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Integrated nutrient management strategies for enhancing growth, yield and yield attributes of Maize (*Zea mays* L.) under Trans-Gangetic plain of India

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Abstract

A field trial was carried out during the 2025 Kharif season at the research farm of the school of Agricultural Sciences, G.D. Goenka university, Sohna, Gurugram, Haryana to study the Integrated Nutrient Management Strategies for Enhancing Growth, Yield and Yield Attributes of Maize (*Zea mays* L.) under Trans- Gangetic Plain of India. The experiment was carried out using maize variety (HQPM-1) and was laid out in Randomized block design with ten treatments and replicated thrice. The result of the experiment revealed that application of 50%RDF +vermicompost @2.5 t ha⁻¹+ LC recorded highest plant height (195.42cm), LAI (4.35), fresh weight (395.56 g plant⁻¹), dry matter accumulation (170.0 g plant⁻¹), grains cob⁻¹ (443.3), Cob length(15.5 cm), Cob Grith (14.5 cm), Test weight (27.86 g), grain yield (4.92 t ha⁻¹), and stover yield (9.74 t ha⁻¹),over sole application of 100% RDF. The number of cobs plant⁻¹ was comparatively higher (1.88) under INM treatment but the difference between treatment was not statistically significant. The control treatment recorded the lowest values for all growth and yield attributes. “As a result, the study concluded that integrating 50% RDF with vermicompost @2.5 t ha⁻¹ and LC emerged as the best nutrient management strategy for enhancing crop growth and maximizing overall maize yield.

Keywords: Maize, integrated nutrient management, vermicompost, liquid consortia growth, yield

1. Introduction

Maize (*Zea mays* L.) is one of the world’s most significant cereal crops, belonging to the poaceae family. The crop serves as a staple food, feed, and industrial raw material. Its grains are high in nutrition, with around 10% protein, 4% oil, and 2-3% crude fibre. It is often referred to as the “queen of cereals,” due to its great genetic yield potential and wide adaptability across diverse Agro-climatic conditions. (Swati 2024) ^[14].

Maize is the world’s most commonly produced cereal crop, occupying about 205 million hectares with a total production of approximately 1,219 million tonnes during 2024-2025. The average production is about 6.0 t ha⁻¹. The US is the top producer, contributing about 31.38% of total worldwide production, followed by China with 23.28%. Other major maize- producing countries are Brazil, and India. Global maize production is gradually expanding, due to rising demand in the food, livestock feed and biofuel industries. The development of single- cross hybrids has further encouraged farmers to adopt maize into their cropping system in order to boost productivity and profitability (FAOUN 2025) ^[3].

In India Maize is the third most significant cereal crop after rice and wheat, it is cultivated throughout the year, but the kharif maize season accounts for the majority of both area and production. According to recent estimates India occupies fourth position with respective of maize cultivation area, covering approximately 10.74 million hectares with total production estimated at 43.41 million tonnes during 2024- 2025. The average productivity is about 3.5t ha, which is lower than the global average. Among states Madhya Pradesh is top producer followed by Karnataka, Bihar, Maharashtra, Telangana. In 2024-2025, India exported 556,416.94 metric tonnes of maize worth ₹ 1,705.93 crores (201.17 million USD), indicating its growing importance in the global maize market. (Maize | APEDA, 2026) ^[6].

One of most intensively cultivated regions in India is the Trans- Gangetic plains, which include parts of Delhi, Haryana, Punjab, and Western Uttar Pradesh. This region played an important

part in green revolution and continues to contribute significantly to the country's food grain production. However, farmer's growing kharif maize in this region were facing many challenges due to continuous cereal-based cropping and indiscriminate use of chemical fertilizers, leading to soil fertility depletion, nutrient imbalances, and declining soil organic carbon. Additionally, excessive ground water extraction has caused a decline in water levels, threatening long-term productivity and sustainability. To address these challenges, Integrated Nutrient Management (INM) has emerged as an effective strategy for enhancing crop and productivity and maintaining soil fertility (Gezahegn *et al.*, 2021) [4]. It involves the balanced and efficient use of inorganic fertilizers in combination with organic amendments, such as FYM, Vermicompost, Neem cake, crop wastes, and biofertilizers, to ensure an adequate and continuous supply of nutrients while maintain soil health. Studies have shown that such integrated approach improves nutrient availability, nutrient uptake, crop growth, and soil fertility. It also improves soil's physical, chemical, and biological qualities, resulting in better nutrient usage efficiency and crop performance. The current study was undertaken to identify the most efficient and sustainable INM practices on growth, yield and yield attributes of maize under Trans-Gangetic plain region.

2. Materials and Methods

The field trial was carried out during kharif season at the research farm of GD Goenka, Sohna, Gurugram, Haryana (122103) located in the Trans- Gangetic plains of India. The experimental site is geographically situated at 28.262859° North latitude and 77.064976° East longitude with an elevation of approximately 217- meter. The climate in this region is extremely hot especially during months of May- June, with maximum temperature rises up to 48 °C, the monsoon season extends from Mid- June to Mid- October, contributing 70-80% of the annual rainfall along with high relative humidity, and remaining rainfall during spring and winter seasons. The maximum and minimum temperatures during all growth phases range from 27 °C to 35 °C, 18 °C to 26 °C, with a relative humidity is 32% to 74% respectively. The soil was loamy sand with low organic carbon, and medium available nitrogen, phosphorous, and low in potassium.

The experiment was laid out in Randomized block design with three replications and ten treatments. The treatments were: T₁ 100% RDF (150:60:60 kg ha⁻¹), T₂ FYM @10 t ha⁻¹ +LC, T₃ vermicompost @ 5 t ha⁻¹ +LC, T₄ 50% RDF+ FYM @ 5 t ha⁻¹ + LC, T₅ 50% RDF+ vermicompost @ 2.5 t ha⁻¹ +LC, T₆ 50% RDF+ neem cake @0.25 t ha⁻¹ +LC, T₇ neem cake @0.375 t ha⁻¹ +25% RDF +LC, T₈ FYM @7.5 t ha⁻¹ +25%RDF+LC, T₉ vermicompost @3.75 t ha⁻¹ +25%RDF+LC, T₁₀ control. The Maize variety HQPM-1 was sown at seed rate of 20 kg/ha with a spacing 60×20cm. Organic sources (FYM, Vermicompost, Neem cake) and liquid consortia was applied before sowing as per treatment, while RDF was applied as basal and top dressing. Observations on plant height(cm), Fresh weight (g plant⁻¹), dry matter accumulation per plant(g plant⁻¹), leaf area index, number of cobs plant⁻¹, cob length(cm), cob girth(cm), number of grains cob⁻¹, test weight (g), grain yield(t ha⁻¹), stover yield(t ha⁻¹), and

harvest index(%) were recorded at different stages of crop growth up to harvest and treatments means were compared according to critical differences (CD) at 5% level of significance as suggested by Gomez are presented in table 3.1 and 3.2 These characters indicate the growth and productivity of the crop.

3. Results and Discussion

3.1 Growth Parameters

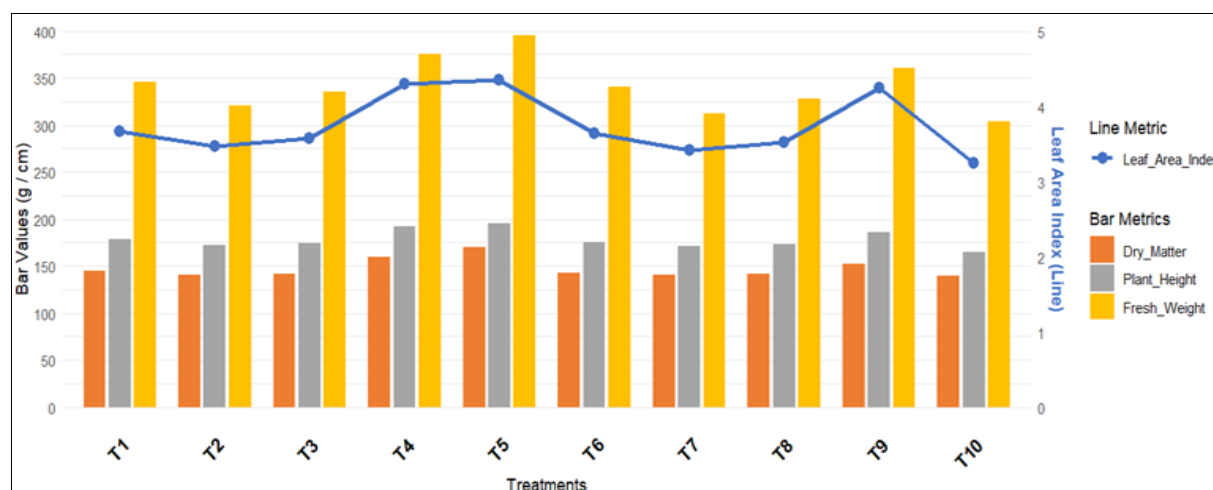
Plant height of maize was influenced by different integrated nutrient management treatments. The data (Table -1) and (Fig-2) indicated that plant height increased progressively with crop growth stages up to harvest. Plant height increased markedly from 30 to 60 DAS, reflecting the active vegetative growth phase of the crop, and further increase from 60 DAS to harvest due to continued cell elongation and efficient utilization of available nutrients. Application of 50% RDF +Vermicompost@ 2.5 t ha⁻¹ +LC resulted in significantly taller plants (195.42cm), followed by +50%RDF+ FYM@ 5 t ha⁻¹ + LC (192.48 cm), vermicompost @ 3.75 t ha⁻¹ + 25%RDF+ LC (186.44cm) and 100%RDF (178.43cm). The lowest plant height was recorded under control (165.0cm), where no nutrient inputs were applied. Treatments receiving integrated application of RDF along with organic sources performed better than application of 100% RDF. The increased plant height under integrated treatments was due to RDF promoting early growth, while organic sources supported later growth through sustained nutrient release. Vermicompost further improved plant height by enhancing nutrient availability, soil properties, and nutrient uptake. Similar observations were recorded by Biswasi *et al.*, 2020 [2].

Leaf area index, fresh weight, and dry matter accumulation of maize were significantly influenced by various INM treatments and followed a similar trend to plant height (Table-1). The highest LAI (4.35), fresh weight (395.56 g plant⁻¹) and dry matter accumulation (170.0g plant⁻¹) were recorded under application 50% RDF+ vermicompost @ 2.5 t ha⁻¹ + LC, 50%RDF+FYM @ 5 t ha⁻¹ +LC LAI (4.30), FW (375.56 g plant⁻¹) and DMA (160.0 g plant⁻¹) and vermicompost @ 3.75 t ha⁻¹ +25%RDF+LC LAI (4.24), FW (360.56 g plant⁻¹) and DMA (152.0 g plant⁻¹), however, these treatments were found to be statically at par with one another. The minimum LAI (3.25), FW (303.43 g plant⁻¹) and DMA (140.0 g plant⁻¹) was observed under control treatment.

The increased leaf area index under integrated treatments was due to improved leaf expansion, greater chlorophyll synthesis and better interception of solar radiation, resulting in enhanced overall canopy development. These observations align with Bhatt *et al.*, 2020 [1] who reported similar canopy improvements in maize as influence by sole and combined application of organic and inorganic fertilizers. The subsequent increase in fresh weight was due to improved plant vigour and continuous and balance nutrient availability, which promoted cell division and enlargement leading to higher vegetative biomass accumulation. which Ultimately, higher dry matter production was due to efficient nutrient use and better conversion of photosynthates into plant biomass under balanced nutrient supply and improved growth conditions- a physiological trend widely supported by Verma *et al.*, 2018 [15].

Table 1: Effect of Integrated nutrient management on Growth Parameters

Treatment combinations	Plant height (cm)	Leaf area index	Fresh weight (g pant ⁻¹)	Dry matter accumulation (g pant ⁻¹)
T ₁ -100% RDF	178.43	3.67	345.56	145.0
T ₂ - 100% FYM+LC	172.41	3.47	320.56	141.0
T ₃ - 100% Vermicompost + LC	174.55	3.58	335.56	142.0
T ₄ - 50% RDF + 50%FYM+LC	192.48	4.30	375.56	160.0
T ₅ - 50%RDF + 50% Vermicompost + LC	195.42	4.35	395.56	170.0
T ₆ - 50%RDF +50%Neem cake+ LC	175.46	3.64	340.56	143.0
T ₇ - 75% Neem cake +25%RDF+ LC	171.54	3.42	312.56	140.5
T ₈ - 75%FYM +25% RDF+LC	173.57	3.52	328.56	141.5
T ₉ - 75% Vermicompost + 25% RDF +LC	186.44	4.24	360.56	152.0
T ₁₀ - Control	165.0	3.25	303.43	140.0
SEm ±	5.38	0.22	16.02	6.26
CD (P=0.05)	16.01	0.66	47.60	18.60

**Fig 1:** Effect of INM on Growth parameters

3.2 Yield attributes

The results presented in (Table-2) showed that INM treatments significantly influenced yield attributes, Except for the number of cobs plant⁻¹ which showed non- significant variation among treatments, demonstrating that this parameter was not influenced by INM treatments. The Application of 50% RDF +vermicompost @ 2.5 t ha⁻¹ +LC recorded the higher test weight (27.86g), whereas, the lowest test weight (22.06g) was observed under control. Similar improvements in test weight under INM have also been reported by Singh *et al.*, 2022^[11]. Similarly, the higher number of grains cob⁻¹ (443.3 g), cob length (15.5 cm) and cob grith (14.5 cm), was obtained under 50%RDF+ vermicompost @ 2.5 t ha⁻¹ + LC. However, this treatment was statically at par with 50%RDF+FYM @ 5 t ha⁻¹ +LC and vermicompost @ 3.75 t ha⁻¹+25%RDF+LC, whereas lowest Number of grains cob⁻¹ (356.0 g) cob length(12.0cm) and cob grith(11.0cm). This increased grain number under integrated treatments due to improved nutrient availability and better physiological activity during reproductive stages, leading to enhanced grain setting (Mahato *et al.*, 2020) ^[5]. Pandit ^[7] observed similar improvement in cob size under integrated nutrient application, indicating better sink development and overall crop growth due to balanced nutrient supply. The number of cobs plant⁻¹ was comparatively higher (1.88) under INM treatment but the difference between treatment was not statistically significant. Similar findings are reported by Singh *et*

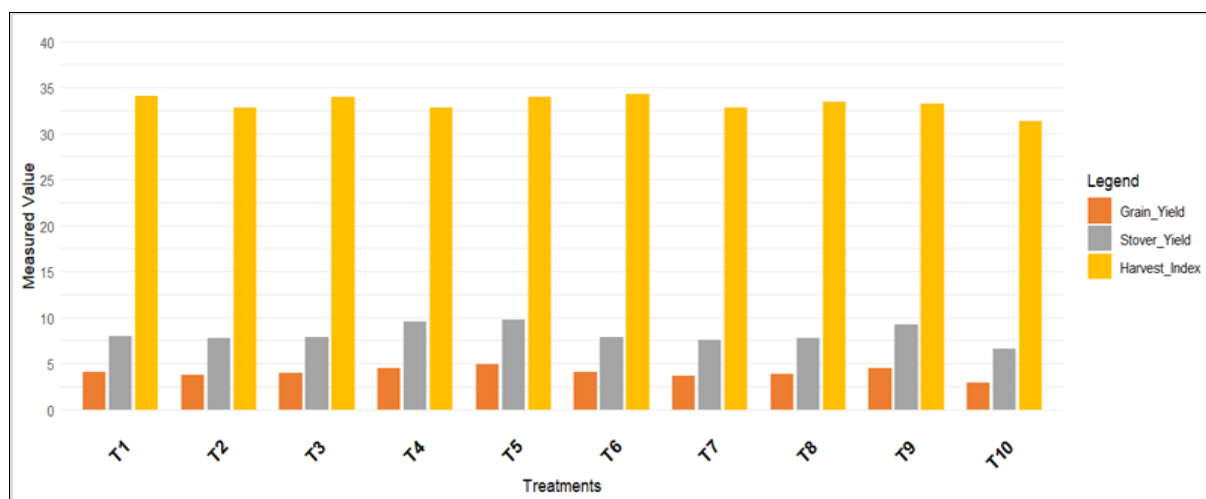
al., 2017^[10].

3.3 Yield

The grain and stover yield also Exhibited a positive response to INM treatments. As the data revealed in (Table 2) and (Fig 2) that the Application of 50%RDF +vermicompost @ 2.5 t ha⁻¹+LC produced significantly higher grain yield (4.92 t ha⁻¹) and stover yield (9.74 t ha⁻¹). This is followed by 50% RDF+ FYM @ 5 t ha⁻¹ + LC which yielded grain (4.54 t ha⁻¹), (9.50t ha⁻¹) stover and (4.51 t ha⁻¹), (9.22 t ha⁻¹) of grain and stover yield respectively obtained under vermicompost @ 3.75 t ha⁻¹+25% RDF+ LC, The lowest grain yield (2.95 t ha⁻¹) and stover yield(6.63 t ha⁻¹)was observed under the control. The increase in grain yield and stover yield due to balanced and continuous supply of nutrients under INM treatments, which improved nutrient uptake and nutrient availability support better leaf growth, stem development and prolonged photosynthetic activity, which maximized dry matter accumulation ultimately leading to greater stover yield. These results are in line with findings of Ponmozhi *et al.*,2019 ^[8]. Sigaye and M. H. 2020 ^[9] found similar results, with better stover yields when organic and inorganic nutrient management approaches were used. Enhanced photosynthetic efficiency and effective movement of food materials to the developing grains, resulting in higher grain yield also reported by Singh *et al.*, 2024^[12].

Table 2: Effect of INM on Yield attributes and Yield

Treatment combinations	No. of Cobs plant ⁻¹	No. of grains cob ⁻¹	Test weight(g)	Cob length (cm)	Cob grith (cm)	Grain yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)	Harvest Index (%)
T ₁ - 100% RDF	1.65	395.0	24.5	13.4	12.3	4.06	8.00	34.12
T ₂ -100% FYM+LC	1.61	370.0	23.7	12.8	11.5	3.75	7.71	32.77
T ₃ -100% Vermicompost + LC	1.64	375.0	24.1	13.1	11.9	3.95	7.85	33.93
T ₄ -50% RDF + 50%FYM+LC	1.75	433.6	26.86	15.3	13.8	4.54	9.50	32.83
T ₅ -50%RDF + 50% Vermicompost + LC	1.88	443.3	27.86	15.5	14.5	4.92	9.74	33.95
T ₆ -50%RDF +50%Neem cake+ LC	1.63	385.0	24.3	13.2	12.1	4.02	7.9	34.33
T ₇ -75% Neem cake +25%RDF+ LC	1.60	366.0	23.4	12.6	11.3	3.65	7.51	32.78
T ₈ -75%FYM +25% RDF+LC	1.62	372.0	23.9	12.9	11.7	3.85	7.8	33.40
T ₉ -75% Vermicompost + 25% RDF +LC	1.70	420.0	25.86	15.1	12.7	4.51	9.22	33.24
T ₁₀ - Control	1.39	356.0	22.06	12.0	11.0	2.95	6.63	31.37
SEm±	0.09	16.16	0.97	0.68	0.66	0.29	0.58	3.700
CD (P=0.05)	NS	48.02	2.89	2.02	1.98	0.86	1.74	NS

**Fig 2:** Effect of INM on Yield Parameters

4. Conclusion

The study clearly demonstrated that integrated nutrient management practices significantly improved the growth, yield attributes, and yield of maize compared to sole application of RDF and control. Among the different treatments, 50% RDF+ Vermicompost @ 2.5 t ha⁻¹+ Liquid consortia recorded the highest plant height, fresh and dry matter accumulation, leaf area index, Cob length, Cob grith, number of grains cob, and test weight. The same treatment also produced the maximum Grain yield and Stover yield. Therefore, the integrated application of 50%RDF+Vermicompost @ 2.5 t ha⁻¹+Lc proved to be the most effective nutrient management practice for enhancing maize productivity under Trans- Gangetic Plain of conditions.

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