

Synergistic Effects of Organic Manure, Inorganic Fertilizers and Biofertilizers on Growth Dynamics and Yield of Maize (*Zea Mays* L.)

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ABSTRACT

The present study was conducted to evaluate the synergistic effects of organic manure, inorganic fertilizers, and biofertilizers on growth dynamics and yield performance of maize (*Zea mays* L.) under field conditions. The experiment was carried out during the kharif seasons of 2024 and 2025 at the Agronomy Research Farm, Galgotias University, Greater Noida, using a Randomized Block Design with ten treatments and three replications. The treatments comprised different combinations of recommended dose of fertilizers (RDF), farmyard manure (FYM), vermicompost, and Azospirillum as a biofertilizer. The results revealed that integrated application of nutrient sources significantly influenced growth parameters, yield attributes, and yield of maize. Among the treatments, application of 100% RDF + 2.5 t ha⁻¹ vermicompost + Azospirillum (T5) recorded significantly higher plant height (210.08 cm), dry matter accumulation (1323.35 g m⁻²), cob length (20.08 cm), number of grains per cob (535.55), and test weight (33.22 g) compared to other treatments. T5 also produced the highest grain yield (60.90 q ha⁻¹), straw yield (97.07 q ha⁻¹), and biological yield (157.96 q ha⁻¹), which were statistically at par with T6 (100% RDF + FYM + biofertilizer) and significantly superior to the control. The enhanced performance under integrated nutrient management may be attributed to improved nutrient availability, balanced nutrient supply, and enhanced microbial activity resulting from the combined application of organic, inorganic, and biological nutrient sources. The findings demonstrate the effectiveness of integrated nutrient management in improving the growth and productivity of maize under field conditions.

Keywords: Maize (*Zea mays* L.); Integrated nutrient management; Organic manure; Vermicompost; Biofertilizers; Azospirillum; Growth attributes; Yield attributes; Grain yield; Sustainable agriculture

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1. Introduction

Maize (*Zea mays* L.) is one of the most widely cultivated cereal crops worldwide and is valued for its diverse applications as food, animal feed, and industrial raw material (Rashid *et al.*, 2024). It plays a vital role in global food security and economic development, thereby highlighting the need for sustainable agricultural practices that balance productivity with environmental conservation. Soil fertility is a key determinant of crop growth, yield, and overall agricultural sustainability (Singh *et al.*, 2021). Achieving higher crop productivity while maintaining soil health, which encompasses the physical, chemical, and biological properties essential for proper soil functioning, remains a major challenge in modern agriculture (Zhang *et al.*, 2021). Healthy soils facilitate nutrient cycling, enhance water retention, and support microbial activity, all of which are critical for sustained crop production. However, excessive reliance on chemical fertilizers and continuous intensive cultivation practices has led to the

degradation of soil quality, ultimately threatening long-term productivity. Therefore, the development of efficient nutrient management strategies is essential for maintaining soil fertility and ensuring sustainable crop production (Khan *et al.*, 2022).

In this context, organic nutrient sources such as compost, farmyard manure (FYM), and poultry manure have gained increasing importance due to their positive effects on soil fertility and sustainability. Organic inputs improve soil structure, enhance water holding capacity, and stimulate microbial activity by contributing organic matter to the soil (Patel *et al.*, 2023; Ahmed *et al.*, 2022). In addition to supplying essential nutrients, they promote beneficial microbial populations, which enhance nutrient cycling and improve the resilience of maize plants under various stress conditions (Kumar *et al.*, 2022). On the other hand, inorganic fertilizers provide nutrients in readily available forms, thereby supporting rapid plant growth and higher yields. However, their excessive and imbalanced use can result in soil acidification, nutrient

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imbalance, and a decline in microbial diversity, adversely affecting soil health (Li *et al.*, 2020). This underscores the importance of integrating organic and inorganic nutrient sources to achieve sustainable crop production.

Integrated Nutrient Management (INM) offers a holistic approach by combining the benefits of organic and inorganic inputs, thereby improving nutrient use efficiency, reducing environmental risks, and enhancing crop productivity (Saddozai *et al.*, 2025). Moreover, the type and combination of nutrient sources significantly influence soil properties and plant growth characteristics, making it essential to evaluate their interactive effects under field conditions (Jain *et al.*, 2022; Singh *et al.*, 2023).

Despite the growing emphasis on integrated nutrient management, limited information is available regarding the comparative effectiveness of different combinations of organic manures and inorganic fertilizers on the growth and yield performance of maize under specific agro-climatic conditions. Therefore, the present study was undertaken to evaluate the synergistic effects of organic and inorganic nutrient sources on the growth and yield of maize.

2. Materials & Methods

2.1 Experimental Site and Soil Characteristics

A field experiment was conducted during the *kharif* seasons of 2024 and 2025 at the Agronomy Research Farm, Department of Agriculture, Galgotias University, Greater Noida, Uttar Pradesh, India. The experimental site is characterized by sandy loam soil with a neutral to slightly alkaline reaction. Before sowing, composite soil samples were collected after proper field preparation and analyzed for initial physico-chemical properties.

The soil had a pH of 8.25, electrical conductivity (EC) of 0.27 dS m⁻¹, and organic carbon content of 0.35%. The available nutrient status indicated low nitrogen (217 kg ha⁻¹), medium phosphorus (21.64 kg ha⁻¹), and medium potassium (297.4 kg ha⁻¹).

2.2 Experimental Design and Treatments

The experiment was laid out in a Randomized Block Design (RBD) with ten treatments and three replications. The treatment details were as follows:

T₁: Control

T₂: 100% Recommended Dose of Fertilizers (RDF: 150:60:40 kg N:P₂O₅: K₂O ha⁻¹)

T₃: Vermicompost @ 2.5 t ha⁻¹

T₄: Farmyard manure (FYM) @ 2.5 t ha⁻¹

T₅: 100% RDF + Vermicompost @ 2.5 t ha⁻¹ + *Azospirillum* @ 2 L ha⁻¹

T₆: 100% RDF + FYM @ 2.5 t ha⁻¹ + *Azospirillum* @ 2 L ha⁻¹

T₇: Vermicompost @ 2.5 t ha⁻¹ + FYM @ 2.5 t ha⁻¹ + *Azospirillum*

T₈: 50% RDF

T₉: 50% RDF + Vermicompost @ 5 t ha⁻¹ + *Azospirillum* @ 2 L ha⁻¹

T₁₀: 50% RDF + FYM @ 7.5 t ha⁻¹ + *Azospirillum* @ 2 L ha⁻¹

Each plot measured 4 m × 4 m.

2.3 Crop Establishment and Nutrient Application

Maize variety PMH-14 was sown at a spacing of 60 cm × 20 cm. The recommended dose of fertilizers (RDF) was applied through urea (N), single super phosphate (P), and muriate of potash (K). Half of the nitrogen, along with the full dose of phosphorus and potassium, was applied as basal at the time of sowing and incorporated into the soil at a depth of approximately 15 cm. The remaining nitrogen was applied as top dressing at 20 days after sowing (DAS). Organic manures (vermicompost and FYM) were applied as per treatment before sowing and thoroughly mixed into the soil. The biofertilizer (*Azospirillum*) was applied as a soil application according to the treatment specifications.

2.4 Observations Recorded

Growth parameters such as plant height and dry matter accumulation were recorded at different growth stages. Yield attributes, including cob length, number of grains per cob, and test weight, were recorded at harvest. The crop was harvested at physiological maturity, and grain yield, stover yield, and biological yield were recorded and expressed in q ha⁻¹.

2.5 Statistical Analysis

The experimental data were statistically analysed using analysis of variance (ANOVA) for Randomized Block Design as described by Panse and Sukhatme (1985). The significance of treatment differences was tested at the 5% level of probability (P = 0.05).

3. Results and Discussion

3.1 Crop Growth Characters

3.1.1 Plant height

The data presented in Table 1 revealed that plant height of maize increased significantly with the application of integrated nutrient sources across both years of study. Among the treatments, T₅ (100% RDF + 2.5 t ha⁻¹ vermicompost + biofertilizer (*Azospirillum*) @ 2 L ha⁻¹) consistently recorded the highest plant height at all growth stages. At harvest, T₅ registered plant heights of 208.70 cm in 2024 and 211.46 cm in 2025, with a pooled mean of 210.08 cm. This treatment exhibited a substantial increase in plant height over T₁ (control), indicating the beneficial effect of combined nutrient application. However, T₅ remained statistically at par with T₆ (100% RDF + 2.5 t ha⁻¹ FYM + biofertilizer (*Azospirillum*) @ 2 L ha⁻¹) and T₂ (100% RDF), suggesting comparable performance among

these treatments. Similar trends were observed at 30, 60, and 90 DAS stages.

The pooled analysis over two years revealed that treatment T₅ (100% RDF + vermicompost @ 2.5 t ha⁻¹ + *Azospirillum* @ 2 L ha⁻¹) recorded a **43.7% higher plant height over T₁ (control), 7.7% over T₂ (100% RDF), 24% over T₃ (vermicompost @ 2.5 t ha⁻¹), and 28.03% over T₄ (FYM @ 2.5 t ha⁻¹)**. In addition, T₅ exhibited an increase of **18.9% over T₇ (vermicompost + FYM + *Azospirillum*), 10.4% over T₉ (50% RDF + vermicompost @ 5 t ha⁻¹ + *Azospirillum*), and 12% over T₁₀ (50% RDF + FYM @ 7.5 t ha⁻¹ + *Azospirillum*)**. When compared to T₈ (50% RDF), T₅ recorded a **15.1% higher plant height**, indicating the importance of balanced nutrient supply for optimum vegetative growth. Although T₆ (100% RDF + FYM @ 2.5 t ha⁻¹ + *Azospirillum*) was statistically at par with T₅, a marginal increase of **3.4%** was observed under T₅, which may be attributed to enhanced nutrient availability and improved root activity under integrated nutrient application (Singh *et al.*, 2018).

The superiority of T₅ may be attributed to the synergistic influence of inorganic fertilizers, organic amendments, and biofertilizers, which collectively enhanced nutrient availability and uptake (Yadav *et al.*, 2024). Vermicompost improves soil structure, aeration, and microbial activity, while biofertilizer (*Azospirillum*) facilitates biological nitrogen fixation and growth-promoting substances, leading to improved vegetative growth (Awasthi *et al.*, 2022). Similar trends were observed at 30, 60, and 90 DAS, indicating a consistent response throughout the crop growth period. The integrated use of these inputs ensures a balanced nutrient supply and promotes efficient utilisation, resulting in enhanced plant growth (Cui *et al.*, 2018).

Dry matter accumulation

The data presented in Table 2 revealed that dry matter accumulation of maize was significantly influenced by the application of different nutrient management practices during both years of study. Among the treatments, T₅ (100% RDF + 2.5 t ha⁻¹ vermicompost + biofertilizer (*Azospirillum*) @ 2 L ha⁻¹) consistently recorded the highest dry matter accumulation at all growth stages. At harvest, T₅ registered dry matter accumulation of 1246.56 g m⁻² in 2024 and 1400.13 g m⁻² in 2025, with a pooled mean of 1323.35 g m⁻². This treatment exhibited a substantial increase in dry matter accumulation over T₁ (control), indicating the positive effect of integrated nutrient application. However, T₅ remained statistically at par with T₆ (100% RDF + 2.5 t ha⁻¹ FYM + biofertilizer (*Azospirillum*) @ 2 L ha⁻¹) and T₂ (100% RDF), suggesting comparable performance among these treatments. Similar trends were observed at 30, 60, and 90 DAS stages, indicating a consistent response throughout the crop growth period.

The pooled mean data indicated that treatment T₅ (100% RDF + vermicompost @ 2.5 t ha⁻¹ + *Azospirillum* @ 2 L ha⁻¹) resulted in a **130.2% higher dry matter**

accumulation over T₁ (control), 19.1% over T₂ (100% RDF), 36.1% over T₃ (vermicompost @ 2.5 t ha⁻¹), and 42.6% over T₄ (FYM @ 2.5 t ha⁻¹). Furthermore, T₅ showed an increase of **32.4% over T₇ (vermicompost + FYM + *Azospirillum*), 19.1% over T₉ (50% RDF + vermicompost @ 5 t ha⁻¹ + *Azospirillum*), and 21.1% over T₁₀ (50% RDF + FYM @ 7.5 t ha⁻¹ + *Azospirillum*)**. In comparison to T₈ (50% RDF), T₅ recorded a **32.7% higher dry matter accumulation**, reflecting improved biomass production under adequate nutrient availability. Although T₆ was statistically at par with T₅, a slight increase of **8.1%** under T₅ may be attributed to better synchronisation of nutrient release and uptake under integrated nutrient management practices (Dhaliwal *et al.*, 2023).

The enhanced dry matter production under T₅ can be attributed to improved nutrient synchronisation and sustained nutrient release throughout the crop growth period (Mahmud *et al.*, 2021). Vermicompost acts as a reservoir of essential nutrients and enhances microbial activity, thereby improving nutrient mineralisation and availability (Meena *et al.*, 2022). Additionally, biofertilizer (*Azospirillum*) contributes to nitrogen fixation and stimulates root growth, leading to higher nutrient uptake and biomass accumulation (Hungria *et al.*, 2022). The combined application of these inputs likely improved photosynthetic efficiency and assimilate partitioning, resulting in higher dry matter accumulation. Similar trends were observed at 30, 60, and 90 DAS stages, confirming the consistent effect of integrated nutrient application. The findings are in agreement with Singh *et al.* (2021), who reported that the combined use of organic manures and biofertilizers enhances soil biological activity and nutrient availability, ultimately improving crop growth and biomass production.

The findings are in conformity with Singh *et al.* (2021), who reported that integrated use of organic manures and biofertilizers enhances nutrient availability and crop growth. The present results are also in agreement with Kumar *et al.* (2019), who observed increased biomass production in maize under integrated nutrient management systems. Similar observations were reported by Patel *et al.* (2022), who highlighted the positive influence of combined nutrient application on the growth and productivity of crops.

3.2 Yield attributes

3.2.1 Number of Cob plant⁻¹

The data presented in Table 3 revealed that the number of cobs per plant increased significantly with the application of integrated nutrient sources during both years of study. Among the treatments, T₅ (100% RDF + 2.5 t ha⁻¹ vermicompost + biofertilizer (*Azospirillum*) @ 2 L ha⁻¹) consistently recorded the highest number of cobs per plant. The treatment T₅ recorded 1.46 cobs plant⁻¹ in 2024 and 1.47 in 2025, with a pooled mean of 1.46. This treatment exhibited a substantial increase over T₁ (control), indicating the beneficial effect of integrated nutrient application. However, T₅ remained statistically at par with

T₆ (100% RDF + 2.5 t ha⁻¹ FYM + biofertilizer (*Azospirillum*) @ 2 L ha⁻¹) and T₂ (100% RDF).

The pooled analysis over two years revealed that treatment T₅ recorded a 30.3% higher number of cobs per plant over T₁ (control), 12.3% over T₂ (100% RDF), 19.6% over T₃ (vermicompost @ 2.5 t ha⁻¹), and 23.7% over T₄ (FYM @ 2.5 t ha⁻¹). In addition, T₅ exhibited an increase of 15.8% over T₇ (vermicompost + FYM + *Azospirillum*), 13.1% over T₉ (50% RDF + vermicompost @ 5 t ha⁻¹ + *Azospirillum*), and 13.1% over T₁₀ (50% RDF + FYM @ 7.5 t ha⁻¹ + *Azospirillum*). When compared to T₈ (50% RDF), T₅ recorded a 14.06% higher number of cobs per plant. Although T₆ was statistically at par with T₅, a marginal increase of 4.28% was observed under T₅.

The increase in the number of cobs per plant under T₅ may be attributed to enhanced nutrient availability and improved physiological efficiency, which promoted reproductive development (Jat *et al.*, 2021). The combined application of organic manure, inorganic fertilisers, and biofertilizer improved root growth, nutrient uptake, and assimilate partitioning towards reproductive structures, resulting in increased cob formation (Mahmud *et al.*, 2021).

3.2.2 Cob Length

The data presented in Table 3 indicated that cob length was significantly influenced by different nutrient management practices during both years. Among the treatments, T₅ recorded the maximum cob length (19.85 cm in 2024 and 20.31 cm in 2025, with a pooled mean of 20.08 cm), which was significantly higher than T₁. However, it remained statistically at par with T₆ and T₂.

The pooled analysis over two years revealed that treatment T₅ recorded a 33.4% higher cob length over T₁ (control), 8.89% over T₂ (100% RDF), 21.03% over T₃ (vermicompost @ 2.5 t ha⁻¹), and 24.1% over T₄ (FYM @ 2.5 t ha⁻¹). Further, T₅ exhibited an increase of 16.7% over T₇, 11.4% over T₉, and 12.6% over T₁₀. In comparison with T₈ (50% RDF), T₅ recorded a 13.9% higher cob length. Although T₆ was statistically at par with T₅, a slight increase of 3.18% was observed under T₅ (Jat *et al.*, 2021).

The increased cob length under T₅ may be attributed to enhanced photosynthetic activity, improved assimilate production, and efficient translocation towards developing cobs (Rehman *et al.*, 2023). Vermicompost ensured a continuous supply of nutrients, while biofertilizer (*Azospirillum*) enhanced nitrogen availability and root growth, resulting in better cob development (Rehman *et al.*, 2023).

3.2.3 Number of Grains per Cob

The data presented in Table 3 showed that the number of grains per cob was significantly affected by different treatments. The treatment T₅ recorded the highest number of grains per cob (529.12 in 2024 and 541.98 in 2025, with a pooled mean of 535.55), which was significantly higher than T₁. However, it remained statistically at par with T₆

(100% RDF + FYM @ 2.5 t ha⁻¹ + *Azospirillum* @ 2 L ha⁻¹) and T₂ (100% Recommended Dose of Fertilizers (RDF: 150:60:40 kg N:P₂O₅: K₂O ha⁻¹)).

The pooled analysis over two years revealed that treatment T₅ recorded a 38.2% higher number of grains per cob over T₁ (control), 8.0% over T₂ (100% RDF), 21.6% over T₃ (vermicompost @ 2.5 t ha⁻¹), and 26.9% over T₄ (FYM @ 2.5 t ha⁻¹). Additionally, T₅ showed an increase of 15.7% over T₇, 8.9% over T₉, and 10.9% over T₁₀. When compared to T₈ (50% RDF), T₅ recorded a 12.8% higher number of grains per cob. Although T₆ was statistically at par with T₅, a marginal increase of 4.5% was observed under T₅.

The higher number of grains per cob under T₅ may be attributed to improved nutrient availability during critical growth stages, which enhanced pollination, fertilisation, and grain setting. The synergistic effect of organic, inorganic, and biological inputs improved sink capacity and assimilate translocation, resulting in higher grain formation (Wang *et al.*, 2020).

3.2.4 Test Weight (g)

The data presented in Table 3 indicated that test weight was not significantly influenced by different nutrient management practices during both years of study. However, T₅ recorded comparatively higher test weight (33.06 g in 2024 and 33.39 g in 2025, with a pooled mean of 33.22 g) as compared to other treatments. The slight improvement observed under T₅ may be attributed to better grain filling due to balanced nutrient supply and improved physiological efficiency under integrated nutrient management (Jat *et al.*, 2021).

3.3 Yield studies

3.3.1 Grain yield

The data presented in Table 4 revealed that grain yield of maize was significantly influenced by different nutrient management practices during both years of study. Among the treatments, T₅ (100% RDF + 2.5 t ha⁻¹ vermicompost + biofertilizer (*Azospirillum*) @ 2 L ha⁻¹) consistently recorded the highest grain yield during 2024 and 2025. However, T₅ remained statistically at par with T₆ (100% RDF + 2.5 t ha⁻¹ FYM + biofertilizer (*Azospirillum*) @ 2 L ha⁻¹).

The pooled analysis revealed that T₅ recorded a 141.5% higher grain yield over T₁ (control), 20.07% over T₂ (100% RDF), 34.7% over T₃ (vermicompost @ 2.5 t ha⁻¹), and 44.9% over T₄ (FYM @ 2.5 t ha⁻¹). Further, T₅ exhibited an increase of 32.07% over T₇, 20.1% over T₉, and 21.5% over T₁₀. When compared with T₈ (50% RDF), T₅ recorded a 33.6% higher grain yield, while a marginal increase of 9.82% was observed over T₆.

The higher grain yield under T₅ can be directly linked to the cumulative improvement in yield attributes such as cob length, number of grains per cob, and number of cobs per plant. The integrated application of vermicompost and biofertilizer (*Azospirillum*) likely enhanced nutrient

availability during critical growth stages, particularly flowering and grain filling, which are highly sensitive to nutrient supply (Bhattacharjee *et al.*, 2008). Vermicompost ensured a gradual release of nutrients and improved microbial activity, whereas *Azospirillum* contributed to biological nitrogen fixation and production of growth-promoting substances (Rehman *et al.*, 2023). This resulted in enhanced photosynthetic activity, greater assimilate production, and efficient translocation towards grains, ultimately increasing economic yield Wang *et al.*, 2020). The synergistic interaction among nutrient sources ensured balanced nutrition and minimised nutrient losses, thereby improving yield performance (Agegnehu *et al.*, 2020)

3.3.2 Stover Yield

The data indicated that the stover yield of maize was significantly influenced by different nutrient management practices during both years. Among the treatments, T₅ recorded the highest stover yield, followed by T₆ (100% RDF + FYM @ 2.5 t ha⁻¹ + *Azospirillum* @ 2 L ha⁻¹) and T₂ (100% Recommended Dose of Fertilisers (RDF: 150:60:40 kg N: P₂O₅: K₂O ha⁻¹), which were statistically at par.

The pooled analysis revealed that T₅ recorded a 138.9% higher stover yield over T₁ (control), 20.5% over T₂, 36.5% over T₃, and 43.3% over T₄. Additionally, T₅ showed an increase of 34.2% over T₇, 19.9% over T₉, and 22.5% over T₁₀. When compared with T₈, T₅ recorded a 34.9% higher stover yield.

The increased stover yield under T₅ may be attributed to enhanced vegetative growth and biomass accumulation resulting from improved nutrient availability and uptake. The combined application of organic manure and biofertilizer improved soil biological activity and root proliferation, leading to efficient absorption of nutrients and water. This enhanced nutrient availability promoted cell division and elongation, leading to increased plant height and dry matter accumulation, which ultimately contributed to higher stover yield (Agegnehu *et al.*, 2020). The balanced supply of nutrients ensured sustained crop growth throughout the growth cycle, minimising nutrient stress and promoting continuous biomass accumulation (Jat *et al.*, 2021). These results indicate that integrated nutrient management plays a crucial role in enhancing both structural and economic yield components (Vanlauwe *et al.*, 2019).

3.3.3 Biological Yield

The data presented in Table 4 revealed that biological yield was significantly influenced by nutrient management practices during both years. Among the treatments, T₅ 100% RDF + Vermicompost @ 2.5 t ha⁻¹ + *Azospirillum* @ 2 L ha⁻¹ recorded the highest biological yield (155.8 q ha⁻¹ in 2024 and 160.11 q ha⁻¹ in 2025, with a pooled mean of 157.96 q ha⁻¹), which was significantly higher than T₁ (control). However, T₅ remained statistically at par with T₆ 100% RDF + FYM @ 2.5 t ha⁻¹ + *Azospirillum* @ 2 L ha⁻¹). The pooled analysis revealed that T₅ recorded a 139.9% higher biological yield over T₁ (control), 20.3%

over T₂, 35.8% over T₃, and 43.9% over T₄. Further, T₅ showed an increase of 33.3% over T₇, 20.03% over T₉, and 22.1% over T₁₀. When compared with T₈, T₅ recorded a 34.4% higher biological yield, while a marginal increase of 9.5% was observed over T₆.

The substantial increase in biological yield under T₅ reflects the combined enhancement of both vegetative and reproductive growth. The integrated application of vermicompost and biofertilizer (*Azospirillum*) likely enhanced nutrient synchronization and sustained availability throughout the crop growth period, thereby resulting in higher total biomass production (Rehman *et al.*, 2023). Vermicompost contributed to sustained nutrient release and enhanced microbial activity, while biofertilizer (*Azospirillum*) improved nutrient transformation and uptake efficiency through enhanced root growth and nutrient acquisition mechanisms (Rehman *et al.*, 2023; Bernados *et al.*, 2024). This led to increased photosynthetic efficiency, better canopy development, and higher dry matter accumulation, which collectively contributed to enhanced biological yield. The results underscore the effectiveness of integrated nutrient management in enhancing overall crop productivity and sustaining higher yield (Singh *et al.*, 2012).

3.3.4 Harvest Index

Different treatments did not significantly influence the harvest index, although slight variations were observed (Table 4). The highest harvest index was recorded under T₅ (0.39%), followed by T₆, while the lowest value was observed under T₁ (control). The relatively higher harvest index under integrated nutrient treatments suggests improved source-sink relationship and efficient translocation of photosynthates from vegetative parts to grains. The balanced supply of nutrients under T₅ ensured optimal partitioning of assimilates between vegetative growth and grain development, preventing excessive diversion toward either component (Singh *et al.*, 2017; Kumar *et al.*, 2019; Tilman *et al.*, 2002). This indicates that integrated nutrient management not only enhances total biomass production but also improves the efficiency of its utilisation to achieve economic yield. These findings are in agreement with Choudhary *et al.* (2016), who reported improved harvest index under integrated nutrient management due to enhanced assimilate partitioning.

4. Conclusion

The findings of the present investigation highlight the significant role of the **synergistic interaction** between inorganic fertilizers, organic amendments and biofertilizer in enhancing maize productivity. Among the treatments, **T₅: 100% RDF + 2.5 t ha⁻¹ vermicompost + biofertilizer (*Azospirillum* @ 2 L ha⁻¹)** recorded superior performance in terms of growth, yield and yield attributes across both years and in pooled analysis, followed closely by T₆.

The improved performance under T₅ may be attributed to the complementary and synergistic effects of these inputs, which ensured balanced nutrient supply, improved nutrient

use efficiency and better crop performance. In contrast, T₁ (control) recorded the lowest values for all parameters.

Thus, it can be concluded that the synergistic use of recommended fertilizers along with organic manures and biofertilizers is an effective approach for achieving higher maize productivity under the given conditions.

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Table 1: Effect of organic manure, inorganic fertilizer and biofertilizer on Plant Height at various growth stages of maize during 2024-2025

Treatment	Plant Height (cm)											
	2023	2024	Mean	2023	2024	Mean	2023	2024	Mean	2023	2024	Mean
	30 DAS			60 DAS			90 DAS			At Harvest		
T ₁	27.20	28.99	28.10	102.70	105.19	103.95	134.80	139.15	136.98	145.20	147.12	146.16
T ₂	41.44	44.23	42.80	145.50	149.03	147.27	180.89	186.73	183.81	193.53	196.09	194.81
T ₃	33.20	35.38	34.30	123.70	126.70	125.20	156.92	161.99	159.46	168.30	170.52	169.41
T ₄	31.07	33.11	32.10	119.50	122.40	120.95	152.29	157.21	154.75	163.00	165.15	164.08
T ₅	47.20	50.30	48.80	157.70	161.52	159.61	195.12	201.42	198.27	208.70	211.46	210.08
T ₆	44.97	47.92	46.40	152.50	156.20	154.35	188.90	195.01	191.96	201.82	204.49	203.16
T ₇	35.93	38.29	37.10	130.50	133.66	132.08	163.86	169.15	166.51	175.50	177.82	176.66
T ₈	38.17	40.67	39.40	135.50	138.78	137.14	169.40	174.87	172.14	181.30	183.69	182.50
T ₉	40.20	42.84	41.50	141.70	145.13	143.42	176.58	182.28	179.43	189.02	191.52	190.27
T ₁₀	39.20	41.78	40.50	139.70	143.09	141.40	173.95	179.57	176.76	186.20	188.66	187.43
SEm (±)	1.95	2.09	2.00	4.27	4.37	103.95	5.39	5.57	5.48	5.44	5.60	5.52
LSD (p<0.05)	5.80	6.20	6.00	12.67	12.98	147.27	16.02	16.54	16.28	16.16	16.64	16.40

Table 2: Combined effect of organic and inorganic nutrient management practices on Dry Matter Accumulation at various growth stages of maize during 2024 to 2025

Treatment	Dry Matter Accumulation (g m ⁻²)											
	2024	2025	Mean	2024	2025	Mean	2024	2025	Mean	2024	2025	Mean

	30 DAS			60 DAS			90 DAS			At Harvest		
T ₁	94.78	100.13	97.46	357.85	388.77	373.31	483.29	536.45	509.87	520.92	585.10	553.01
T ₂	223.07	235.67	229.37	790.98	859.32	825.15	981.25	1089.19	1035.22	1046.13	1175.01	1110.57
T ₃	178.11	188.17	183.14	663.61	720.94	692.28	862.10	956.93	909.52	915.75	1028.57	972.16
T ₄	164.01	173.28	168.65	630.88	685.38	658.13	829.73	921.00	875.37	873.72	981.37	927.55
T ₅	284.65	300.73	292.69	951.05	1033.22	992.14	1174.19	1303.35	1238.77	1246.56	1400.13	1323.35
T ₆	259.84	274.52	267.18	881.22	957.36	919.29	1089.24	1209.06	1149.15	1152.81	1294.83	1223.82
T ₇	191.57	202.39	196.98	695.72	755.83	725.78	887.65	985.29	936.47	940.96	1056.89	998.93
T ₈	196.31	207.40	201.86	696.94	757.16	727.05	887.25	984.85	936.05	938.68	1054.33	996.51
T ₉	224.05	236.71	230.38	789.75	857.99	823.87	984.82	1093.15	1038.99	1046.13	1175.01	1110.57
T ₁₀	217.13	229.39	223.26	773.79	840.64	807.22	967.65	1074.09	1020.87	1028.58	1155.30	1091.94
SEm (±)	9.17	9.69	9.43	23.79	25.85	24.82	30.63	34.00	32.32	32.70	36.73	34.72
LSD (p≤0.05)	27.25	28.79	28.02	70.70	76.80	73.75	91.00	101.01	96.01	97.16	109.13	103.15

Table 3: Combined effect of organic and inorganic nutrient management practices on yield attributes at various growth stages of maize during 2024 to 2025

Treatment	Yield Attributes											
	No. of Cob plant ⁻¹			Cob Length (cm)			No. of grain cob ⁻¹			Test weight (g)		
	2024	2025	Mean	2024	2025	Mean	2024	2025	Mean	2024	2025	Mean
T ₁	1.12	1.13	1.12	14.88	15.23	15.05	382.81	392.12	387.46	27.18	27.45	27.31
T ₂	1.34	1.35	1.3	18.23	18.65	18.44	489.02	502.71	495.86	30.93	31.24	31.08
T ₃	1.22	1.23	1.22	16.40	16.78	16.59	434.92	445.49	440.20	29.21	29.50	29.35
T ₄	1.18	1.19	1.18	16.00	16.37	16.18	416.88	427.02	421.95	28.40	28.68	28.54
T ₅	1.46	1.47	1.46	19.85	20.31	20.08	529.12	541.98	535.55	33.06	33.39	33.22
T ₆	1.40	1.41	1.40	19.24	19.68	19.46	506.07	518.37	512.22	32.05	32.36	32.20
T ₇	1.26	1.27	1.26	17.01	17.40	17.20	456.97	468.08	462.52	30.02	30.32	30.17
T ₈	1.27	1.29	1.28	17.42	17.82	17.62	468.99	480.39	474.69	30.43	30.73	30.58
T ₉	1.29	1.30	1.29	17.82	18.23	18.02	487.03	495.87	491.45	30.63	30.93	30.78
T ₁₀	1.28	1.30	1.29	17.62	18.03	17.82	477.01	488.61	482.81	30.53	30.83	30.68
SEm (±)	0.05	0.05	0.05	0.57	0.59	0.58	13.84	14.18	14.01	1.01	1.02	1.01

LSD ($p \leq 0.05$)	0.15	0.16	0.15	1.70	1.74	1.72	41.12	42.12	41.62	NS	NS	NS
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Table 4: Combined effect of organic and inorganic nutrient management practices on yield ($q\ ha^{-1}$) and Harvest Index (%) of maize during 2024 to 2025

Treatment	Yield ($q\ ha^{-1}$) Analysis											
	Grain Yield ($q\ ha^{-1}$)			Stover Yield ($q\ ha^{-1}$)			Biological Yield ($q\ ha^{-1}$)			Harvest Index (%)		
	2024	2025	Mean	2024	2025	Mean	2024	2025	Mean	2024	2025	Mean
T ₁	25.08	25.34	25.21	40.03	41.21	40.62	65.10	66.55	65.83	38.49	38.01	38.25
T ₂	50.35	51.09	50.72	80.42	80.56	80.49	130.80	131.65	131.23	38.50	38.80	38.65
T ₃	44.05	46.31	45.18	70.42	71.72	71.07	114.50	118.03	116.27	38.43	39.18	38.81
T ₄	41.98	42.05	42.02	67.23	68.23	67.73	109.20	110.28	109.74	38.49	38.18	38.34
T ₅	59.85	61.95	60.90	95.97	98.17	97.07	155.80	160.11	157.96	38.47	38.70	38.59
T ₆	55.39	55.50	55.45	88.71	88.80	88.76	144.10	144.30	144.20	38.43	38.45	38.44
T ₇	45.30	46.91	46.11	72.32	72.32	72.32	117.60	119.23	118.42	38.61	39.46	39.04
T ₈	45.51	45.64	45.58	71.82	71.99	71.91	117.30	117.63	117.47	38.79	38.80	38.80
T ₉	50.34	50.99	50.67	80.42	81.42	80.92	130.80	132.40	131.60	38.47	38.47	38.47
T ₁₀	49.88	50.34	50.11	78.70	79.70	79.20	128.60	130.04	129.32	38.79	38.71	38.75
SEm (\pm)	1.56	2.59	2.08	2.68	4.11	3.40	4.14	6.34	5.24	0.86	0.87	0.87
LSD ($p \leq 0.05$)	4.64	7.71	6.18	7.95	12.21	10.08	12.31	18.85	15.58	NS	NS	NS