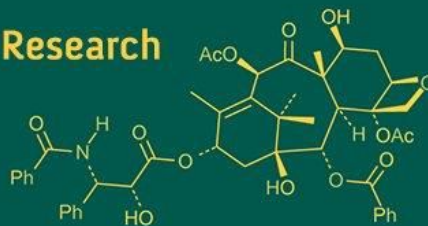
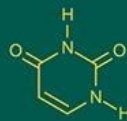
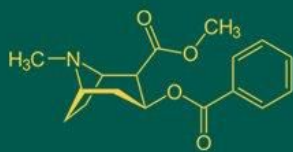


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Fortification with micronutrients and plant growth regulators improves the vegetative and reproductive parameters of bananan cv. Popoulu (AAB)

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Abstract

The experiment was conducted at ICAR-All India Coordinated Research Project on Fruits, Kittur Rani Channamma College of Horticulture, Arabhavi to study the response of micronutrients with plant growth regulators on vegetative and reproductive characteristics of banana cv. Popoulu (AAB) during 2024-25. It was laid out in a Randomized Complete Block Design with ten treatments and three replications. The results revealed statistically significant difference among treatments with foliar application of micronutrients and plant growth regulators. The maximum pseudostem height (263.19 and 293.34 cm), pseudostem girth (82.41 and 85.55 cm), number of functional leaves (16.47 and 18.36), leaf area (12.73 and 16.34 m²), chlorophyll content (44.33 and 49.98 SPAD units) and number of suckers per plant (9.80 and 1.03) were recorded at 6th and 7th MAP in T₈ (ICAR-NRCB Banana shakthi powder @ 1 per cent + GA₃ 80 ppm applied at 6th, 7th, 8th, 9th and 10th MAP). This treatment also resulted in early shooting (209.59 days), minimum days from shooting to maturity (68.92 days), reduced crop duration (278.51) and highest bunch weight (23.64 Kg) compared to other treatments.

Keywords: Micronutrients, Popoulu, banana shakthi, GA₃, plant growth regulators

Introduction

Banana (*Musa* spp.) is an herbaceous, perennial monocotyledonous plant belonging to the family Musaceae and order Scitamineae with the chromosome number X=11 and origin South East Asia. It is most widely cultivated and consumed fruit in India, with a long history of cultivation dating back to prehistoric times.

The term "banana" originated from West Africa and was introduced by the Portuguese, while "plantain," referring to cooking types, comes from the Spanish *plantano* (Purseglove, 1975) [27]. Bananas are mainly eaten as dessert fruits, whereas starchier plantains are used for cooking and form an essential dietary component in Africa, the Caribbean and Latin America. Ripe bananas are nutritious, energy-rich and easily digestible (Aurore *et al.*, 2009) [5].

Globally, banana ranks fourth after rice, wheat and maize in production value. It serves as both a staple and dessert fruit, rich in easily digestible carbohydrates (67-137 k cal/100 g) and a good source of vitamins A, C, B₁ and B₂ (Premalatha and Suresh, 2019) [25].

In India, banana is second most important crop next to mango. The global production of banana is around 139.6 million tonnes. In India, present area is 9.95 lakh ha and production is 374.74 lakh tonnes. In Karnataka, it is cultivated in 1.71 lakh ha area with the production of 29.13 lakh tonnes (Anon., 2023) [1].

In Karnataka, major banana cultivars include Dwarf Cavendish, Robusta, Rasthali, Poovan, Nendran and Red Banana. Among these, Nendran is the leading commercial cultivar for chips preparation, highly preferred by both consumers and processors. However, Nendran has low yield potential (10-12 kg/plant). To address this, "Popoulu," an AAB group cultivar from the Pacific Islands, was introduced by NBPGR, New Delhi, from the Musa International Transit Centre, Belgium and evaluated at the Banana Research Station, Kannara, Kerala (Menon *et al.*, 2014) [20].

Popoulu is a cooking banana cultivar growing 2-3 m tall with a sturdy pseudostem and large, green, paddle-shaped leaves. Its fruits are short, thick and angular, suitable for chips

preparation with 33% recovery, comparable to cv. Nendran and it can also be used as a dessert fruit (Manju and Pushpalatha, 2022) ^[19].

Plant growth, yield and fruit quality are all significantly impacted by balanced nutrition. The banana is an exhaustive crop that needs a sufficient amount of nutrients to support its robust growth, high yield and biomass production throughout its growth cycle.

Micronutrients are essential for the crop growth and are equally important as primary and secondary nutrients. They have an important role in the balance of plant nutrition for the stabilization of crop yield and quality of produce. Though these micronutrients are necessary in very small amounts, but are essential for controlling plant development and fostering physiological reactions in them. Because of the limited nutrient absorption through the root system, foliar application of micronutrients has been successfully used to improve flowering, synchronize blooming, enhance fruit size through cell division, which ultimately increases the yield.

Plant growth regulators (PGRs) are natural hormones that influence plant physiological processes by stimulating enzymes that control metabolism. They promote cell division, elongation, differentiation, root growth, shoot growth, flowering, fruiting and are used to enhance yield and reduce stress (Rajan *et al.*, 2017) ^[28].

Since Popoulu variety possesses superior yield and quality parameters compared to Nendran variety and because of its increasing demand in processing industries, there is a need to increase its quality production. Therefore, the present study aims to investigate the effect of micronutrients and plant growth regulators on vegetative and reproductive characteristics of banana cv. Popoulu (AAB).

Material and methods

This experiment was carried out at ICAR-All India Coordinated Research Project on Fruits, located at Kittur Rani Channamma College of Horticulture, Arabhavi, Belagavi district of Karnataka, India during the year 2024-2025. The experiment laid out in Randomized Complete Block Design with ten treatments and three replications. The spacing used here was 1.8 x 1.8 m. The treatment combination are as follows, T₁ (ICAR-IIHR Banana special @ 0.5%), T₂ (ICAR-NRCB Banana shakthi powder @ 1%), T₃ (Sampoorna KAU multimix @ 1%), T₄ (ICAR-IIHR Banana special @ 0.5% + CPPU 4 ppm), T₅ (ICAR-NRCB Banana shakthi powder @ 1% + CPPU 4 ppm), T₆ (Sampoorna KAU multimix @ 1% + CPPU 4 ppm), T₇ (ICAR-IIHR Banana special @ 0.5% + GA₃ 80 ppm), T₈ (ICAR-NRCB Banana shakthi powder @ 1% + GA₃ 80 ppm), T₉ (Sampoorna KAU multimix @ 1% + GA₃ 80 ppm) and T₁₀ (Control - water spray) sprayed at 6th, 7th, 8th, 9th and 10th month after planting.

The recommended dose of fertilizer followed in the experiment was 200:100:300 g NPK/plant/year, as per the Package of Practice of UHS, Bagalkot, Karnataka and was applied uniformly to all treatments. The 5 g IIHR banana special, 10 g of each NRCB Banana shakthi and Sampoorna KAU multimix were accurately measured and dissolved in one litre of water separately. Similarly, 0.04 ml of CPPU and 0.08 g of pro-gib (GA₃) were measured. The required concentrations of micronutrients and plant growth regulators were prepared by directly mixing the respective quantities in water and freshly prepared solutions were used for spraying

during 6th, 7th, 8th, 9th and 10th month after planting using knapsack power sprayer.

Observations were recorded for various growth parameters such as pseudostem height, measured from the soil surface to the base of the leaf-emerging point using a measuring tape; pseudostem girth, measured from 15 cm above the ground using a measuring tape; number of functionally active leaves, were manually counted; leaf area, determined by multiplying leaf length, breadth and the number of leaves with a constant factor of 0.80, as per Murray's method (1960); Chlorophyll content in leaves was measured using a SPAD meter, number of suckers per plant were counted manually before their removal and recorded at 6th and 7th months after planting. Reproductive parameters such as number of days taken for shooting, number of days taken from shooting to maturity, total crop duration and bunch weight were documented. The obtained data were statistically analyzed in a randomized complete block design (RCBD) by using analysis of variance by Fisher and Yates (1963). When F-test showed significance in comparing treatment means, critical differences (C.D. at 5%) were calculated.

Results and Discussion

Vegetative parameters

Pseudostem height and girth (cm)

The data on pseudostem height and girth of banana cv. Popoulu was significantly influenced by foliar application of micronutrients and plant growth regulators. Among the different treatments, the maximum pseudostem height (263.19 and 293.34 cm) and greatest pseudostem girth (82.41 and 85.55 cm) were recorded in T₈ (ICAR-NRCB Banana shakthi powder @ 1 per cent + GA₃ @ 80 ppm applied at 6th, 7th, 8th, 9th and 10th MAP). Whereas, the minimum pseudostem height (204.50 and 225.50 cm) and lowest pseudostem girth (55.00 and 58.64 cm) were registered in T₁₀ (control) at 6th and 7th MAP, respectively.

The increase in pseudostem height and girth might be due to the foliar application of micronutrients that enhance cell enlargement and metabolic activity with zinc promoting auxin production, copper aiding enzyme activation and chlorophyll formation (Ram and Bose, 2000) ^[29], resulting in vigorous pseudostem growth. These findings were well supported by Kumar and Jeyakumar (2001) ^[17] in cv. Robusta, Yadlod and Kadam (2003) ^[35] in banana cv. Grand Naine, Rashid and Mondal (2007) ^[30] in banana cv. Amritsagar, Jeyabaskaran and Pandey (2008) ^[14] in cv. Karpuravalli, Bashma *et al.* (2018) ^[8] in cv. Nendran, Nisarga *et al.* (2022) ^[23] in banana cv. Rajapuri, Arthi and Shakila (2023) ^[4] in banana cv. Red Banana and Balaji *et al.* (2023) ^[6] in banana cv. Poovan.

Enhanced pseudostem height and girth could be attributed to the application of GA₃ which stimulates the physiological processes that promote cell division, elongation and cambial activity, resulting in greater vascular development, efficient nutrient transport and overall pseudostem thickening and elongation. The similar observations were noticed by Yadlod and Kadam (2008) ^[36] in banana cv. Ardhapuri, Fathi *et al.* (2011) ^[11] in persimmon cv. Costata, Muralidhara *et al.* (2014) ^[21] in seedlings of mango var. Bappakkai, Singh *et al.* (2018) ^[31] in Papaya cv. Pusa Nanha and Kanwar *et al.* (2024) ^[15] in citrus cv. Nagpur mandarin.

Number of functional leaves (no.)

Admst all different treatments, the maximum number of functionally active leaves (16.47 and 18.36) were documented in T₈ (ICAR-NRCB Banana shakthi powder @ 1 per cent + GA₃ @ 80 ppm at 6th, 7th, 8th, 9th and 10th MAP). Whereas, the least number of functional leaves (11.49 and 12.07) at 6th and 7th MAP, respectively were recorded in T₁₀ (control).

The application of micronutrient mixture, which optimize the availability of essential trace elements that serves as cofactors in enzymatic and metabolic pathways, that facilitates the chlorophyll biosynthesis and maintain higher photosynthetic rates resulting in increased number of functionally active leaves. These results are in agreement in banana with Kumar and Jeyakumar (2001) [17] in cv. Robusta, Rashid and Mondal (2007) [30] in cv. Amritsagar, Jeyabaskaran and Pandey (2008) [14] in cv. Karpuravalli, Yadav *et al.* (2010) [34] cv. Grand Naine, Pathak *et al.* (2011) [24] in cv. Marthaman, Krishnamoorthy and Noorjahan (2017) [16] in cv. Poovan, Bashma *et al.* (2018) [8] in cv. Nendran, Premalatha *et al.* (2020) [26] in cv. Nendran, Nisarga *et al.* 2022 [23] in banana cv. Rajapuri, Arthi and Shakila (2023) [4] in cv. Red Banana and Balaji *et al.* (2023) [6] in cv. Poovan.

GA₃ might accelerate meristematic activity and leaf primordia development, increasing the rate of leaf emergence and overall leaf count. The above results were found parallel with findings of Yadlod and Kadam (2008) [36] in banana cv. Ardhapuri, Bhat *et al.* (2011) [9] in grape vines of cv. Tas-A-Ganesh, Fathi *et al.* (2011) [11] in persimmon cv. Costata, Kumar *et al.* (2012) [18] in strawberries and Singh *et al.* (2018) [31] in Papaya cv. Pusa Nanha.

Leaf area (m²)

The treatment T₈ (ICAR-NRCB Banana shakthi powder @ 1 per cent + GA₃ @ 80 ppm at 6th, 7th, 8th, 9th and 10th MAP) recorded the highest leaf area (12.73 and 16.34 m²) at the 6th and 7th MAP, respectively, while the lowest leaf area (8.00 and 10.93 m²) was registered in T₁₀ (control) at the corresponding stages.

The application of micronutrients contributes to the production of essential auxins, which promote cell division and chlorophyll synthesis, leading to enhanced leaf enlargement. In addition, micronutrients improve photosynthetic efficiency and facilitate protein synthesis, thereby increasing the total leaf area. Similar findings were reported by Jeyabaskaran and Pandey (2008) [14] in cv. Karpuravalli, Yadav *et al.* (2010) [34] in cv. Grand Naine, Krishnamoorthy and Noorjahan (2017) [16] in cv. Poovan, Bashma *et al.* (2018) [8] in cv. Nendran, Arthi and Shakila (2023) [4] in cv. Red Banana, and Nisarga *et al.* (2022) [23] in cv. Rajapuri.

In addition to this GA₃ also enhances phloem loading and transport of assimilates and minerals to developing leaves, supporting rapid lamina expansion as suggested by Bhat *et al.* (2011) [9] in grape vines of cv. Tas-A-Ganesh.

Chlorophyll content (SPAD units)

Among the treatments, T₈ (ICAR-NRCB Banana shakthi powder @ 1 per cent along with GA₃ @ 80 ppm applied at 6th, 7th, 8th, 9th and 10th MAP) recorded the highest chlorophyll levels, with values (44.33 and 49.98 SPAD units). On the other hand, the lowest

Table 1: Impact of micronutrients and plant growth regulators on vegetative characters of banana cv. Popoulu (AAB)

Treatment	Pseudostem height (cm)		Pseudostem girth (cm)		Number of functional leaves		Leaf area (m ²)		Chlorophyll content (SPAD units)		Number of suckers per plant	
	6 MAP	7 MAP	6 MAP	7 MAP	6 MAP	7 MAP	6 MAP	7 MAP	6 MAP	7 MAP	6 MAP	7 MAP
T ₁ - ICAR-IIHR Banana special @ 0.5 per cent	228.37	251.33	62.89	69.33	13.00	13.99	9.40	12.70	39.52	41.52	5.80	6.78
T ₂ - ICAR-NRCB Banana shakthi powder @ 1 per cent	230.67	254.00	63.34	69.89	13.01	14.00	10.00	13.00	39.70	41.78	6.50	7.067
T ₃ - Sampoorana (KAU multimix) @ 1 per cent	226.04	250.00	62.19	66.45	12.98	13.59	9.20	12.61	39.00	41.12	5.63	6.50
T ₄ - ICAR-IIHR Banana special @ 0.5 per cent + CPPU 4 ppm	231.00	258.00	63.65	68.00	13.08	14.14	10.20	13.07	40.27	42.21	6.91	7.60
T ₅ - ICAR-NRCB Banana shakthi powder @ 1 per cent + CPPU 4 ppm	241.79	270.26	75.69	78.73	14.99	16.90	11.78	15.03	42.04	43.68	9.13	10.29
T ₆ - Sampoorana (KAU multimix) @ 1 per cent + CPPU 4 ppm	234.00	261.71	66.88	70.66	13.97	14.79	10.60	13.77	41.76	42.99	7.30	8.13
T ₇ - ICAR-IIHR Banana special @ 0.5 per cent + GA ₃ 80 ppm	232.00	259.78	64.22	68.30	13.50	14.41	10.43	13.40	41.30	42.70	7.00	7.90
T ₈ - ICAR-NRCB Banana shakthi powder @ 1 per cent + GA ₃ 80 ppm	263.19	293.34	82.41	85.55	16.47	18.36	12.73	16.34	44.33	49.98	9.80	11.03
T ₉ - Sampoorana (KAU multimix) @ 1 per cent + GA ₃ 80 ppm	237.00	266.33	67.86	74.16	14.00	15.08	10.80	13.95	41.96	43.32	8.36	9.17
T ₁₀ - Control	204.50	225.50	55.00	58.64	11.49	12.07	8.00	10.93	35.20	36.83	4.63	5.03
S. Em ±	7.21	7.77	2.19	2.29	0.47	0.49	0.32	0.44	1.24	1.23	0.22	0.25
CD @ 5%	21.43	23.09	6.53	6.81	1.41	1.46	0.95	1.30	NS	3.65	0.67	0.74
CV (%)	5.95	5.19	5.73	5.60	6.12	5.78	5.41	5.65	5.28	5.00	5.57	5.45

Spraying at 6th, 7th, 8th, 9th and 10th MAP

MAP- Months after planting, NS- Non-significant

chlorophyll values were recorded in the control treatment T₁₀, with readings (35.20 and 36.83 SPAD units) at 6th and 7th MAP, respectively. The increase in chlorophyll content may be due to magnesium's role in chlorophyll formation and involvement of micronutrients like iron, zinc, manganese and copper as cofactors in chlorophyll biosynthesis and photosynthesis, thereby enhancing chloroplast development and reducing chlorophyll degradation. These results are in line with Kumar and Jeyakumar (2001)^[17] in cv. Robusta and Jayachandran *et al.* (2005) in guava cv. Lucknow-49.

GA₃ treatment may increase chlorophyll content by enhancing chlorophyll-synthesizing enzymes and delaying leaf senescence. This finding is supported by Fathi *et al.* (2011)^[11] in persimmon cv. Costata.

Number of suckers (no.)

The treatment T₈ (ICAR-NRCB Banana shakthi powder @ 1 per cent combined with GA₃ @ 80 ppm at 6th, 7th, 8th, 9th and 10th MAP) resulted in the highest number of suckers, recording (9.80 and 11.03) at 6th and 7th MAP, respectively. The least number of suckers (4.63 and 5.03) were recorded in T₁₀ (control) at the corresponding stages.

Foliar application of micronutrients at appropriate crop growth stages enhances their uptake and physiological use, thereby stimulating vigorous growth and promoting increased sucker initiation which is similar with the findings of Pathak *et al.* (2011)^[24] in cv. Martaman and Anu Shetty *et al.* (2022)^[3] in cv. Rajapuri.

The positive influence of GA₃ on sucker production could be attributed due to its ability to enhance overall plant growth, which in turn improve nutrient uptake efficiency and thereby promote initiation and development of more suckers (Swennen *et al.*, 1984)^[33] in plantain.

Reproductive parameters

Among all the treatments, T₈ (ICAR-NRCB Banana shakthi powder @ 1 per cent combined with GA₃ @ 80 ppm at 6th, 7th, 8th, 9th and 10th MAP) showcased early shooting (209.59 days), early maturity (68.92 days) and a shorter crop duration of (278.51 days) which was lesser than other treatments. However, T₁₀ (control) exhibited delayed shooting (230.82 days), late maturity (95.04 days) and a longer crop duration (325.86 days).

Table 2: Impact of micronutrients and plant growth regulators on reproductive characters and bunch weight of banana cv. Popoulu (AAB)

Treatment	Reproductive parameters			Bunch weight (kg)
	Number of days taken for shooting (days)	Number of days taken from shooting to maturity (days)	Total crop duration (days)	
T ₁ - ICAR-IIHR Banana special @ 0.5 per cent	224.93	80.21	305.14	15.31
T ₂ - ICAR-NRCB Banana shakthi powder @ 1 per cent	224.06	78.86	302.92	16.06
T ₃ - Sampoorna (KAU multimix) @ 1 per cent	225.34	81.56	306.90	14.60
T ₄ - ICAR-IIHR Banana special @ 0.5 per cent + CPPU 4 ppm	221.86	79.63	301.49	17.03
T ₅ - ICAR-NRCB Banana shakthi powder @ 1 per cent + CPPU 4 ppm	213.73	72.11	285.84	20.96
T ₆ - Sampoorna (KAU multimix) @ 1 per cent + CPPU 4 ppm	220.12	74.57	294.69	19.45
T ₇ - ICAR-IIHR Banana special @ 0.5 per cent + GA ₃ 80 ppm	223.14	76.25	299.39	18.43
T ₈ - ICAR-NRCB Banana shakthi powder @ 1 per cent + GA ₃ 80 ppm	209.59	68.92	278.51	23.64
T ₉ - Sampoorna (KAU multimix) @ 1 per cent + GA ₃ 80 ppm	217.49	73.26	290.75	20.09
T ₁₀ - Control	230.82	95.04	325.86	11.89
S. Em ±	6.44	3.18	10.76	0.89
CD @ 5%	19.14	9.46	31.97	2.68
CV (%)	5.07	5.81	5.00	5.55

Spraying at 6th, 7th, 8th, 9th and 10th MAP

MAP- Months after planting, NS- Non-significant

Crop duration is an important factor to be considered in banana cultivation. In the present experiment, it was recorded that the use of micronutrients and plant growth regulators resulted in early floral bud differentiation, due to optimum vegetative growth, which in turn led to early shooting. Similar findings were reported by Balakrishnan and Rajangam (2002)^[7] in cv. Red banana, Yadlod and Kadam (2003)^[35] in cv. Grand Naine, Rashid and Mondal (2007)^[30] in cv. Amritsagar, Yadav *et al.* (2010)^[34] in cv. Grand Naine, Pathak *et al.* (2011)^[24] in cv. Martaman, Krishnamoorthy and Noorjahan (2017)^[16] in banana cv. Poovan, Anu Shetty *et al.* (2022)^[3] in cv. Rajapuri and Nisarga *et al.* (2022)^[23] in cv. Rajapuri.

Application of GA₃ might delay the leaf senescence and maintain higher chlorophyll content, improving nutrient mobilization and sustain photosynthetic efficiency to accelerate floral initiation and fruit development, resulting in early shooting, maturity and reduced crop duration as found in banana by Anilkumar and Brahmachari (2006)^[2] in var. Harichal, Ebeed *et al.* (2008)^[10] cv. Grand Naine and earliest flowering was observed in guava cv. Allahabad Safeda (Suman *et al.*, 2021)^[32].

Conclusion

The present study revealed that foliar application of ICAR-NRCB Banana Shakthi powder @ 1% + GA₃ @ 80 ppm

applied at 6th, 7th, 8th, 9th and 10th MAP was most effective in enhancing vegetative traits such as pseudostem height, pseudostem girth, number of functional leaves per plant, leaf area, chlorophyll content in leaves and number of suckers per plant. In addition, this treatment also recorded early shooting, early maturity, minimum crop duration and highest bunch weight.

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