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Effect of integrated nutrient management on growth, yield and quality of spinach beet (*Beeta vulgaris var. bengalensis*)

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Abstract
The present investigation was conducted at the Agricultural Research Farm, Department of Horticulture, at Suresh Gyan Vihar University, Jaipur (Rajasthan) during the *Rabi* season of 2023-24 to study the "Effect of Integrated Nutrient Management on Growth, Yield, and Quality of Spinach Beet (*Beta vulgaris var. bengalensis)."* The experiment was arranged in a Randomized Block Design (RBD) with 12 treatments, each replicated three times using the variety 'All Green.' The treatments were: Control (T_0), Poultry Manure (4 tons/ha) (T_1), Vermicompost (10 tons/ha) (T_2), Phosphate Solubilizing Bacteria (PSB) - 10 kg/ha (T_3), *Azotobacter* (100%) - 10 kg/ha (T_4), RDF (50%) + Poultry Manure (50%) (T_5), RDF (50%) + Vermicompost (50%) (T_6), RDF (25%) + Poultry Manure (50%) + *PSB* (25%) (T_7), RDF (25%) + Vermicompost (50%) + *PSB* (25%) (T_8), RDF (25%) + Poultry Manure (50%) + *Azotobacter* (25%) (T_9), RDF (25%) + Vermicompost (50%) + *Azotobacter* (25%) (T_{10}), RDF (25%) + Vermicompost (25%) + *PSB* (25%) + *Azotobacter* (25%) (T_{11}).
The maximum values for plant height (25.07 cm), the number of leaves per plant (36.22 cm), fresh weight of the whole plant (118.68 g), fresh weight of shoot (74.45 g), fresh weight of root (44.12 g), yield/ plot (6.79 kg/ha), yield (107.50 q/ha), moisture content (90.35%), shelf life (2.44 days), Vitamin A (12.67 IU/100 g), Ascorbic acid content (63.80 mg/100 g), chlorophyll (38.90 mg/100 g), and iron content (1.71 mg/100 g) were recorded in T_{11}, which applied RDF (25%) + Vermicompost (25%) + *PSB* (25%) + *Azotobacter* (25%). And the shoot-to-root ratio (2.76) was highest in T_5.

Keywords: RBD, biofertilizers, vermicompost, Azotobacter, PSB, spinach beet

Introduction
Spinach Beet, or Indian Spinach (*Beta vulgaris* var. bengalensis), is a leafy vegetable from the Chenopodiaceae family, native to Indo-China. It is rich in vitamin A and calcium and thrives in various soil types, making it highly nutritious (Gowda *et al*., 2022) [2]. The leaves contain 88.4% moisture, 3.4% protein, 0.8 g fat, 3.7% fiber, 6.5% carbohydrates, 46 calories, 5862 IU vitamin A, and significant amounts of vitamins C, B1, B2, calcium, phosphorus, potassium, iron, and antioxidants. Spinach Beet grows best in well-drained loamy soil with a pH of 6-6.5 and is sensitive to high temperatures, which can cause bolting. It is a cool-season crop prevalent in tropical and subtropical regions (Toppo *et al*., 2022) [10].
Vegetables like Spinach Beet are vital for a balanced diet, providing essential nutrients. In India, Spinach Beet is a primary leafy vegetable, and sustainable farming practices, such as Integrated Nutrient Management (INM), are increasingly used to enhance its production.
Vermicompost is an organic fertilizer created by earthworms and microorganisms. It offers a slow-release source of nutrients and enhances soil health, proving more effective than chemical fertilizers over time (Vishwakarma & Chauhan, 2023) [12].
Biofertilizers contain beneficial microbes that improve soil productivity, plant health, and yield quality. For example, Bacillus species aid in nutrient uptake and disease resistance. Poultry Manure (PM) is a cost-effective, eco-friendly option that enhances soil structure and nutrient content, particularly nitrogen levels, reducing the need for chemical fertilizers (Gururani *et al*., 2023) [3].

Materials and Methods

The experiment was conducted during the *Rabi* season of 2023 at the Agricultural Research Farm, Department of Horticulture at Suresh Gyan Vihar University, Jagatpura, Jaipur. The variety used was 'All Green' of Spinach beet, and the study followed a Randomized Block Design (RBD) with twelve treatments in three replications. The treatments included organic sources of nutrients like poultry manure, vermicompost, and biofertilizers such as *Azotobacter* and *PSB*, combined with chemical fertilizers applied as 25% and 50% Recommended Dose of Fertilizers (RDF).

The treatments were: Control (T_0), Poultry Manure (4 tons/ha) (T_1), Vermicompost (10 tons/ha) (T_2), *Phosphate Solubilizing Bacteria (PSB)* - 10 kg/ha (T_3), *Azotobacter* (100%) - 10 kg/ha (T_4), RDF (50%) + Poultry Manure (50%) (T_5), RDF (50%) + Vermicompost (50%) (T_6), RDF (25%) + Poultry Manure (50%) + *PSB* (25%) (T_7), RDF (25%) + Vermicompost (50%) + *PSB* (25%) (T_8), RDF (25%) + Poultry Manure (50%) + *Azotobacter* (25%) (T_9), RDF (25%) + Vermicompost (50%) + *Azotobacter* (25%) (T_{10}), RDF (25%) + Vermicompost (25%) + *PSB* (25%) + *Azotobacter* (25%) (T_{11}).

Experimental plots, each measuring 3 meters by 2 meters, were established after careful field preparation. Biofertilizers were mixed with organic manure and applied according to the treatment specifications. Three to four seeds were sown per hill with a spacing of 15×10 cm. Thinning was done 20 days after sowing, and all other cultural and plant protection practices were followed as recommended for a healthy crop.

Quality parameters such as moisture content, shelf life, carotene content, vitamin C, chlorophyll content, and iron content were observed. Data were analyzed statistically using analysis of variance (ANOVA), with statistical significance tested using the 'F' value at a 5% significance level. When the F value was significant, the critical difference was calculated at the same level (Bindu *et al.*, 2021) [1].

Poultry manure, vermicompost, and biofertilizers were applied before sowing, while half of the nitrogen (N) and all of the phosphorus (P) and potassium (K) doses of chemical fertilizers were applied as a basal dose. The remaining half of the nitrogen was applied after cutting.

Results and Discussion

Growth parameters, such as plant height (cm) and the number of leaves per plant, were recorded and presented in tables.

Plant height (cm)

The data presented in Table 1 on plant height reveal significant differences among the treatments at both 30 and 60 days after sowing (DAS). At 30 DAS, the tallest plants were recorded in treatment T_{11}, reaching 25.07 cm, with treatment T_{10} (23.44) following closely behind. In contrast, the shortest plants were observed in the control treatment (T_0), with a height of 9.56 cm (Jabeen *et al.*, 2017) [4]. At 60 DAS, treatment T_{11} again led with a plant height of 32.91 cm. Treatments T_{10} (32.06 cm), T_9 (31.96 cm), and T_8 (31.26 cm) showed similar results to T_{11}, while the control (T_0) continued to record the minimum height.

The observed increase in plant height can be attributed to the enhanced availability of nitrogen from inorganic sources and biofertilizers, which promoted root and shoot growth through nitrogen fixation and improved phosphorus availability from microbial inoculation. Moreover, the foliar application of Azotobacter and PSB likely contributed to better nutrient uptake, photosynthesis, and a balanced distribution of nutrients between source and sink tissues, all of which are essential for various biochemical processes (Vishwakarma & Chauhan, 2023) [12] in Indian spinach.

Number of leaves per plant

The data on the number of leaves per plant, as presented in Table 1, demonstrate significant variations among the different treatments applied to spinach beet. Treatment T_{11} exhibited the highest number of leaves per plant (36.22), closely followed by T_{10} (35.03). Conversely, the control treatment (T_0) resulted in the fewest leaves per plant (21.73). The increase in leaf count is likely due to enhanced metabolic activity driven by an optimal nitrogen supply, which promotes the production of carbohydrates and phytohormones (Gowda *et al.*, 2022) [2].

Yield Parameters

Fresh Weight of the Whole Plant

The analysis revealed that treatment T_{11} achieved the highest fresh weight of the whole plant (118.54 g), significantly exceeding the other treatments under evaluation and statistically comparable to treatments T_{10}, T_9, and T_8. The control treatment (T_0) recorded the lowest fresh weight (60.17 g). The superior plant weight observed in treatment T_{11} is likely due to the combined application of 25% RDF, 25% Vermicompost, 25% Azotobacter, and 25% PSB, which together provided an optimal nitrogen supply. The microbial consortium within the biofertilizers, comprising nitrogen-fixing, phosphorus-solubilizing, and zinc-solubilizing microbes, likely enhanced protein synthesis, thereby increasing the plant's overall weight (Varikuppala *et al.*, 2021) [11].

Fresh Weight of the Shoot

The data also indicated significant differences in shoot weight across the various treatments. Treatment T_{11} once again led with the highest shoot weight (74.42 g), outperforming the other treatments. It was followed by treatments T_{10}, T_8, and T_7. The control treatment (T_0) exhibited the lowest shoot weight (36.10 g). The integrated use of nutrient sources appears to enhance photosynthesis and regulate enzyme activity, which boosts metabolic processes in spinach beet (Shinde *et al.*, 2018) [8].

Fresh weight of root

In the Table 1 Significant differences were observed in the root weight of spinach beet as a result of various treatment combinations. The data showed that the highest root weight (45.12 g) was recorded in treatment T_8, which was statistically comparable to treatments T_{11}, T_{10}, T_9, and T_7. In contrast, the lowest root weight (21.69 g) was observed in treatment T_5. The role of biofertilizers in enhancing root health is crucial, as they contribute to the overall growth of both the shoot and stem in beetroot (Mounika *et al.*, 2021) [5].

Shoot-to-Root Ratio

In the Table 1 data on the fresh weight of marketable produce indicated variations in the shoot- to-root ratio across different biofertilizer treatments in spinach beet. The highest shoot-to-root ratio (2.75) was recorded in treatment T_5, surpassing all other treatments in the study. Treatments T_4 and T_3 followed closely. The lowest shoot-to-root ratio (1.36) was observed in treatment T_1, where poultry manure was applied (Shinde *et al.*, 2018) [8].

Yield per Plot (kg)

The yield per plot also showed significant differences based on the application of various treatment combinations. Treatment T_{11}

recorded the highest yield per plot (6.79 kg), significantly outperforming the other treatments and being statistically on par with T_{10}. The lowest yield (2.77 kg) was recorded in the control treatment (T_0). The combined use of nutrient sources, including inorganic fertilizers, organic fertilizers, and biofertilizers, has been shown to enhance plant height, leaf number per plant, and overall plant weight in crops like lettuce (Nathi *et al.*, 2023) [6].

Yield per hectare (q)

Table 1 reveals significant differences in yield per hectare (q) among the various treatments. The study found that the maximum yield per hectare (107.50 q) was recorded in treatment T_{11}, which was statistically on par with treatment T_{10}. In contrast, the lowest yield per hectare (45.83 q) was obtained in the control treatment (T_0). The yield per hectare is influenced by overall plant growth, the weight of the entire plant, and the total yield per plot of spinach beet (Paithanker and Gore, 2019) [7].

Quality Parameters

Moisture Content (%)

The data showed significant variations in moisture content resulting from different treatment combinations applied to spinach beet. The highest moisture content (95.24%) was recorded in the control treatment (T_0). The lowest moisture content (90.15%) was observed in treatment T_{11}. Vegetables with higher moisture content tend to deteriorate more rapidly. The reduced moisture content in treatment T_{11} could be attributed to higher dry matter accumulation, a result of increased photosynthetic activity and the availability of macro- and micronutrients (Bindu *et al.*, 2021) [1], consistent with findings in spinach beet.

Shelf Life (Days)

Table 2 indicates significant differences in shelf life (days) across the different treatments. The longest shelf life (2.44 days) was recorded in treatment T_{11}, which was statistically comparable to treatment T_{10}. On the other hand, the shortest shelf life (1.42 days) was observed in the control treatment (T_0). The extended shelf life resulting from the combined application of inorganic nutrients, Azotobacter, PSB, and vermicompost could be due to an improved nutrient supply, which helps maintain metabolic balance even post-harvest. A healthy plant with moderate moisture and reduced carbohydrate loss likely contributed to the prolonged shelf life (Bindu *et al.*, 2021) [1].

Ascorbic acid content (mg/100g)

The data indicated significant differences in moisture content resulting from the application of various treatment combinations in spinach beet. The study revealed that the ascorbic acid content was significantly highest (63.80 mg/100 g) in treatment T_{11}, outperforming the other treatments and statistically comparable to treatments T_{10}, T_9, T_8, and T_7. The lowest ascorbic acid content (47.10 mg/100g) was observed in the control treatment (T_0). The use of biofertilizers may have stimulated the production of growth-promoting substances, thereby accelerating physiological processes such as carbohydrate synthesis in spinach beet (Zalte *et al.*, 2023) [14].

Vitamin A Content (IU/100g)

Table 2 shows significant differences in vitamin A content among the different treatments. The study revealed that the highest vitamin A content (12.67 IU/100g) was recorded in treatment T_{11}, which was statistically on par with treatments T_{10} and T_9. Conversely, the lowest vitamin A content (4.65 IU/100g) was found in the control treatment (T_0). The combined application of nutrient sources, such as 25% RDF, 25% vermicompost, 25% Azotobacter, and 25% PSB, significantly enhanced the carotene content in spinach beet (Thampi *et al.*, 2019) [9].

Chlorophyll Content (mg/100g)

The data revealed significant differences in chlorophyll content across the different treatments in spinach beet. The highest chlorophyll content (38.90 mg/100g) was recorded in treatment T_{11}, statistically similar to treatments T_{10}, T_9, T_7, and T_8. The lowest chlorophyll content (31.01 mg/100g) was observed in treatment T_2 (Paul *et al.*, 2018) [15]. The superior chlorophyll content in treatment T_{11} can be attributed to the application of 25% RDF, 25% vermicompost, 25% Azotobacter, and 25% PSB, which provided an optimal supply of nitrogen. The microbial consortium in the biofertilizer, including nitrogen-fixing, phosphorus-solubilizing, and zinc- solubilizing microbes, likely enhanced protein synthesis, leading to an increase in chlorophyll levels in spinach beet. These findings are consistent with the results of Paithankar and Gore (2019) [7].

Iron content (mg/100g)

The data on iron content (mg/100g) presented in Table 2 showed significant differences among the various treatments. The study found that the highest iron content (1.71 mg/100g) was recorded in treatment T_{11}, which was statistically similar to treatments T_{10} and T_9. On the other hand, the lowest iron content (1.10 mg/100g) was observed in the control treatment (T_0). These results are consistent with findings in spinach reported by Zalte *et al.*, (2023) [14].

Economics

Net Return (Rupees)

The analysis indicated significant variations in net returns due to the application of different treatment combinations in spinach beet. The data revealed that the highest net return (Rs. 99, 926.00) was recorded in treatment T_{11}, outperforming the other treatments. Conversely, the lowest net return (Rs. 27,265.29) was found in the control treatment (T_0) as reported by Mounika *et al.*, (2021) [5].

B: C Ratio Regarding the benefit-cost (B: C) ratio, Table 2 highlighted significant differences among the various treatments. The study demonstrated that the highest B: C ratio (3.34) was recorded in treatment T_{11}. In contrast, the lowest B: C ratio (1.26) was observed in the control treatment (T_0). These findings are in alignment with the results of Yadav *et al.*, (2019) [13].

Table 1: Effect of integrated nutrient management on growth and yield of Spinach beet (*Beeta vulgaris var. bengalensis*)

Treatment	Plant height at 30 DAS	Plant height at 60 DAS	No. of leaves/plant	Fresh weight of whole plant (g)	Weight of shoot (g)	Weight of root (g)	Shoot: root ratio	Yield / Plot (kg)	Yield/ ha (q.)
T_0	9.56	18.09	21.73	60.17	36.10	24.07	1.50	2.77	45.83
T_1	15.78	24.57	29.87	72.35	41.73	30.29	1.36	4.26	71.00
T_2	17.55	26.51	29.81	87.11	54.01	33.10	1.63	5.91	98.66
T_3	16.47	25.10	27.20	78.94	50.63	27.31	1.86	4.60	76.66
T_4	18.80	28.25	30.82	90.03	62.50	27.53	2.27	4.85	80.83
T_5	16.86	27.88	28.24	82.02	60.33	21.69	2.76	4.73	78.83
T_6	20.19	29.49	32.90	102.32	64.30	40.35	1.59	5.29	88.16
T_7	21.17	30.64	33.10	110.73	71.52	39.54	1.81	5.22	87.15
T_8	21.73	31.26	34.06	115.62	73.39	45.23	1.62	5.49	94.33
T_9	22.37	31.96	34.40	111.16	70.40	40.76	1.73	5.66	93.50
T_{10}	23.44	32.06	35.03	114.68	73.37	41.31	1.78	6.25	104.16
T_{11}	25.07	32.91	36.22	118.68	74.45	44.12	1.68	6.79	107.50
S.E.(m) +_	0.61	1.07	1.07	4.40	3.05	2.40	0.06	0.31	3.26
CD at 5%	1.86	3.25	3.26	13.35	9.26	7.29	0.21	0.93	9.88

Table 2: Effect of integrated nutrient management on quality and economics of Spinach beet (*Beeta vulgaris var. bengalensis*)

Treatment	Moisture%	Shelf Life (Days)	Ascorbic acid content (mg/100 g)	Vit. A (IU/100 g)	Chlorophyll (mg/100 g)	Iron (mg/100 g)	Net Return	B: C Ratio
T_0	95.24	1.42	47.1	4.65	32.19	1.1	27265.29	1.26
T_1	95.07	1.51	50.2	6.35	33.8	1.15	51500.00	1.53
T_2	94.39	1.63	52.13	7.21	31.01	1.2	66696.00	1.29
T_3	94.09	1.72	55.06	8.1	35.64	1.22	68396.00	3.03
T_4	93.43	1.79	59.83	8.52	32.98	1.25	73896.00	3.28
T_5	93.40	1.81	54.33	8.7	34.04	1.27	64657.50	2.28
T_6	93.53	1.90	56.5	9.38	34.22	1.32	63516.08	1.69
T_7	92.80	2.01	58.07	9.46	36.43	1.47	76325.46	2.71
T_8	90.70	2.10	59.9	10.2	35.02	1.52	71795.94	2.26
T_9	92.45	2.13	60.95	10.74	37.16	1.57	86479.41	3.06
T_{10}	90.55	2.32	62.95	11.05	37.51	1.65	87305.33	2.34
T_{11}	90.35	2.44	63.8	12.67	38.9	1.71	99926.00	3.34
S.E.(m) +_	2.85	0.07	2.30	0.41	1.39	0.06		
CD at 5%	8.66	0.22	6.76	1.20	4.09	0.18		

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