International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(9): 1082-1085
Received: 12-06-2025
Accepted: 15-07-2025

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Effect of organic manures and bio-fertilizers on the growth and yield of finger millet

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DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i9o.3900

Abstract
A field experiment entitled "Effect of Organic Manures and Bio-fertilizers on Growth and Yield of Finger Millet" was conducted during the Kharif season of 2024 at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.), India. The objective was to assess the response of different organic manures and bio-fertilizers on growth and yield performance of finger millet. The experimental soil was sandy loam, nearly neutral in reaction (pH 7.8), and low in organic carbon (0.35%). The trial was laid out in a Randomized Block Design with ten treatments replicated thrice, comprising combinations of farmyard manure (FYM), vermicompost, poultry manure, Azotobacter, and Azospirillum.
Significant variability was observed across treatments. The treatment with vermicompost @ 2.5 t/ha + Azotobacter @ 3 kg/ha + Azospirillum @ 5 kg/ha (T6) recorded the maximum plant height (81.48 cm), tillers per plant (8.30), plant dry weight (19.37 g/plant), fingers per plant (7.42), test weight (3.71 g), seed yield (3.35 t/ha), stover yield (4.62 t/ha), and harvest index (45.99%). This treatment also achieved the highest economic returns with a gross return of INR 1,40,855/ha, net return of INR 1,03,955/ha, and a B:C ratio of 2.82.
The results suggest that the integration of vermicompost with Azotobacter and Azospirillum is highly effective in enhancing growth, yield, and profitability of finger millet under sandy loam soils of Prayagraj.

Keywords: Organic manure, bio- fertilizer, growth and yield, economics, finger millet, Prabhet

Introduction

Finger millet (*Eleusine coracana* L.), commonly known as ragi, is renowned for its exceptionally high calcium (Ca) content, averaging about 0.34% in whole seeds compared to 0.01-0.06% in most other cereals (Kumar *et al*., 2016; Gupta *et al*., 2017) [19, 4]. In addition, the grains are a rich source of dietary fiber, iron, essential amino acids (isoleucine, leucine, methionine, phenylalanine), phytates, and trypsin inhibitors, while being naturally gluten-free (Chandra *et al*., 2016; Sood *et al*., 2016) [2, 15]. Of the 2.70 million hectares under millet cultivation in India, ragi alone accounts for 1.60 mha, contributing nearly 75% of total millet production. With an annual production of 2.1 million tonnes and an average productivity of 1300 kg/ha, India is the world's largest producer of finger millet, where it ranks fourth in productivity after wheat, rice, and maize (O'Kennedy *et al*., 2006) [9].

Among biofertilizers, Azospirillum spp. are facultative endophytic diazotrophs that colonize the rhizosphere and root interiors of cereals, legumes, millets, and grasses (Tejera *et al*., 2005; Bashan *et al*., 2004) [22, 1]. These Gram-negative, spiral-shaped bacteria exhibit polymorphism and contain poly-β-hydroxybutyrate (PHB) granules. They are known to improve nitrogen availability and stimulate plant growth by producing phytohormones such as auxins, gibberellins, and cytokinins (Mane *et al*., 2000) [7].

Similarly, Azotobacter spp., free-living nitrogen-fixing bacteria, play an important role in enhancing plant growth and yield in non-leguminous crops. These Gram-negative, polymorphic organisms exhibit motility via peritrichous flagella in younger cells, while older cells form resistant cysts capable of withstanding adverse conditions. They also produce polysaccharides that aid in soil aggregation. However, Azotobacter populations are sensitive to acidic pH, high salinity, and temperatures above 35 °C, which can limit their activity.

Materials and Methods

The experimental field soil was classified as sandy loam, with a pH of 7.3, low organic carbon content (0.60%), and available nitrogen (178.48 kg/ha), phosphorus (41.3 kg/ha), and potassium (244.6 kg/ha). The treatments comprised three levels of organic manures FYM (5 t/ha), vermicompost (2.5 t/ha), and poultry manure (2.5 t/ha) in combination with two levels of bio-fertilizers, Azotobacter (3 kg/ha) and Azospirillum (5 kg/ha).

The experiment was conducted in a Randomized Block Design (RBD) with 10 treatments replicated thrice, including a control. The treatment details were as follows:

- **T1:** FYM 5 t/ha + Azotobacter 3 kg/ha
- **T2:** FYM 5 t/ha + Azospirillum 5 kg/ha
- **T3:** FYM 5 t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha
- **T4:** Vermicompost 2.5 t/ha + Azotobacter 3 kg/ha
- **T5:** Vermicompost 2.5 t/ha + Azospirillum 5 kg/ha
- **T6:** Vermicompost 2.5 t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha
- **T7:** Poultry manure 2.5 t/ha + Azotobacter 3 kg/ha
- **T8:** Poultry manure 2.5 t/ha + Azospirillum 5 kg/ha
- **T9:** Poultry manure 2.5 t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha
- **T10:** Control (FYM 10.5 t/ha)

Data on growth and yield parameters plant height (cm), plant dry weight (g), number of tillers per plant, number of fingers per plant, test weight (g), seed yield (kg/ha), and straw yield (kg/ha) were recorded and subjected to analysis of variance (ANOVA) following the method described by Gomez and Gomez (1976).

Results and Discussion

1. Plant height (cm)

At 80 DAS, the treatment vermicompost 2.5 t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha recorded the significantly highest plant height (81.48 cm). This was statistically at par with vermicompost 2.5 t/ha + Azospirillum 5 kg/ha, indicating the effectiveness of vermicompost-based combinations. The enhanced plant growth may be attributed to the rapid mineralization of vermicompost, which supplies readily available nutrients—particularly nitrogen—that are vital for cell division and elongation. These findings are consistent with Thimmaiah *et al*. (2016), who reported similar positive effects of organic sources on plant growth.

2. Plant dry weight (g)

At 80 DAS, the maximum plant dry weight (19.37 g/plant) was also observed in the treatment vermicompost 2.5 t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha. This treatment was statistically comparable with vermicompost 2.5 t/ha + Azospirillum 5 kg/ha and poultry manure 2.5 t/ha + Azospirillum 5 kg/ha. The increased dry matter accumulation can be attributed to the balanced and continuous supply of nutrients from organic manures in combination with biofertilizers. Adequate nitrogen availability enhanced photosynthetic efficiency, assimilation of carbohydrates, and efficient translocation of assimilates, which collectively resulted in higher ear production, improved test weight, and ultimately better grain yield. These results are in agreement with Chaudhari *et al*. (2011) [3].

3. Number of tillers per plant

The highest number of tillers per plant (8.30) was recorded in the treatment vermicompost 2.5 t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha. This was statistically comparable with vermicompost 2.5 t/ha + Azospirillum 5 kg/ha and poultry manure 2.5 t/ha + Azospirillum 5 kg/ha. The improvement in tillering can be attributed to the continuous supply of nitrogen from organic fertilizers and the mineralization of vermicompost, which enhanced soil nutrient availability and created a favorable environment for plant growth. These observations are in agreement with Saunshi *et al*. (2014) [14].

4. Number of fingers per plant

The maximum number of fingers per plant (7.42) was recorded in vermicompost 2.5 t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha, with other vermicompost- and poultry manure-based treatments being statistically at par. Inoculation with Azotobacter and Azospirillum likely enhanced the effective number of fingers per ear, ear length, and test weight by increasing nitrogen availability through biological nitrogen fixation in the rhizosphere. Enhanced nitrogen nutrition promoted better root proliferation, vigorous vegetative growth, and improved ear development. These results are consistent with the findings of Sushila and Giri (2000) [18].

5. Test weight (g)

The highest test weight (3.71 g) was recorded in the treatment vermicompost 2.5 t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha, while vermicompost 2.5 t/ha + Azospirillum 5 kg/ha and poultry manure 2.5 t/ha + Azospirillum 5 kg/ha were statistically at par. The enhancement in test weight can be attributed to the synergistic effect of vermicompost and biofertilizers in supplying essential nutrients, particularly nitrogen, which supports protein synthesis and grain development.

6. Seed yield (t/ha)

The maximum seed yield (3.35 t/ha) was also observed in vermicompost 2.5 t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha, with other treatments showing comparable results. The improvement in seed yield is likely due to enhanced photosynthetic activity and efficient assimilation of organic compounds facilitated by the vermicompost-biofertilizer combination. Adequate nitrogen supply, essential for protein synthesis, ensured efficient translocation to growing plant parts, thereby supporting higher grain formation. These findings are in agreement with Mane *et al*. (2000) [7].

7. Straw yield (t/ha)

The highest straw yield (4.62 t/ha) was recorded in the treatment vermicompost 2.5 t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha, while vermicompost 2.5 t/ha + Azospirillum 5 kg/ha and poultry manure 2.5 t/ha + Azospirillum 5 kg/ha were statistically comparable. The increase in straw yield can be attributed to the synergistic effect of biofertilizers, which enhance nutrient uptake and promote vegetative growth, thereby increasing both grain and fodder production. These findings are in agreement with Patel *et al*. (2014) [12].

8. Harvest Index (%)

The maximum harvest index (45.99%) was also observed in vermicompost 2.5 t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha, with other vermicompost- and poultry manure-based treatments being statistically at par. The higher harvest index indicates improved partitioning of assimilates towards grain formation, reflecting the positive impact of organic manures and biofertilizers on crop productivity.

Economic Analysis

1. Cost of cultivation (INR/ha)

The highest cost of cultivation (INR 61,600/ha) was recorded in the treatment FYM 5 t/ha + Azospirillum 5 kg/ha, which was higher than all other treatments due to the larger input of organic manure.

2. Gross returns (INR/ha):

The maximum gross returns (INR 1,40,855/ha) were obtained in vermicompost 2.5 t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha, reflecting the superior productivity of this treatment combination.

3. Net returns (INR/ha): Similarly, the highest net returns (INR 1,03,955/ha) were recorded in vermicompost 2.5 t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha, indicating its economic advantage over other treatments.

4. Benefit-Cost ratio (B:C)

The highest benefit-cost ratio (2.82) was also observed in vermicompost 2.5 t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha, demonstrating the treatment's profitability and efficiency in maximizing returns relative to cost.

These results suggest that the integration of vermicompost with biofertilizers not only improves crop growth and yield but also ensures higher economic returns, making it a viable and sustainable option for finger millet cultivation.

Table 1: Influence of organic manures and bio-fertilizers on Growth Attributes of finger millet

S. no	Treatment combination	Plant height (cm)	Plant dry weight (g)	Number of tillers per plant
1.	FYM 5t/ha + Azotobacter 3 kg/ha	60.58	17.93	4.47
2.	FYM 5t/ha + Azospirillum 5 kg/ha	63.75	18.10	6.30
3.	FYM 5t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha	64.15	18.23	7.60
4.	Vermicompost 2.5t/ha + Azotobacter 3 kg/ha	64.65	18.38	6.90
5.	Vermicompost 2.5t/ha + Azospirillum 5 kg/ha	74.14	19.15	8.38
6.	Vermicompost 2.5t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha	81.48	19.37	8.30
7.	Poultry manure 2.5t/ha + Azotobacter 3 kg/ha	66.48	18.98	7.50
8.	Poultry manure 2.5t/ha + Azospirillum 5 kg/ha	73.32	19.14	7.10
9.	Poultry manure 2.5t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha	69.18	18.80	8.20
10.	Control: FYM (10.5 t/ha)	59.41	16.43	5.60
	F - Test	S	S	S
	S.Em (±)	4.37	0.34	0.18
	CD (p= 0.05)	13.00	1.01	0.55

Table 4: Economical Analysis

S. No	Treatment Combination	Cost of cultivation (INR/ha)	Gross returns (INR/ha)	Net returns (INR/ha)	B:C ratio
1.	FYM 5t/ha + Azotobacter 3 kg/ha	40900.00	90200.00	49300.00	1.21
2.	FYM 5t/ha + Azospirillum 5 kg/ha	61600.00	93090.00	51490.00	1.24
3.	FYM 5t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha	41900.00	119650.00	77750.00	1.86
4.	Vermicompost 2.5t/ha + Azotobacter 3 kg/ha	41900.00	126510.00	90610.00	2.52
5.	Vermicompost 2.5t/ha + Azospirillum 5 kg/ha	35900.00	128930.00	92330.00	2.52
6.	Vermicompost 2.5t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha	36600.00	140855.00	103955.00	2.82
7.	Poultry manure 2.5t/ha + Azotobacter 3 kg/ha	36900.00	124985.00	89085.00	2.48
8.	Poultry manure 2.5t/ha + Azospirillum 5 kg/ha	35900.00	126980.00	90380.00	2.47
9.	Poultry manure 2.5t/ha + Azotobacter 3 kg/ha + Azospirillum 5 kg/ha	36900.00	119845.00	82945.00	2.25
10.	Control: FYM (10.5 t/ha)	27950.00	73975.00	46025.00	1.65

Conclusion

The present study revealed that the integrated application of vermicompost (2.5 t/ha) with Azotobacter (3 kg/ha) and Azospirillum (5 kg/ha) (T6) significantly enhanced the growth, yield, and economic performance of finger millet. This treatment consistently produced the highest values for plant height, number of tillers, fingers per plant, plant dry weight, test weight, seed yield, straw yield, and harvest index. The improvement in growth and yield attributes can be attributed to the balanced and continuous supply of nutrients from vermicompost, coupled with the nitrogen-fixing and growth-promoting activities of biofertilizers, which enhanced photosynthetic efficiency, nutrient assimilation, and translocation of assimilates to grain. Economically, T6 provided the maximum gross and net returns along with the highest benefit-cost ratio, indicating its profitability and sustainability. These findings suggest that the combined use of vermicompost and biofertilizers is an effective and eco-friendly strategy to improve finger millet productivity and farmer income.

Acknowledgement

The authors are thankful to Dr. Umesha C., Assistant Professor, Department of Agronomy, Naini Agricultural Institute, Prayagraj, Sam Higginbottom University of Agriculture Technology and sciences, (U.P) India for providing necessary facilities to undertake the studies.

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