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Influence of Organic Manures and Bio-fertilizers on the Growth and Productivity of Indian Spinach

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Authors' contributions

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

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ABSTRACT

The present study was conducted during the winter season of 2024–2025 at CRC-3, Turari, Department of Horticulture, ITM University, Gwalior (M.P.). The experiment was laid out in a Randomized Block Design (RBD) comprising ten treatments, replicated thrice. Treatments included combinations of organic manures (FYM and Vermicompost) and bio-fertilizers (PSB and *Azotobacter*). The results demonstrated that the combined application of FYM (10 t/ha), Vermicompost (4 t/ha), PSB (8 kg/ha), and *Azotobacter* (8 kg/ha) (T_{10}) significantly enhanced growth and yield attributes. The highest plant height (25.50 cm), number of leaves per plant (15.00), fresh weight per plant (88.61 g), yield per plot (7.60 kg), and yield per hectare (168.88 q/ha) were recorded under T_{10}. In contrast, quality parameters such as chlorophyll content (7.93 mg/100g), and total soluble solids (8.06 °Brix) were highest in T_7 (FYM 12 t/ha + Vermicompost 5 t/ha + PSB 10 kg/ha). Root length (13.73 cm) was maximized in T_5 (Vermicompost 10 t/ha + PSB 10 kg/ha), and

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the highest number of roots per plant (2.97) was recorded under T_3 (FYM 25 t/ha + PSB 10 kg/ha). Treatments T_7 and T_{10} were found to be significantly superior in enhancing both quality and yield parameters.

Keywords: Farm Yard Manure (FYM); Vermicompost (VC); Phosphate Solubilizing Bacteria (PSB) and Azotobacter.

1. INTRODUCTION

Indian spinach (*Beta vulgaris* var. *bengalensis*), a leafy vegetable belonging to the family Chenopodiaceae, has a chromosome number of 2n = 2x = 18. It is native to the Indo-Chinese region and is known for its high nutritional value, often referred to as a "mine of minerals." The crop is a rich source of essential nutrients including vitamin A, vitamin C, calcium, thiamine, folic acid, niacin, antioxidants, amino acids, and minerals such as iron, potassium, copper, and zinc. These constituents play a significant role in maintaining human health by contributing to blood pressure regulation, red blood cell formation, nucleic acid synthesis, and digestion (Thamburaj & Singh, 2015). Additionally, Indian spinach exhibits therapeutic benefits against conditions such as cancer, cataracts, and ulcers.

This crop is considered economically viable for vegetable production due to its high yield potential and the production of tender, succulent green leaves (Nayak & Maji, 2018). In India, the major spinach-producing states include Uttar Pradesh, Gujarat, Maharashtra, and West Bengal. In the Jammu region, it is cultivated extensively in the districts of Jammu, Samba, Kathua, Udhampur, Reasi, Ramban, Doda, Kishtwar, and Poonch, covering an area of approximately 83 thousand hectares with an annual production of 0.9 million metric tonnes (FAO, 2023).

Indian spinach thrives under warm climatic conditions, although excessively high temperatures may induce premature bolting, leading to reduced marketable yield. It is adaptable to a wide range of soil types, provided they have good fertility and drainage. Optimal soil moisture at the time of sowing is essential to ensure successful germination and vigorous early growth.

The use of organic manures such as farmyard manure (FYM) and vermicompost has been shown to enhance not only crop yield but also the physical, chemical, and biological properties of soil. These improvements in soil health contribute to better fertility, enhanced productivity, and greater water-holding capacity Bio-fertilizers, including phosphate-solubilizing bacteria (PSB) and nitrogen-fixing organisms such as *Azotobacter*, are eco-friendly, cost-effective alternatives to chemical fertilizers. They support sustainable agriculture by improving nutrient availability and uptake, reducing dependency on synthetic inputs.

In recent years, increasing concern has been raised regarding the presence of chemical residues and heavy metals in leafy vegetables, which may pose risks to both human health and soil ecology. The adoption of organic manures and bio-fertilizers in vegetable production offers a sustainable solution that not only ensures crop productivity but also enhances food safety and environmental health.

Despite these known benefits, limited research has been conducted on the integrated use of organic manures and bio-fertilizers in the cultivation of leafy vegetables such as palak (Indian spinach). Therefore, the present investigation was undertaken to evaluate the impact of these inputs on the growth, yield, and quality of Indian spinach under field conditions.

Keeping in view the above consideration the present investigation is under taken with following objectives: -

1. To study the impact of organic manures and bio-fertilizers on growth parameters
2. To determine the impact of organic manures and bio-fertilizers on yield

2. MATERIALS AND METHODS

A field experiment was conducted during the winter season of 2024–2025 at the Crop Research Centre (CRC-3), Turari, Department of Horticulture, ITM University, Gwalior, Madhya Pradesh. The trial was laid out in a Randomized Block Design (RBD) with ten treatments replicated three times. The treatments included

different combinations of organic manures and biofertilizers, as detailed below:

- T_1 – Control (no inputs)
- T_2 – FYM @ 25 t/ha
- T_3 – FYM @ 25 t/ha + PSB @ 10 kg/ha
- T_4 – Vermicompost @ 10 t/ha
- T_5 – Vermicompost @ 10 t/ha + PSB @ 10 kg/ha
- T_6 – FYM @ 12 t/ha + Vermicompost @ 5 t/ha
- T_7 – FYM @ 12 t/ha + Vermicompost @ 5 t/ha + PSB @ 10 kg/ha
- T_8 – Azotobacter @ 10 kg/ha
- T_9 – Azotobacter @ 10 kg/ha + PSB @ 10 kg/ha
- T_{10} – FYM @ 10 t/ha + Vermicompost @ 4 t/ha + PSB @ 8 kg/ha + Azotobacter @ 8 kg/ha

Each experimental plot measured 3 m × 1.5 m, with a plant spacing of 45 cm between rows and 10 cm between plants. The field was thoroughly prepared by ploughing and levelling to create a uniform seedbed. Standard cultural practices, including weeding, thinning, and irrigation, were carried out as needed to ensure proper crop growth. Well-decomposed farmyard manure (FYM), vermicompost (VC), phosphate solubilizing bacteria (PSB), and Azotobacter were used for treatment applications. Organic manures were incorporated into the soil as a basal dose prior to sowing, while the biofertilizers (PSB and Azotobacter) were used as seed treatments. The control plot (T_1) received no organic or biofertilizer input. The Indian spinach variety 'Pusa All Green' was used for the study. Observations were recorded at the time of harvest. For each treatment, data were collected from five randomly selected plants per plot. The following growth, yield, and quality parameters were recorded:

- Plant height (cm)
- Number of leaves per plant
- Leaf length (cm)
- Leaf breadth (cm)
- Fresh weight of whole plant (g)
- Root length (cm)
- Number of roots per plant
- Yield per plot (kg/plot)
- Yield per hectare (q/ha)
- Leaf chlorophyll content (mg/100 g)
- Total soluble solids (°Brix)

The collected data were subjected to appropriate statistical analysis to interpret treatment effects on the growth, yield, and quality of Indian spinach. The results are presented and discussed in the following sections.

3. RESULTS AND DISCUSSION

The data pertaining to growth, yield, and quality parameters of Indian spinach as influenced by different organic manures and biofertilizers are presented in Table 1 and Table 2. The results revealed that application of organic inputs and biofertilizers significantly enhanced the growth, yield, and quality attributes of Indian spinach compared to the control treatment.

Plant height ranged from 20.58 cm to 25.50 cm, with an overall mean of 23.28 cm. The tallest plants (25.50 cm) were observed in treatment T_{10} [FYM (10 t/ha) + Vermicompost (4 t/ha) + PSB (8 kg/ha) + Azotobacter (8 kg/ha)], which was statistically at par with T3 (24.23 cm) and T8 (24.66 cm). The shortest plants (20.58 cm) were recorded in the control (T_1). The enhanced plant height under T10 may be attributed to the synergistic effect of FYM, vermicompost, and biofertilizers that play a crucial role in enhancing cell division, elongation, and overall metabolic activity. These results are in line with the findings of Thapa et al. (2021) and Krishna et al. (2022) in spinach.

The number of leaves per plant ranged from 9.50 to 15.33, with an average of 12.45. The highest number of leaves (15.33) was recorded under T_{10}, which was statistically at par with T_4 (13.61). The lowest number of leaves (9.50) was observed in T_1 (control). The increase in the number of leaves may be due to improved soil aeration, microbial activity, and nutrient availability promoted by organic inputs and biofertilizers. Similar findings have been reported by Anwar et al. (2017), Sharma & Agarwal, 2014, Jamoh O (2021), and Krishna et al. (2022) in leafy vegetables.

Leaf length ranged between 11.53 cm to 13.16 cm, with a mean of 12.03 cm. The longest leaves were recorded in T_9 (13.16 cm), followed by T_5 (12.63 cm) and T2 (12.33 cm), all statistically at par. The shortest leaves (11.53 cm) were found in T_1 (control). The improved leaf length under treatments with biofertilizers may be due to better cell elongation and tissue formation induced by enhanced nutrient uptake. These observations are supported by Khadse et al. (2021) and Vishwakarma & Chauhan (2023).

Table 1. Impact of organic manures and biofertilizers on plant height (cm), number of leaves per plant, leaf length (cm), leaf breath (cm), Fresh weight of whole plant (g), root length(cm) of Indian Spinach at time of harvest

Treatment No.	Treatments	Plant height (cm)	Number of leaves per plant	Leaf length (cm)	Leaf breath (cm)	Fresh weight of whole plant (g)	Root length(cm)
T_1	Control	20.58	9.50	11.53	6.13	65.08	11.62
T_2	FYM (25 t/ha)	22.80	13.00	12.33	7.06	75.55	12.68
T_3	FYM (25 t/ha) + PSB (10 kg/ha)	24.23	13.13	12.03	6.60	75.61	13.33
T_4	Vermicompost (10 t/ha)	23.51	13.61	11.63	6.93	77.88	12.99
T_5	Vermicompost 10 t/ha + PSB (10 kg/ha)	24.06	11.53	12.63	6.60	72.26	13.73
T_6	FYM (12 t/ha) + Vermicompost (5 t/ha)	23.89	10.78	11.60	6.60	70.61	12.90
T_7	FYM (12 t/ha) + Vermicompost (5 t/ha) + PSB (10 kg/ha)	23.88	13.14	11.90	7.53	72.97	12.41
T_8	Azotobacter (10 kg/ha)	24.66	13.21	11.63	6.40	83.15	12.21
T_9	Azotobacter + PSB each @10 kg/ha	23.70	11.53	13.16	7.46	69.40	11.63
T_{10}	FYM (10 t/ha) + Vermicompost (4 t/ha) + PSB (8 kg/ha) + Azotobacter (8 kg/ha)	25.50	15.00	11.86	6.66	88.61	13.68
SEm (±)		0.61	0.68	0.46	0.28	1.58	0.64
CD (5%)		1.29	1.43	0.97	0.60	3.23	1.35

Table 2. Impact of organic manures and biofertilizers on, number of roots per plant, yield per plot (Kg/ha), yield per hectare (q/ha), leaf chlorophyll content (mg/100g), total soluble solid (°B) of Indian Spinach at time of harvest

Treatment No.	Treatments	Number of roots per plant	Yield per plot (Kg/ha)	Yield per hectare (q/ha)	Leaf chlorophyll content (mg/100g)	Total soluble solid (°B)
T_1	Control	1.56	5.19	115.47	5.22	5.40
T_2	FYM (25 t/ha)	2.59	6.53	145.18	5.68	6.13
T_3	FYM (25 t/ha) + PSB (10 kg/ha)	2.97	6.81	151.47	6.80	6.63
T_4	Vermicompost (10 t/ha)	2.72	6.85	152.36	6.23	7.16
T_5	Vermicompost 10 t/ha + PSB (10 kg/ha)	2.94	6.46	143.70	6.72	6.73
T_6	FYM (12 t/ha) + Vermicompost (5 t/ha)	2.70	6.69	148.66	6.39	7.03
T_7	FYM (12 t/ha) + Vermicompost (5 t/ha) + PSB (10 kg/ha)	2.64	6.85	152.29	7.93	8.06
T_8	Azotobacter (10 kg/ha)	2.52	6.94	154.36	7.66	6.76
T_9	Azotobacter + PSB each @10 kg/ha	2.52	6.18	137.33	6.33	6.33
T_{10}	FYM (10 t/ha) + Vermicompost (4 t/ha) + PSB (8 kg/ha) + Azotobacter (8 kg/ha)	2.55	7.60	168.88	7.26	7.96
SEm (±)		0.25	0.22	5.07	0.40	0.46
CD (5%)		0.54	0.48	10.66	0.84	0.98

Leaf breadth varied from 6.13 cm to 7.53 cm, with a mean value of 6.80 cm. The maximum leaf breadth (7.53 cm) was recorded in T_7 [FYM (12 t/ha) + Vermicompost (5 t/ha) + PSB (10 kg/ha)], which was statistically at par with T_4 (6.93 cm). The minimum value (6.13 cm) was found in T_1. The increase in leaf breadth may be attributed to the steady nutrient availability from organic inputs. Similar results were observed by Bindu et al. (2021) in Spinach beet.

Fresh weight ranged from 65.08 g to 88.61 g, with a mean of 75.12 g. The maximum fresh weight (88.61 g) was observed in T_{10}, while the minimum (65.08 g) was found in the control. The significant increase in plant biomass under T_{10} may be due to improved carbohydrate accumulation, photosynthesis, and overall plant vigor due to enhanced microbial activity. These results are supported by Nadre, V. P. (2022) and Vishwakarma & Chauhan (2023).

Root length ranged from 11.62 cm to 13.73 cm, with an average of 12.72 cm. The longest roots (13.73 cm) were recorded in T_5 [Vermicompost 10 t/ha + PSB 10 kg/ha], which was statistically at par with T_2, T_4, T_6, and T_7. The shortest root length (11.62 cm) was recorded in T_1. Enhanced root growth can be attributed to improved soil structure, moisture retention, and nutrient uptake facilitated by organic manures. Similar results were reported by Kumar et al. (2018) in palak.

The number of roots per plant ranged from 1.56 to 2.97, with an average of 2.57. The highest root number (2.97) was recorded in T_3 [FYM 25 t/ha + PSB 10 kg/ha] and was statistically at par with several treatments including T_2, T_4, T_5, T_6, T_7, T_8, T_9, and T_{10}. The minimum (1.56) was noted in the control. The increased root number may be due to enhanced root stimulation and nutrient mobilization by biofertilizers. This is in accordance with the findings of Kumawat et al. (2020).

The yield per plot varied from 5.19 kg to 7.60 kg, with an average of 6.48 kg. The highest yield was recorded in T_{10}, followed by T6 (5.78 kg). The lowest yield was observed in T_1. The improvement in yield could be attributed to the integrated nutrient management that provided a balanced supply of macro and micronutrients (Jha et al., 2009). Similar findings were reported by Jabeen et al. (2018) and Krishna et al. (2022).

The yield per hectare ranged from 115.47 q/ha to 168.88 q/ha, with an average of 144.03 q/ha. The maximum yield was recorded under T_{10}, while the minimum was observed in the control. The yield increase under T_{10} may be due to improved plant growth parameters and better nutrient availability. These results are supported by Diana and Nehru (2014), who reported similar effects of biofertilizers and organic inputs on leafy vegetable yields.

Chlorophyll content varied from 5.22 to 7.93 mg/100g, with an average of 6.62 mg/100g. The highest value was recorded in T_7 [FYM 12 t/ha + Vermicompost 5 t/ha + PSB 10 kg/ha], followed by T_8 (7.66 mg/100g) and T_{10} (7.26 mg/100g), all statistically at par. The lowest content (5.22 mg/100g) was found in the control. Enhanced chlorophyll levels may be attributed to improved nitrogen availability, a key component of chlorophyll. Similar observations were made by Jabeen et al. (2018) and Krishna et al. (2022). Furthermore, maximum chlorophyll was recorded during the first cutting, decreasing in subsequent harvests, consistent with Gairola et al. (2009).

TSS values ranged from 5.40 to 8.06 °Brix, with a mean of 6.82 °Brix. The maximum TSS (8.06 °Brix) was observed in T_7, which was statistically at par with T_4 (7.16 °Brix) and T_{10} (7.96 °Brix). The lowest TSS (5.40 °Brix) was found in the control. The increase in TSS may be attributed to enhanced photosynthetic activity and carbohydrate accumulation supported by organic and biofertilizer treatments. These results are corroborated by Kumar et al. (2020).

4. CONCLUSION

On the basis of the recorded data, it was observed that different doses of FYM, Vermicompost, Azotobacter and PSB significantly impacted the quality character of Indian Spinach. It was observed that the plant when applied FYM (10 t/ha) + Vermicompost (4 t/ha) + PSB (8 kg/ha) + Azotobacter (8 kg/ha) (T_{10}) showed the significantly effective response in improving the growth and yield related parameters. The plant height (cm), number of leaves per plant, fresh weight of whole plant (g), yield per plot (Kg/ha), yield per hectare (q/ha) of Indian Spinach was recorded significantly highest with (T_{10}) compared to the control. However, the quality parameter viz., chlorophyll content (mg/100g) and total soluble solid (^oB) was recorded significantly maximum in (T_7) FYM (12 t/ha) + Vermicompost (5 t/ha) + PSB (10 kg /ha).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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