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Effect of Organic Manures and Biofertilizers on Growth and Yield of Herbage Amaranthus (*Amaranthus tricolor* L.)

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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 investigation was conducted during the kharif season of 2026 at the Horticulture Research Farm, Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, Uttar Pradesh. The experimental site was located at 25.57° N latitude and 81.05° E longitude, at an altitude of 98 m above mean sea level. The experiment was conducted to evaluate the effects of different organic manures and biofertilizers on the growth, yield attributes, herbage yield, and economic performance of amaranthus. The soil of the experimental field was medium black, well drained, and suitable for vegetable cultivation. The experiment was laid out in a Randomised Block Design (RBD) using different combinations of organic manures and biofertilizers. The treatments consisted of farmyard manure (FYM), vermicompost, poultry manure, biofertilizers (Azotobacter + PSB), and their combinations. Among all treatments, T_8 (FYM @ 10 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} + Azotobacter + PSB) exhibited the best performance and recorded significantly higher growth and yield parameters than the

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other treatments and the control. The application of T_8 (FYM @ 10 t/ha + vermicompost @ 2.5 t/ha + Azotobacter + PSB) resulted in the maximum plant height (42.97 cm), number of leaves per plant (47.27), number of branches per plant (6.03), plant spread (38.41 cm²), and leaf length (13.51 cm), and the minimum number of days to first clipping (39 days). The maximum spike length (11.76 cm) was observed in T_8. The highest herbage yield was also recorded with T_8 (FYM @ 10 t/ha + vermicompost @ 2.5 t/ha + Azotobacter + PSB), producing 144.88 g plant⁻¹, 12.75 kg plot⁻¹, and 318.74 q ha⁻¹, whereas the control treatment recorded the lowest herbage yield of 39.58 g plant⁻¹, 3.48 kg plot⁻¹, and 87.08 q ha⁻¹. The maximum benefit-cost ratio (2.92:1) was recorded in treatment T6 (vermicompost @ 5 t/ha + Azotobacter + PSB). These findings indicate that the combined application of farmyard manure, vermicompost, and biofertilizers improved vegetative growth and herbage production under the agro-climatic conditions of Prayagraj. The treatment response observed in this study supports the use of integrated organic nutrient management for amaranthus production under comparable field conditions.

Keywords: Organic manures; biofertilizers; Amaranthus tricolor; farmyard manure; vermicompost; Azotobacter; phosphate-solubilizing bacteria; vegetative growth; herbage yield; integrated nutrient management.

1. Introduction

Amaranthus tricolor L., commonly referred to as vegetable amaranth, is a significant leafy vegetable species belonging to the *Amaranthaceae* family. The Amaranthus genus comprises approximately 60–70 species distributed across tropical, subtropical, and temperate regions worldwide. Among these species, A. tricolor is extensively cultivated as a nutritious leafy vegetable because of its substantial biomass production capacity, adaptability to varied agro-climatic environments, and comprehensive nutritional profile. The crop is particularly popular across Asian countries, including India, where its young leaves and tender shoots are used as vegetables in culinary preparations. The plant is also recognised for its ornamental appeal, characterised by visually striking leaf pigmentation ranging from green to red and purple hues (Grubben, 1976; Rastogi & Shukla, 2013). The nutritional significance of A. tricolor is centred predominantly on its leaves, which are abundant sources of proteins, dietary fibre, minerals, vitamins, and bioactive compounds. The foliage provides substantial concentrations of calcium, iron, magnesium, potassium, and vitamins A and C, thereby contributing meaningfully to nutritional intake, especially in developing nations where micronutrient insufficiencies are prevalent. The presence of essential amino acids and high-quality plant proteins further enhances its value as a functional vegetable. Consequently, the inclusion of A. tricolor in diets may contribute to improved nutritional security and human health outcomes (Shukla *et al.*, 2006; Venskutonis & Kraujalis, 2013). Vegetable amaranth is predominantly cultivated for herbage production (green leaf and tender shoot yield), whereas seed production is undertaken principally for genetic preservation, varietal development, and grain amaranth applications. Within the Indian agricultural context, crop production yields approximately 20–40 tonnes of fresh herbage per hectare, depending on genotype, seasonal conditions, soil fertility status, irrigation practices, and harvesting techniques. Seed production typically ranges from 0.8 to 2.5 tonnes per hectare in improved cultivars, although higher yields have been documented under optimal management. Yield fluctuations are predominantly attributed to genetic diversity, plant population density, nutrient application strategies, and climatic variables (Rastogi & Shukla, 2013). Comprehensive nutrient management systems incorporating farmyard manure, vermicompost, poultry manure, phosphate-solubilizing bacteria, and Azotobacter represent a sustainable approach to increasing amaranthus productivity while preserving soil integrity. The combined application of organic amendments and microbial inoculants facilitates consistent nutrient supply, optimises nutrient availability, stimulates soil microbial communities, and improves nutrient-use efficiency. These integrated approaches not only enhance morphological characteristics and leaf production but may also improve product quality and reduce environmental degradation associated with indiscriminate chemical fertiliser application. Consequently, investigating the combined effects of farmyard manure, vermicompost, poultry manure, phosphate-solubilizing bacteria, and Azotobacter on amaranthus growth and productivity is important for developing economically feasible and environmentally responsible nutrient-management strategies (Kumar *et al.*, 2018; Yadav *et al.*, 2013).

Recent studies provide additional support for these considerations. Nutritional characterisation of red amaranth has confirmed its value as a source of nutrients, minerals, amino acids, and phytochemicals (Jahan *et al.*, 2022). Field research on vegetable amaranth has further shown that crop yield responds to nutrient management and harvesting frequency (Birhanu *et al.*, 2024). In *Amaranthus tricolor*, the integrated use of organic manures, biofertilizers, and mineral nutrients has been associated with improved germination, growth, and yield performance (Yadav *et al.*, 2024). Vermicompost-based organic cultivation has likewise been reported to improve the growth and yield-related performance of *Amaranthus* compared with cultivation without vermicompost (Swarnalakshmi *et al.*, 2023). In organically grown red amaranth, compost type has also been associated with differences in the plant-associated microbial community, indicating a biological dimension to organic nutrient management (Sharma *et al.*, 2024).

However, the relative performance of the specific combinations of farmyard manure, vermicompost, poultry manure, *Azotobacter*, and phosphate-solubilizing bacteria used in the present experiment requires field evaluation under the agro-climatic conditions of Prayagraj, particularly with respect to growth, clipping, herbage yield, and economic performance.

1.1 Objective

The objective of the present study was to evaluate the effects of organic manures and biofertilizers, applied alone and in combination, on the growth, clipping behaviour, herbage yield, and economic performance of *Amaranthus tricolor* L. under the agro-climatic conditions of Prayagraj, Uttar Pradesh.

2. Materials and Methods

The present investigation was carried out during the *kharif* season of 2026 at the Horticulture Research Farm, Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, under the agro-climatic conditions of Prayagraj. The field experiment was conducted in a Randomised Block Design with three replications and ten treatments: T0, control (recommended dose only); T1, FYM @ 20 t/ha; T2, vermicompost @ 5 t/ha; T3, poultry manure @ 5 t/ha; T4, biofertilizer (Azotobacter + PSB); T5, FYM @ 20 t/ha + Azotobacter + PSB; T6, vermicompost @ 5 t/ha + Azotobacter + PSB; T7, poultry manure @ 5 t/ha + Azotobacter + PSB; T8, FYM @ 10 t/ha + vermicompost @ 2.5 t/ha + Azotobacter + PSB; and T9, FYM @ 10 t/ha + poultry manure @ 2.5 t/ha + Azotobacter + PSB. The experiment was laid out with three replications on 02/04/26. Sowing was carried out by the line-sowing method at a spacing of 0.30 × 0.15 m between rows and plants, respectively, with 88 plants in each plot. The recommended cultivation practices were adopted to maintain a healthy crop, and a trellis system was used for vine climbing. The seeds were sown uniformly in shallow furrows at a depth of 1–2 cm. Immediately after sowing, the seeds were covered uniformly with moist soil. The mean values of all 10 characters for each of the 10 treatments and three replications were calculated to compile the data, after which the data were subjected to statistical analysis (Fisher, 1948).

3. Results and Discussion

The data presented in Table 1 revealed that the application of different organic manures and biofertilizers significantly influenced the growth and herbage yield of amaranthus at 60 DAS. Plant height increased progressively with crop age under all treatments. The combined application of organic manures and biofertilizers was superior to the sole application of organic manures or biofertilizers, indicating a synergistic effect of integrated nutrient management on growth and herbage yield. At 60 DAS, the trend observed at earlier stages continued. The highest plant height (42.97 cm) was recorded under T8 (FYM @ 10 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} + Azotobacter + PSB), whereas the minimum plant height (24.16 cm) was observed in the control (T0). The consistent performance advantage of T8 across the stages of crop development reflects the combined effects of farmyard manure, vermicompost, and biofertilizers in maintaining nutrient supply and improving overall soil quality. Increased microbial populations, improved nutrient utilisation, enhanced root development, and the production of plant growth regulators may collectively have contributed to greater plant height. The limited growth observed in the control may be explained by relatively restricted nutrient availability and the absence of supplementary organic materials and beneficial microbial populations. Comparable findings have been documented by Kumar *et al.* (2018), Yadav *et al.* (2019), and Yadav *et al.* (2024), who reported improved growth and productivity under integrated nutrient-management approaches.

At 60 DAS, the highest number of leaves per plant (47.27) was again recorded under T8 (FYM @ 10 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} + Azotobacter + PSB), whereas the minimum number of leaves per plant (24.27) was recorded in the control (T0). The consistently superior performance of T8 throughout crop development reflects the combined beneficial effects of farmyard manure, vermicompost, and biofertilizers. This integrated approach sustained nutrient supply during the growing season, increased soil microbial activity, improved nutrient absorption efficiency, and promoted the production of plant growth-regulating compounds. Consequently, these mechanisms may have enhanced leaf emergence and retention, thereby supporting more vigorous vegetative development. Conversely, the control recorded the minimum leaf number, which may be associated with restricted nutrient availability and the absence of organic soil amendments and beneficial microbial populations. Comparable findings have been reported by Kumar *et al.* (2018), Yadav *et al.* (2019), and Yadav *et al.* (2024), who documented improved vegetative growth and leaf/yield performance under integrated nutrient-management treatments. At 60 DAS, T8 (FYM @ 10 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} + Azotobacter + PSB) maintained its superiority by recording the highest number of branches per plant (6.03), followed by T9 (5.94) and T6 (5.74). In contrast, the control (T0) recorded the lowest number of branches per plant (3.17). Although a marginal decrease in branch number was noted at 60 DAS compared with 45 DAS, the combined nutrient-management treatments performed better than the sole organic amendments and the control. The superior performance of T8 may be associated with increased soil microbial activity, improved nutrient-use efficiency, and the sustained availability of essential nutrients throughout crop development. Organic amendments improved soil structural and biochemical properties, whereas Azotobacter and PSB facilitated nutrient release and uptake, thereby supporting plant vigour and branch proliferation through the harvest stage. Comparable findings have been documented in integrated nutrient-management studies involving organic manures and biofertilizers (Kumar *et al.*, 2018; Yadav *et al.*, 2019; Yadav *et al.*, 2024). Similarly, at 60 DAS, T8 produced the maximum plant spread (38.41 cm^2), followed by T9 (37.23 cm^2) and T6 (35.16 cm^2). The minimum plant spread (22.75 cm^2) was recorded in the control (T0). The increase in plant spread under the integrated application of organic manures and biofertilizers was statistically significant, as indicated by the CD value (0.844 cm^2). The present findings indicate that integrated organic nutrient management improved plant spread. Broader evidence shows that organic amendments and integrated nutrient sources can enhance plant growth and soil fertility (Kumar *et al.*, 2018; Sharma *et al.*, 2017; Yadav *et al.*, 2013), while amaranth-specific studies have reported improved growth and yield with vermicompost and integrated manure-biofertilizer treatments (Swarnalakshmi *et al.*, 2023; Yadav *et al.*, 2024). At 60 DAS, the maximum leaf length was again recorded under T8 (13.51 cm), followed by T9 (13.35 cm), whereas the minimum value was recorded in T0 (9.10 cm). The greater leaf length under T8 indicates the potential value of integrating organic nutrient sources with beneficial microorganisms to maintain nutrient availability throughout crop development. The consistent supply of nitrogen, phosphorus, and supplementary micronutrients from farmyard manure and vermicompost, together with biological nitrogen fixation and phosphorus solubilisation by biofertilizers, may have supported cell division, cell expansion, and chlorophyll formation, thereby promoting leaf development.

The earliest clipping was recorded under treatment T8 (FYM @ 10 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} + Azotobacter + PSB), which required 25.16 days. The maximum number of days to clipping was recorded in the control treatment (T0), at 33.06 days. The reduction in days to clipping under integrated organic manure and biofertilizer treatments might be attributed to improved nutrient availability, enhanced microbial activity, and better soil conditions, which promoted faster vegetative growth and earlier plant maturity. A similar reduction in time to harvest under integrated nutrient management was reported for amaranth by Yadav *et al.* (2024). The data presented in Table 1 revealed that the application of organic manures and biofertilizers significantly influenced herbage yield per plant in amaranthus. Among all treatments, T8 (FYM @ 10 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} + Azotobacter + PSB) recorded the maximum herbage yield (144.88 g $plant^{-1}$), which was significantly higher than that of the other treatments. The

Table 1. Effect of organic manures and biofertilizers on growth and herbage yield of amaranthus (*Amaranthus tricolor* L.)

Treatment notation	Treatment details	Growth and herbage yield								
		Plant height (cm) at 60 DAS	Number of leaves per plant at 60 DAS	Number of branches per plant at 60 DAS	Plant spread (cm^2) at 60 DAS	Leaf length (cm) at 60 DAS	Days to clippings	Herbage yield per plant (g)	Herbage yield (kg plot-1)	Herbage yield (q ha-1)
T0	Control (Recommended dose only)	24.16	24.27	3.17	22.75	9.10	33.06	39.58	3.48	87.08
T1	FYM @ 20 t/ha	31.35	30.58	4.69	26.72	12.51	29.09	120.48	10.60	265.06
T2	Vermicompost @ 5 t/ha	34.33	35.03	5.23	30.52	12.76	28.09	105.18	9.26	231.40
T3	Poultry manure @ 5 t/ha	32.70	33.23	5.09	27.96	12.69	28.51	98.52	8.67	216.74
T4	Biofertilizer (Azotobacter + PSB)	30.16	28.92	4.27	25.59	12.06	30.05	54.57	4.80	120.05
T5	FYM @ 20 t/ha + Azotobacter + PSB	36.79	41.25	5.48	32.98	13.10	26.68	125.51	11.04	276.12
T6	Vermicompost @ 5 t/ha + Azotobacter + PSB	38.98	44.01	5.74	35.16	13.24	26.36	135.77	11.95	298.69
T7	Poultry manure @ 5 t/ha + Azotobacter + PSB	35.00	37.78	4.67	31.07	13.03	27.29	115.32	10.15	253.70
T8	FYM @ 10 t/ha + Vermicompost @ 2.5 t/ha + Azotobacter + PSB	42.97	47.27	6.03	38.41	13.51	25.16	144.88	12.75	318.74
T9	FYM @ 10 t/ha + Poultry manure @ 2.5 t/ha + Azotobacter + PSB	41.26	45.11	5.94	37.23	13.35	25.73	142.13	12.51	312.69
	F-Test	S	S	S	S	S	S	S	S	S
	C.D. at 0.5%	0.725	0.923	0.299	0.844	0.157	0.515	2.629	0.232	5.788
	S.Ed. ($\pm$)	0.342	0.436	0.141	0.398	0.074	0.243	1.242	0.110	2.734
	C.V.	1.205	1.452	3.440	1.582	0.726	1.063	1.406	1.411	1.407

minimum herbage yield (39.58 g plant^{-1}) was recorded under T0 (control: recommended dose only). The higher herbage yield under T8 may be attributed to the combined effects of farmyard manure and vermicompost, which improved soil physical properties, nutrient availability, microbial activity, and water-holding capacity. Concurrently, inoculation with Azotobacter and phosphate-solubilizing bacteria (PSB) facilitated biological nitrogen fixation and improved phosphorus availability. This integrated nutrient-management strategy provided a consistent supply of essential nutrients throughout crop development, thereby supporting vegetative growth and biomass accumulation. Comparable improvements in growth and yield under integrated nutrient management have been reported for vegetable crops and amaranth (Kumar *et al.*, 2018; Yadav *et al.*, 2019; Yadav *et al.*, 2024). Vermicompost-associated increases in plant growth and yield have also been reported in other horticultural crops (Arancon *et al.*, 2004). The data presented in Table 1 further showed that the different organic amendments and biofertilizer treatments had statistically significant effects on herbage yield (kg plot^{-1} and q ha^{-1}) of amaranthus. The maximum herbage yield (12.75 kg plot^{-1} and 318.74 q ha^{-1}) was recorded under treatment T_8 (FYM @ 10 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} + Azotobacter + PSB), which was significantly higher than that of the other treatments. The minimum herbage yield (3.48 kg plot^{-1} and 87.08 q ha^{-1}) was recorded under the control treatment (T_0). The improved performance may be attributed to the combined effects of farmyard manure, vermicompost, and biofertilizers. Farmyard manure improves soil structure and water-holding capacity, whereas vermicompost supplies readily available nutrients, humic compounds, enzymes, and plant growth-regulating substances. The application of Azotobacter promotes biological nitrogen fixation, while phosphate-solubilizing bacteria (PSB) increase phosphorus availability by converting unavailable phosphorus into plant-available forms. This integrated approach may have improved nutrient uptake, plant growth, photosynthetic performance, and consequently herbage production. Comparable evidence from integrated nutrient-management studies has also shown improved leaf yield and crop performance relative to less integrated nutrient inputs (Yadav *et al.*, 2019).

4. Conclusion

The present investigation showed that the combined application of FYM @ 10 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} with Azotobacter and PSB (T8) produced the strongest overall response among the evaluated treatments. At 60 DAS, T8 recorded the highest plant height, leaf number, branch number, plant spread, and leaf length, together with the earliest clipping. It also produced the highest herbage yield per plant, per plot, and per hectare. In contrast, the control recorded the lowest values for several growth and yield attributes. These results indicate that integrating organic manures with biofertilizers can support vegetative growth and herbage production of *Amaranthus tricolor* L. under the agro-climatic conditions of Prayagraj. The response of T8 suggests that combining farmyard manure and vermicompost with Azotobacter and phosphate-solubilizing bacteria may provide a practical nutrient-management option for this crop.

5. Limitation

The study was conducted during a single kharif season at one experimental location in Prayagraj, Uttar Pradesh, using a Randomised Block Design with three replications. Therefore, the observed responses to organic manures and biofertilizers represent the specific soil, climatic, and management conditions of the study site and season. The findings may not be directly generalisable to other agro-climatic regions or production seasons. Future studies should evaluate the treatments across multiple seasons and locations, with additional replications, to confirm the consistency and wider applicability of the observed growth and herbage-yield responses.

Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the 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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