Asian Journal of Biology

Volume 20, Issue 2, Page 1-6, 2024; Article no.AJOB.111922
ISSN: 2456-7124

Review on Improvement of Banana Quality and Yield

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJOB/2024/v20i2385

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/111922

Review Article

Received: 24/11/2023
Accepted: 29/01/2024
Published: 07/02/2024

ABSTRACT

The review paper, "Improvement of Banana Quality and Yield," delves into strategies and practices essential for enhancing banana crop productivity and quality. Beyond securing food sources, the focus extends to sustaining farmer livelihoods and meeting global market demands. The paper covers recommended cultivation practices, disease and pest management, and underscores the importance of continuous learning and adaptation for enduring success in banana farming. By implementing these measures, banana growers can significantly elevate the quality and yield of their crops. The paper emphasizes the broader impact of these improvements, contributing not only to the prosperity of farmers but also ensuring the availability of high-quality bananas for consumers globally. Ultimately, the comprehensive approach outlined in the paper seeks to foster a sustainable and thriving banana industry, addressing the needs of both producers and consumers.

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Keywords: Banana; crop nutrition; fertilizer; quality; yield.

1. INTRODUCTION

"Bananas, deemed one of the most vital tropical fruit trees, stand as the fifth most crucial agricultural crop in global trade, serving as a major export commodity and primary income source across Latin America, Africa, and Asia" [1]. "In the realm of tropical and subtropical agriculture in southern China, banana planting takes precedence. Despite this, China's average banana productivity in 2019 was a mere 33.4 t ha–1, representing roughly half of the highest global productivity. Numerous environmental factors, particularly prevalent in highly weathered acid soils, act as constraints on banana productivity. These soils are characterized by acidic pH, low organic matter content, and inadequate phosphorus (P) availability in tropical and subtropical regions" [2]. "Moreover, unsuitable fertilization practices, including the excessive use of chemical fertilizers, are commonplace in banana production. Regrettably, these practices have significantly contributed to soil degradation, water eutrophication, limitations in nutrient absorption, and imbalances in biodiversity, posing threats to the ecosystem services of banana plantations and, ultimately, jeopardizing environmental quality and human health" [3]. "In addition to environmental concerns, inappropriate fertilization practices also lead to diminished disease resistance in banana plants, resulting in decreased productivity and quality" [4,5]. Consequently, the development of suitable fertilization practices becomes imperative to address the current challenges facing banana production.

2. CROP NUTRITION AND BANANA QUALITY

2.1 Biofertilizers

"Biofertilizers consist of living or latent cells of efficient strains of agriculturally beneficial microorganisms, aiding in the enhancement of nutrient availability and uptake by plants when introduced into soil or seeds" [6]. (Giri et al., 2019). "The application of biofertilizers is not only crucial for reducing the need for inorganic nutrients or organic manures but also for fostering a positive impact on soil flora and fauna. Inoculating crops with nitrogen-fixing microorganisms before sowing has been shown to improve nodulation and nitrogen fixation, leading to increased growth and grain yield. Predominantly found in α-proteobacteria, six genera, namely Rhizobium, Allorhizobium, Bradyrhizobium, Mesorhizobium, Sinorhizobium (formerly Ensifer), and Azorhizobium, contribute to nitrogen fixation. Additionally, β-proteobacteria such as Burkholderia and Ralstonia have been reported to possess nitrogen-fixing capabilities" [7].

"Studies on specific strains illustrate the positive effects of biofertilizers. For instance, *Rhizobium meliloti* RMP3 and RMP5 significantly improved seed germination, seedling biomass, nodule number, and nodule fresh weight in groundnuts" [8]. Another study by Verma et al. (2013) demonstrated "increased nodulation, root and shoot dry weight, grain and straw yield, and nitrogen and phosphorus uptake in chickpeas when treated with Mesorhizobium sp. BHURC03 and Pseudomonas aeruginosa BHUPSB02". "Similarly, the application of *Rhizobium laguerreae* strain PEPV40 was found to enhance leaf number, size, weight, chlorophyll, and nitrogen contents in spinach" [9].

Moreover, the use of phosphate-solubilizing microorganisms (PSM) contributes to a more sustainable and environmentally friendly approach by reducing the need for expensive phosphatic fertilizers. Viruel et al. (2014) reported that "Pseudomonas tolaasii IEXb significantly stimulated various growth parameters in maize". In another study, Garcia-Lopez et al [10]. observed "increased total phosphorus content and uptake in cucumber with the application of Trichoderma asperellum T34. Furthermore, co-inoculation of P-solubilizers with other beneficial bacteria or mycorrhizal fungi enhances phosphorus-solubilization efficiency". Franco-Correa et al [11]. demonstrated that "treating clover with Streptomyces MCR9 and Glomus sp. significantly increased shoot and root biomass and mycorrhizal root length". "Additionally, the inoculation of Pantoea agglomerans and Burkholderia anthina enhanced shoot and root length, shoot and root dry matter, and phosphorus uptake in mung beans" [12].

2.2 Chemical Fertilizers

"Banana, being a high-demanding crop, requires substantial quantities of nitrogen and potassium, followed by phosphorus, calcium, and magnesium for optimal growth, yield, and biomass production" [13]. "These essential nutrients are typically supplied through inorganic chemical sources in the soil. Nitrogen, a crucial component of amino acids and nucleic acids, plays a central role in plant metabolism. While plants rely on combined or fixed forms of nitrogen, such as ammonia and nitrate, as they cannot utilize atmospheric nitrogen, its primary contribution in bananas is associated with promoting robust vegetative growth. Although nitrogen is evenly distributed throughout the plant, its highest concentration is typically found in suckers and leaves" (Thangaselvabai et al., 2004). "Potassium is another vital nutrient in banana production due to its significant accumulation in both fruit and plant tissues. Adequate potassium fertilization not only boosts growth and yield but also enhances fruit quality, overall plant physiology, and resistance against biotic and abiotic stresses. Potassium catalyzes critical reactions like respiration, photosynthesis, translocation of photosynthates, chlorophyll formation, and water regulation in banana" (Kumar et al., 2020). Given the high demand, banana requires a substantial quantity of potassium for optimal growth and development up to the flowering stage. In contrast, the phosphorus requirement for bananas is comparatively lower than nitrogen and potassium.

"Phosphorus has a positive impact on the young root system, stimulating growth. However, excessive phosphorus application can have adverse effects on the number, weight, and size of banana fingers. Studies on integrated nutrient management (INM) practices have demonstrated positive effects on banana production. For instance, Azospirillum inoculation combined with 100% nitrogen application enhanced various growth parameters and nutrient contents in leaves of banana cv. Poovan compared to plants receiving nitrogen alone. Other studies have highlighted the positive impact of organic manures, biofertilizers, and inorganic fertilizers on banana growth and leaf nutrient contents in different stages of development. To illustrate, the combined application of organic manures (FYM, vermicompost, and neem cake), biofertilizers (VAM, Azospirillum, PSB, and Trichoderma harzianum) with inorganic fertilizers improved leaf nutrient contents and overall growth parameters in banana. Additionally, a balanced application of 80% recommended dose of fertilizer (RDF) in inorganic form, along with 20% RDF in organic form and biofertilizers, exhibited positive effects on plant height, pseudostem girth, and nutrient concentrations in banana leaves at various stages of growth" [14,15].

2.3 Increase Banana Yield

Optimal banana yields are achieved on well-drained soils that allow for effective water drainage, preventing water limitations. Thorough soil preparation prior to planting, coupled with maintaining an optimum pH, ensures robust root development and the ready availability of nutrients. Returning crop residues as mulch serves a dual purpose, acting as both a protective layer and a valuable nutrient source. Careful selection of banana cultivars and appropriate spacing, tailored to the site and climate, is crucial to maximize environmental conditions and achieve peak banana yields [16]. Effective control of salinity in the root environment and efficient water supply management are essential for maximizing banana growth and ensuring optimal nutrient availability. Fertilizer nutrition plays a vital role in achieving high banana yields. Managing wind impact is crucial, as strong winds can tear leaves and compromise photosynthetic activity, leading to potential damage and destruction of plantations. The shallow-rooted nature of many banana crops exacerbates the problem, necessitating the use of windbreaks and supports to minimize crop damage. Additionally, hail poses a threat in subtropical regions, causing damage to leaves and adversely affecting fruit quality and storage viability [17].

Addressing crop nutrition is key to enhancing banana yield. Nitrogen and potassium play pivotal roles in promoting leaf, pseudostem, and sucker growth, optimizing flowering, fruit set, and fill, ultimately impacting yield potential. However, excessive nitrogen use can weaken the pseudostem, increasing vulnerability to storm damage and bunch drop [18]. Potassium, while critical for banana yield, requires careful management to avoid inducing calcium and magnesium deficiencies, which can negatively impact overall productivity. The peak demand for potassium coincides with the flowering stage. Phosphorus is essential for early growth, rooting, flowering, and fruit set, while calcium ensures vigorous root, leaf, and sucker development, contributing to high yields. Magnesium and sulfur directly influence yield by increasing the number and weight of fruits per bunch. The poor availability of micronutrients hampers plant growth, particularly productive leaf area, resulting in reduced bunch weight and overall yield [19].

2.4 Influence Bunch Weight in Banana Production

"Applied nitrogen is used for dry matter production and yield, including bunch weight in banana. The use of nitrate-nitrogen, compared to largely urea-based sources, maintains good uptake and availability of other nutrients e.g., calcium, magnesium and potassium. Trails confirm that where nitrate-nitrogen sources are predominantly used, banana bunch weights are higher. In trails, calcium nitrate increases root and sucker development through raising soil and leaf Ca-supplies. This research also confirms reduced risk of root disease and direct increases in leaf size form use of calcium nitrate. This improved vegetative development increases the mean bunch weight in banana" [20].

2.5 Magnesium

Magnesium significantly influences the weight of banana bunches. In cases of deficiency, plant growth is adversely impacted, leading to a decline in the uptake of potassium and calcium. Consequently, this deficiency results in an overall reduction in banana yield [21].

2.6 Boron and Copper

Experiments investigating the impact of boron, sometimes in conjunction with copper, indicate that both micronutrients contribute positively to growth, resulting in enhanced banana bunch weight. In the case of boron deficiency, it can impede bunch development, leading to poor outcomes. Despite copper being required in minimal amounts (less than 1% of the manganese rate), these small quantities play a crucial role in sustaining rapid and productive growth [21].

2.7 Crop Nutrition

Applied nitrogen plays a crucial role in dry matter production and overall yield, influencing factors such as the number of hands per banana bunch. Unlike some plants, banana plants cannot store nitrogen within the pseudostem. Thus, any deficiency in nitrogen leads to slow growth, causing the plant to enter a state of "shut-down." Adequate potassium nutrition contributes to an increased number of fruits per plant. Conversely, insufficient potassium supply results in decreased plant dry matter production, fragile branches, and diminished plant vigor. Optimal yield responses are achieved by splitting potassium applications into frequent and small doses, particularly beneficial in high rainfall areas and on light soils. Adequate potassium nutrition positively influences crop height, girth, the number of green leaves, and the overall number of fruits per plant. In contrast, low potassium supply leads to reduced plant dry matter production, fragile branches, and compromised plant vigor. Potassium's importance lies in facilitating the transfer of carbohydrates from the leaf to the fruit, thereby enhancing pulp content and fruit size. Magnesium plays a critical role in chlorophyll production and serves as a metabolic activator for carbohydrates, fats, and proteins. It is also involved in phosphorus transport. Magnesium directly impacts bunch weight and banana yield. Maintaining the correct potassium-to-magnesium ratios in soils is crucial; otherwise, yields may suffer. Large applications of potassium often impede magnesium uptake. Critical ratios for soil magnesium in comparison to potassium and calcium are outlined in "Optimum Ca, K, and Mg Ratios in Soil" [22].

2.8 How to Influence Banana Fruit Length and Diameter

"Potassium plays a crucial role in facilitating the transfer of carbohydrates from the leaf to the fruit, thereby enhancing pulp content and fruit size. Achieving the highest yield responses is best attained by splitting potassium applications into frequent and small doses, especially in areas with high rainfall and on light soils. Excessive nitrogen can lead to crops that are more susceptible to disease, characterized by smaller fingers, reduced bunch size, and poor bunch uniformity. Such bunches may be inadequately filled and prone to dropping from the plant, with a diminished green life after harvest. To mitigate these issues, caution is necessary in the use of nitrogen sources to minimize leaching, and adopting a "little and often" approach to applications is advisable. In tropical plantations, nitrogen is commonly applied every two weeks. In trials, calcium nitrate has been shown to enhance root and sucker growth, expedite leaf development, and elevate soil and leaf calcium supplies. This research also supports a reduced risk of root diseases and direct increases in leaf size resulting from the use of calcium nitrate" [23].

2.9 Production Unit

In commercial plantations, a production unit typically consists of one 'mother plant' and a 'daughter sucker,' and most plantations have a density ranging from 1500 to up to 3000 production units per hectare. In hot, dry areas, higher planting rates are deemed more suitable to enhance yields and provide shade to alleviate heat stress. For long-term plantations lasting 4-5 years or more, less dense plantings are preferable. Larger banana varieties, such as Williams, are also well-suited to wider spacings. However, opting for less intensive plantings reduces disease pressure in the crop [24-29].

3. CONCLUSION

Enhancing banana quality and yield is crucial not only for securing food sources but also for sustaining the livelihoods of numerous farmers and meeting global market demands. By adhering to the suggested practices provided in this guide, banana growers can elevate the productivity and quality of their crops, simultaneously addressing challenges related to pests and diseases. A dedicated commitment to continuous learning and adaptability is pivotal for achieving long-term success in banana cultivation. In the broader picture, these endeavors contribute not just to the prosperity of farmers but also to ensuring the availability of high-quality bananas for consumers worldwide, fostering a sustainable and flourishing banana industry.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/111922