$ 85% + PSB + *Azotobacter* ($T_{10}$). This treatment showed a close relationship with the combination of 85% N + 100% P2O5 + PSB + *Azotobacter* ($T_8$) and 70% N + 85% P2O5 + PSB + *Azotobacter* ($T_{13}$).

In a study conducted by Gautam *et al.* (2012) found that the treatment T8, which included N 500g + P 250g + K 250g /tree + vermicompost 10 kg + 50 kg FYM, had a positive impact on various yield contributing parameters. This treatment increased the number of fruits/panicles, fruit yield, fruit width, length, weight, pulp weight and vegetative growth parameters such as maximum canopy or plant spreading (E-W) and (N-S) and plant height. These findings suggest that the T8 treatment is superior to other therapies in enhancing the overall performance of cv. Sunderja.

Yadav *et al.* (2011) opined some interesting findings about the physical parameters of cv. Amrapali. The highest fruit width was measured at 6.62 and 6.48 cm, while the fruit length was 9.88 and 10.08 cm. The weight of the fruit was found to be 151.25 and 153.00 g, with the stone weight being 26.45 and 26.62 g. The pulp weight was recorded as 97.06 and 97.08 g. The maximum TSS was also measured at 23.72 and 23.91°Brix and the pulp: stone ratio was 3.693 and 3.694. The study also observed the number of flowers (1710.67 and 1756.00), sex ratio (0.690 and 0.691), number of fruits per tree (163.33 and 184.67), fruit set (194.67 and 201.33) and fruit yield (25.00 and 26.72 q/ha). The treatment of T8, which consisted of RDF of NPK + PSB + *Azotobacter* + vermicompost + paclobutrazol+ Fe + Zn, showed the closest results to the desired parameters. T12, which included RDF of NPK + PSB + *Azotobacter* + BD compost + paclobutrazol + Fe + Zn, also showed promising results over the two experimental years.

Singh *et al.* (2015) found that the $T_6$ treatment, which included 500g N, 250g P and 250g K per tree per year, along with 250 g *Azospirillium* and 50kg FYM, resulted in the highest tree height (108.00 cm), fruit weight (263.10 g), plant spread in the N-S (105 cm) and E-W (123cm) direction, tree volume (85.95 $m^3$), total number of fruits (234.12) and yield per tree (58.56 kg) compared to the other treatments.

Hasan *et al.* (2013) systemised that applying vermicompost with a specific combination of nutrients significantly improved various aspects of Mango Fruit cv. Himsagar. The fruit length increased to 9.53 cm, weight to 273.20 g and TSS reached 21.57 °Brix. Additionally, the pulp weight increased to 180.20; total sugar content increased to 11.32%; ascorbic acid content reached 25.68 mg per 100.00g and pulp content increased to 65.96%. Furthermore, this treatment had the lowest acid content compared to other treatments.

Talang *et al.* (2017) study revealed that specific treatments significantly impacted the growth and yield of mango fruit cv. Himsagar. The T6 treatment, which included half NPK/tree, 50 kg FYM, *Azospirillium* and potassium mobiliser, resulted in an enormous stem girth, tallest plant height and widest tree spread. The $T_8$ treatment, which included half NPK/tree, 50 kg FYM, vermicompost and potassium mobiliser, produced the highest fruit number, yield, weight and total sugars.

A study by Sharma *et al.* (2016) demonstrated that applying a specific combination of nutrients and organic materials to Mango Fruit cv. Amrapali plants can have a positive impact. The application included 520g of nitrogen, 160g of phosphorus and 450g of potassium per plant, along with 25 kg of vermicompost, 2.5 kg of oil cake and various beneficial microorganisms such as PSB, VAM, *Azotobacter* and TV (100g each). The recorded measurements for the crown height, length, width (east-west and north-south), shoot length, number of panicles and length of panicle were all higher than those of the control and other treatments.

**Peach (*Prunus persica*)**

Solanki *et al.* (2020) noted that the Peach cv. July Elberta showed a significantly higher yield (20.16 kg per tree) and fruit set (87.70%) when treated with RDF 75% + 15 kg vermicompost/tree. This suggests that applying this specific combination of fertilisers can significantly enhance the productivity of Peach trees. The study revealed some impressive findings, such as the cumulative breadth of fruit measuring 61.89 mm, the highest length of fruit at 64.06 mm, total sugar content of 7.51%, a TSS (Total Soluble Solids) measurement of 13.33 ºB and a weight of 129.51 g under the application of RDF 75% + 15 kg vermicompost per tree.

**Apricot (*Prunus armeniaca*)**

Kumara *et al.* (2024) study on mature "New Castle" apricot trees in Solan, Himachal Pradesh, observed a combination of 50% Nitrogen, *Azotobacter*, Phosphate Solubilizing Bacteria and Vermicompost showed superior performance. This treatment increased trunk girth, leaf chlorophyll content, leaf area, fruit set and yield. It also showed the highest elevated nutrient levels, with $T_2$ yielding the largest economic returns. The study highlights the benefits of combining organic manures and bio-fertilisers with chemical fertilisers for improved productivity and soil health.

**Pomegranate (*Punica granatum*)**

Gajbhiye *et al.* (2020) confirmed that the treatment $T_7$ (INM: Compost + Solubilisers + RDF + Umber (*Ficus racemosa*) Rhizosphere hybridised soil) resulted in the highest fruit set (84.39%), number of flowers (204.75), fruit weight (244.82 g) and yield (41.21 kg/tree) for pomegranate. The treatment $T_6$ (INM: compost + solubilisers + RDF + Antibiotics) also showed positive results with values such as number of flowers (189.50), maximum fruit set (82.08%), yield (37.53 kg tree$^{-1}$) and maximum weight (240.49 g) compared to other treatments. On the other hand, the control treatment $T_1$ had the lowest number of flowers (61.25), minimum fruit set (68.15%), weight (188.38 g) and yield (9.08 kg tree-$^{1}$).

**Papaya (*Carica papaya*)**

Singh and Tripathi (2020) recorded various traits which was positively influenced by the application of NPK + PSB and NPK + *Azotobacter*are as follows: Number of nodes to first flowering (25.79), Days to first flowering (85.33), Fruit developmental period (140.25 days), Fruit drop percentage (47.23%), Fruit retention percentage (51.33%), Fruit yield (63.76 kg plant$^{-1}$), Fruit weight (1460.00 g), Fruit volume (1385.00 cc), Pulp percentage (86.66%), Peel percentage (9.78%), Total Soluble Solids (TSS) (14.00 °Brix), Total sugar content (11.56%) and Titratable acidity content (0.101%).

Singh and Tripathi (2020) discovered that plant spread ranged from 189.15 cm to 191.08 cm north to south and 173.86 cm to 182.22 cm east to west. Fruiting heights ranged from 35.92 cm to 46.12 cm, while leaf count varied between 25.65 and 36.52. Biomass production ranged from 11.65 kg to 29.00 kg. The fruiting developmental period spanned 140.25 to 164.00 days. Flower production ranged from 72.24 to 104.80 and fruit set varied from 22.80 to 43.00 per plant. Maximum fruit yields ranged from 60.44 kg to 67.08 kg, with minimum yields between 22.34 kg and 23.49 kg.

Kanwar *et al.* (2020) conducted a study on Papaya fruit cv. Red Lady and recognised that it had the greatest fruit number (78.33), yield (71.32 kg/plant), fruit weight (1486 g) and length (22.66 cm) among all the treatments. The red lady was undergoing treatment $T_8$, consisting of 75% of the recommended dose of fertiliser (RDF), 100.00g of *Azotobacter*, 100.00g of PSB and 10 kilograms of vermicompost per plant. This treatment was closely followed by $T_9$ and $T_7$ treatments. The number of fruits produced in $T_9$ and $T_7$ were 74.33 and 71.00 respectively. The fruit yield in $T_9$ and $T_7$ were 67.86 kg and 66.93 kg, respectively. The lengths of the fruits in $T_9$ and $T_7$ were 19.33 and 21.33, respectively. The fruit weights in $T_9$ and $T_7$ were 1423.33 grams and 1340.00 grams respectively. In contrast, T0 (RDF + Control) had a lower number of fruits and yield.

Singh and Varu (2013) pinpointed that in the papaya cv. Madhu Bindu, the treatment consisting of half the recommended dose of fertiliser (N 100.00g + P 100.00g + K 125 g /plant) + PSB 2.5g /$m^2$ + *Azotobacter* 50 g/plant ($T_8$) resulted in increased yield and growth parameters, along with the highest survival rate (98.67 per cent), fruit length (30 cm), weight (1670 g), girth (22 cm), number of fruits (45.33) and yield per plant, hectare, or plot (78 kg/313 kg/259.97 t, respectively). In the same application, the quality variables such as TSS (Total Soluble Solids), total sugars, reducing sugars and non-reducing sugars were seen to be at their highest levels, measuring 15.47 °Brix, 13.58 %, 11.10 % and 2.43 % correspondingly. However, it was discovered that it is equal to a combination of 1/4 recommended dose of fertiliser (RDF) and 3/4 Jivamrut (T13). Control has also exhibited a decrease in output across all metrics.

Singh *et al.* (2008) ascertained that in the papaya cv. Surya, the highest leaf numbers (18.73), stem girth (0.26 m), average weight (0.85 kg), number of fruits (46), thickness of pulp (3.5 cm), TSS (15.8 °B), Vit. A (2280 IU per 100-gram pulp) and shelf life (12 days) were achieved with a treatment consisting of 75% RDF + bacteria culture of rhizosphere + 25% vermicompost. On the other hand, the mean height of the plant (185.35 cm) and the length of the petiole (8.42 cm) were observed under the treatment of 100% RDF alone. The combination of 75% RDF (Recommended Dose Fertiliser) and a bacterium culture of the rhizosphere, along with 25% vermicompost, was found to be superior and economically viable compared to other treatments.

Tandel *et al.* (2014) foundthat in Papaya cv. Red Lady, the T6 treatment, which consisted of 50% RDN from inorganic fertiliser and 25% RDN from a combination of bio compost and castor cake, resulted in higher growth metrics. These included a plant height of 185.39 cm, stem girth of 50.51 cm and leaf number of 44.92. This therapy also impacted other physiological measures, including the photosynthetic rate, transpiration rate, total chlorophyll content and leaf temperature.

Singh and Tripathi (2020) determined the effects of several fertiliser treatments on plant growth, flowering, fruit production, yield and quality to maximise performance. The treatment that consisted of 75% RDF (Recommended Dose of Fertiliser), 100.00g of *Azotobacter*, 100.00g of PSB (Phosphate Solubilising Bacteria) and 2 kg of vermicompost per plant had the maximum effectiveness. It resulted in the greatest biomass, flower and fruit set and overall fruit production while shortening the time required for flowering. This treatment resulted in fruits that exhibited the highest measurements in length, width, weight, TSS (Total Soluble Solids) and total sugar content while simultaneously displaying the lowest titratable acidity levels. Conversely, plants that were not fertilised displayed the smallest and lowest-quality fruits, accompanied by the highest titratable acidity during the entire duration of the trial.

**Kinnow (*Citrus reticulata* × *Citrus sinensis*)**

Bakshi *et al.* (2018) demonstrated that the treatment of 100% N as urea + *Azotobacter*, along with prescribed MOP and SSP, resulted in the maximum plant height (14.30%), canopy volume (38.95%) and plant spreading direction (E-W 14.0% and N-S 14.05%) in Kinnow Mandarin. The higher yield was obtained by applying N 50% through poultry manure or 50% remaining N through urea in conjunction with *Azotobacter*, with contributing factors such as fruit width (6.53 cm), length (5.84 cm), number of fruits (165.5), fruit volume (191.83 cc), fruit weight (188.18 g) and kinnow fruit yield (31.14 kg) per plant. The study determined that replacing the application of 50% nitrogen in the form of urea with the application of poultry manure, together with *Azotobacter* treatment, is a viable alternative.

**Acid lime (*Citrus aurantifolia*)**

Kumar *et al.* (2020) originated from their study that Acid Lime had the highest fruit length (5.27 cm), diameter (4.93 cm), number of seeds (8.17), seed weight (1.24 g), juice percentage (56.94%), specific gravity (1.36), peel thickness (1.94 mm), moisture content of peel (84.28 %) and moisture content of pulp (93.89 %) under treatment $T_{12}$-50% RDF + 75% FYM + 75% Vermicompost + Biofertilizers (25g *Azotobacter* + 25g PSB + 150g VAM). The control group yielded the lowest results.

In their study, Lal and Dayal (2014) reported that the treatment $T_6$, which consisted of a 50% recommended dose of fertiliser (RDF) and 50% goat manure, resulted in the highest yield (7.58 kg/tree) and the best fruit growth. The fruits treated with T6 had the most extended length (4.43 cm), heaviest weight (35.71 g) and largest diameter (3.99 cm) compared to the other treatments. Similarly, the approach also resulted in the highest TSS (10.42 %), juice yield (43.37 %) and ascorbic acid content (86.33 mg per 100-gram juice), along with a lower number of seeds (1.15 %) and acidity content (6.06 %).

**Lemon (*Citrus limon*)**

Ghosh *et al.* (2020) disclosed that Lemon cv. Assam Lemon plants had the highest number of flowers per plant (399, 371.67 and 250.33) in the $N_4$ treatment, which consisted of 75% of the recommended dose of fertiliser (RDF) along with VAM, *Azotobacter* and Vermicompost. On the other hand, the lowest number of flowers (360, 386.33 and 224.33) was observed in the Vermicompost treatment ($N_3$) during the *Mrig, Ambe* and *Hasth* bahar seasons, respectively. The involvement of bio-fertilisers in nitrogen fixation from the atmosphere and VAM in phosphorus solubilisation is responsible for maintaining a healthy environment or soil, which is ultimately reflected in the flowering of trees. The treatment with N4 resulted in the maximum fruit yield, with 7.67 kg, 13.83 kg and 2.14 kg per plant.

In their study, Mahakulkar *et al.* (2016) detected that Rough Lemon Fruits treated with T8 [75% RDF (450 g N + 225 g $P_2O_5$ + 225 g $K_2O$/plant) + 500 g AM (*Actinomycetes*)/plant + 100.00g *Azotobacter*/plant + 100.00g PSB/plant + 15 kg vermicompost/plant] exhibited improved fruit volume (150.95 cc), fruit diameter (8.00 cm), seed germination (68.21 %) and seed vigour (1273.35). However, the TSS and acidity of the fruits did not show any significant differences across the different treatment combinations.

Kumar *et al.* (2018) conceivedthat applying 75% NPK (315g N + 210g P + 315g K) +10kg NC + 200g PSB + 200g *Azotobacter* to Lemon fruit had a statistically significant and beneficial effect. This treatment resulted in the highest increase in tree height (14.44 % and 15.34 %), tree spread (16.20 % and 17.68 %), trunk diameter (11.21 % and 13.55 %), fruit set (79.19 % and 80.54 %) and fruit retention. The control treatment had the highest fruit drop (64.34 % and 63.35 %) during 2011-12 and 2012-13, respectively.

**Guava (*Psidium guajava*)**

Kumar *et al.* (2014) evaluated the effects of 75% RDF of NPK combined with 200 g each of *Azotobacter*, *Azospirillum* and PSB on guava (*P. guavajava*). This treatment yielded optimal results, with maximum fruit set (52.46%), retention (57.50%) and yield (26.82 kg/plant), alongside improved fruit size and quality, including high TSS (11.82° Brix), total sugars (10.76%) and low acidity (0.23%). These findings suggest that this nutrient management approach effectively enhances guava yield and quality during the winter season in northern India.

In their study, Dhewareet *al.* (2020) diagnosed that the treatment $T_4$, which consisted of 250 g of PSB, 30 kg of vermicompost and 250 g of *Azospirillum*, resulted in the highest flowering rate (92.33%) and the highest total soluble solids (10.37 °Brix) in Guava Fruit cv. Allahabad Safeda. On the other hand, the treatment T6, which involved the application of 30 kg of vermicompost, 250 g of PSB, 250 g of *Azospirillum* and a foliar spray of vermi wash (diluted with water at a ratio of 1:1), led to the maximum average weight of fruits (400 g), fruit yield (29.60 kg/tree and 11.84 t/ha) and the lowest acidity content (0.19%).

According to Sharma *et al.* (2013), the study verified that guava's quality and yield could be improved by using a treatment containing 75% nitrogen from inorganic sources and 25% nitrogen from FYM (farmyard manure). Another treatment with 50 % nitrogen from inorganic sources 50% nitrogen from FYM and*Azotobacter* also showed positive results. These treatments resulted in the highest levels of total sugars (8.61%) or TSS (12.95 °B) and the lowest physiological weight loss (14.29 %) over ten days under suitable conditions.

Binepal *et al.* (2013) concluded that the treatment $T_9$ (100%N + P2O5 100% + PSB + *Azospirillum* + Vermicompost 10 kg) resulted in significantly larger Guava fruit with a maximum length of 7.52 cm, diameter of 7.91 cm, volume of 217.41 ml, thickness of pulp of 2.46 cm and weight of pulp of 211.61 g. The treatment also led to a higher weight of seed at 8.76 g. On the other hand, the treatment T10 (75% N + 75% P2O5 + PSB + *Azospirillum* + Vermicompost 10 kg) resulted in a lower percentage of pulp at 96.08 %, which was still higher than the control.

In a study by Goswami *et al.* (2012), the effects of fertiliser-enriched FYM mixed with half the recommended fertiliser dose on five-year-old guava cv. Pant Prabhat plants were evaluated from 2007 to 2009. Utilising a Randomized Block Design with 11 treatments, the research found that applying a half dose of fertilisers (225 g N, 195 g P, 150 g K) along with 50 kg of FYM and 250 g of *Azospirillum* per tree annually significantly enhanced vegetative growth and increased leaf nitrogen (N) and potassium (K) content. The combination of half the prescribed fertilisers, 50 kg of FYM and 250 g each of Trichoderma and Pseudomonas fluorescens resulted in the highest leaf phosphorus content. These findings highlight the effectiveness of integrating biofertiliser-enriched FYM with reduced chemical fertilisers to produce high-quality guava fruits.

According to Shukla *et al.* (2009), the treatment of NPK 50% + 250 g *Azotobacter* + 50 kg FYM (T7) significantly increases the size of the canopy (201.42 $m^3$), the amount of ascorbic acid in the pulp (198.30 mg per 100.00gram), the weight of the fruit (153.30 g), the total sugar content (8.10 %), the reducing sugar content (4.77%), the TSS (14%) and the nitrogen, phosphorus and potassium content in the leaves (1.40%, 0.46%, 1.17%, respectively) of Guava cv. Sardar. Applying a mixture containing 50% NPK, 250 grams of *Azotobacter* and 50 kilograms of FYM ($T_7$) resulted in a significantly increased yield of 28.95 kg and the highest B: C ratio of 2.53:1.

In their study, Pilania *et al.* (2010) traced the pruning effect achieved through the application of 50g N + 20g P + 50g K + *Aspergillus niger* + *Azotobacter* + 5 kg vermicompost + 25% pruning intensity (F5 I1), resulted in the highest number of flowers per shoot (57.83) and canopy volume (0.96 m3). On the other hand, the application of 50g N + 20g P + 50g K + *Aspergillus niger* + *Azotobacter* + 5 kg vermicompost + 75% pruning intensity (F5 I3) led to the maximum diameter of fruit (5.31 cm), fruit weight (158.06 g), pulp seed ratio (39.93) and pulp weight (154.19 g) in both years of the study. The highest area of the leaf (59.46 $cm^2$) and yield (6.68 kg/plant and 33.43 t/ha) are achieved with a combination of 50g N + 20g P + 50g K + Aspergillus niger + *Azotobacter* + 5 kg vermicompost + pruning intensity of 50% (F5 I2), resulting in a B: C ratio of 4.33.

Jamwal *et al.* (2018) comprehended that the application of *Azotobacter* + (100% Nitrogen through urea) T11 resulted in the highest tree height (21.99 %), canopy spread in the north-south direction (23.57%) and canopy spread in the east-west direction (23.50 %) for Guava fruit. Treatment T14, which involved *Azotobacter* + (75% Nitrogen through urea + Vermicompost 25%), resulted in the highest number of fruits per tree (21), average fruit weight (190.10 gm), fruit length (7.10 cm), fruit diameter (7.15 cm), fruit volume (192.13), yield per tree (3.99 kg) and fruit yield per hectare (199.58 q).

**Isabgol (*Plantago ovate* Forsk.)**

Tripathi *et al.* (2013) investigated the effects of integrated nutrient management on Isabgol (*Plantago ovata* Forsk.), applying treatments of RDF, vermicompost and*Azotobacter* and pioneered that the combination of vermicompost with 75% of the recommended fertiliser, notably improved plant height, leaf and tiller numbers, spike count and length and seeds per spike, while reducing maturity time to 106.5 and 105 days. This treatment yielded the highest unhusked seed production (10.20 and 10.16 q/ha) and husk yield (2.92 and 2.90 q/ha), showing significant benefits of integrated nutrient application.

**Plum (*Prunus domestica*)**

Kamatyanatti *et al.* (2019) perceived that in Plum cv. Kala Amritsari, the treatment T11, which consisted of 75% nitrogen (N), 12.5% N from farmyard manure (FYM), 12.5% N from vermicompost and bio-fertilisers, resulted in the highest plant height (0.27 m), percentage increase in height (4.91%), leaf area (13.13 $cm^2$), chlorophyll index (23.88) and annual shoot growth (70.63 cm). The treatment T9, which included 75% N, bio-fertilisers and 25% N from FYM, also showed significant growth. In contrast, the control treatment (T1) had the lowest plant height of 0.14 m. The highest fruit output (52.14 kg/tree) was seen in treatment T11, whereas the lowest yield (38.63 kg/tree) was recorded in treatment T2, which received 50% of nitrogen (N) and 50% of nitrogen from farmyard manure (FYM).

**Litchi (*Litchi chinensis*)**

Raghavan *et al.* (2018) distinguished that the Litchi cv. had the highest fruit number (1281), total sugars (26.14 %), yield (30.01 kg) and reducing sugar (14.51 %) per tree. Muzaffarpur was treated with a combination of 500 grams of NPK, consisting of 250 grams of nitrogen, 250 grams of phosphorus and 250 grams of potassium, along with 100.00grams of VAM, 100.00grams of PSM, 150 grams of *Azotobacter* and 100.00 kilograms of FYM (T9). On the other hand, the control group received a higher dosage of NPK, consisting of 1000 grams of nitrogen, 500 grams of phosphorus and 500 grams of potassium, resulting in the highest incidence of fruit cracking. The most effective method for improving fruit yield and quality in litchi was the application of a combination of 500 g of nitrogen (N), 250g of phosphorus (P), 250 g of potassium (K), 100.00g of vesicular-arbuscular mycorrhiza (VAM), 100g of phosphate solubilising microorganisms (PSM), 150 g of *Azotobacter* and100.00kg of farmyard manure (FYM) in the foothills of Arunachal Pradesh.

Kumar (2008) investigated organic nutrient management for Bombai litchi in West Bengal, India, using organic sources (farm yard manure, poultry manure, vermicompost, neem cake) with biofertilisers (e.g., *Azotobacter*, *Azospirillum*, phosphorus solubilisers (PSB), potash mobilisers). Farm yard manure and biofertilisers yielded the highest fruit weight (24.73 g), total soluble solids (17.79 °Brix) and total sugars (17.57%), while vermicompost with bio-fertilisers maximised fruit count (2556) and yield (61.59 kg/tree). Neem cake with bio-fertilisers produced the highest vitamin C content (53.48 mg/100.00g pulp). Vermicompost at 42.86 kg/tree per year with biofertilisers was recommended for optimal litchi production.

Dutta *et al.* (2010) inspected the impact of incorporating organic manures and bio-fertilisers on the litchi cv. Bombai with or without chemical fertilisers. Treatment involving 50 kg of farmyard manure per tree, 150 g of *Azotobacter*, 100.00g of vesicular-arbuscular mycorrhiza (VAM) and 500 g of nitrogen, 250 g of phosphorus pentoxide ($P_2O_5$) and 500 g of potassium oxide ($K_2O$) per tree per year resulted in the highest fruit production (98.72 kg per plant). Furthermore, this treatment significantly improved various aspects of fruit quality, such as total soluble solids (TSS), total sugars, ascorbic acid content, TSS to acid ratio, fruit weight and size. The same treatment led to the highest levels of nitrogen (N) and potassium (K) in the leaves, as well as a microbial population of $8.3 \times 10^6$ colony-forming units per gram of soil (cfu/g). Although using organic manure and biofertilisers resulted in better fruit quality when compared to using only chemical fertilisers, their effect on productivity was less significant. Applying organic treatments resulted in fruits with the highest concentration of anthocyanins, measuring 22.45 mg per 100.00g of peel.

**Sapota (*Manilkara zapota*)**

Meena *et al.* (2019) scrutinised 17 integrated nutrient management (INM) combinations on sapota in the Chambal region, India by utilising 2/3 of RDF + 50 kg FYM + 250 g *Azospirillum* + 250 g *Azotobacter* per plant ($T_{11}$) resulted in the highest fruit yield (327.88 fruits/plant, 29.03 kg/plant, 4.52 t/ha), with 32% yield increase compared to control. The highest microbial counts were found in 2/3 RDF + 10 kg vermicompost + 250 g *Azospirillum* + 250 g *Azotobacter* ($T_{15}$), with fungi (8.89 cfu $g^{-1}$), bacteria (11.19 cfu $g^{-1}$) and actinomycetes (5.60 cfu $g^{-1}$). T15 also had the highest leaf nitrogen content (2.03%), while T11 had the highest phosphorus (0.28%) and potassium (1.80%). These findings emphasise the benefits of integrated nutrient management for sapota yield and soil health.

Sheik *et al.* (2019) investigated sapota (cv. Kirthabarthi) and assessed the impact of integrated nutrient management (INM) on fruit quality. The highest quality was achieved with 12.5 kg vermicompost/tree + RDF (1000 g N, 1000 g P, 1500 g K/tree) + EM (1:250 dilution), showing the highest TSS (19.86°B and 19.80°B), ascorbic acid (2.85 mg/100.00g and 2.69 mg/100.00g), total sugar (18.35% and 18.19%), reducing sugar (13.10% and 13.02%), non-reducing sugar (5.25% and 5.17%) and lowest acidity (0.18% and 0.16%). The control treatment recorded the lowest quality and highest acidity. During peak season, I generally showed higher values.

Tasleema *et al.* (2019) experimented on twenty-year-old sapota trees (cv. Kirthabarthi) planted at 8 m × 8 m spacing, with eight treatments replicated thrice. The treatments included combinations of FYM, vermicompost, RDF and EM inoculation. The results showed that the treatments significantly influenced plant height, spread and canopy volume. The highest plant height (7.29 m), widest plant spread (7.20 m North-South, 7.19 m East-West) and maximum canopy volume (96.49 $m^3$) were recorded in trees receiving RDF, vermicompost (12.5 kg/tree) and EM.

**Phalsa (*Grewia asiatica*)**

Sutariya *et al.* (2018) catalogued the quality characteristics of Phalsa cv. Local, specifically juice content (53.07 %), TSS (23.17 °Brix), total sugar (6.55 %), reducing sugar (2.77%) and ascorbic acid (38.20 mg/100.00g of fresh pulp), were significantly higher in the $T_7$ treatment. The $T_7$ treatment consisted of 50 % nitrogen applied through urea, 25% nitrogen applied through vermicompost per plant, 100.00g $P_2O_5$ applied through SSP, 50 g $K_2O$ applied through MOP per plant and the use of AAU PGPR consortium. Additionally, the $T_7$ treatment showed the lowest acidity level (2.02 %).

**Bael (*Aegle marmelos*)**

Vishwakarma *et al.* (2017) disentangled that in the Bael cv. Narendra Bael-9, the highest measurements for fruit length (24.00 cm and 24.62 cm), fruit width (18.08 cm and 19.32 cm), fruit weight (2.41kg/fruit and 2.45 kg/fruit), number of seeds per fruit (114.50 and 120.75), minimum shell weight (303.44 g and 306.50 g), maximum TSS (35.66 °Brix and 37.85 °Brix), ascorbic acid content (20.75 mg/100g pulp and 21.26 mg/100g pulp) and total carotene content (55.84 µg/100g pulp and 55.72 µg/100g pulp) were observed when T7-50

Kg FYM + 100% NPK + 200g each (*Azotobacter* + PSB) was applied, followed by the use of T8 75% NPK + 200g PSB + 200g *Azotobacter* + 50 Kg FYM. These results were superior to the other treatments during the two years of the experiment.

**Walnut (*Juglans regia*)**

Bhattarai and Tomar (2009) reported that applying NPK + 50 kg vermicompost and ¾ NPK + vermicompost 68.75 kg improved walnut leaf nutritional quality.

**Pineapple (*Ananas comosus*)**

Baraily and Deb (2018) traced in their study, that treatment $T_9$, which consisted of 75 % RDF of NPK, bio-fertiliser and 7.5 t/ha Vermicompost, resulted in the highest values for fruit length without crown (21.92 cm), crown length (14.91cm), crown weight (170.7 g), estimated yield without crown (63.41t/ha), fruit juice content (0854.8 g), TSS (13.56 $^0$Brix) and reducing sugar (5.77 %). These results were similar to those obtained with treatment T8, which included 100.00% RDF of NPK, bio-fertiliser and 5 t/ha Vermicompost.

**Strawberry (*Fragaria* × *ananassa*)**

Kumar and Tripathi(2020) analysed the effect of *Azotobacter*, PSB and vermicompost on the growth, flowering, yield and quality of strawberry (*Fragaria x ananassa* Duch.) cv. Chandler. The application of *Azotobacter* at 7 kg/ha significantly enhanced plant growth, with an increase in plant height (16.25 cm), number of leaves (55.40), crowns (6.60) and runners (5.25) per plant. It also led to the maximum number of flowers (75.45) and fruit set (28.35) per plant, along with a longer harvesting duration (67.90 days). The earliest first flowering (61.85 days) and the highest yield (185.75 g/plant) were observed. The berries showed the most significant length (3.80 cm), width (2.52 cm) and weight (7.40 g), as well as higher TSS (9.21 °Brix), total sugars (8.21%) and ascorbic acid (55.29 mg/100g) with the lowest titratable acidity (0.601%).

Tripathi *et al.* (2016b) assessed the impact of varying levels of *Azotobacter*, *Azospirillum*, PSB and black polythene mulch on strawberry cv's growth, yield and quality. Chandler. Treatments with *Azotobacter* at 7 kg/ha combined with black polythene mulch led to significantly improved plant height (18.70 cm), leaf number (16.75), runner count (2.17) and crown number (2.64) per plant. This treatment also reduced days to first flowering (65.33), increased flower (15.87) and fruit set (14.72) per plant, extended harvest duration (67 days) and enhanced yield (107 g/plant). Quality traits of berries improved, with greater length (2.90 cm), width (1.79 cm), weight (7.11 g), volume (4.36 cc), TSS (7.16 °Brix), total sugars (5.60%), ascorbic acid (56.00 mg/100g) and reduced acidity (0.249%) under North central plain of the Indian subcontinent.

Tripathi *et al.* (2015) investigated the effects of *Azotobacter* and vermicompost on strawberry growth and quality. The study employed nine treatments, including a control with FYM as a basal dose. The highest plant height (18.70 cm), leaf count (61.60), crowns (6.77) and runners (4.83) were observed with *Azotobacter* at 7 kg/ha and vermicompost at 30 t/ha. Meanwhile, *Azotobacter* at 6 kg/ha combined with vermicompost at 30 t/ha resulted in the most flowers (56.69), fruit set (25.87) and prolonged harvesting duration (66.80 days), along with fewer days to first flower (55.17) and fruit set (6.19). This treatment also produced the maximum yield (322.38 g/plant) and berries with optimal measurements: length (4.76 cm), width (2.49 cm), weight (8.75 g), volume (5.97 cc), total soluble solids (9.80 °Brix), total sugars (9.23%) and ascorbic acid (54.72 mg/100.00g), while maintaining the lowest acidity (0.50%) under plains of central Uttar Pradesh.

Tripathi *et al.* (2016a) collected the effects of *Azotobacter*, *Azospirillum* and PSB on strawberry cv. Chandler over two years. The application of *Azotobacter* at 7 kg/ha notably increased plant height (16.05 cm), leaf number (54.75), crown count (6.34), runner production (4.93), flower count (52.38), fruit set (25.66) and yield (180.89 g/plant). Quality characteristics were enhanced as well, with larger berries (3.55 cm length, 2.35 cm width), higher TSS (9.13° Brix), total sugars (8.20%) and ascorbic acid (56.01 mg/100g pulp), highlighting the efficacy of *Azotobacter* at 7 kg/ha for improved strawberry yield and quality.

Chaurasia *et al.* (2022) investigated the impact of several combinations of biofertilisers on the growth, fruit production and features of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn in a vertical farming setup. The study employed a total of 10 treatments, including a control group. These treatments consisted of various combinations of organic and microbial sources, such as vermicompost, FYM, *Azotobacter*, *Azospirillum* and PSB. The experiment was performed three times using a Randomized Block Design. The application of Treatment $T_9$, which consisted of a mixture of 50% soil and 50% vermicompost together with 2g each of *Azotobacter* and *Azospirillum*, resulted in the most significant outcomes regarding plant height, spread, leaf number and area. Additionally, this treatment led to the earliest flowering and the most considerable number of flowers per plant. Additionally, this treatment resulted in the most tremendous fruit weight, quantity of fruits per plant and overall production. It had the highest Benefit: Cost ratio (1:3.39) compared to $T_7$ (Soil 50% + FYM 50% + PSB 2g + *Azotobacter* 2g) because it had a lower cost of manufacture. Regarding both productivity and fruit quality, T9 demonstrated higher performance overall.

Umar *et al.* (2008) found that the best crop yield of 372.89q per hectare was achieved when entirely nitrogen (N) was applied using urea + *Azotobacter*. The second highest yield of 358.43q per hectare was obtained when 75% of the nitrogen was applied as urea and 25% as FYM (Farm Yard Manure) + *Azotobacter*. These two treatments showed a close relationship in terms of production.

Nazir *et al.* (2015) documented the growth characteristics of a plant, including its maximum height (23.39 cm), number of runners per plant (13.03) and plant spread (24.21 cm). They found that the treatment involving PSB + wood ash + *Azotobacter* + poultry manure + mustard oil cake resulted in the highest yield (238.95 g) and improved physical fruit characteristics, such as diameter (3.11 cm), length (3.95 cm), weight (11.11 g) and volume (20.39 $cm^3$). Additionally, this treatment had positive effects on chemical characteristics, such as TSS (9.01 °B), total sugars (7.95 %) and acidity (0.857%) content.

Bhagat and Panigrahi (2020) exposed that the flowering and physical characteristics of the fruit were significantly affected by the treatment T11, which included the application of RDF, *Azospirillum*, Phosphate Solubilizing Bacteria and VAM. The observed values for the number of flowers, number of fruits, diameter, length, volume, weight of fruit and fruit yield were 43.41, 41.80/plant, 4.85 cm, 6.64 cm, 37.17 cc, 43.33 g and 355.84 q/ha, respectively. On the other hand, the control treatment (T0) resulted in the lowest values for these parameters. Furthermore, the treatment with the highest benefit-cost ratio was the same as the one mentioned earlier, with a ratio of 4.20:1. Conversely, the treatment with the lowest value of 2.20:1 was observed in the RDF + control treatment.

Anushi *et al.* (2024) investigated the effects of bio-stimulants and organic mulch on soil microbes in strawberry cv. Katrain Sweet. The treatment combining *Azotobacter*, *Trichoderma harzianum*, PSB and dried leaves significantly boosted bacterial ($8.97\times10^5$ cfu $g^{-1}$) and fungal ($5.93\times10^3$ cfu $g^{-1}$) populations, surpassing the control. These results highlight the potential of bio-stimulants and organic mulch in enhancing soil microbial activity for sustainable strawberry production.

## Conclusion

The inconsistent and imbalanced use of chemical fertilisers negatively affects soil productivity and plant yield, leading to stagnation or a loss in crop output. To maximise yield capacity, optimising the consumption of fertilisers is essential. The use of chemical fertilisation has undeniably enhanced crop production. However, it also has the potential to cause soil erosion and soil health problems. On the other hand, relying solely on organic manures without adding inorganic fertilisers may not meet the nutrient needs of high-demand crops due to these organic fertiliser sources' large quantity and slow-release properties. Using cost-effective and environmentally friendly bio-fertilisers holds immense promise in modern agriculture for enhancing crop yield. However, it is exceedingly challenging to effectively provide all the nutritional requirements by using organic manures and bio-fertilisers. Therefore, based on the study, as mentioned earlier, it is recommended that 50% of the necessary nutrients be provided using inorganic fertilisers and that the remaining amount be obtained from organic sources. The integrated nutrition management strategy can enhance crop output through synergistic effects and contribute to sustaining soil conditions.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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