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Combined effects of organic, inorganic and biological nutrient inputs with phytosterols on growth and yield of banana (*Musa spp.*, cv. Poovan)

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Abstract

This study analyzed how combining different nutrient types with phytosterols influenced the growth and yield of Banana (*Musa spp.*, cv. Poovan). This study is with ten treatments which includes the combination of Bio NPK liquid consortia with different levels of vermicompost (4kg, 8kg per plant), neem cake (1 kg, 2 kg per plant), campesterol and stigmasterol (0.1%, 0.2%) and inorganic fertilizer at three different levels such as (RDF 100%, RDF 75%, RDF 50%) arranged in a randomized block design (RBD) with three replications. The results showed that (T₉) 75% RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.2% demonstrated superior performance across all parameters such as plant height (88.27, 155.86, 206.51 and 267.62 cm) at 3 MAP, 5 MAP, 7 MAP and shooting. Pseudostem girth (32.72, 42.63, 52.19 and 64.42cm) at 3 MAP, 5 MAP, 7 MAP, shooting. Phyllochron (7.02 days), Days taken from planting to shooting (237.28 days), Days taken from shooting to Harvest (106.42 days), Total crop duration (343.70 days). T₁-RDF 100% (Control) showed the lowest performance. Similarly in yield attributes such as number of fingers per hand (15.33), number of fingers per bunch (186.11), bunch weight (19.43 kg/plant), total yield (43.91 t/ha) was found to be maximum T₉-75% RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.2%, while the lowest values were noted in the T₁-RDF 100% (Control) exhibiting the least desirable outcomes. Based on the findings, it can be concluded that application of T₉ 75% RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.2% is the most effective practice for enhancing the growth and yield attributes.

Keywords: Neem cake, vermicompost, campesterol & stigmasterol, banana, Poovan

Introduction

Banana is a globally important fruit crop, predominantly cultivated across tropical and subtropical regions. It belongs to the family Musaceae and genus *Musa*, of the order Scitaminae. Bananas contribute significantly to human nutrition due to their high carbohydrate content and the presence of essential minerals such as potassium, phosphorus, calcium, magnesium, zinc, and iron, along with B-complex vitamins. In addition to their nutritional value, bananas contain bioactive compounds that have been reported to reduce the risk of several health disorders, including cancer, asthma, and hypertension (Koeppal, 2008) [8]. Banana have also been utilized in the development of edible vaccines against the Hepatitis B virus (HBV), with plant-based HBV vaccines produced in edible banana offering a cost-effective approach for human healthcare (Uma *et al.*, 2008) [18]. Furthermore, in Ayurvedic medicine, banana is traditionally used to treat certain stomach and intestinal disorders. Banana is grown worldwide over an estimated area of about 5.9 million hectares, with a total production of nearly 135 million tonnes and an average productivity of 23 tonnes per hectare (NAB, 2024) [11]. India occupies the leading position in global banana production, covering approximately 8.8 lakh hectares and producing 324.54 lakh tonnes (NHB, 2022). Among Indian states, banana cultivation is most prominent in Andhra Pradesh (108.10 ha), Karnataka (108.00 ha), Tamil Nadu (97.80 ha), Maharashtra (83.20 ha), Gujarat (59.20 ha), and Madhya Pradesh (27.00 ha), making them the principal producers of the crop. Bananas are a highly nutritious fruit that remains widely available and economically accessible throughout the year.

Poovan banana belongs to the *Musa* AAB genomic group and is widely cultivated across different regions because of its broad adaptability and high drought tolerance under perennial cropping systems, making it the leading commercial cultivar in Tamil Nadu. Banana, owing to its large biomass and rapid growth rate, requires substantial amounts of nutrients to attain higher yield and superior fruit quality. Although the application of inorganic fertilizers significantly enhances productivity, their continuous use alone is insufficient to maintain soil fertility over time. Considering the present concerns related to soil health and environmental sustainability, the combined use of organic manures and inorganic fertilizers has become necessary. Therefore, the present study was undertaken to evaluate the effects of organic manure, inorganic fertilizers, Bio NPK liquid consortia, campesterol and stigmasterol on the growth, yield of banana. The results are expected to assist farmers in selecting appropriate combinations of organic, inorganic fertilizers, Bio NPK liquid consortia and campesterol and stigmasterol to achieve efficient crop management.

Materials and Methods

The study was conducted during 2023-2024 at farmer's field in Ramanayaganpatti Village, Batlagundu, Tamil Nadu, India. The sword suckers were procured from farmer's field at Kulithalai, Tiruchirappalli. The suckers were treated to prevent from fungal disease, nematode infestation and planted in the pits size of 45 cm³ with the spacing of 2.1 m × 2.1 m. Top soil and 10kg of FYM were applied to each pit during filling. The experimental field was maintained weed-free through regular hand weeding. Irrigation was applied in the interval of 7-8 days in winter and 4-5 days interval in summer. The experimental plots were arranged in a Randomized Block Design (RBD) with 10 treatments and three replicates. The treatment details are T₁.100% recommended dose of fertilizers (RDF), T₂.75% RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia, T₃.50% RDF + Vermicompost @ 8 kg plant⁻¹ + Neem cake @ 2 kg plant⁻¹ + Bio NPK liquid consortia, T₄.100% RDF + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.1%, T₅.75% RDF + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.1%, T₆.50% RDF + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.1%, T₇.75% RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.1%, T₈.50% RDF + Vermicompost @ 8 kg plant⁻¹ + Neem cake @ 2 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.1%, T₉.75% RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.2%, T₁₀.50% RDF + Vermicompost @ 8 kg plant⁻¹ + Neem cake @ 2 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.2%. The recommended dose of fertilizers (RDF) of 110:35:330 g NPK per plant was applied at three levels. Nitrogen and potassium fertilizers were applied in three equal splits during the 2nd, 4th, and 6th months after planting, while the entire phosphorus dose was applied as a basal treatment. Vermicompost and neem cake were applied at two levels in two splits: First split as a basal application and the second split at 4th month after planting. Bio NPK liquid consortia applied as basal dose. Campesterol and Stigmasterol were

applied as foliar spray at three levels in three splits at 4th, 6th and 8th month after planting. Different growth and yield parameters obtained during the study were subjected to statistical analysis by using Randomized Block Design (RBD) as per procedure given by Panse and Sukhatme (1978) [13].

Results and Discussion

The present investigation aimed to evaluate the combined effects of organic, inorganic and biological nutrient inputs with phytosterols on growth and yield of banana (*Musa* spp., cv. Poovan). The results revealed that T₉.75% RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.2% demonstrated superior performance and T₁.100% recommended dose of fertilizers (RDF) exhibited the least desirable outcomes.

Plant height

The data pertaining to the combined effects of organic, inorganic and biological nutrient inputs with phytosterols on growth and yield of banana (*Musa* spp., cv. Poovan) are presented in Table 1. Among the treatments, T₉.75% RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.2% (88.27, 155.86, 206.51, 267.62 cm) at 3 MAP, 5 MAP, 7 MAP, shooting. recorded the maximum plant height, followed by T₇.75% RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.1% (85.66, 152.57, 202.90, 264.09 cm) at 3 MAP, 5 MAP, 7 MAP, shooting. The minimum plant height was observed in T₁.100% RDF (control) (62.71, 126.38, 172.92, 233.17) at 3 MAP, 5 MAP, 7 MAP, shooting.

The superior plant height observed under treatment T₉ can be attributed to the synergistic supply of nitrogen through RDF, vermicompost, and neem cake. Adequate nitrogen availability promotes the synthesis of proteins and amino acids, which are essential for new tissue development (Shelke *et al.*, 2025) [17]. In addition to that inorganic phosphorus co-administration with vermicompost enhances the intake of some basic plant nutrients (NPK) and increases the plant height (Muhammad *et al.*, 2016) [22]. Bacterial production of auxins, gibberellins and cytokinins appears to growth promoting effects. These beneficial effects in plants inoculated with consortium of biofertilizers enhanced the growth attributes such as plant height (Senthilkumar *et al.*, 2014) [15]. Stigmasterol and Campesterol played a significant role in stimulating vegetative growth. Stigmasterol enhanced the production of growth hormones like IAA and GA₃ and improved the uptake of essential nutrients such as K⁺, Ca²⁺, and P³⁻, which supported pseudostem elongation and overall plant vigor, contributed to sustained growth. Campesterol aids plant growth by stabilizing cell membranes, thereby improving nutrient absorption and internal transport, which enhanced the metabolic activity and biomass accumulation (Bhat *et al.*, 2011) [4].

Plant girth

The data pertaining to the combined effects of organic, inorganic and biological nutrient inputs with phytosterols on growth and yield of banana (*Musa* spp., cv. Poovan) are presented in the Table 1. Among the treatments, T₉.75% RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg

plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.2% showed maximum pseudostem girth (32.72, 42.63, 52.19, 64.42 cm) at 3 MAP, 5 MAP, 7 MAP, shooting followed by T_{7-75%} RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.1% (31.98, 42.12, 51.44, 63.68 cm) at 3 MAP, 5 MAP, 7 MAP, shooting. Minimum pseudostem girth was observed in T_{1-100%} RDF (control) (25.52, 37.72, 44.86, 57.24 cm) at 3 MAP, 5 MAP, 7 MAP, shooting.

The increased pseudostem girth recorded in treatment T₉ may be due to the combined application of RDF and vermicompost, which enhanced nitrogen availability required for protein synthesis and protoplasmic development (Pattnaik and Reddy 2010; Abbey *et al.*, 2012) [14, 1]. The role of consortium biofertilizer in slow release and mobility of nutrients to the plants enhanced the pseudostem girth. In addition to that, the increase pseudostem girth can be attributed to the role of stigmasterol in maintaining membrane fluidity and permeability, which are essential for cell elongation and division (Du *et al.*, 2022; Valitova *et al.*, 2024) [21, 20].

Phyllochron

The data pertaining to the combined effects of organic, inorganic and biological nutrient inputs with phytosterols on growth and yield of banana (*Musa* spp., cv. Poovan) are presented in the Table 1. Phyllochron is the number of days for the successive leaf production. Among the treatments, T_{9-75%} RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.2% recorded minimum number of days (7.02 days) for the successive leaf production followed by T_{7-75%} RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.1% (7.35 days). maximum number of days (10.11 days) for the successive leaf production was recorded in T_{1-100%} RDF (Control).

Maximum number of days was observed in T_{1-100%} RDF (Control). The minimum number of days was observed in T₉. This positive effect on early phyllochron in banana may be attributed due to the combined application of RDF, vermicompost, neem cake, and Bio NPK liquid consortia. This ensured a continuous and balanced supply of nutrients, particularly nitrogen. Improved nutrient availability and uptake enhanced photosynthetic activity and metabolic processes, thereby promoting rapid leaf initiation and emergence, resulting in minimum number of days for the successive leaf production.

Crop duration

The data pertaining to the study on the combined effects of organic, inorganic and biological nutrient inputs with phytosterols on growth and yield of banana (*Musa* spp., cv. Poovan) are presented in the Table 1. Among the treatments, T_{9-75%} RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.2% recorded minimum number of days from planting to shooting, shooting to harvest and total duration (237.28, 106.42, 343.70 days) followed by T_{7-75%} RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.1% (240.84, 107.94, 348.78 days). Maximum number of days from planting to shooting,

shooting to harvest and total duration was registered in T_{1-100%} RDF (control) (272.21, 121.32, 393.53 days).

The minimum number of days was observed in T₉ attributed to better microbial activity of Azospirillum and PSB in vegetative growth. This might be due to the optimum quantity of nutrients available through chemical and organic fertilizers such as vermicompost, neem cake which might have increased the process of initiation and emergence of inflorescence due to rapid production of leaves with better disposition of photosynthetic activity resulting in higher required net assimilation (Kuttamani *et al.*, 2013) [9]. In case of shooting to harvest T₉ recorded minimum number of days for the maturity. This might be due to the better source sink relationship in this treatment which recorded more leaf area that might have enhanced the photosynthetic activity and translocating the carbohydrates more efficiently to the developing bunch. (Arumugam Shakila and Manivanan, 2001 and Sharma, 2002) [2, 16]. Shorter the vegetative stage and minimum the number of days for the maturity lead to reduction in the total crop duration.

Yield Parameters

The data pertaining to the combined effects of organic, inorganic and biological nutrient inputs with phytosterols on growth and yield of banana (*Musa* spp., cv. Poovan) are presented in the Table 2. Among the treatments, T_{9-75%} RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.2% recorded the highest number of fingers per hand (15.33) and number of fingers per bunch (186.11), followed by T_{7-75%} RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.1% for number of fingers per hand (15.00), number of fingers per bunch (181.80), whereas the lowest values were observed in T_{1-100%} RDF (control) (12.51) and (150.25).

The increased number of fingers in T₉ may be due to the application of the recommended dose of fertilizers, vermicompost, neem cake along with the microbial consortium. The enhanced phosphorus availability through phosphorus-solubilizing bacteria, along with the production of growth-promoting substances such as IAA by Azotobacter, could have increased endogenous hormonal levels in plant tissues. This improved nutrient uptake and hormonal balance would have stimulated better floral development, cell division and fruit growth, ultimately leading to increased number of fingers per bunch in banana. Application of stigmasterol enhanced reproductive yield components through increased growth regulator activity and improved photosynthetic efficiency. A similar physiological mechanism enhanced the number of fruits per bunch in banana under a treatment stigmasterol and campesterol.

Maximum bunch weight (19.43 Kg/plant), Total yield (43.91 t/ha) was observed in T_{9-75%} RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.2% which was followed by T_{7-75%} RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + Campesterol & Stigmasterol (SL) @ 0.1% (18.69 Kg/plant) (42.24 t/ha). Minimum bunch weight (13.38 kg/plant) and yield (30.24 t/ha) was recorded in T_{1-100%} RDF (control). The maximum bunch weight recorded in T₉ may be due to the integrated application of RDF, vermicompost, neem cake which collectively enhanced key

physiological processes such as chlorophyll synthesis, nutrient absorption, photosynthetic efficiency during fruit development, ultimately resulting in increased bunch weight (Vanilarasu and Balakrishnamurthy, 2014) [19]. In addition to that, effective role of consortium of biofertilizers increased the input use efficiency and the active association of microbes with roots might have afforded more uptake of moisture, increased percent of water and nutrients which enhanced the bunch weight and total yield. (Senthilkumar *et al.*, 2014) [15]. Similar findings by (Lalmuanpuui *et al.*, 2025)

[10]. In addition to that, stigmasterol and campesterol, played crucial roles in improving traits like bunch weight and total yield by supporting the membrane integrity and nutrient uptake (Cabanca *et al.*, 2021; Griebel & Zeier, 2010) [5, 7]. These sterols may work with plant growth regulators (PGRs) to optimize growth, enhancing bunch weight (Flouda, 2022) [6]. Manipulating sterol levels has shown promising results in increasing total yield (Berli *et al.*, 2021) [3].

Table 1: Effects of organic, inorganic and biological nutrient inputs with phytosterols on growth of banana (*Musa* spp., cv. Poovan).

Treatments	Plant height (cm)				Pseudostem girth (cm)				Phyllochron (Days)	Days from Planting to shooting (Days)	Days taken from shooting to harvest (Days)	Total crop duration (Days)
	3 MAP	5 MAP	7 MAP	Shooting	3 MAP	5 MAP	7 MAP	Shooting				
T ₁	62.71	126.38	172.92	233.17	25.52	37.72	44.86	57.24	10.11	272.21	121.32	393.53
T ₂	74.72	139.51	188.16	248.68	28.74	39.96	48.28	60.47	8.77	256.01	114.57	370.58
T ₃	71.85	136.51	184.33	244.76	27.90	39.38	47.43	59.64	9.12	260.24	116.36	376.60
T ₄	77.53	142.85	192.12	252.90	29.60	40.48	49.06	61.28	8.39	252.11	112.80	364.91
T ₅	68.75	133.05	180.38	240.79	27.07	38.83	46.49	58.88	9.44	264.38	118.11	382.49
T ₆	65.80	130.06	176.59	236.92	26.27	38.31	45.62	58.04	9.78	268.35	119.74	388.09
T ₇	85.66	152.57	202.90	264.09	31.98	42.12	51.44	63.68	7.35	240.84	107.94	348.78
T ₈	80.29	145.83	195.83	256.69	30.43	41.02	49.86	62.07	8.02	248.35	111.13	359.48
T ₉	88.27	155.86	206.51	267.62	32.72	42.63	52.19	64.42	7.02	237.28	106.42	343.70
T ₁₀	83.00	149.01	199.43	260.42	31.22	41.59	50.67	62.89	7.7	244.55	109.49	354.04
S.Ed	1.27	1.48	1.69	1.73	0.35	0.25	0.37	0.35	0.16	1.75	0.74	2.49
CD @ 5%	2.56	2.95	3.36	3.45	0.72	0.49	0.73	0.72	0.31	3.49	1.49	4.98

Table 2: Effects of organic, inorganic and biological nutrient inputs with phytosterols on yield of banana (*Musa* spp., cv. Poovan).

Treatments	Number of fingers per hand	Number of fingers per bunch	Bunch weight (Kg/plant)	Total yield (t/ha)
T ₁	12.51	150.25	13.38	30.24
T ₂	13.70	165.22	15.94	36.02
T ₃	13.41	161.59	15.31	34.60
T ₄	14.03	169.48	16.62	37.56
T ₅	13.11	157.84	14.67	33.15
T ₆	12.80	153.98	14.04	31.73
T ₇	15.00	181.80	18.69	42.24
T ₈	14.35	173.49	17.29	39.08
T ₉	15.33	186.11	19.43	43.91
T ₁₀	14.69	177.75	17.99	40.66
S.Ed	0.13	1.79	0.30	0.69
C.D @ 5%	0.28	3.59	0.61	1.37

Conclusion

The findings of the present investigation demonstrated that integrating organic manures with campesterol, stigmasterol, and reduced inorganic fertilizer levels significantly enhanced growth and yield attributes of banana cv. Poovan. Among the thirteen treatments, T₉-75% RDF + Vermicompost @ 4 kg plant⁻¹ + Neem cake @ 1 kg plant⁻¹ + Bio NPK liquid consortia + campesterol and stigmasterol (SL) @ 0.2% consistently recorded superior performance in all growth parameters including plant height, pseudostem girth, phyllochron and crop duration, as well as yield attributes such as number of fingers per hand, number of fingers per bunch, bunch weight and total yield. The application of inorganic fertilizer alone T₁-100% RDF resulted in the lowest growth and yield. These results conclude that the combined use of organic inputs with reduced chemical fertilizer, campesterol and stigmasterol is more effective in enhancing banana productivity. Therefore,

the treatment T₉ can be recommended for achieving improved growth and higher yield in Poovan banana cultivation.

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