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ORIGINAL ARTICLE

Growth, Yield Attributes and Yield of Pearl Millet (*Pennisetum glaucum* L.) under Integrated Nutrient Management and Foliar Application of Chelated Micronutrients

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ABSTRACT
Integrated use of organic manures and biofertilizers with mineral fertilizers is widely recommended for pearl millet, but its combination with foliar chelated micronutrients has received little attention. A field experiment was conducted during kharif 2024 and 2025 at GD Goenka University, Sohna, Haryana, with hybrid MP 7288 to compare twelve nutrient management treatments laid out in a randomized block design with three replications. The treatments combined the recommended dose of fertilizers (RDF, 60:30:30 kg N:P_2O_5: K_2O ha^{-1}) with farmyard manure (FYM), vermicompost, Azotobacter, phosphate solubilizing bacteria (PSB) and a foliar spray of chelated micronutrients. All growth parameters and yield attributes except 1000-grain weight responded significantly to the treatments. The combination of 75% RDF + 25% N through vermicompost + Azotobacter + PSB + foliar chelated micronutrients (T11) produced the tallest plants at harvest (253.48 and 258.26 cm), the driest matter (123.86 and 128.42 g $plant^{-1}$), the highest leaf area index at 90 DAS (2.84 and 2.91), and the most effective tillers (4.96 and 5.14 $plant^{-1}$) and heaviest panicles (62.84 and 64.38 g) in 2024 and 2025, respectively. Grain yield under T11 (29.18 and 30.26 q ha^{-1}) was about 65% higher than under 100% RDF, although it did not differ significantly from that of 100% RDF + Azotobacter + PSB + foliar chelated micronutrients (T12; 27.64 and 28.72 q ha^{-1}). Harvest index was not affected by the treatments. Adding bio-inoculants and a foliar chelated micronutrient spray to the fertilizer schedule, with or without vermicompost, raised the growth and grain yield of pearl millet well above the level obtained with RDF alone.
Keywords: *Bio-inoculants, Chelated micronutrients, Crop growth rate, Pearl millet, Vermicompost, Yield attributes*

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INTRODUCTION

Pearl millet (*Pennisetum glaucum* L.) is the main cereal of the arid and semi-arid tracts of India. It tolerates heat, drought and soils of low fertility better than most cereals, and its grain is an inexpensive source of energy, protein and minerals for rural households [1].

The crop is nevertheless responsive to nutrient supply, and yields are often held back by insufficient or unbalanced fertilization. Continued reliance on chemical fertilizers without organic inputs also depletes soil organic carbon and lowers the efficiency with which applied nutrients are used [2].

Integrated nutrient management (INM) combines mineral fertilizers with organic manures and biofertilizers. Farmyard manure and vermicompost release nutrients slowly and add organic matter to the soil, *Azotobacter* fixes atmospheric nitrogen, and phosphate solubilizing bacteria (PSB) convert sparingly soluble soil phosphorus into forms that roots can absorb [3].

Micronutrients are a further constraint. Zinc, iron, manganese, copper and boron are involved in chlorophyll formation, enzyme activity, auxin synthesis and pollen development, and soils that are low in organic matter or slightly alkaline often supply too little of them. A foliar spray of chelated micronutrients delivers these elements directly to the leaf, where the chelate keeps the metal soluble and available for absorption [4].

Earlier studies have mostly tested organic sources, biofertilizers or micronutrients one at a time. Few have examined how a pearl millet hybrid responds when all three are combined with a reduced fertilizer dose in the Trans-Gangetic Plains. The present study therefore measured the growth, yield attributes and yield of pearl millet under twelve combinations of RDF, organic manures, bio-inoculants and foliar chelated micronutrients.

MATERIAL AND METHODS

Experimental site and soil

The experiment was conducted during *kharif* 2024 and 2025 at the Crop Research Centre, School of Agricultural Sciences, GD Goenka University, Sohna, Haryana, India (28.26° N, 77.06° E; 237 m above mean sea level), which lies in the Trans-Gangetic Plains at the foothills of the Aravalli range. The climate is sub-tropical. During the 2024 crop season, mean weekly maximum temperature ranged from 32.1 to 36.7 °C and mean weekly minimum temperature from 18.3 to 28.6 °C; most of the rain fell in July and August, and no rain was received after the third week of September.

The soil of the experimental field (0 to 30 cm) was a sandy loam with 70.9% sand, 8.1% silt and 21.1% clay [5]. It had a pH of 7.58 and an electrical conductivity of 0.59 dS m^{-1} [6], was low in organic carbon (0.40%) [7] and available nitrogen (192.5 kg ha^{-1}) [8], and was medium in available phosphorus (15.4 kg ha^{-1}) [9] and available potassium (248.0 kg ha^{-1}) [6].

Treatments and experimental design

Twelve treatments were laid out in a randomized block design with three replications. The gross and net plot sizes were 5.20 m × 4.00 m and 4.40 m × 3.50 m, respectively. The treatments were:

T1: Control (no fertilizer)
T2: 100% RDF (60:30:30 kg N:P_2O_5:K_2O ha^{-1})
T3: 75% RDF + 25% N through FYM
T4: 75% RDF + 25% N through vermicompost
T5: 75% RDF + *Azotobacter* + PSB
T6: 100% RDF + foliar spray of chelated micronutrients
T7: 75% RDF + 25% N through vermicompost + *Azotobacter* + PSB
T8: 75% RDF + 25% N through FYM + foliar spray of chelated micronutrients
T9: 75% RDF + 25% N through vermicompost + foliar spray of chelated micronutrients
T10: 75% RDF + *Azotobacter* + PSB + foliar spray of chelated micronutrients
T11: 75% RDF + 25% N through vermicompost + *Azotobacter* + PSB + foliar spray of chelated micronutrients
T12: 100% RDF + *Azotobacter* + PSB + foliar spray of chelated micronutrients

Farmyard manure (0.56% N, 0.28% P, 0.52% K) at 5 t ha^{-1} and vermicompost (1.28% N, 0.56% P, 0.62% K) at 2 t ha^{-1} were incorporated into the soil before sowing in the treatments that received them. For the bio-inoculant treatments, seeds were coated with a slurry of *Azotobacter* and PSB cultures, dried in shade and sown immediately. The chelated micronutrient formulation, a commercial product containing Zn-EDTA 3%, Mn-EDTA 1%, Cu-EDTA 1%, Fe as an organic complex 2.5%, B 0.5% and Mo 0.1%, was sprayed at 1g L^{-1} of water (spray volume 500 L ha^{-1}) at 30 DAS, before panicle initiation, using a knapsack sprayer

Crop management

Pearl millet hybrid MP 7288 was sown on 27 July 2024 and 6 August 2025 at a spacing of 45 cm × 15 cm, using 5 kg seed ha^{-1}. Seedlings were thinned to one per hill at 10 days after sowing (DAS). Weeds were controlled with one herbicide application followed by one hand weeding, and all other operations were kept uniform across treatments.

Observations

Plant height was measured on five tagged plants per net plot at 30, 60 and 90 DAS and at harvest. Dry matter was recorded at the same stages from destructively sampled plants dried at 60 °C to constant weight. Leaf area was measured with a leaf area meter, and leaf area index (LAI) was calculated as leaf area per unit ground area [10]. Crop growth rate (CGR, g m^{-2} day^{-1}) was calculated as $(W_2 - W_1)/(t_2 - t_1)$, where W_1 and W_2 are the dry weights per square metre at times t_1 and t_2; plant dry weight was converted to a ground-area basis using the plant population at 45 cm × 15 cm spacing [11]. Effective tillers, panicle length and panicle weight were recorded at harvest on the tagged plants, and 1000-grain weight on a random grain sample from each plot. Grain and biological yields were taken from the net plot, and harvest index was calculated as grain yield divided by biological yield and expressed as a percentage [12].

Statistical analysis

Data for each year were analysed separately by analysis of variance for a randomized block design [13]. When the F-test was significant at P = 0.05, treatment means were compared using the critical difference (CD); non-significant effects are shown as NS.

RESULTS AND DISCUSSION

Growth parameters

Plant height

Plant height rose steadily until harvest, and the treatments differed significantly at every stage in both years (Table 1). At harvest, the tallest plants were under T11 (253.48 cm in 2024 and 258.26 cm in 2025), with T7, T9, T10 and T12 in the same statistical group; the shortest were in the unfertilized control (176.43 and 179.18 cm). Every treatment that was statistically at par with T11 combined at least two of the three supplements tested (vermicompost, bio-inoculants and the foliar spray). A continuous supply of N and P through the vegetative phase therefore appears to have driven stem elongation: *Azotobacter* adds fixed N, PSB releases bound P near the roots, and both favour cell division and internode growth. Comparable gains in plant height under INM were reported by [14] and [15].

Dry matter accumulation

Dry matter per plant increased throughout the season (Table 2). T11 accumulated the most dry matter at harvest (123.86 and 128.42 g plant^{-1}), followed by T12 (118.64 and 123.18 g plant^{-1}), which was statistically similar; all other treatments were significantly lower. Plants in the control produced only 51.84 and 53.42 g plant^{-1}, less than half the T11 value. The larger leaf area of T11 (Table 3) gave it more photosynthetic surface, and continued nutrient release from vermicompost late in the season allowed the crop to keep adding biomass. [16] observed a similar increase in the dry matter of pearl millet under INM.

Leaf area index

LAI increased up to 90 DAS in all treatments (Table 3). T11 had the highest LAI at each stage: 0.437 and 0.448 at 30 DAS, 2.027 and 2.081 at 60 DAS, and 2.839 and 2.914 at 90 DAS in 2024 and 2025, respectively. At 90 DAS, T12 (2.753 and 2.826) was at par with T11, while the control lagged well behind (1.554 and 1.595). Leaf expansion depends heavily on nitrogen, and the foliar spray also supplied Zn and Fe, which are needed for chlorophyll synthesis; together these probably kept leaves larger and green for longer. [17] reported a similar increase in LAI with integrated nutrient supply.

Crop growth rate

CGR was highest between 60 and 90 DAS and declined sharply towards harvest (Table 4). T11 again recorded the highest values: 19.57 and 20.34 g m^{-2} day^{-1} between 30 and 60 DAS, 27.06 and 28.16 g m^{-2} day^{-1} between 60 and 90 DAS, and 10.97 and 11.21 g m^{-2} day^{-1} from 90 DAS to harvest. Between 60 and 90 DAS, T7, T9, T10 and T12 were statistically at par with T11. Treatment differences from 90 DAS to harvest were significant in 2024 but not in 2025. The higher CGR of T11 follows from its larger leaf area, since a bigger canopy intercepts more radiation and converts it into dry matter faster. [18] likewise recorded higher CGR in pearl millet that received both soil and foliar nutrient applications.

Yield attributes

Effective tillers

T11 produced 4.96 and 5.14 effective tillers plant^{-1} in 2024 and 2025 (Table 5). T12 (4.82 and 4.99) was at par in both years, and T10 (4.79) in 2025. The control produced fewer than three effective tillers per plant (2.84 and 2.96). Late tillers of pearl millet often fail to bear panicles when N and P are short at tillering, and the extra N and P supplied by the bio-inoculants and vermicompost probably allowed more tillers to survive to heading. [19] found a comparable increase in productive tillers with INM in summer pearl millet.

Panicle length

Panicle length ranged from 18.42 cm in the control to 30.16 cm under T11 in 2024, and from 18.76 to 30.68 cm in 2025 (Table 5). T12 and T10 were at par with T11. All three of these treatments received the foliar spray; zinc and boron are involved in auxin metabolism and pollen viability, and their supply during panicle development may account for the longer panicles. [19] reported similar improvements in panicle length under integrated nutrient supply.

Panicle weight

Panicle weight followed the same order (Table 5). T11 recorded 62.84 and 64.38 g, at par with T12 (59.76 and 61.18 g) and significantly above all other treatments, whereas control panicles weighed 28.64 and 29.38 g. longer panicles with better grain set and filling explain this difference. [15] also observed heavier panicles of pearl millet under INM in north-western Rajasthan.

1000-grain weight

Test weight varied only from 8.42 to 8.93 g in 2024 and from 8.51 to 9.02 g in 2025, and the treatments had no significant effect on it (Table 5). Grain size in pearl millet hybrids is largely fixed by genotype. The yield gains described below therefore came from more productive tillers and more grains per panicle; individual grains were no heavier.

Yield

Grain yield

Grain yield ranged from 10.84 q ha^{-1} in the control to 29.18 q ha^{-1} under T11 in 2024, and from 11.26 to 30.26 q ha^{-1} in 2025 (Table 6). T12 (27.64 and 28.72 q ha^{-1}) did not differ significantly from T11, and both were significantly superior to the remaining ten treatments. T11 out-yielded 100% RDF (T2) by 65.6% in 2024 and 65.0% in 2025. Replacing 25% of fertilizer N with FYM (T3) gave lower yield than 100% RDF, significantly so in 2025, whereas the same substitution with vermicompost (T4) gave yield at par with T2; the slower nutrient release from FYM probably did not keep pace with crop demand.

The advantage of T11 can be traced through the yield components: it had the most effective tillers and the heaviest panicles, while grain size stayed the same. Vermicompost supplied readily mineralizable N, the bio-inoculants improved N and P availability, and the foliar spray supplied micronutrients that the soil could not provide in sufficient quantity. [20] obtained similar yield increases from integrated nutrient management in pearl millet.

Table 1. Effect of nutrient management treatments on plant height (cm) of pearl millet

Tr. No.	Treatments	Plant Height (cm)							
		30 DAS		60 DAS		90 DAS		Harvest	
		2024	2025	2024	2025	2024	2025	2024	2025
T1	Control (No fertilizers)	34.82	35.41	108.56	110.28	168.94	171.26	176.43	179.18
T2	100% RDF (60:30:30 NPK)	38.15	38.76	132.47	135.18	201.63	204.72	211.28	214.96
T3	75% RDF + 25% N through FYM	37.46	38.12	126.88	129.47	194.27	197.18	203.15	206.84
T4	75% RDF + 25% N through Vermicompost	38.82	39.51	134.36	137.18	205.48	208.76	214.02	218.15
T5	75% RDF + Azotobacter + PSB	39.11	39.84	137.25	140.16	209.64	213.18	218.53	222.47
T6	100% RDF + Foliar Spray of Chelated Micronutrients	40.34	41.08	142.81	145.74	216.42	220.18	225.86	229.74
T7	75% RDF + 25% N via Vermicompost + Azotobacter + PSB	41.27	42.06	146.55	149.68	221.78	225.64	231.44	235.72
T8	75% RDF + 25% N through FYM + Foliar Spray of Chelated Micronutrients	40.86	41.58	144.92	147.86	218.63	222.47	228.15	232.28
T9	75% RDF + 25% N through Vermicompost + Foliar Spray of Chelated Micronutrients	41.74	42.51	148.37	151.64	224.56	228.72	234.38	238.86
T10	75% RDF + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	42.68	43.47	152.84	156.18	230.71	234.86	240.92	245.38
T11	75% RDF + 25% N via Vermicompost + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	44.35	45.18	160.42	164.18	242.86	247.18	253.48	258.26
T12	100% RDF + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	43.91	44.72	157.68	161.24	238.75	243.16	248.97	253.68
SE(m)±		1.54	1.56	5.32	5.46	8.43	8.31	8.80	8.58
CD (P=0.05)		4.51	4.57	15.60	16.00	24.72	24.36	25.81	25.15

RDF, recommended dose of fertilizers (60:30:30 kg N:P_2O_5:K_2O ha^{-1}); FYM, farmyard manure; PSB, phosphate solubilizing bacteria; DAS, days after sowing; CD, critical difference; NS, non-significant.

Biological yield

Biological yield followed grain yield closely (Table 6). T11 produced 81.26 and 83.58 q ha^{-1}, T12 77.42 and 79.64 q ha^{-1} (at par), and the control 35.82 and 36.94 q ha^{-1}. These results agree with the plant height, LAI and dry matter data, all of which placed T11 and T12 at the top. [21] also found higher biological yield of pearl millet under INM.

Harvest index

Harvest index varied from 30.26 to 35.91% in 2024 and from 30.48 to 36.20% in 2025, and the differences were not significant (Table 6). T11 had the highest value and the control the lowest, but grain and biological yield rose in roughly equal proportion, so the share of biomass going to grain changed little. The treatments raised yield mainly by increasing total biomass. [22] reported harvest index values of a similar order for pearl millet under INM.

Table 2. Effect of nutrient management treatments on dry matter accumulation (g plant^{-1}) of pearl millet

Tr. No.	Treatments	Dry Matter Accumulation (g plant^{-1})							
		30 DAS		60 DAS		90 DAS		Harvest	
		2024	2025	2024	2025	2024	2025	2024	2025
T1	Control (No fertilizers)	3.84	4.02	18.62	19.48	43.76	45.18	51.84	53.42
T2	100% RDF (60:30:30 NPK)	5.18	5.42	31.84	33.12	68.42	70.86	82.64	85.38
T3	75% RDF + 25% N through FYM	4.86	5.08	28.76	29.94	62.84	65.12	75.92	78.46
T4	75% RDF + 25% N through Vermicompost	5.34	5.58	32.76	34.08	71.26	73.84	85.18	88.24
T5	75% RDF + Azotobacter + PSB	5.52	5.76	34.18	35.56	74.82	77.46	89.42	92.68
T6	100% RDF + Foliar Spray of Chelated Micronutrients	5.86	6.12	36.72	38.18	79.64	82.48	95.16	98.74
T7	75% RDF + 25% N via Vermicompost + Azotobacter + PSB	6.18	6.46	39.24	40.82	84.28	87.42	101.36	105.28
T8	75% RDF + 25% N through FYM + Foliar Spray of Chelated Micronutrients	6.02	6.28	38.16	39.68	81.76	84.72	98.24	102.18
T9	75% RDF + 25% N through Vermicompost + Foliar Spray of Chelated Micronutrients	6.34	6.62	40.18	41.78	86.42	89.68	104.28	108.46
T10	75% RDF + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	6.58	6.86	42.16	43.84	91.24	94.68	110.42	114.86
T11	75% RDF + 25% N via Vermicompost + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	7.18	7.48	46.82	48.68	101.64	105.72	123.86	128.42
T12	100% RDF + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	6.94	7.24	44.86	46.62	97.42	101.18	118.64	123.18
SE(m)±		0.23	0.24	1.43	1.45	3.05	3.32	3.79	3.66
CD (P=0.05)		0.67	0.70	4.19	4.25	8.97	9.74	11.12	10.75

RDF, recommended dose of fertilizers (60:30:30 kg N:P_2O_5:K_2O ha^{-1}); FYM, farmyard manure; PSB, phosphate solubilizing bacteria; DAS, days after sowing; CD, critical difference; NS, non-significant.

Table 3. Effect of nutrient management treatments on leaf area index of pearl millet

Tr. No.	Treatments	Leaf Area Index					
		30 DAS		60 DAS		90 DAS	
		2024	2025	2024	2025	2024	2025
T1	Control (No fertilizers)	0.276	0.283	1.100	1.129	1.554	1.595
T2	100% RDF (60:30:30 NPK)	0.324	0.332	1.461	1.500	2.055	2.111
T3	75% RDF + 25% N through FYM	0.307	0.315	1.354	1.390	1.903	1.954
T4	75% RDF + 25% N through Vermicompost	0.333	0.342	1.509	1.549	2.123	2.179
T5	75% RDF + Azotobacter + PSB	0.343	0.352	1.560	1.601	2.190	2.249
T6	100% RDF + Foliar Spray of Chelated Micronutrients	0.360	0.369	1.643	1.686	2.309	2.371
T7	75% RDF + 25% N via Vermicompost + Azotobacter + PSB	0.378	0.388	1.725	1.771	2.421	2.486
T8	75% RDF + 25% N through FYM + Foliar Spray of Chelated Micronutrients	0.370	0.380	1.684	1.728	2.368	2.431
T9	75% RDF + 25% N through Vermicompost + Foliar Spray of Chelated Micronutrients	0.388	0.399	1.767	1.814	2.487	2.552
T10	75% RDF + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	0.402	0.413	1.850	1.899	2.599	2.667
T11	75% RDF + 25% N via Vermicompost + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	0.437	0.448	2.027	2.081	2.839	2.914
T12	100% RDF + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	0.423	0.434	1.963	2.015	2.753	2.826
SE(m)±		**0.012**	**0.012**	**0.052**	**0.054**	**0.074**	**0.076**
CD (P=0.05)		**0.035**	**0.036**	**0.152**	**0.158**	**0.217**	**0.223**

RDF, recommended dose of fertilizers (60:30:30 kg N:P_2O_5:K_2O ha^{-1}); FYM, farmyard manure; PSB, phosphate solubilizing bacteria; DAS, days after sowing; CD, critical difference; NS, non-significant.

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Table 4. Effect of nutrient management treatments on crop growth rate (g m^{-2} day^{-1}) of pearl millet

Tr. No.	Treatments	Crop growth rate (g m^{-2} day^{-1})					
		30–60 DAS		60–90 DAS		90 DAS–Harvest	
		2024	2025	2024	2025	2024	2025
T1	Control (No fertilizers)	7.30	7.63	12.41	12.69	3.99	4.07
T2	100% RDF (60:30:30 NPK)	13.16	13.68	18.06	18.63	7.02	7.17
T3	75% RDF + 25% N through FYM	11.80	12.27	16.82	17.37	6.46	6.59
T4	75% RDF + 25% N through Vermicompost	13.54	14.07	19.01	19.63	6.87	7.11
T5	75% RDF + Azotobacter + PSB	14.15	14.71	20.06	20.69	7.21	7.51
T6	100% RDF + Foliar Spray of Chelated Micronutrients	15.24	15.83	21.19	21.87	7.66	8.03
T7	75% RDF + 25% N via Vermicompost + Azotobacter + PSB	16.32	16.96	22.24	23.01	8.43	8.82
T8	75% RDF + 25% N through FYM + Foliar Spray of Chelated Micronutrients	15.87	16.49	21.52	22.24	8.14	8.62
T9	75% RDF + 25% N through Vermicompost + Foliar Spray of Chelated Micronutrients	16.71	17.36	22.83	23.65	8.82	9.27
T10	75% RDF + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	17.57	18.26	24.23	25.10	9.47	9.96
T11	75% RDF + 25% N via Vermicompost + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	19.57	20.34	27.06	28.16	10.97	11.21
T12	100% RDF + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	18.72	19.44	25.95	26.93	10.48	10.86
SE(m)±		0.59	0.75	1.79	1.87	0.72	1.57
CD (P=0.05)		**1.74**	**2.20**	**5.25**	**5.48**	**2.11**	**NS**

RDF, recommended dose of fertilizers (60:30:30 kg N:P_2O_5:K_2O ha^{-1}); FYM, farmyard manure; PSB, phosphate solubilizing bacteria; DAS, days after sowing; CD, critical difference; NS, non-significant.

Table 5. Effect of nutrient management treatments on yield attributes of pearl millet

Tr. No.	Treatments	Yield attributes							
		Effective tillers $plant^{-1}$		Panicle length (cm)		Panicle weight (g)		1000-grain weight (g)	
		2024	2025	2024	2025	2024	2025	2024	2025
T1	Control (No fertilizers)	2.84	2.96	18.42	18.76	28.64	29.38	8.42	8.51
T2	100% RDF (60:30:30 NPK)	3.62	3.76	22.86	23.24	39.72	40.68	8.58	8.67
T3	75% RDF + 25% N through FYM	3.44	3.57	21.74	22.12	36.86	37.74	8.51	8.60
T4	75% RDF + 25% N through Vermicompost	3.78	3.92	23.48	23.88	41.26	42.24	8.64	8.73
T5	75% RDF + Azotobacter + PSB	3.91	4.06	24.16	24.58	43.18	44.22	8.68	8.77
T6	100% RDF + Foliar Spray of Chelated Micronutrients	4.08	4.23	25.32	25.76	46.84	47.96	8.73	8.82
T7	75% RDF + 25% N via Vermicompost + Azotobacter + PSB	4.32	4.48	26.48	26.94	50.26	51.48	8.79	8.88
T8	75% RDF + 25% N through FYM + Foliar Spray of Chelated Micronutrients	4.21	4.36	25.92	26.36	48.72	49.86	8.76	8.85
T9	75% RDF + 25% N through Vermicompost + Foliar Spray of Chelated Micronutrients	4.45	4.61	27.18	27.66	52.18	53.46	8.82	8.91
T10	75% RDF + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	4.62	4.79	28.24	28.74	55.42	56.76	8.86	8.95
T11	75% RDF + 25% N via Vermicompost + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	4.96	5.14	30.16	30.68	62.84	64.38	8.93	9.02
T12	100% RDF + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	4.82	4.99	29.42	29.92	59.76	61.18	8.89	8.98
SE(m)±		0.11	0.12	0.69	0.80	1.31	1.52	0.26	0.25
CD (P=0.05)		0.32	0.36	2.02	2.33	3.85	4.45	NS	NS

RDF, recommended dose of fertilizers (60:30:30 kg N:P_2O_5:K_2O ha^{-1}); FYM, farmyard manure; PSB, phosphate solubilizing bacteria; DAS, days after sowing; CD, critical difference; NS, non-significant.

Table 6. Effect of nutrient management treatments on grain yield, biological yield and harvest index of pearl millet

Tr. No.	Treatments	Yield (q ha^{-1})				Harvest Index (%)	
		Grain Yield		Biological Yield			
		2024	2025	2024	2025	2024	2025
T1	Control (No fertilizers)	10.84	11.26	35.82	36.94	30.26	30.48
T2	100% RDF (60:30:30 NPK)	17.62	18.34	52.46	53.98	33.59	33.98
T3	75% RDF + 25% N through FYM	15.86	16.48	48.72	50.14	32.55	32.87
T4	75% RDF + 25% N through Vermicompost	18.42	19.18	54.68	56.24	33.69	34.10
T5	75% RDF + Azotobacter + PSB	19.36	20.12	57.34	58.96	33.76	34.12
T6	100% RDF + Foliar Spray of Chelated Micronutrients	21.24	22.08	62.18	63.94	34.16	34.53
T7	75% RDF + 25% N via Vermicompost + Azotobacter + PSB	23.18	24.06	66.82	68.74	34.69	35.00
T8	75% RDF + 25% N through FYM + Foliar Spray of Chelated Micronutrients	22.14	23.02	64.38	66.22	34.39	34.76
T9	75% RDF + 25% N through Vermicompost + Foliar Spray of Chelated Micronutrients	24.06	24.98	69.16	71.18	34.79	35.09
T10	75% RDF + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	25.62	26.58	72.84	74.96	35.17	35.46
T11	75% RDF + 25% N via Vermicompost + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	29.18	30.26	81.26	83.58	35.91	36.20
T12	100% RDF + Azotobacter + PSB + Foliar Spray of Chelated Micronutrients	27.64	28.72	77.42	79.64	35.70	36.06
SE(m)±		**0.62**	**0.62**	**1.73**	**2.02**	**1.26**	**1.46**
CD (P=0.05)		**1.83**	**1.80**	**5.06**	**5.94**	**NS**	**NS**

RDF, recommended dose of fertilizers (60:30:30 kg N:P_2O_5:K_2O ha^{-1}); FYM, farmyard manure; PSB, phosphate solubilizing bacteria; DAS, days after sowing; CD, critical difference; NS, non-significant.

CONCLUSION

Integrating vermicompost, *Azotobacter*, PSB and a foliar spray of chelated micronutrients with 75% RDF (T11) gave the best growth, yield attributes and grain yield of pearl millet hybrid MP 7288 in both seasons, raising grain yield by about 65% over RDF alone. Applying the bio-inoculants and the foliar spray with full RDF (T12) produced statistically similar results. Either combination can be recommended for pearl millet on the sandy loam soils of the Trans-Gangetic Plains.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

DATA AVAILABILITY

The data supporting the findings of this study are available from the corresponding author on reasonable request.

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