

ORIGINAL ARTICLE**Response of Maize (*Zea mays* L.) to Integrated Nutrient Management and Bio-inoculants under Field Conditions****Vikrant Malik* and Shiv Singh Tomar**

School of Agricultural Sciences, GD Goenka University, Sohna, Gurugram, India 122103.

Corresponding Author ID: vikrantbhigan@gmail.com

ABSTRACT

A field experiment was conducted during the kharif seasons of 2024 and 2025 at the Crop Research Centre, School of Agricultural Sciences, GD Goenka University, Sohna, Haryana, India, to evaluate the effect of integrated nutrient management (INM) and bio-inoculation on the growth and yield performance of maize (*Zea mays* L.). The experiment was laid out in a Randomized Block Design with three replications and twelve treatments comprising different combinations of recommended dose of fertilizers (RDF), farmyard manure (FYM), vermicompost, and bio-inoculants (*Azotobacter* and phosphate-solubilizing bacteria). The results revealed significant variations among treatments for growth and yield parameters during both years. Among all treatments, T12 (25% vermicompost + 75% RDF) recorded the highest plant height at harvest (212.41 and 216.73 cm), maximum dry matter accumulation (1233.32 and 1267.56 g m⁻²), highest leaf area index at 90 DAS (4.96 and 5.17), and superior crop growth rate during 90 DAS to harvest (19.96 and 20.82 g m⁻² day⁻¹) during 2023–24 and 2024–25, respectively. The same treatment also produced the highest grain yield (6822.98 and 7007.42 kg ha⁻¹), stover yield (14340.91 and 14717.92 kg ha⁻¹), and biological yield (21163.89 and 21725.34 kg ha⁻¹), which remained statistically at par with T2 (100% RDF). The enhanced performance under T12 may be attributed to the balanced and sustained nutrient supply through combined application of vermicompost and inorganic fertilizers, which improved nutrient availability, soil microbial activity, and biomass accumulation. Therefore, the study concludes that integration of 25% vermicompost with 75% RDF is an efficient and sustainable nutrient management strategy for improving growth, productivity, and yield of maize under semi-arid subtropical conditions.

Keywords: Maize, Integrated Nutrient Management, Vermicompost, RDF, Bio-Inoculants, Grain Yield, Sustainable Agriculture

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How to cite this article:Vikrant M and Shiv Singh T. Response of Maize (*Zea mays* L.) to Integrated Nutrient Management and Bio-inoculants under Field Conditions. Adv. Biores., Vol 17 (4) April 2026: 11-17.**INTRODUCTION**

Maize (*Zea mays* L.) is an important cereal crop cultivated widely for food, feed, and industrial purposes across the world. It possesses high yield potential and adaptability to diverse agro-climatic conditions, making it a key contributor to food security and agricultural economies [1]. In India, maize occupies a prominent position among cereal crops and plays a vital role in sustaining livestock and agro-based industries [2]

However, continuous and imbalanced use of chemical fertilizers has led to declining soil fertility, reduced nutrient-use efficiency, and environmental degradation [3]. These challenges necessitate the adoption of sustainable nutrient management strategies. Integrated Nutrient Management (INM), which involves the combined use of chemical fertilizers, organic manures, and bio-fertilizers, has been recognized as an effective approach to maintain soil health and enhance crop productivity [4]

Bio-inoculants such as *Azotobacter* and phosphate-solubilizing bacteria (PSB) play a crucial role in improving nutrient availability through biological nitrogen fixation and phosphorus solubilization, while also enhancing soil microbial activity and plant growth [5,6]. Since maize is a nutrient-exhaustive crop, balanced nutrient supply is essential for achieving higher productivity and improved grain quality [7].

Although individual nutrient sources have been extensively studied, information on their combined effects under integrated approaches remains limited. Therefore, the present study was undertaken to

evaluate the response of integrated nutrient management and bio-inoculation on the growth, yield, and quality of maize.

MATERIAL AND METHODS

Experimental site and climate

The field experiment was conducted during the *kharif* seasons of 2024 and 2025 at the Crop Research Centre, School of Agricultural Sciences, GD Goenka University, Sohna, Haryana, India (28.26° N latitude, 77.06° E longitude; 237 m above mean sea level). The region experiences a sub-tropical climate characterized by hot and humid summers and cool, dry winters. During the crop period, mean maximum temperature ranged from 32.1 to 36.7°C, while minimum temperature varied between 18.3 and 28.6°C, with variable rainfall distribution.

Soil characteristics

The experimental soil was sandy loam in texture, slightly alkaline in reaction (pH 7.58), and low in organic carbon and available nitrogen, medium in available phosphorus, and high in available potassium. Soil samples (0–15 cm depth) were collected, processed, and analyzed using standard procedures [8,9,10]

Experimental design and treatments

The experiment was laid out in a Randomized Block Design (RBD) with three replications and twelve treatments comprising different combinations of inorganic fertilizers, farmyard manure (FYM), vermicompost, and bio-inoculants (*Azotobacter* and phosphate-solubilizing bacteria). Treatments included control, 100% recommended dose of fertilizers (RDF: 120:80:60 kg N:P₂O₅:K₂O ha⁻¹), and their combinations with organic and biological inputs.

Crop management

Maize hybrid 'Royal RS 5101' was sown at a spacing of 60 cm × 20 cm using a seed rate of 18 kg ha⁻¹. Fertilizers were applied as per treatment specifications, with nitrogen applied in split doses, while phosphorus, potassium, and zinc were applied as basal. Standard agronomic practices, including irrigation, weed management, and plant protection measures, were followed uniformly across treatments.

Observations recorded

Growth parameters such as plant height, number of leaves, leaf area index (LAI), crop growth rate (CGR), and relative growth rate (RGR) were recorded at different growth stages. Grain yield, stover yield, and biological yield were computed at harvest. Harvest index was calculated as per the method suggested by [12].

Economic analysis

Economic parameters such as cost of cultivation, gross returns, net returns, and benefit-cost ratio were calculated based on prevailing market prices.

Statistical analysis

The data were statistically analyzed using analysis of variance (ANOVA) appropriate for RBD as described by [13]. The significance of treatment effects was tested using the F-test at 5% probability level, and critical difference (CD) values were calculated for comparison of treatment means [14]

RESULTS AND DISCUSSION

Plant Height

Plant height of maize increased significantly under different nutrient management treatments during both the years. At harvest, the treatment T12 (25% Vermicompost + 75% RDF) recorded the maximum plant height of 212.41 cm and 216.73 cm during 2023-24 and 2024-25, respectively. This treatment was found statistically *at par* with T2 (100% RDF) which recorded 210.30 cm and 214.45 cm. The minimum plant height was recorded under T1 (Control) with 109.99 cm and 112.24 cm during the respective years. The increased plant height under T12 might be due to the balanced and continuous supply of nutrients through integrated application of vermicompost and inorganic fertilizers. Vermicompost improved soil physical properties and microbial activity, while RDF ensured readily available nutrients, resulting in enhanced cell division and elongation. Similar findings have been reported in maize under integrated nutrient management systems where combined nutrient sources improved vegetative growth significantly [15].

Tr. No.	Treatments	Plant Height (cm)							
		30 DAS		60 DAS		90 DAS		Harvest Stage	
		2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
T1	Control (No fertilizer)	63.91	64.53	83.41	85.29	107.28	108.45	109.99	112.24
T2	100% RDF (N, P, K)	64.55	65.18	159.58	162.96	205.25	207.20	210.30	214.45
T3	75% RDF + 25% FYM	64.47	65.09	153.48	156.38	197.40	198.77	202.40	205.66
T4	50% RDF + 50% FYM	64.38	65.01	146.35	148.39	188.21	188.71	192.94	195.33
T5	25% RDF + 50% FYM + Azotobacter + PSB	64.23	64.86	136.16	138.52	175.07	176.06	179.44	182.14
T6	100% Vermicompost + Azotobacter + PSB	64.16	64.78	126.96	129.53	163.31	164.72	167.45	170.50
T7	75% Vermicompost + Azotobacter + PSB	64.10	64.71	123.49	125.70	158.81	159.76	162.80	165.29
T8	50% Vermicompost + 50% RDF	64.42	65.05	152.32	156.36	195.83	198.67	200.73	205.48
T9	25% RDF + 50% Vermicompost + Azotobacter + PSB	64.28	64.88	141.43	143.79	181.93	182.86	186.54	189.28
T10	100% FYM + Azotobacter + PSB	64.04	64.66	122.26	124.53	157.19	158.35	161.12	163.90
T11	75% FYM + Azotobacter + PSB	63.94	64.56	118.79	120.58	152.80	153.31	156.67	158.69
T12	25% Vermicompost + 75% RDF	64.58	65.21	161.12	164.78	207.18	209.46	212.41	216.73
SE(m)±		3.68	3.67	6.50	6.38	8.13	7.78	8.11	7.74
LSD (P=0.05)		NS	NS	19.06	18.71	23.85	22.81	23.78	22.70

Table 1: Response of INM and Bio-inoculation on Plant Height (cm) of Maize

Dry Matter Accumulation

Dry matter accumulation differed significantly among the treatments. At harvest, the maximum dry matter accumulation was recorded under T12 with 1233.32 g m⁻² and 1267.56 g m⁻², which was *at par* with T2 (1221.04 and 1251.09 g m⁻²). The lowest dry matter accumulation was observed under T1 with 645.06 and 663.35 g m⁻².

Higher dry matter accumulation under T12 may be attributed to enhanced nutrient availability and improved root growth, which led to greater photosynthetic efficiency and biomass production. The synergistic effect of vermicompost and RDF helped in sustained nutrient release and improved nutrient uptake, thereby increasing dry matter production [16].

Leaf Area Index

The highest leaf area index at 90 DAS was recorded under T12, with values of 4.96 and 5.17, which was statistically *at par* with T2 (4.90 and 5.11). The lowest leaf area index was recorded under T1 (2.57 and 2.68).

The higher leaf area index under T12 indicates improved canopy development due to better nutrient supply. Adequate nitrogen and organic matter availability enhanced leaf expansion, resulting in greater interception of solar radiation and improved crop growth [17].

Crop Growth Rate

During 90 DAS to harvest, the highest crop growth rate was recorded under T12 with 20.16 and 21.09 g m⁻² day⁻¹, which was *at par* with T2 (19.96 and 20.82 g m⁻² day⁻¹). The lowest values were recorded under T1 (10.54 and 11.04 g m⁻² day⁻¹).

The enhanced crop growth rate under T12 may be due to greater dry matter production resulting from efficient nutrient utilization. Balanced fertilization with vermicompost and RDF ensured continuous nutrient availability during reproductive growth stages, improving biomass accumulation rate.

Table 2: Response of INM and Bio-inoculation on dry matter accumulation (g m⁻²) of Maize

Tr. No.	Treatments	Dry matter accumulation (g m ⁻²)							
		30 DAS		60 DAS		90 DAS		Harvest Stage	
		2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
T ₁	Control (No fertilizer)	47.30	49.80	214.55	220.03	434.21	442.62	645.06	663.35
T ₂	100% RDF (N, P, K)	89.54	93.92	406.12	414.98	821.92	834.79	1221.04	1251.09
T ₃	75% RDF + 25% FYM	86.52	90.15	392.41	398.43	794.09	801.60	1179.62	1201.57
T ₄	50% RDF + 50% FYM	82.42	86.23	373.84	381.04	756.58	766.53	1123.97	1148.81
T ₅	25% RDF + 50% FYM + Azotobacter + PSB	76.77	80.30	348.23	354.80	704.77	713.71	1047.02	1069.62
T ₆	100% Vermicompost + Azotobacter + PSB	71.92	75.45	326.22	333.38	660.16	670.62	980.69	1005.01
T ₇	75% Vermicompost + Azotobacter + PSB	69.91	72.89	317.18	322.13	642.10	648.06	954.10	971.35
T ₈	50% Vermicompost + 50% RDF	85.69	90.24	388.69	398.70	786.61	802.02	1168.58	1201.93
T ₉	25% RDF + 50% Vermicompost + Azotobacter + PSB	79.94	83.45	362.83	368.79	734.87	741.91	1092.27	1111.99
T ₁₀	100% FYM + Azotobacter + PSB	69.17	72.43	313.72	320.06	634.88	643.87	943.15	965.02
T ₁₁	75% FYM + Azotobacter + PSB	67.54	70.28	306.39	310.54	620.22	624.68	921.54	936.20
T ₁₂	25% Vermicompost + 75% RDF	90.46	95.13	410.27	420.39	830.23	845.71	1233.32	1267.56
SE(m)±		3.41	3.76	15.78	16.83	32.62	34.10	49.10	51.66
LSD (P=0.05)		10.01	11.03	46.28	49.35	95.67	100.01	144.02	151.52

Table 3: Response of INM and Bio-inoculation on leaf area index of Maize

Tr. No.	Treatments	Leaf area index					
		30 DAS		60 DAS		90 DAS	
		2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
T ₁	Control (No fertilizer)	1.247	1.286	2.33	2.42	2.57	2.68
T ₂	100% RDF (N, P, K)	1.259	1.299	4.44	4.61	4.90	5.11
T ₃	75% RDF + 25% FYM	1.255	1.294	4.28	4.43	4.73	4.90
T ₄	50% RDF + 50% FYM	1.257	1.297	4.08	4.21	4.51	4.67
T ₅	25% RDF + 50% FYM + Azotobacter + PSB	1.254	1.294	3.79	3.92	4.19	4.34
T ₆	100% Vermicompost + Azotobacter + PSB	1.249	1.288	3.55	3.68	3.92	4.07
T ₇	75% Vermicompost + Azotobacter + PSB	1.247	1.287	3.44	3.56	3.80	3.94
T ₈	50% Vermicompost + 50% RDF	1.257	1.297	4.24	4.42	4.69	4.89
T ₉	25% RDF + 50% Vermicompost + Azotobacter + PSB	1.247	1.287	3.95	4.08	4.36	4.52
T ₁₀	100% FYM + Azotobacter + PSB	1.249	1.288	3.41	3.54	3.76	3.91
T ₁₁	75% FYM + Azotobacter + PSB	1.243	1.283	3.32	3.42	3.66	3.79
T ₁₂	25% Vermicompost + 75% RDF	1.261	1.300	4.49	4.67	4.96	5.17
SE(m)±		0.06	0.06	0.15	0.14	0.16	0.15
LSD (P=0.05)		NS	NS	0.43	0.42	0.46	0.43

Table 4: Response of INM and Bio-inoculation on mean crop growth rate of Maize

Tr. No.	Treatments	Mean crop growth rate (g/m ² /day)					
		30-60 DAS		60-90 DAS		90 DAS - Harvest Stage	
		2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
T ₁	Control (No fertilizer)	5.58	5.67	7.32	7.42	10.54	11.04
T ₂	100% RDF (N, P, K)	10.66	10.84	14.00	14.18	20.16	21.09
T ₃	75% RDF + 25% FYM	10.20	10.28	13.39	13.44	19.28	20.00
T ₄	50% RDF + 50% FYM	9.71	9.83	12.76	12.85	18.37	19.11
T ₅	25% RDF + 50% FYM + Azotobacter + PSB	9.05	9.15	11.89	11.96	17.11	17.80
T ₆	100% Vermicompost + Azotobacter + PSB	8.48	8.60	11.13	11.24	16.03	16.72
T ₇	75% Vermicompost + Azotobacter + PSB	8.24	8.31	10.83	10.86	15.60	16.16
T ₈	50% Vermicompost + 50% RDF	10.10	10.28	13.26	13.44	19.10	20.00
T ₉	25% RDF + 50% Vermicompost + Azotobacter + PSB	9.43	9.51	12.40	12.44	17.87	18.50
T ₁₀	100% FYM + Azotobacter + PSB	8.15	8.25	10.71	10.79	15.41	16.06
T ₁₁	75% FYM + Azotobacter + PSB	7.96	8.01	10.46	10.47	15.07	15.58
T ₁₂	25% Vermicompost + 75% RDF	10.55	10.70	13.86	13.99	19.96	20.82
SE(m)±		0.41	0.44	0.56	0.58	0.82	0.88
LSD (P=0.05)		1.21	1.28	1.65	1.69	2.42	2.58

Grain Yield

The maximum grain yield was recorded under T12, with 6822.98 kg ha⁻¹ and 7007.42 kg ha⁻¹, which was statistically *at par* with T2 (6747.75 and 6878.86 kg ha⁻¹). The minimum grain yield was recorded under T1, with 3498.12 kg ha⁻¹ and 3606.73 kg ha⁻¹.

The higher grain yield under T12 was mainly due to improved growth attributes and better yield components such as grains per cob and cob weight. Vermicompost improved nutrient use efficiency and soil microbial activity, while RDF supplied sufficient nutrients for optimum crop growth, resulting in higher grain productivity [18]

Stover Yield

The maximum stover yield was recorded under T12, with 14340.91 kg ha⁻¹ and 14717.92 kg ha⁻¹, which was *at par* with T2. The minimum stover yield was recorded under T1, with 7500.68 kg ha⁻¹ and 7702.28 kg ha⁻¹.

Higher stover yield under T12 was due to vigorous vegetative growth and higher biomass accumulation resulting from the balanced supply of nutrients through organic and inorganic sources [19]

Biological Yield

The highest biological yield was observed under T12, with 21163.89 kg ha⁻¹ and 21725.34 kg ha⁻¹, which was *at par* with T2. The lowest was recorded under T1, with 10998.80 kg ha⁻¹ and 11309.00 kg ha⁻¹.

Improved biological yield under T12 was the result of enhanced vegetative growth and grain yield due to balanced nutrient nutrition, leading to maximum total biomass production [20].

Harvest index (%)

Harvest index showed relatively less variation among treatments, with T12 recording the highest value (27.07%), remaining *at par* with T2. This indicates that although total biomass production varied among treatments, the partitioning of assimilates towards grain remained relatively stable, particularly under balanced nutrient supply.

The improvement in harvest index indicates efficient partitioning of assimilates towards economic yield under integrated nutrient supply [20].

Table 5: Response of INM and Bio-inoculation on Yield of Maize

Tr. No.	Treatments	Yield (kg ha ⁻¹)						Harvest index (%)	
		Grain yield		Strover yield		Biological Yield		2023-24	2024-25
		2023-24	2024-25	2023-24	2024-25	2023-24	2024-25		
T1	Control (No fertilizer)	3498.12	3606.73	7500.68	7702.28	10998.80	11309.00	31.91	31.95
T2	100% RDF (N, P, K)	6747.75	6878.86	14198.13	14526.68	20945.88	21405.54	32.22	32.26
T3	75% RDF + 25% FYM	6482.75	6618.32	13716.53	13951.75	20199.28	20570.07	32.20	32.24
T4	50% RDF + 50% FYM	6178.79	6311.70	13069.40	13339.08	19248.19	19650.77	32.14	32.16
T5	25% RDF + 50% FYM + Azotobacter + PSB	5738.52	5863.73	12174.66	12419.59	17913.18	18283.32	32.06	32.07
T6	100% Vermicompost + Azotobacter + PSB	5332.78	5469.27	11403.42	11669.40	16736.20	17138.68	32.04	32.06
T7	75% Vermicompost + Azotobacter + PSB	5178.12	5289.12	11094.15	11278.54	16272.27	16567.66	32.01	32.04
T8	50% Vermicompost + 50% RDF	6438.79	6600.27	13588.10	13955.90	20026.89	20556.17	32.16	32.18
T9	25% RDF + 50% Vermicompost + Azotobacter + PSB	5932.78	6101.83	12700.81	12911.62	18633.59	19013.45	32.11	32.13
T10	100% FYM + Azotobacter + PSB	5121.23	5260.62	10966.90	11205.06	16088.13	16465.68	31.97	32.03
T11	75% FYM + Azotobacter + PSB	4986.19	5098.85	10715.53	10870.49	15701.72	15969.34	31.93	32.01
T12	25% Vermicompost + 75% RDF	6822.98	7007.42	14340.91	14717.92	21163.89	21725.34	32.24	32.29
SE(m)±		222.30	219.37	570.98	599.87	643.48	711.21	--	--
LSD (P=0.05)		651.98	643.90	1674.68	175.37	1887.27	2085.92	--	--

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