PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol x(x): xx–xx
https://doi.org/10.14719/pst.6946

HORIZON
e-Publishing Group
HePG

RESEARCH ARTICLE

Enhancing yield and quality of ney poovan banana through bunch feeding with nutrients and growth regulators

Sangeeth Shyam Sundar SS[1], C Rajamanickam[1*], S Saraswathy[1], K Venkatesan[2], A Vijayasamundeeswari[1*], C Sankar[1]

[1]Department of Fruit Science, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam 625 604,Tamil Nadu, India
[2]Departmentof Floriculture and Landscape Gardening, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam 625 604,Tamil Nadu, India

*Email: rajamanickamctnau@gmail.com, vijayasamundeeswari.a@tnau.ac.in

OPEN ACCESS

ARTICLE HISTORY
Received: 28 December 2024
Accepted: 27 January 2025
Available online
Version 1.0 : 04 May 2025

Check for updates

Additional information
Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

CITE THIS ARTICLE
Sangeeth SSSS, Rajamanickam C, Saraswathy S, Venkatesan K, Vijayasamundeeswari A, Sankar C. Enhancing yield and quality of ney poovan banana through bunch feeding with nutrients and growth regulators. Plant Science Today (Early Access). https://doi.org/10.14719/pst.6946

Abstract

Ney Poovan, a banana variety renowned for its distinct taste and nutritional value, often suffers from yield and quality limitations due to poor nutrient management. This study aimed to overcome this issue by investigating the influence of bunch-feeding treatments with nutrients and growth regulators on the yield and quality of Ney Poovan. The specific objectives were to study the effects of bunch feeding on yield and to evaluate its impact on fruit quality. A field experiment was conducted at the Grapes Research Station, Royappanpatti, Theni, in a randomized block design with 10 treatments. These included growth regulators, nutrients, their combinations and a control. The biometric and quality parameters showed that treatment T_9 performed significantly better than the control. This treatment significantly improved key parameters, including higher bunch weight (12.65 kg), finger length (10.81 cm), yield (28.69 t/ha), total soluble solids (23.94 ˚Brix) and reduced titratable acidity (0.22%), while also enhancing shelf life (7.51 days), pulp-to-peel ratio (7.01), TSS (23.94 ˚Brix) and ascorbic acid content (3.46 mg/100 g). Enhanced fruit development due to T_9 treatment underscores its potential as an effective bunch-feeding strategy. These findings highlight the potential of Treatment T_9 as a sustainable strategy for enhancing banana production.

Keywords

bunch feeding; fruit quality; growth regulators; nutrients; ney poovan; yield

Introduction

Banana (*Musa* spp.) is one of the most important fruits internationally cultivated for 1000 of years. It is vital in many tropical and subtropical countries' agricultural, nutritional and economic sectors. India is a leading producer of bananas (1). Among various cultivars of banana, Ney Poovan (AB group), known as Elakkibale, Mitli and Puttablae, is cultivated on a large scale, particularly in Karnataka and Tamil Nadu (2). This cultivar is highly regarded for its export potential due to its edible quality, unique taste and attractive yellow color after ripening (3). Banana cultivation originated in ancient Southeast Asian civilizations, (4)where they were domesticated and integrated into traditional farming methods (4). Over time, banana farming expanded across continents, demonstrating resilience to diverse climates, soil types and cultural practices. Traditional banana production relied on natural fertility and indigenous agricultural techniques, often resulting in variable yields and quality. In modern continuous cropping systems, balanced fertilizer application is essential for improving banana output and soil health (5). As the global demand for bananas increased, systematic farming practices emerged. These included the introduction of manures and irrigation systems, aiming to enhance productivity. However, many nutrient management practices focused primarily on foliar and soil applications.

Modern research into plant physiology has revolutionized banana cultivation by identifying the critical role of nutrients and growth regulators in fruit development. Banana plants are heavy feeders and require a lot of potassium and nitrogen because of their rapid development. Nitrogen and potash were provided in three successive doses using standard farming procedures, with the last dosage given in the seventh month after 18 months of planting, just before shooting. However, nutrients are necessary until harvesting, when many photosynthates are transported from source to sink. Providing the proper nutrients is essential to achieve optimal fruit size and quality at this critical stage. These nutrients influence banana bunch size, enhance fruit quality and reduce the poor development often observed in the last hand of the bunch. As a result, bunch feeding is a nutrition-feeding physiological strategy that supplies nutrients straight to the stalk end of a bunch (6). Bunch feeding is particularly effective for cultivars like Ney Poovan, where uniformity and post-harvest characteristics are paramount for market acceptability.

Significant benefits were observed by following the application of growth regulators, including gibberellic acid (GA_3), brassinosteroids, citric acid and ascorbic acid. These benefits were further enhanced by adding macro and micronutrient fertilizers such as potassium sulfate (K_2SO_4), urea, 19:19:19 NPK, zinc sulfate ($ZnSO_4$) and borax. These inputs enhance physiological processes, including photosynthesis, nutrient translocation and cell division, supporting fruit growth and reducing physiological disorders (7). Research continues to refine these techniques, integrating advancements in precision agriculture and sustainable practices. Bunch feeding is recognized as a method to enhance productivity, optimize resource use, reduce environmental impact and meet the demands of consumers and industries for high-quality produce. This paper explores the evolution and modern applications of bunch-feeding combinations in Ney Poovan, highlighting its potential to transform banana cultivation into a more sustainable and profitable enterprise. While many studies have demonstrated the benefits of bunch spraying and soil application of nutrients and growth regulators in bananas (5, 8), limited research exists on the combined use of growth regulators and nutrients in bunch feeding. This study evaluated the effect of bunch feeding on the yield and quality of Ney Poovan bananas, with specific objectives to assess its influence on yield and fruit quality.

Materials and Methods

Experimental site and design

This study was conducted at the Grapes Research Station, Royappanpatti, Theni District, Tamil Nadu, India, from 2023 to 2024. The objective was to evaluate the impact of bunch feeding with nutrients and growth regulators on the yield and quality of bananas. The experiment was laid out in a Randomized Complete Block Design (RCBD) with 10 treatments and 3 replications. Five Ney Poovan banana plants were utilized for each replication, with a plant spacing of 2.1 m X 2.1 m. Each treatment was applied to Ney Poovan banana plants at the critical stage of banana fruit development, during the "early fruit filling", providing the proper nutrients is essential to achieve optimal fruit size and quality. The treatments utilized in this experiment are GA_3 at the rate of 50 ppm (T_1), GA_3 at the rate of 100 ppm (T_2), GA_3 at the rate of 150 ppm (T_3), K_2SO_4 at the rate of 0.5% (T_4), K_2SO_4 at the rate of 1.0% (T_5), urea at the rate of 1.0% (T_6), 19:19:19 NPK at the rate of 0.5% (T_7), 19:19:19 NPK at the rate of 1.0% (T_8), Growth regulators and nutrients combination (comprises of K_2SO_4 at the rate of 0.5%, urea at the rate of 0.1%, borax 0.25%, $ZnSO_4$ at the rate of 0.25%, citric acid at the rate of 0.0125%, ascorbic acid at the rate of 100 ppm, Brassinosteroids at the rate of 0.1 ppm and GA_3 at the rate of 50 ppm)(T_9) and control/ denavelling (T_{10}). To prepare our bunch feeding solution, gather clean water, balanced fertilizers, growth regulators and additional additives. Mix the combination thoroughly with water, ensuring the ingredients are fully dissolved. The preparation of chemicals for bunch feeding is shown in Fig. 1. Test the pH of the solution using a pH meter or test strips, as bananas prefer slightly acidic soil. Apply the solution to the base of the banana plants, targeting bunch stalks where fruits are developing. The preparation of different bunch feeding combinations based on treatments is given below in Table 1. The control treatment (T_{10}) consisted solely of denavelling.

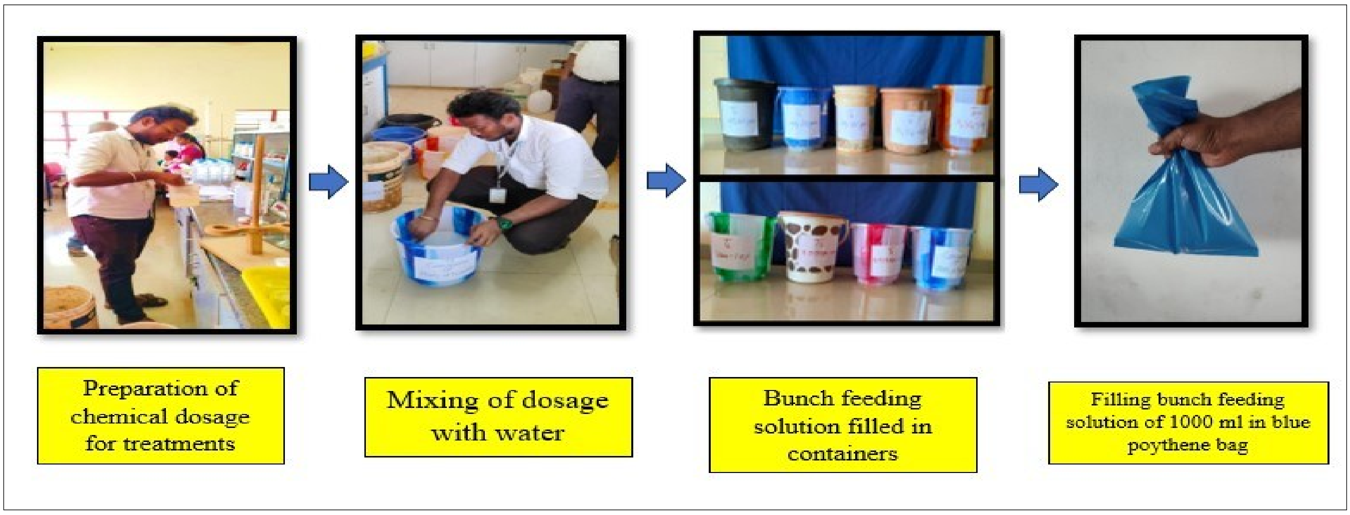

Fig. 1. Chemical preparation for bunch feeding.

Table 1. Preparation of different bunch feeding solutions based on treatments

Treatment	PGR/ Nutrient	Preparation of mixture
T_1	GA_3 at the rate of 50 ppm	0.75 g of GA_3 + 15 L of water
T_2	GA_3 at the rate of 100 ppm	1.50 g of GA_3 + 15 L of water
T_3	GA_3 at the rate of 150 ppm	2.25 g of GA_3 + 15 L of water
T_4	K_2SO_4 at the rate of 0.5%	75 g of K_2SO_4 + 15 L of water
T_5	K_2SO_4 at the rate of 1.0%	150 g of K_2SO_4 + 15 L of water
T_6	Urea at the rate of 1.0%	150 g of Urea + 15 L of water
T_7	19:19:19 NPK at the rate of 0.5%	75 g of 19:19:19 NPK + 15 L of water
T_8	19:19:19 NPK at the rate of 1.0%	150 g of 19:19:19 NPK + 15 L of water
T_9	Growth regulators and nutrients combination comprises of K_2SO_4 at the rate of 0.5%, Urea at the rate of 0.1%, borax 0.25%, $ZnSO_4$ at the rate of 0.25%, citric acid at the rate of 0.0125%, ascorbic acid at the rate of 100 ppm, brassinosteroids at the rate of 0.1 ppm and GA_3 at the rate of 50 ppm	75 g of K_2SO_4, 15 g of Urea, 37.5 g of borax, 37.5 g of $ZnSO_4$, 1.875 g of citric acid, 1.50 g of ascorbic acid, 0.015 g of brassinosteroids, 0.75 g of GA_3 + 15 L of water
T_{10}	Control	Nil

Treatment implementation

For bunch stalk feeding, uniform bunches were chosen based on criteria such as similar fruit size, color and shape, with minimal variation in the number of hands and fruits per bunch from each treatment. A slant cut was made to remove the rachis and male bud from the distal end of the bunch after the pistillate (female) flowers had set fruits, approximately 15 days after flower emergence or after the loss of four bracts. The field view and de-navelling operation are shown in Fig. 2. A fresh slurry was prepared by combining the specified fertilizer doses and dissolving them in 1 L of water before applying them to Ney poovan banana bunches immediately after de-navelling. The mixture, prepared with various combinations of chemicals and fertilizers based on the treatment, was placed in a thick blue polythene bag. The excised rachis was immersed in the bag and the bunch feeding was performed, as demonstrated in Fig. 3. The bag was kept until the harvest of the banana bunches.

Fig. 3. Bunch feeding.

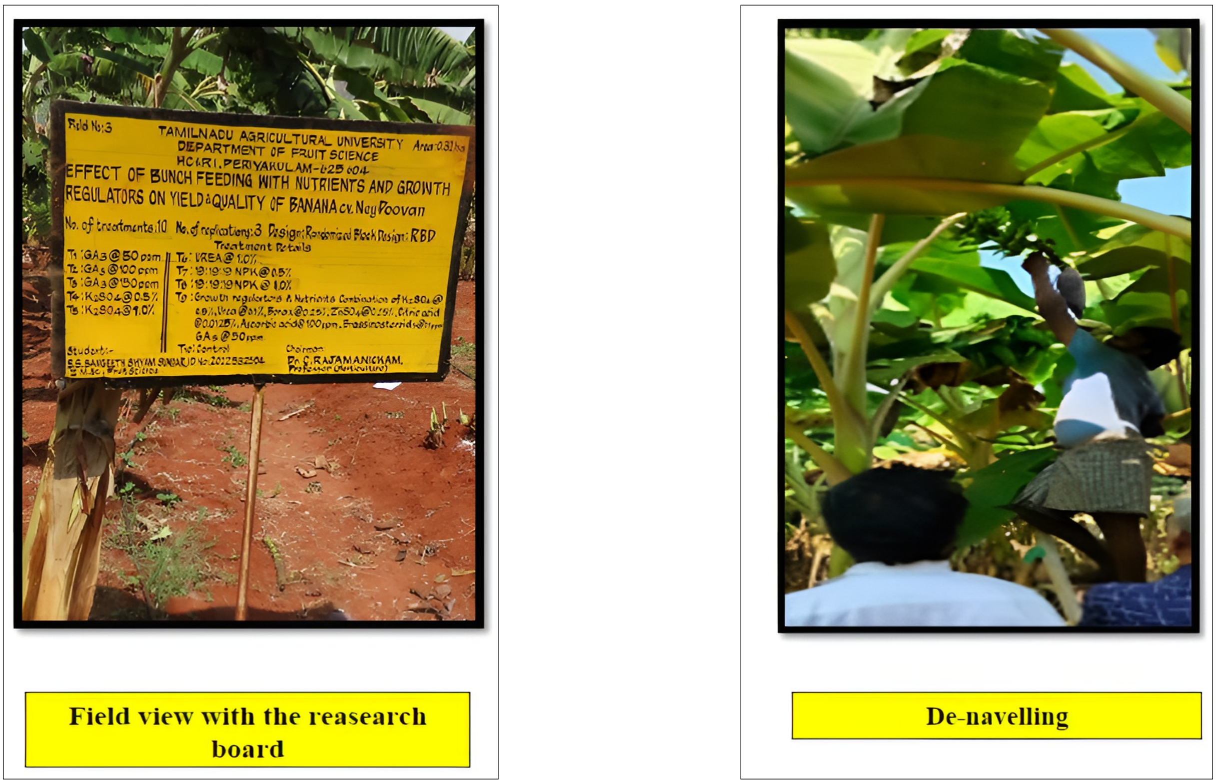

Fig. 2. Field view and de-navelling.

Data collection

After harvest, growth, yield and quality parameters were recorded for each treatment. Growth parameters such as days taken from shooting to harvest were calculated as the number of calendar days between the visible emergence of the inflorescence and the harvest date when the fruits reached maturity (absence of angles in fingers) and it was expressed in days. The total duration of the banana was measured as the time (in days) from planting to harvest under specified environment and management conditions. Yield metrics such as bunch weight (kg), hand weight (kg), individual finger weight (g), finger length (cm), finger girth (cm), finger volume (cc), yield per hectare (t/ ha), pulp weight (g), peel weight (g) and pulp to peel ratio were measured and evaluated. Biochemical and quality attributes like fruit firmness (N), total soluble solids (˚Brix), titratable acidity (%), ascorbic acid content (mg/ 100 g), total sugars (%), reducing sugars (%), sugar to acid ratio and shelf life (days) were measured using standard methods to determine fruit quality. Fruit firmness was measured with the help of a standard penetrometer, total soluble solids by a digital hand refractometer, titrable acidity was calculated by a standardized method (9) and ascorbic acid content in banana fruits was evaluated by the AOAC method. Total and reducing sugars were also measured using a standardized protocol (10).

Statistical Analysis

All data were subjected to analysis of variance (ANOVA) using KAU GRAPES statistical software. Significant differences among treatment means were tested at a 5% significance level (11) and results were reported as mean.

Results and Discussion

Effect of bunch feeding on growth parameters

Growth parameters, such as shooting to maturity and the total crop duration until the harvest, were observed. Table 2 illustrates the effect of bunch feeding with nutrients and growth regulators on banana growth attributes, highlighting differences across treatments.

Shooting to maturity

The results revealed that the treatments differed significantly in banana plants' total days taken from shooting to harvest. The growth regulators and nutrients combination treatment (T_9), which includes K_2SO_4 at the rate of 0.5%, urea at the rate of 0.1%, borax 0.25%, $ZnSO_4$ at the rate of 0.25%, citric acid at the rate of 0.0125%, ascorbic acid at the rate of 100 ppm, brassinosteroids at the rate of 0.1 ppm and GA_3 at the rate of 50 ppm, reported the shortest days taken from shooting to harvest (122.01 days). This was statistically on par with T_5 (1% K_2SO_4; 122.09 days), T_3 (150 ppm GA_3; 123.72 days) and T_4 (0.5% K_2SO_4; 124.04 days), followed by T_2 (100 ppm GA_3; 125.94 days). The maximum number of days taken from shooting to maturity was observed in T_{10} (control) of 130.10 days, which was on par with T_6 (urea at the rate of 1.0%) of 129.81 days, T_1 (GA_3 at the rate of 50 ppm) of 128.99 days and T_7 (0.5% 19:19:19 NPK) of 128.15 days. The number of days from shooting to harvest is a key metric in banana cultivation as it affects productivity, quality and marketability, enabling earlier harvests. The early maturity observed in treated plants may be attributed to the effects of bunch feeding with chemicals, nutrients and plant growth regulators, which likely accelerated finger growth and maturity (7, 12, 13).

Total duration

The treatments significantly impacted the total crop duration of banana plants, a crucial factor influencing harvest cycles and profitability. The lowest crop duration, which is economically beneficial to the farmers, was registered in T_9 (growth regulators and nutrients combination comprises of K_2SO_4 at the rate of 0.5%, urea at the rate of 0.1%, borax 0.25%, $ZnSO_4$ at the rate of 0.25%, citric acid at the rate of 0.0125%, ascorbic acid at the rate of 100 ppm, brassinosteroids at the rate of 0.1 ppm and GA_3 at the rate of 50 ppm) of 363.20 days followed by K_2SO_4 at the rate of 1.0% (T_5) which registered the total duration of 370.92 days. The highest total crop duration (403.87 days) was noticed in control (T_{10}), which was on par with T_6 (urea at the rate of 1.0%) at 394.04 days, T_1 (GA_3 at the rate of 50 ppm) at 393.41 days, T_7 (19:19:19 NPK at the rate of 0.5%) at 391.65 days, T_8 (19:19:19 NPK at the rate of 1.0%) at 390.54 days and T_4 (K_2SO_4 at the rate of 0.5%) at 389.95 days. The finding conformed with the fact that the bunch-feeding chemicals in growth regulators and nutrient combinations such as potassium, sulfur, urea, ascorbic acid, GA3 and brassinosteroids might accelerate the finger's development and reduce the harvesting duration. (14-17) The shorter crop duration may also be attributed to micronutrients like boron, which promote early harvesting by enhancing physiological processes (14-17).

Table 2. Effect of bunch feeding on growth attributes of banana cv. Ney Poovan

Treatment	Shooting to maturity (days)	Total duration (days)
T_1 - GA_3 at the rate of 50 ppm	128.99	393.41
T_2 - GA_3 at the rate of 100 ppm	125.94	384.45
T_3 - GA_3 at the rate of 150 ppm	123.72	376.52
T_4 - K_2SO_4 at the rate of 0.5%	124.04	389.95
T_5 - K_2SO_4 at the rate of 1.0%	122.09	370.92
T_6 - Urea at the rate of 1.0%	129.81	394.04
T_7 - 19:19:19 NPK at the rate of 0.5%	128.15	391.65
T_8 - 19:19:19 NPK at the rate of 1.0%	126.37	390.54
T_9 - Growth regulators and nutrients combination	121.01	363.20
T_{10} - Control	130.10	403.87
Mean	126.02	385.85
SEd	1.91	7.33
C.D (P = 0.005%)	4.02	15.40

Effect of bunch feeding on yield parameters

Bunch feeding treatments significantly improved the yield parameters, including bunch weight, hand weight, individual finger weight, finger length, finger girth, fruit volume and yield per hectare, as depicted in Table 3. Pulp parameters, such as pulp weight, peel weight and pulp-to-peel ratio, also showed significant differences, as presented in Table 4.

Bunch weight and hand weight

A significant difference was observed in bunch weight influenced by feeding with nutrients and growth regulators combined on banana CV. Ney Poovan. Among the treatments, T_9 (growth regulators and nutrient combination) recorded the highest bunch weight (12.65 kg) and hand weight (1.25 kg), significantly outperforming all other treatments. T_5 (K_2SO_4 at the rate of 1.0%) recorded the next highest weights of (11.97 kg and 1.18 kg) followed by T_3 (GA_3 at the rate of 150 ppm) of 11.32 kg and 1.12 kg respectively. Nevertheless, the minimum values in the control (T_{10}) were observed at 8.40 kg and 0.87 kg. This outcome aligns with findings suggesting that GA_3, ascorbic acid, potassium, sulfur, urea, 19-19-19 NPK and brassinosteroids in the solution accelerated sink activity by promoting cell division, elongation and differentiation. This enhanced the translocation and accumulation of photosynthates and metabolites from the source to the sink (7). This ultimately increases the bunch and hand weight of bananas (13, 18, 19).

Individual finger weight

A significant difference between treatments was observed in individual fruit weight when bunch feeding with nutrients and growth regulators in banana cv. Ney Poovan. The highest individual finger weight (68.87 g) was observed in T_9 (growth regulators and nutrient combination), significantly superior to all other treatments. This was followed by T_5 (1% K2SO4; 59.87 g) and T_3 (150 ppm GA3; 57.09 g). The lowest individual finger weight was observed in the control (T_{10}) of 42.52 g. The next lowest value was T_6 (urea at the rate of 0.1%) at 46.77 g, which was on par with T_1 (GA_3 at the rate of 50 ppm) at 48.36 g. This outcome may be attributed to the findings that banana bunches fed with chemicals, nutrients and plant growth regulators exhibit enhanced sink activity, cell division and multiplication. These factors, combined with improved nutrient availability, promote better growth, elongation and increased finger weight (18, 20, 21).

Finger length and finger girth

The current study results showed that T_9 (Growth regulators and nutrients combination) had exhibited the maximum finger length (10.81 cm) and finger girth (3.63 cm) as against the control (T_{10}) of 7.13 cm and 2.07 cm. The next best values were reported in the treatment T_5 (K_2SO_4 at the rate of 0.5%) of 10.15 cm and 3.25 cm respectively. This might be due to the application of bunch-feeding chemicals containing nutrients and growth regulators, which lead to cell elongation, multiplication and expansion, resulting in increased finger

Table 3. Effect of bunch feeding on bunch weight, hand weight, individual finger weight, finger length, finger girth, finger volume and yield per hectare of banana cv. Ney Poovan

Treatment	Bunch weight (kg)	Hand weight (kg)	Individual finger weight (g)	Finger length (cm)	Finger girth (cm)	Finger volume (cc)	Yield per hectare (t/ ha)
T_1 - GA_3 at the rate of 50 ppm	9.07	0.90	48.36	8.56	2.32	51.76	20.59
T_2 - GA_3 at the rate of 100 ppm	10.80	1.08	54.31	9.05	2.89	58.97	24.49
T_3 - GA_3 at the rate of 150 ppm	11.32	1.12	57.09	10.01	3.12	69.96	25.67
T_4 - K_2SO_4 at the rate of 0.5%	11.01	1.09	56.76	9.44	3.05	61.53	24.97
T_5 - K_2SO_4 at the rate of 1.0%	11.97	1.18	59.87	10.15	3.25	71.54	37.52
T_6 - Urea at the rate of 1.0%	8.92	0.89	46.77	7.86	2.24	51.04	20.23
T_7 - 19:19:19 NPK at the rate of 0.5%	10.19	1.01	50.11	8.86	2.46	52.32	23.11
T_8 - 19:19:19 NPK at the rate of 1.0%	10.69	1.06	52.67	8.98	2.56	53.23	24.24
T_9 - Growth regulators and nutrients combination	12.65	1.25	68.87	10.81	3.63	74.47	28.69
T_{10} - Control	8.40	0.87	42.52	7.13	2.07	46.60	19.05
Mean	10.50	1.04	53.73	7.13	2.76	59.14	23.82
SEd	0.19	0.01	1.10	0.13	0.06	1.27	0.54
C.D (P = 0.005%)	0.41	0.03	2.31	0.28	0.12	2.67	1.14

Table 4. Effect of bunch feeding on pulp weight, peel weight and pulp-to-peel ratio of banana cv. Ney Poovan

Treatment	Pulp weight (g)	Peel weight (g)	Pulp-to-peel ratio
T_1 - GA_3 at the rate of 50 ppm	42.87	6.70	6.39
T_2 - GA_3 at the rate of 100 ppm	48.45	6.92	7.00
T_3 - GA_3 at the rate of 150 ppm	50.98	7.31	6.96
T_4 - K_2SO_4 at the rate of 0.5%	49.15	7.04	6.97
T_5 - K_2SO_4 at the rate of 1.0%	51.58	7.95	6.49
T_6 - Urea at the rate of 1.0%	39.79	6.66	5.97
T_7 - 19:19:19 NPK at the rate of 0.5%	42.82	6.77	6.32
T_8 - 19:19:19 NPK at the rate of 1.0%	44.10	6.83	6.46
T_9 - Growth regulators and nutrients combination	56.69	8.08	7.01
T_{10} – Control	37.12	6.32	5.87
Mean	46.35	7.06	6.54
SEd	0.74	0.15	0.11
C.D (P = 0.005%)	2.22	0.32	0.23

length and finger girth. Potassium supplementation indirectly enhances protein synthesis and nitrogen uptake, increasing finger length (22). The higher fruit length may be attributed to urea, which accelerates cell elongation more than cell multiplication and expansion, resulting in increased finger length and girth. The urease activity correlated with the lengthening of fruits (23, 24). The use of urea is thought to increase nitrogen availability, essential for encouraging vegetative growth and fruit development. The results conform to the findings that this increase in nitrogen concentration is directly related to enhanced fruit girth (25, 26).

Finger volume

A significant difference was observed in the finger volume of banana cv. Ney Poovan and the results revealed that, among the different treatments, T_9 (Growth regulators and nutrient combination) had exhibited the highest fruit volume of 74.47 cc. The next best treatment was T_5 (1% K_2SO_4) at 71.54 cc and T_3 (150 ppm GA_3) at 69.96 cc. The lowest finger volume (46.60 cc) was found in control (T_{10}), followed by T_7 (0.5% 19:19:19 NPK; 51.04 cc), which was on par with T_6 (1% urea; 51.04 cc). The intent behind the result of increased fruit volume was due to boron's direct involvement in fruit development or indirectly due to increased accumulation and translocation of dietary components, resulting in bigger fruits and higher fruit volume (27-29).

Yield

The fruit yield per hectare exhibited significant differences in banana cv. Ney Poovan. The highest yield (28.69 t/ha) was recorded in T_9 (Growth regulators and nutrient combination), which was superior to all other treatments. T_5 (K_2SO_4 at the rate of 1.0%) recorded a higher yield of 27.14 t/ ha and T_3 (GA_3 at 150 ppm) of 25.67 t/ ha. However, control (T_{10}) recorded the lowest fruit yield per hectare of 19.05 t/ ha. This result may be due to the application of bunch-feeding chemicals, including nutrients, macronutrients, micronutrients and plant growth regulators, which induce metabolic activity, cell division and elongation. These processes increase finger and bunch weights, ultimately enhancing the yield per hectare (7, 13). The significant increase in yield per hectare (28.69 t/ha in T9) enhances farmers' income potential, making this method economically viable for small-scale operations.

Pulp weight

A significant difference was observed in pulp weight when bunch feeding with nutrients and growth regulators in banana cv. Ney Poovan. T_9 (nutrients and growth regulator combination) recorded the highest pulp weight (56.69 g), followed by T_5 (1% K_2SO_4; 51.58 g), which was on par with T_3 (50 ppm GA_3; 50.98 g). Treatment T_{10} (control) recorded the lowest pulp weight (37.12 g), followed by T_6 (urea at the rate of 1.0%) recorded a value of 39.79 g. The results align with the findings that the application of chemicals, macro and micronutrients, as well as plant growth regulators which regulated cell division and elongation and water absorption, which leads to enhanced fruit size and weight, which may also lead to an increase in pulp weight (30, 31).

Peel weight

A significant difference in peel weight was observed, with T_9 (nutrients and growth regulators combination) recording the highest peel weight (8.08 g), significantly superior to all other treatments. T_5 (1% K_2SO_4; 7.95 g) was on par with T_9, followed by T_3 (50 ppm GA_3; 7.31 g). The control (T_{10}) recorded the lowest peel weight of 6.32 g. The next lowest value (6.66 g) was recorded in T_6 (urea at the rate of 1.0%), which was on par with T_1 (GA_3 at the rate of 50 ppm) of 6.70 g. These results might be due to the bunch-feeding chemicals containing macro and micronutrients along with growth regulators, leading to the accumulation of storage materials into the fruits, which enhanced the peel thickness (7). Similar results were also pointed out that applying ascorbic acid leads to enhanced fruit peel thickness (32).

Pulp-to-peel ratio

The current investigation demonstrated that T_9 (a combination of nutrients and growth regulators) recorded the highest pulp-to-peel ratio of 7.01. This was on par with T_2 (GA_3 at the rate of 100 ppm) at 7.00, T_4 (K_2SO_4 at the rate of 0.5%) at 6.97 and T_3 (GA_3 at the rate of 150 ppm) at 6.96, followed by T_5 (K_2SO_4 at the rate of 1.0%) at 6.49. The minimum pulp: peel ratio was recorded in control (T_{10}) of 5.87, which was on par with T_6 (1% urea) of 5.87.

Effect of bunch feeding on quality parameters

The quality parameters, such as fruit firmness, TSS, titratable acidity and ascorbic acid content, varied significantly among the treatments, as shown in Fig. 4. The key post-harvest parameters, such as total sugars, reducing sugars, sugar-to-acid ratio and shelf life, showed significant effects on bunch feeding with nutrients and growth regulators and their results are shown in Fig. 5.

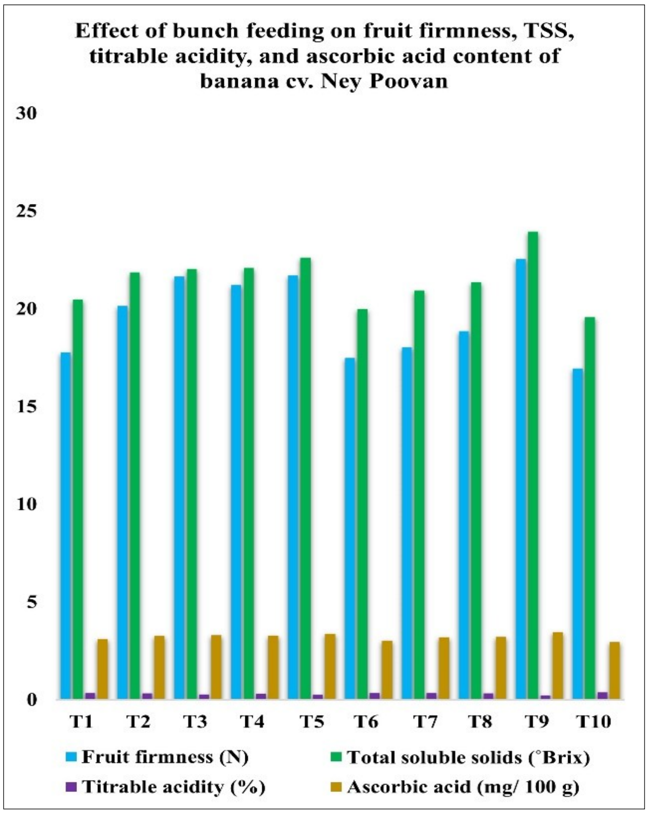

Fig. 4. Effect of bunch feeding on fruit firmness, TSS, titrable acidity and ascorbic acid content of banana cv. Ney Poovan.

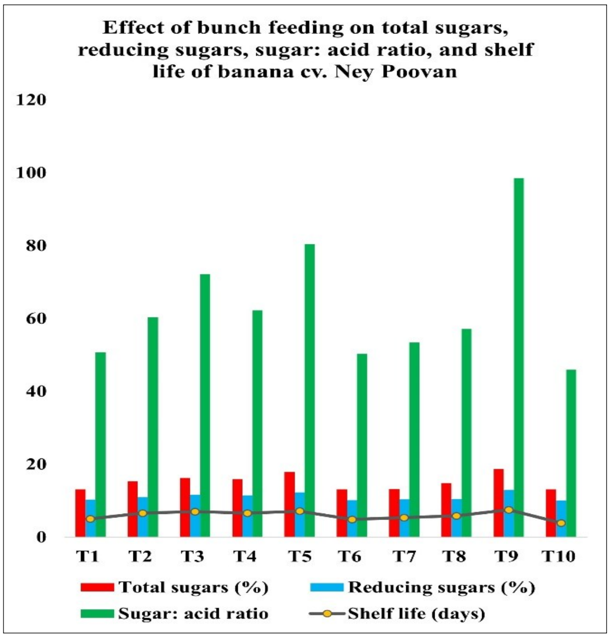

Fig. 5. Effect of bunch feeding on total sugars, reducing sugars, sugar to acid ratio and shelf life of banana cv. Ney Poovan.

Fruit firmness

A significant difference between the treatments observed in fruit firmness and the outcomes clarified that, among the treatments, the highest fruit firmness was observed in T9 treatment (growth regulators and nutrients combination) of 22.55 N, which is significantly superior to all other treatments. This was followed by T_5 (K_2SO_4 at the rate of 1.0%) of 21.69 N, which was on par with T_3 (GA_3 at the rate of 150 ppm) of 21.65 N and T_4 (K_2SO_4 at the rate of 0.5%) of 21.21 N. The lowest fruit firmness was recorded in T_{10} (16.95 N), which was on par with T_6 (urea at the rate of 1.0%) at 17.48 N and T_1 (GA_3 at the rate of 50 ppm) at 17.77 N. This may be due to the application of bunch-feeding growth regulators, such as GA_3, which influence various physiological processes, including the regulation of pectin metabolism essential for maintaining cell wall integrity and stiffness (33, 34). As a result, the best treatment (T_9) reduced pectin solubility during ripening, enhancing fruit firmness and prolonging shelf life.

Total soluble solids

The highest TSS content (23.94˚Brix) was observed in T_9 (growth regulators and nutrients combination), significantly superior to all other treatments. This was followed by T_5 (1% K_2SO_4; 22.61 ˚Brix), which was on par with T_4 (0.5% K_2SO_4; 22.09 ˚Brix), T_3 (150 ppm GA_3; 22.04 ˚Brix) and T_2 (100 ppm GA_3; 21.86 ˚Brix). However, treatment T_{10} (control) recorded the lowest TSS content (19.56 ˚Brix), which was on par with T_6 (Urea at the rate of 1.0%) of 19.99 ˚Brix and T_1 (GA_3 at the rate of 50 ppm) of 20.48 ˚Brix. The results might be due to bunch feeding with nutrients and plant growth regulators, which increased TSS content (7, 35).

Ascorbic acid content

The study results reported that the highest ascorbic acid content (3.46 mg/ 100 g) was recorded in treatment T_9 (nutrients and growth regulators combination), which was on par with T_5 (K_2SO_4 at the rate of 1.0%) of 3.38 mg/ 100 g, which was followed by T_3 (GA_3 at the rate of 150 ppm) of 3.31 mg/ 100 g, T_4 (K_2SO_4 at the rate of 0.5%) of 3.28 mg/ 100 g and T_2 (GA_3 at the rate of 100 ppm) of 3.26 mg/ 100 g respectively. However, the lowest ascorbic acid content (2.95 mg/ 100 g) in fruits was observed in control (T_{10}), which was on par with T_6 (urea at the rate of 1.0%) of 3.02 mg/ 100 g, followed by T_1 (GA_3 at the rate of 50 ppm) of 3.11 mg/ 100 g. Increased ascorbic acid content might be attributed to the presence of potassium and sulfate, which could have helped to slow down the enzyme system that favored the oxidation of ascorbic acid, thus allowing the plants to accumulate more ascorbic acid content in the fruits. It was also stated that high energy status in potassium-rich crops promotes the formation of ascorbic acid content in fruits (36-38).

Titratable acidity

A significant difference among the treatments was observed in titratable acidity in banana cv. Ney Poovan. The results reported that T_9 (nutrients and growth regulators combination) exhibited the lowest titratable acidity (0.22%), which was superior to all other treatments, which was followed by T_5 (K_2SO_4 at the rate of 1.0%) of 0.26%. The highest titratable acidity was observed in control (T_{10}) of 0.37%, followed by T_6 (urea at the rate of 1.0%) of 0.35, which was on par with T_1 (GA_3 at the rate of 50 ppm) of 0.35% and T_7 (19:19:19 NPK at the rate of 0.5%) of 0.34% respectively. This may be attributed to altered metabolic activity induced by applying bunch-feeding chemicals, nutrients and growth regulators (39).

Sugar to acid ratio

The results indicated that among the various treatments, the highest sugar: acid ratio (98.54) was recorded in T_9 (combination of nutrients and growth regulators), significantly superior to all the treatments. It was followed by T_5(1.0% K_2SO_4) at 80.46 and T_3 (GA_3 at the rate of 150 ppm) at 72.22. The lowest sugar: acid ratio was registered in control (T_{10}) of 45.92, followed by T_6 (urea at the rate of 1.0%) of 50.29, which was on par with T_1 (50 ppm GA_3) of 50.69.

Reducing sugars and total sugars

The treatment T_9 (growth regulators and nutrients combination) recorded the maximum reducing sugars (12.95%) and total sugars (18.68%), whereas the control (T_{10}) observed the lowest reducing sugars (10.09%) and total sugars (13.09%). This increase in sugar levels may be attributed to applying bunch-feeding chemicals, nutrients and plant growth regulators after male bud removal and post-shooting. These practices conserve and efficiently utilize energy, resulting in higher sugar accumulation in the fingers (40, 41). It is also due to the identical result that using ascorbic acid may cause dehydration, leading to a rise in total sugar levels (42, 43).

Shelf life

The most crucial quality parameter, "shelf life" had shown significant differences among treatments in banana cv. Ney Poovan. The study results indicated that the highest shelf life (7.51 days) was registered in T9 (growth regulators and nutrients combination) and was significantly superior to all treatments. The next best value was observed in T_5 (K_2SO_4 at the rate of 1%) at 7.13 days, which was on par with T_3 (GA_3 at the rate of 150 ppm) at 7.02 days. The lowest shelf life was recorded in T_{10} of 3.86 days. It was due to the potassium treatment, which significantly extends the shelf life of bananas by increasing fruit quality, minimizing physiological problems and controlling ripening-related metabolic processes (44). It was also stated that bunches fed with chemicals containing citric acid treatment enhance shelf life by increasing peroxidase (POD) activity (45, 46). Improvements in fruit firmness and shelf life directly address market demands for high-quality produce, increasing export potential and reducing post-harvest losses.

Conclusion

This research found that bunch feeding with nutrients and growth regulators (T_9) significantly improved the yield and quality of Ney Poovan. The efficient nutrient utilization observed with T_9 treatment minimizes input wastage, supports environmental sustainability and reduces costs for farmers. It addressed the limitations of conventional nutrient management, proving to be a practical and sustainable strategy for maximizing production and market value. Adopting this technology can enhance farmer profitability and support sustainable banana cultivation. We recommend its inclusion in agricultural training programs and policies to benefit farmers and the broader industry.

Acknowledgements

This research was conducted to provide farmers with actionable insights into improving banana cultivation. We express our gratitude to the stakeholders who supported the practical implementation of this study. The author is very thankful to Embryo Seeds, Hyderabad, for providing funds and specialities to conduct the research.

Authors' contributions

SSSSS carried out the experiment, took observations and drafted the manuscript. CR formulated the concept and correction of the manuscript. SSSSS participated in the data analysis and performed the statistical analysis. SS conceived the study and participated in its design and coordination. SSSSS provided statistical tools for the analysis of the manuscript. AV and CS participated in the data analysis and revised manuscript. KV and SS participated in the overall correction of the manuscript. All authors reviewed the results and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

While preparing this work, the authors used ChatGPT AI tool to improve language and readability. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

References

1. Evans EA, Ballen FH, Siddiq M. Banana production, global trade, consumption trends, postharvest handling and processing. In: Siddiq M, Ahmed J, Lobo MG, editors. Handbook of banana production, postharvest science, processing technology and nutrition. Hoboken: Wiley; 2020. p. 1-18 https://doi.org/10.9734/arja/2024/v17i2427
2. Supriya T. Influence of foliar application of secondary nutrients and banana special on yield and quality of banana cv. Ney Poovan under hill zone of Karnataka. M.Sc. [Thesis]. Shivamogga: Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences; 2023. https://krishikosh.egranth.ac.in/server/api/core/bitstreams/5a9cdbba-4b0c-4785-b849-35554b0844ea/content.
3. Sathish BR, Kumar YHS, Ganapathi M, Swamy NM. Effect of bunch feeding and bunch spraying on vegetative and yield parameters of tissue culture banana CV. Ney Poovan. Pharma Innova. 2021;10(9):1301-06. https://doi.org/10.22271/tpi.2021.v10.i9o.7768
4. Bebber DP. The long road to a sustainable banana trade. Plants People Planet. 2023;5(5):662-71. https://doi.org/10.1002/ppp3.10331
5. Rajput A, Memon M, Memon KS, Sial TA, Laghari HB. Integrated nutrient management in banana: comparative role of FYM and composted pressmud for the improvement of soil properties. Pak J Bot. 2022;54(1):355-62. https://doi.org/10.30848/PJB2022-1(34)
6. Prameela K, Honnabyraiah M, Sakthivel T, Suresha G. Enhancement of yield of banana cv. Ney Poovan (AB) through bunch feeding. In: Ahirwar MK, editor. Research trends in horticulture sciences. Vol. 15. New Delhi: AkiNik Publications; 2020. p. 31-41
7. Balakrishnan K, Subbiah A, Balaguru P, Rajangam J. Influence of post shooting bunch feeding of nutrients and growth regulators on yield and quality of Banana cv. Grand Naine. Res J Agric Sci. 2018;9(4):892-94.
8. Mulagund J. Influence of post-shooting sprays of sulphate of potash and certain growth regulators on bunch characters and fruit yield of banana cv. Nendran (French Plantain *Musa* AAB). Bioscan. 2015;10(1):153-60.
9. Ranganna S. Manual of analysis of fruit and vegetable products. New York: Tata McGraw-Hill; 1977
10. 10. Miller GL. Use of dinitrosalicylic acid reagent for determination of reducing sugar. Anal Chem. 1959;31(3):426-28. https://doi.org/10.1021/ac60147a030
11. Cowles M, Davis C. On the origins of the five level of statistical significance. Am Psychol. 1982;37(5):553-58. https://doi.org/10.1037/0003-066X.37.5.553
12. Pathak M, Bauri FK, Misra DK, Bandyopadhyay B, Chakraborty K. Application of micronutrients on growth, yield and quality of banana. J Crop Weed. 2011;7(1):52-54.
13. Rajamanickam C. Foliar application of arka banana special as micronutrients increase yield of banana. J Krishi Vigyan. 2021;10(1):101-04. https://doi.org/10.5958/2349-4433.2021.00071.4
14. Yadav MK, Patel NL, Parmar BR, Kirtibarhan, Singh P. Effect of micronutrients on growth and crop duration of Banana cv. Grand Naine. Prog Hort. 2010;42(2):162-64.
15. Arthi LR, Shakila A. Effect of micronutrients on growth and yield of Banana (*Musa* spp.) cv. Red Banana. Int J Plant Soil Sci. 2023;35(11):143-46. https://doi.org/10.9734/IJPSS/2023/v35i112955
16. Kumar T, Panigrahi HK, Singh P, Dikshit S. Influence of different micro-Nutrients on growth parameters of Banana (*Musa paradisiaca* L.) cv. Grand Naine. Trends Biosci. 2018;10(31):6532-36.
17. Mandal KK, Bhattacharya B, Singh DK. Studies on the effect of foliar application of different micronutrients on growth and yield

of Dwarf Cavendish banana (Musa, AAA, Sub-group-Cavendish, cv. Giant Governor). J Interacademicia. 2002;20:150–55.

18. Jegadeeswari D, Dheebakaran GA, Pandi PVK. Foliar application of micronutrients for enhancing productivity of banana under irrigated conditions through farmers' participatory approach. Int J Chem Stud. 2018;6(5):1094-97.

19. Krishnamoorthy V, Noorjahan HAKA. Influence of micronutrients on growth and yield of banana. J Krishi Vigyan. 2017;5(2):87-89. https://doi.org/10.5958/2349-4433.2017.00020.4

20. Damodhar VP. Effect of nutrients and plant growth regulators on yield quality and post-harvest life of banana cv. Grand Naine. PhD [Thesis]. Parbhani: Vasantrao Naik Marathwada Krishi Vidyapeeth; 2019 [cited 2025 Feb 1]. https://krishikosh.egranth.ac.in/items/9bcd1ac3-0a4e-4f3e-aa88-26f32633ee91/full

21. Devraj RP, Honnabyraiah MK, Swamy GSK, Shivanna M, Halesh GK. Effect of bunch feeding of macro and micronutrients on yield of tissue culture banana cv. Grand Naine (AAA). Int J Chem Stud. 2019;7(2):252-56.

22. Millik TT, Baruah K, Kumar V, Barik N. Effect of bunch feeding of nitrogen (N) and potassium (K) on yield characters in banana, cv. Barjahaji (*Musa* AAA Group) under assam condition, India. Curr J Appl Sci Technol. 2018;26(1):1-7. https://doi.org/10.9734/CJAST/2018/38889

23. Ancy TK, Kurien S, Augustin A, Balachandran PV. Urease activity in banana fruit. J Plant Nutr. 1998;21(10):2127-40. https://doi.org/10.1080/01904169809365549

24. Chaichuay C, Chaichuay R, Makornpas C, Wiangsamut B. Effect of organic fertilizer and organic fertilizer plus chemical fertilizer on growth and yield quality of Kamphaeng Phet emperor banana. Int J Agric Technol. 2013;9(5):1297-308. https://www.thaiscience.info/Journals/Article/IJAT/10895607.pdf

25. Sarma I, Borgohain R, Phukon M. Effect of post shooting application of urea and sulphate of potash at the denavelled, distal stalk end of banana cv. Borjahaji. Asian J Biol Sci. 2014;9(2):296-98. https://doi.org/10.15740/HAS/AJBS/9.2/296-298

26. Dhillon WS, Gill PPS, Singh NP. Effect of nitrogen, phosphorus and potassium fertilization on growth, yield and quality of pomegranate 'Kandhari'. Acta Hortic. 2011;890:327-32. https://doi.org/10.17660/ActaHortic.2011.890.45

27. Singh SK, Marboh ES, Litch NV. In: Rajasekharan PE, Rao VR, editors. Fruit and nut crops. Singapore: Springer Nature Singapore; 2023. p. 1-28 https://doi.org/10.1007/978-981-99-1586-6_12-1

28. Beerappa PS, Hipparagi K, Patil DR, Suma R, Biradar IB. Effect of foliar application of gibberellic acid (GA_3) and nutrients on yield and quality of pomegranate (*Punica granatum* L.) cv. Bhagwa. Int J Chem Stud. 2019;7:2579-84.

29. Poojan S, Pandey D, Trivedi A, Pandey A, Pandey M. Efficacy of foliar application of nutrients on yield and quality of guava. J Environ Biol. 2020;41:1265-72. https://doi.org/10.22438/jeb/41/5/MRN-1336

30. Anitha R, Jeyakumar P, Devi DD, Bangarusamy U. Effect of plant growth regulators and chemicals on morphological traits and yield of banana cv. Grand Naine. Madras Agric J. 2005;92 (jan-mar):1. https://doi.org/10.29321/MAJ.10.A00008

31. Paul A, Nair C. Effect of foliar application of nutrients on quality characters of banana (*Musa* AAB) Nendran. Int J Appl Pure Sci Agric. 2015:101-05.

32. El-badawy HEM, El-gioushy SF, Baiea MHM, El-khwaga AA. Impact of citric acid, ascorbic acid and some nutrients (Folifert, Potaqueen) on fruit yield and quality of Washington navel orange trees. Asian J Adv Agric Res. 2018;4(3):1-13. https://doi.org/10.9734/AJAAR/2017/37900

33. Sembok WZW, Hamzah Y, Loqman NA. Effect of plant growth regulators on postharvest quality of banana (*Musa* sp. AAA Berangan). J Trop Plant Physiol. 2016;8:52-60.

34. Aquino CF, Salomao LCC, Azevedo AM, Oliveira JAA. Gibberellic acid in the postharvest quality of 'Nanicão' banana. Comun Sci. 2020;11:e3503-e. https://doi.org/10.14295/cs.v11i.3503

35. Rao V, Swamy GSK. Performance of Banana cv. Grand Naine (AAA) for direct bunch feeding of major and micronutrients on bunch yield. Int J Curr Microbiol App Sci. 2017;6(11):1577-81. https://doi.org/10.20546/ijcmas.2017.611.189

36. Ananthi S. Comparative efficacy of sulphate of potash and muriate of potash on yield and quality of chilli (*Capsicum annuum* L.) [M.Sc. dissertation on the Internet]. Coimbatore: Tamil Nadu Agricultural University; 2002 Available from: https://krishikosh.egranth.ac.in/handle/1/5810160196.

37. Shira VD, Singh YS, Bauri FK. Effect of post shoot application of potassium through bunch feeding on fruit quality characters of banana in West Bengal. J Crop Weed. 2013;9(2):196-97.

38. Baiea MHM, El-Sharony T, Abd El-Moneim EAA. Effect of different forms of potassium on growth, yield and fruit quality of mango cv. Hindi. Int J Chemtech Res. 2015;8(4):1581-87.

39. Kumar RA, Kumar N. Sulfate of potash foliar spray effects on yield, quality and post-harvest life of banana. Better Crops. 2007;91(2):22-4.

40. Avani P, Bauri F, Sarkar S. Effect of potassium spray on fruit quality and shelf life of banana cv. Grand Naine (AAA). Environ and Ecol. 2017;35(1A):368-71.

41. Singh H. Handbook of Horticulture. New Delhi: Indian Council of Agricultural Research; 2001

42. Singh J, Mirza A. Influence of ascorbic acid application on quality and storage life of fruits. Int J Curr Microbiol Appl Sci. 2018;7(7):4319-28. https://doi.org/10.20546/ijcmas.2018.707.503

43. Hafez OM, Hamouda HA, Abd-El-Mageed MA. Effect of calcium and some antioxidants treatments on storability of Le Conte pear fruits and its volatile components. Selcuk J Agric Food Sci. 2010;24(3):87-100.

44. Sree MR, Patil SN, Sabarad AI, Amulya S, Singh SK. Post-shooting sprays of nutrients for improving fruit quality, antioxidant properties and shelf-life in banana (*Musa* sp.). Indian J Agric Sci. 2023;93(10):1097-102. https://doi.org/10.56093/ijas.v93i10.130762

45. Ducamp-Collin M-N, Ramarson H, Lebrun M, Self G, Reynes M. Effect of citric acid and chitosan on maintaining red colouration of litchi fruit pericarp. Postharvest Biol Technol. 2008;49(2):241-46. https://doi.org/10.1016/j.postharvbio.2008.01.009

46. Yang C, Chen T, Shen B, Sun S, Song H, Chen D, et al. Citric acid treatment reduces decay and maintains the postharvest quality of peach (*Prunus persica* L.) fruit. Food Sci Nutr. 2019;7(11):3635-43. https://doi.org/10.1002/fsn3.1219