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Organic farming in banana: A sustainable approach to cultivation

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Abstract
"Bananas (*Musa* spp.) are a globally significant fruit crop, crucial for food security, income, and nutrition, particularly in tropical and subtropical climates. Their rapid biomass accumulation and shallow root system necessitate considerable nutrient uptake, especially nitrogen and potassium. Historically, synthetic fertilizers have been the primary method for banana cultivation. While effective, their prolonged use raises environmental and economic concerns. Consequently, there's a growing shift towards sustainable practices, with organic fertilizers gaining prominence as a feasible alternative. Organic nutrient sources, including vermicompost, farmyard manure, poultry manure, neem cake, and wood ash, have been documented to substantially improve vegetative growth, fruit yield, and quality in bananas. These organic amendments improve soil structure, stimulate microbial activity, and enhance nutrient availability, thereby fostering healthier plant development. Furthermore, biofertilizers such as Azospirillum, phosphate-solubilizing bacteria (PSB), arbuscular mycorrhizal fungi (AMF), and Trichoderma play a role in nutrient cycling, disease resistance, and stress tolerance. Integrated organic approaches, such as combining composts with bio-inoculants and natural preparations like jeevamrutha, have demonstrated improvements in key physiological traits and reduced crop cycles, while also enhancing parameters like bunch weight, fruit size, total soluble solids (TSS), and pulp-to-peel ratio. These findings underscore the potential of organic fertilizers in promoting sustainable banana cultivation without compromising yield or quality. Nevertheless, further research is required to optimize formulations and application methods for different banana varieties and specific agro-climatic conditions."

Keywords: Banana, organic fertilizers, vermicompost, biofertilizers, sustainable production, fruit quality

1. Introduction
Bananas, a widely cultivated tropical fruit, is grown in over 122 countries globally. As a member of the Musaceae family, they hold significant importance as a commercial fruit crop within tropical agricultural systems. Often referred to as "Adam's Fig" or the "Apple of Paradise," the banana originated in Southeast Asia before spreading to numerous tropical and subtropical regions worldwide. Following rice, wheat, and maize, bananas and plantains rank as the fourth most important agricultural crops globally (Ganapathi *et al*., 1999) [3]. They serve as a crucial source of dietary energy and a primary starchy staple for populations residing in tropical and humid climates (Onwuka & Onwuka, 2005) [14]. Beyond their caloric value, bananas and plantains are nutritionally rich, providing substantial amounts of starch, natural sugars, vitamins A and C, along with essential minerals like potassium and calcium (Doymaz, 2010) [2]. According to the United States Department of Agriculture, a medium-sized banana (100 g) supplies 89 calories, 22.84 g of carbohydrates, 12.23 g of sugars, 1.09 g of protein, and 0.33 g of fat. Bananas are an excellent source of potassium, with a 100 g serving containing 358 mg of potassium, 8.7 mg of Vitamin C, 0.367 mg of Vitamin B-6, and 27 mg of Magnesium. Their consistent year-round availability, affordability, versatility, appealing taste, and nutritional and medicinal properties make them a favored fruit across all societal segments. They are frequently consumed fresh, while the central core of the pseudostem can be eaten as a vegetable. The pseudostem is also utilized in the production of paper and boards. World O Stats reported that as of 2022, global banana production reached approximately 135 million tonnes. The leading banana-producing nations are India, China, Indonesia, Brazil, and Ecuador. India is the world's largest producer, followed by China.

India's annual banana production is approximately 34.5 million tonnes, accounting for over 25% of the global total. Bananas are extensively cultivated in Indian states such as Tamil Nadu, Maharashtra, Gujarat, Andhra Pradesh, and Kerala.

Banana plants typically require substantial fertilization to flourish, particularly with nutrients like nitrogen and potassium (Ganeshamurthy *et al*., 2011) [4]. Achieving high yields of superior quality bananas necessitates the appropriate application of essential nutrients, alongside other enhanced cultural practices. To fulfill the nutritional requirements of banana plants, these elements are frequently supplied to the soil, predominantly through synthetic chemical fertilizers (Mia *et al*., 2010) [12]. Furthermore, due to their shallow and sparse root systems, banana plants absorb nutrients primarily from the topsoil. This limited rooting depth, combined with high water demands, often results in significant nutrient losses, especially nitrogen, through leaching, volatilization, and denitrification processes. Adding to these challenges, the rising cost of chemical fertilizers further burdens farmers. Beyond economic concerns, these fertilizers are also linked to environmental pollution, as their manufacturing and usage contribute to air, soil, and water contamination. Consequently, researchers have increasingly focused on exploring alternative, more sustainable nutrient management approaches.

Organic farming in banana cultivation offers several agronomic and ecological advantages that contribute to sustainable production. Organic practices, such as the application of compost, vermicompost, and farmyard manure, enhance soil organic matter, improve nutrient availability, and foster beneficial microbial populations that support plant growth (Athani *et al*., 2009) [1]. These methods aid in improving soil structure and water-holding capacity, which are vital for banana crops given their shallow root systems and high water requirements. Moreover, organic inputs reduce the risk of nutrient leaching and chemical accumulation in the soil, thereby preserving soil and water quality (Padmanaban *et al*., 2021) [15]. In addition to promoting soil health, organic farming helps decrease reliance on synthetic fertilizers and pesticides, mitigating environmental pollution and fostering agroecosystem biodiversity (Gomiero *et al*., 2011) [5]. Research indicates that organically grown bananas can be as profitable as conventionally grown ones, while also offering improved taste and extended shelf life—making them particularly attractive to health-conscious consumers and premium markets (Sharma & Mittra, 2015) [16]. Therefore, organic farming presents a viable approach to banana cultivation that balances sustainability, economic benefits, and environmental resilience.

2. Effect of organic fertilizers on vegetative growth in banana

Research by Singh *et al*. (2021) [17] at the College of Forestry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, investigated how organic manures affect the vegetative growth and yield of banana (Musa spp.) cultivars G-9 and Cavendish Dwarf under an agroforestry system. Their findings indicated that applying 100% vermicompost significantly boosted growth and yield in 'Grand Naine' banana. This included optimal plant height (238.43 cm), number of leaves (33.25), plant girth (56.68 cm), and a shooting stage of 274.32 days. Additionally, the highest yield parameters were observed with 100% vermicompost, leading to maximum bunch weight (21.32 kg), number of hands per bunch (11.67), number of fingers per hand (21.70), total fingers per bunch (253.22), average fruit length (17.60 cm), average fruit width (13.46 cm), and fruit yield (65.78 t/ha). Similarly, Zonthansiami *et al*. (2021) [21] reported that combining poultry manure with biofertilizers (Azotobacter, PSB, and KSB) substantially improved banana plant growth. Their study showed that this combination (T11) resulted in the greatest pseudostem height (255.67 cm) and girth (69.33 cm) compared to control plants (201.67 cm, 58.83 cm). The total number of leaves per plant was also highest in T11 (24.27), followed closely by poultry manure alone (T4: 24.13), with control plants exhibiting the fewest leaves (17.07). Further supporting the benefits of organic amendments, Njeru *et al*. (2008) [13] from the Kenya Agricultural Research Institute found that poultry manure application significantly enhanced banana plant growth parameters, including a 26% increase in plant height, 42% in pseudostem girth, and 46% in total biomass, all relative to control treatments. This also considerably improved soil fertility, with nitrogen and phosphorus levels rising by 54% and 190%, respectively.

More recently, Hassan *et al*. (2022) [6] explored different substrate combinations, noting that T8 (33.3% vermiculite + 33.3% vermicompost + 33.3% sand) was superior for increasing plant and root length, stem diameter, leaf width, and shoot dry weight, while also providing satisfactory root dry weight. Meanwhile, T3 (50% peat moss + 50% vermicompost) yielded the highest number of leaves, stem diameter, and leaf length. Additionally, T9 (25% vermiculite + 50% vermicompost + 25% sand) was found to maximize leaf width and both shoot and root fresh weight.

3. Effect of organic fertilizers on yield in banana

Research consistently highlights the benefits of integrated nutrient management (INM) in banana cultivation, particularly in enhancing yield and productivity. For instance, Manju and Pushpalatha (2022) [10] documented impressive results, reporting the highest bunch weight of 9.60 kg and a fruit yield of 23.99 t/ha. Their integrated approach involved applying per plant: 10 kg farmyard manure, 1.25 kg neem cake, 5 kg vermicompost, 1.75 kg wood ash, triple green manuring with cowpea, and a biofertilizer blend consisting of 25 g arbuscular mycorrhizal fungi (AMF), 50 g Trichoderma harzianum, 50 g phosphate-solubilizing bacteria (PSB), and 50 g Azospirillum. This comprehensive strategy significantly boosted both yield and overall productivity. In another study, Kavitha *et al*. (2022) [8] explored the impact of different levels of ghanajeevamrutha and liquid jeevamrutha on banana performance in Karnataka. Their findings indicated that the optimal treatment (T9), which combined 600 kg/acre ghanajeevamrutha with 300 L/acre liquid jeevamrutha, led to the highest values for several key yield parameters. These included a bunch length of 58.33 cm, bunch width of 30.47 cm, finger length of 11.10 cm, finger girth of 3.33 cm, finger weight of 76.67 g, finger volume of 71.08 cc, a yield of 9.35 kg per plant, and 5.19 t per acre, underscoring the effectiveness of their integrated organic nutrient management.

Similarly, Hema *et al*. (2016) [7] investigated the effects of

organic nutrient sources on 'Grand Naine' banana at Dr. Y. S. R. Horticultural University, Andhra Pradesh. Their research demonstrated that an integrated application of 15 kg farmyard manure, 1.875 kg neem cake, 7.5 kg vermicompost, and 9.94 kg ash per plant resulted in superior yield attributes. These included 9.39 hands per bunch, a fruit length of 21.42 cm, a fruit girth of 12.91 cm, a significant bunch weight of 36.13 kg, and an impressive yield of 89.22 t/ha, further validating the benefits of organic nutrient management for enhanced productivity. Furthermore, Selvamani and Manivannan (2009) [9] conducted a study on INM's influence on both crop performance and fruit quality in banana. Their most effective treatment involved combining 50% of the recommended inorganic fertilizers with 12.5 kg farmyard manure, 3 kg vermicompost, 1.0 kg neem cake, 100 g vesicular arbuscular mycorrhizae (VAM), and 50 g each of Phosphobacteria and Azospirillum per plant. This comprehensive approach led to a reduced phyllochron interval (7.62 days), earlier flowering (252.41 days), and a shortened total crop duration. It also produced the highest bunch weight (22.25 kg), attributed to a moderate number of hands (12.78), greater individual finger weight (96.80 g), longer fruit size (14.75 cm), and an optimal peel-to-pulp ratio (4.83%). Additionally, fruits from this treatment exhibited superior quality, characterized by higher total soluble solids, increased total sugars, and lower acidity. Even though a 100% organic input treatment yielded moderately, it still significantly improved the fruit's quality characteristics.

4. Effect of organic fertilizers on quality of banana

Studies underscore the effectiveness of integrated nutrient management and organic fertilization in enhancing banana fruit quality and post-harvest longevity. For instance, Vanilarasu *et al*. (2014) [19] conducted research at the Horticultural College and Research Institute, TNAU, Coimbatore, demonstrating that an integrated approach incorporating farmyard manure (FYM), neem cake, vermicompost, wood ash, green manuring, intercropping, and biofertilizers led to significant improvements. This included enhanced fruit quality parameters like total soluble solids (TSS) (23.23%), acidity (0.82%), and ascorbic acid content (12.92 mg/100g), alongside an extended shelf life of 14.03 days and a reduction in physiological weight loss to 7.44%.

Further supporting these findings, Meghwal *et al*. (2017-2018) [11] carried out a field experiment at the Banana Research Station, Kannara, under Kerala Agricultural University, Thrissur. Their work focused on the impact of various manurial combinations on Nendran banana yield and quality. They observed that while a modified package of practices based on soil test recommendations yielded the highest total soluble solids (TSS) content (26.23° Brix), a different organic-rich treatment proved superior for overall yield and fruit quality. This particular treatment—comprising a basal application of 15 kg FYM and 0.5 kg lime, along with split applications of 14 kg poultry manure and 4 kg ash, and complemented by in situ green manuring—resulted in the maximum yield (160.88 kg per plot) and optimal fruit quality traits, such as total sugars (17.55%), reducing sugars (11.38%), and the highest sugar-to-acid ratio (45.07). Both studies highlight the considerable potential of integrating sustainable and organic practices to boost banana fruit quality and extend its storability.

5. Conclusion

For banana cultivation, adopting organic fertilizers provides a sustainable and environmentally conscious alternative to traditional chemical practices. Evidence from research highlights the significant benefits of integrating organic inputs—such as vermicompost, poultry manure, farmyard manure, neem cake, and biofertilizers—which consistently enhance vegetative growth, optimize yield parameters, and elevate fruit quality. These inputs do more than just supply the necessary nutrients for banana plants; they actively improve soil structure, foster beneficial microbial communities, and mitigate environmental risks. Implementing an integrated nutrient management strategy, by blending organic materials with helpful microbes, offers a potent method for improving crop yields while simultaneously nurturing a healthy and balanced ecosystem. With growing consumer preference for residue-free produce and heightened environmental awareness, organic nutrient management offers a promising direction for establishing banana production systems that are both sustainable and economically viable.

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