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ORIGINAL ARTICLE

Influence of Integrated Nutrient Management Practices on Profitability and Productivity of Maize (*Zea mays* L.)

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 rabi seasons of 2023-24 and 2024-25 to evaluate the effect of integrated nutrient management (INM) and bio-inoculation on the yield and economics of maize. The experiment comprised twelve treatments involving different combinations of recommended dose of fertilizers (RDF), farmyard manure (FYM), vermicompost, Azotobacter, and phosphate solubilizing bacteria (PSB), laid out in a randomized block design with three replications. The results revealed that yield and economic parameters were significantly influenced by different nutrient management practices. Among the treatments, application of 25% vermicompost + 75% RDF (T_{12}) recorded 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}) during 2023-24 and 2024-25, respectively, which remained statistically at par with 100% RDF (T_2). The harvest index was not markedly affected by treatments and remained within a narrow range, with the highest value under T_{12} (32.24 and 32.29%). Economic analysis showed that the maximum gross return (₹209,175 and ₹227,050 ha^{-1}), net return (₹158,672 and ₹176,017 ha^{-1}), and benefit-cost ratio (3.14 and 3.45) were also obtained under T_{12}, whereas the lowest values were recorded under the control treatment. Although the highest cost of cultivation was observed with 100% FYM + Azotobacter + PSB, it resulted in lower profitability due to reduced economic returns. The study concluded that integrated application of 25% vermicompost + 75% RDF proved to be the most productive and economically viable nutrient management strategy for maize cultivation.

Keywords: *Maize, Integrated Nutrient Management, Vermicompost, RDF, Bio-Inoculants, Grain Yield, Economics*

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INTRODUCTION

Maize is one of the most important cereal crops cultivated globally for food, feed, and industrial uses. Owing to its high productivity potential and wide adaptability under diverse agro-climatic conditions, maize plays a vital role in ensuring food security and supporting agricultural economies [1]. In India, maize ranks among the major cereal crops and contributes significantly to livestock nutrition and various agro-industrial sectors [2]

Nevertheless, prolonged and unbalanced application of inorganic fertilizers has adversely affected soil fertility, lowered nutrient use efficiency, and increased environmental concerns [3]To address these issues, sustainable nutrient management approaches are essential. Integrated Nutrient Management (INM), involving the combined use of inorganic fertilizers, organic manures, and biofertilizers, has emerged as a viable strategy for sustaining soil fertility and improving crop performance [4]

Biofertilizers such as Azotobacter and phosphate-solubilizing bacteria are beneficial in enhancing nutrient availability by fixing atmospheric nitrogen and solubilizing insoluble phosphorus. These microbial inoculants also stimulate soil microbial activity and promote plant growth [5,6]Since maize is a heavy nutrient-demanding crop, a balanced and efficient nutrient supply is necessary to achieve higher yields and better grain quality [7]

Although several studies have evaluated individual nutrient sources, information regarding their combined effects under integrated nutrient management systems is still limited. Therefore, the present investigation was undertaken to assess the influence of integrated nutrient management and bio-inoculation on the growth, yield, and quality of maize.

MATERIAL AND METHODS

Experimental site and climatic conditions

The field experiment was carried out during the kharif seasons of 2024 and 2025 at the Crop Research Centre, School of Agricultural Sciences, GD Goenka University, Sohna, Haryana, India, located at 28.26° N latitude and 77.06° E longitude with an altitude of 237 m above mean sea level. The experimental site falls under a sub-tropical climatic zone, characterized by hot and humid summers followed by cool and dry winters. During the cropping period, the maximum temperature ranged from 32.1 to 36.7°C, while the minimum temperature varied from 18.3 to 28.6°C, with uneven rainfall distribution.

Soil properties

The soil of the experimental field was sandy loam in texture with a slightly alkaline reaction (pH 7.58). It was low in organic carbon and available nitrogen, medium in available phosphorus, and high in available potassium. Soil samples were collected from 0–15 cm depth before sowing and analyzed using standard analytical procedures [8,9,10,11]

Experimental design and treatments

The experiment was laid out in a Randomized Block Design (RBD) with three replications comprising twelve treatments. The treatments included various combinations of recommended dose of fertilizers (RDF), farmyard manure (FYM), vermicompost, and bio-inoculants such as Azotobacter and phosphate-solubilizing bacteria. The recommended fertilizer dose was 120:80:60 kg $N:P_2O_5:K_2O$ ha^{-1} along with a control treatment.

Crop management practices

The 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 according to the treatment schedule, with nitrogen supplied in split applications, whereas phosphorus, potassium, and zinc were applied as basal doses. All agronomic practices including irrigation, weed control, and plant protection were uniformly maintained throughout the crop growth period.

Data recording

Yield parameters such as grain yield, stover yield, and biological yield were measured at harvest. Harvest index was calculated following the method suggested by [12] and the economics of various tratments.

Economic analysis

The economic viability of different treatments was evaluated by calculating the cost of cultivation, gross returns, net returns, and benefit–cost ratio based on prevailing market prices.

Statistical analysis

The recorded data were analyzed statistically using analysis of variance (ANOVA) suitable for Randomized Block Design as outlined by [13] Treatment differences were tested for significance using the F-test at 5% probability level, and the critical difference (CD) was computed for comparison of treatment means following the procedures described by Panse and [14].

RESULTS AND DISCUSSION

Cost of Cultivation

The cost of cultivation varied among different nutrient management treatments due to differences in the quantity and type of nutrient inputs used. The highest cost of cultivation was recorded under T10 (100% FYM + Azotobacter + PSB), amounting to ₹66,244 ha^{-1} during 2023-24 and ₹66,774 ha^{-1} during 2024-25. This higher cost was mainly due to the large quantity of farmyard manure and associated labour charges required for its application **[15].** In contrast, the lowest cost of cultivation was observed under the control treatment (T1) with ₹39,644 ha^{-1} and ₹40,174 ha^{-1} during the respective years, owing to the absence of fertilizer and manure application costs.

Among the integrated nutrient treatments, T12 (25% Vermicompost + 75% RDF) incurred a moderate cultivation cost of ₹50,902 ha^{-1} in 2023-24 and ₹51,032 ha^{-1} in 2024-25, which was economically efficient considering the returns obtained.

Gross Return

Gross return was markedly influenced by the nutrient management treatments. The highest gross return was obtained under T12 (25% Vermicompost + 75% RDF) with ₹209,175 ha^{-1} during 2023-24 and ₹227,050 ha^{-1} during 2024-25. This was due to the superior grain and stover yield recorded under this treatment. The enhanced nutrient availability through integrated application of vermicompost and RDF might have contributed to better crop growth and yield, thereby increasing gross income. [16]

The treatment T2 (100% RDF) also produced comparable gross returns of ₹206,663 ha^{-1} and ₹223,007 ha^{-1} in the two years, respectively. On the other hand, the lowest gross return was recorded in the control treatment (T1) with ₹107,836 ha^{-1} and ₹117,371 ha^{-1}, due to significantly lower productivity in the absence of nutrient application.

Net Return

Net return is the most important economic indicator reflecting the profitability of the treatment after deducting cultivation costs. The maximum net return was observed in T12 (25% Vermicompost + 75% RDF), which recorded ₹158,672 ha^{-1} during 2023-24 and ₹176,017 ha^{-1} during 2024-25. The higher net return under this treatment was mainly due to increased grain yield and higher gross return coupled with a comparatively moderate cost of cultivation[18]

This was closely followed by T2 (100% RDF) with net returns of ₹156,408 ha^{-1} and ₹172,222 ha^{-1}, indicating that both treatments were highly profitable. In contrast, the minimum net return was obtained in T1 (control) with ₹68,192 ha^{-1} and ₹77,197 ha^{-1}, owing to poor crop yield under nutrient-deficient conditions.

Benefit-Cost Ratio

The benefit-cost ratio provides a measure of economic efficiency of the treatments. The highest B:C ratio was recorded under T12 (25% Vermicompost + 75% RDF) with values of 3.14 in 2023-24 and 3.45 in 2024-25, indicating that this treatment was the most profitable and economically efficient among all treatments. The higher B:C ratio was mainly due to greater net returns achieved with relatively lower input costs. [**19]**

The treatment T2 (100% RDF) also showed a high B:C ratio of 3.11 and 3.39, which was very close to T12. However, the lowest B:C ratio was recorded under T10 (100% FYM + Azotobacter + PSB) with values of 1.38 and 1.56, indicating lower economic feasibility because of the high cost of organic inputs and comparatively lower yield.

Thus, the findings indicate that T12 (25% Vermicompost + 75% RDF) was the most economically viable nutrient management practice, resulting in maximum profitability and economic efficiency in maize cultivation.

Table 1: Response of INM and Bio-inoculation on economics of Maize

Tr.No.	**Treatments**	**Economics**							
		Total cost of cultivation		**Gross return**		**Net return**		**B:C Ratio**	
		2023-24	**2024-25**	**2023-24**	**2024-25**	**2023-24**	**2024-25**	**2023-24**	**2024-25**
T1	Control (No fertilizer)	39644	40174	107836	117371	68192	77197	1.72	1.92
T2	100% RDF (N, P, K)	50255	50785	206663	223007	156408	172222	3.11	3.39
T3	75% RDF + 25% FYM	54002	54532	199107	214647	145105	160115	2.69	2.94
T4	50% RDF + 50% FYM	56749	57279	189756	204837	133007	147558	2.34	2.58
T5	25% RDF + 50% FYM + Azotobacter + PSB	55646	56176	176381	190408	120735	134232	2.17	2.39
T6	100% Vermicompost + Azotobacter + PSB	56244	56774	164268	177940	108024	121166	1.92	2.13
T7	75% Vermicompost + Azotobacter + PSB	52494	53024	159590	172053	107096	119029	2.04	2.24
T8	50% Vermicompost + 50% RDF	51749	52279	197615	214230	145866	161951	2.82	3.10
T9	25% RDF + 50% Vermicompost + Azotobacter + PSB	50846	51376	182808	198090	131962	146714	2.60	2.86
T10	100% FYM + Azotobacter+ PSB	66244	66774	157815	171075	91571	104301	1.38	1.56
T11	75% FYM + Azotobacter+ PSB	59994	60524	153805	165854	93811	105330	1.56	1.74
T12	25% Vermicompost + 75% RDF	50902	51032	209175	227050	158672	176017	3.14	3.45

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 [20]

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 [21]

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 [21]

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 [21].

Table 2: 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	1759.37	1887.27	2085.92	--	--

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