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Influence of organic amendments, inorganic fertilizers and biofertilizers on growth and yield of maize (*Zea mays* L.) in saline soils

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Abstract

A field experiment was conducted at the experimental farm of Galgotias University, Greater Noida, Uttar Pradesh, during the *kharif* season of 2024–2025 to evaluate the effect of integrated nutrient management on the growth, productivity, and quality of maize (*Zea mays* L.) under saline soil conditions. The experiment was laid out in a randomized block design with three replications comprising ten treatments, including combinations of recommended dose of fertilizers (RDF), vermicompost, farmyard manure (FYM), and biofertilizer (*Azospirillum*). The results revealed that the application of 100% RDF along with 2.5 t ha⁻¹ vermicompost and *Azospirillum* recorded significantly higher growth and yield parameters compared to other treatments. This treatment resulted in maximum dry matter accumulation (951.05 g m⁻² at 60 DAS and 1246.56 g m⁻² at harvest), plant height (157.70 cm at 60 DAS and 208.70 cm at harvest), and plant population (8.33 and 8.15 plants m⁻² at 30 DAS and harvest, respectively). It also produced the highest grain yield (59.85 q ha⁻¹), stover yield (95.97 q ha⁻¹), biological yield (155.8 q ha⁻¹), and harvest index (38.47%). The study demonstrates that the integrated application of inorganic fertilizers, organic amendments, and biofertilizers enhances crop performance and productivity in saline soils and can be recommended as a sustainable nutrient management strategy for maize cultivation.

Keywords: Integrated nutrient management, maize (*Zea mays* L.), saline soil, vermicompost, farmyard manure, biofertilizer (*Azospirillum*), grain yield, soil fertility

1. Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops globally and serves as a staple food for over 900 million people in developing countries. It ranks as the third most significant cereal after rice and wheat and is widely utilized for human consumption, animal feed, and various industrial products such as starch, oil, protein, and biofuel. Owing to its wide adaptability and relatively lower sensitivity to photoperiod, maize performs well under diverse climatic conditions, making it a suitable crop under changing climate scenarios (Sarangi *et al.*, 2017) [19]. Despite its importance, maize productivity in certain regions remains relatively low, with an average yield of about 3.25 t ha⁻¹ and limited cultivation area, highlighting the need for improved nutrient management strategies (Behera *et al.*, 2020) [3].

Maize is a highly nutrient-exhaustive crop due to its rapid growth and high genetic yield potential. It requires substantial amounts of essential nutrients, particularly nitrogen (N) and phosphorus (P), throughout its growth stages to achieve optimum productivity. Continuous cultivation of maize often leads to significant depletion of soil nutrients, thereby affecting soil fertility and long-term sustainability (Sarkar *et al.*, 2018) [21]. Among various nutrients, efficient nitrogen management plays a crucial role in enhancing maize yield (Sarangi *et al.*, 2020) [20]. However, soil fertility is inherently variable across space and time, making it essential to adopt site-specific and balanced nutrient management practices (Kolawole *et al.*, 2018) [12].

In this context, integrated nutrient management (INM), which combines inorganic fertilizers with organic amendments and biofertilizers, has emerged as a sustainable approach to improve soil health and crop productivity. Therefore, the present study was undertaken to evaluate the effect of inorganic nutrient levels and organic supplements on the growth, productivity, and quality of maize under saline soil conditions.

2. Materials and Methods

A field experiment was conducted at the Research Farm of Galgotias University, Greater Noida, Uttar Pradesh, India, during the *kharif* season 2024–2025. The experimental site is located at 28°21'58" N latitude and 77°32'31" E longitude, at an altitude of 212 m above mean sea level, and is characterized by a semi-arid tropical climate with an average annual rainfall of 748 mm.

The soil of the experimental field was classified as very fine clay loam (Vertisol). Before the initiation of the experiment, soil samples (0–15 cm depth) were collected and analyzed, revealing the following properties: pH 8.2 (1:2.5 soil: water suspension), electrical conductivity (EC) 0.26 dS m⁻¹, organic carbon 0.35% (medium), available nitrogen 259.9 kg ha⁻¹, available phosphorus 49.2 kg P₂O₅ ha⁻¹, and available potassium 412.0 kg K₂O ha⁻¹.

The experiment was laid out in a randomized block design with three replications and ten treatments. The treatments included: T₁ (control), T₂ (100% recommended dose of fertilizers, RDF), T₃ (2.5 t ha⁻¹ vermicompost), T₄ (2.5 t ha⁻¹ farmyard manure, FYM), T₅ (100% RDF + 2.5 t ha⁻¹ vermicompost + *Azospirillum*), T₆ (100% RDF + 2.5 t ha⁻¹ FYM + *Azospirillum*), T₇ (2.5 t ha⁻¹ vermicompost + 2.5 t ha⁻¹ FYM + *Azospirillum*), T₈ (50% RDF), T₉ (50% RDF + 5 t ha⁻¹ vermicompost + *Azospirillum*), and T₁₀ (50% RDF + 7.5 t ha⁻¹ FYM + *Azospirillum*).

The maize variety used was PHM-14 (Pusa Hybrid Makka-14). The recommended fertilizer dose comprised 150 kg N ha⁻¹, 60 kg P₂O₅ ha⁻¹, and 40 kg K₂O ha⁻¹. Urea, single super phosphate (SSP), and muriate of potash (MOP) were used as sources of nitrogen, phosphorus, and potassium, respectively. Full doses of phosphorus and potassium and half of the nitrogen were applied as basal at sowing, while the remaining nitrogen was applied as top dressing at 20 days after sowing (DAS), as per treatment specifications. Two irrigations were applied, one at sowing and the other at 20 DAS. All other recommended agronomic practices were followed uniformly across treatments to ensure healthy crop growth. Observations on growth parameters, yield attributes, and yield were recorded at appropriate growth stages and at harvest. Grain and biological yields were measured at maturity.

Soil samples were analyzed for organic carbon, pH, and available N, P, and K using standard analytical methods. Nitrogen content (%) in grain and straw was determined, and nutrient uptake was calculated by multiplying the yield by the respective nutrient concentration. The recorded data were subjected to statistical analysis using standard procedures appropriate for a randomized block design (Panse & Sukhatme 1985) [16].

3. Results and Discussion

3.1 Growth parameters

3.1.1 Plant height

Figure 1 illustrates the effect of organic amendments and inorganic nutrient levels on plant height at 60 days after sowing (DAS) and at harvest. Significantly higher plant height was recorded with the application of 100% RDF + 2.5 t ha⁻¹ vermicompost + *Azospirillum* (157.70 cm at 60 DAS and 208.70 cm at harvest), which was statistically at par with 100% RDF + 2.5 t ha⁻¹ FYM + *Azospirillum* (152.50 cm and 201.82 cm at 60 DAS and harvest, respectively). The lowest plant height was observed in the control treatment at both growth stages.

Application of 100% RDF resulted in 2.68%, 4.15%, and 7.38% higher plant height compared to 50% RDF + 5 t ha⁻¹ vermicompost + *Azospirillum*, 50% RDF + 7.5 t ha⁻¹ FYM + *Azospirillum*, and 50% RDF alone, respectively. Furthermore, the combined application of vermicompost (2.5 t ha⁻¹) and FYM (2.5 t ha⁻¹) along with *Azospirillum* increased plant height by 5.49% and 9.20% over the sole application of vermicompost and FYM, respectively.

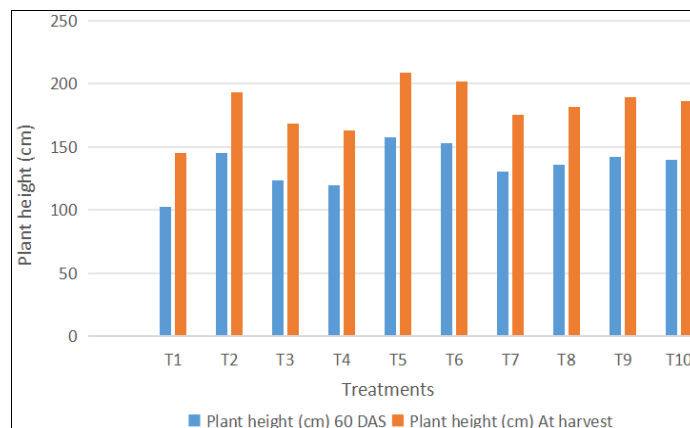


Fig 1: Effect of organic supplements and inorganic nutrient levels on plant height of maize at 60 DAS and at harvest

The increase in plant height under integrated nutrient management can be attributed to improved nutrient availability and uptake during crop growth. The intercalary meristem contributes to cell elongation, thereby enhancing plant height. Fertilizer treatments significantly influenced plant height at different stages, as also reported by Parveen Gill *et al.* (2018) [17].

The combined application of organic and inorganic sources ensures a balanced nutrient supply, with inorganic fertilizers providing immediate availability and organic sources releasing nutrients gradually. Enhanced soil fertility and nitrogen availability further support plant growth. Similar results were reported by Boomsma *et al.* (2009) [4] and Khan *et al.* (2016) [11]. Improved soil properties and nutrient uptake under integrated nutrient management also promote vegetative growth and photosynthetic activity, leading to better plant performance (Yamini *et al.*, 2025) [25].

3.1.2 Plant population

Figure 2 illustrates the effect of organic supplements and inorganic nutrient levels on plant population at 30 DAS and at harvest. Significantly higher plant population was recorded with the application of 100% RDF + 2.5 t ha⁻¹ vermicompost + biofertilizer (*Azospirillum*) (8.33–8.15 m⁻²), which was statistically at par with 100% RDF + 2.5 t ha⁻¹ FYM + biofertilizer (*Azospirillum*) (8.27–8.08 m⁻²). The lowest plant population was observed under control at both stages.

Application of 100% RDF recorded 0.49%, 0.73%, and 0.98% higher plant population compared to 50% RDF + 5 t ha⁻¹ vermicompost + biofertilizer (*Azospirillum*), 50% RDF + 7.5 t ha⁻¹ FYM + biofertilizer (*Azospirillum*), and 50% RDF, respectively. Furthermore, the combined application of 2.5 t ha⁻¹ vermicompost + 2.5 t ha⁻¹ FYM + biofertilizer (*Azospirillum*) resulted in 1.38% and 2.29% higher plant population compared to the sole application of vermicompost and FYM, respectively.

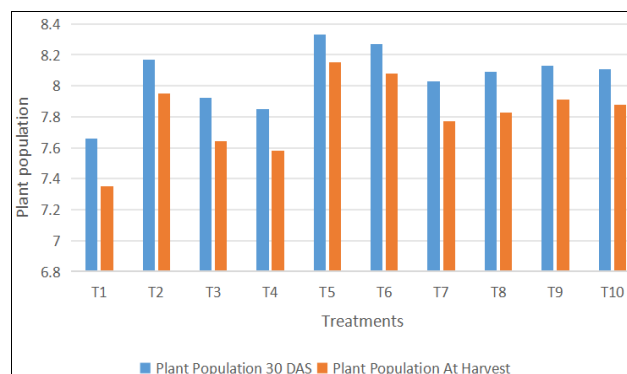


Fig 2: Effect of organic supplements and inorganic nutrient levels on the plant population of maize at 30 DAS and at harvest

Plant population is a crucial indicator of a crop's ability to germinate, establish, and survive under specific soil and environmental conditions. The higher plant population observed under integrated nutrient management (INM) treatments compared to control and inorganic fertilizers alone may be attributed to the beneficial effects of organic amendments such as FYM, compost, and green manure (Kamboj *et al.*, 2024) [6]. These organic inputs improve soil physical properties, including aeration, structure, and moisture retention, thereby enhancing seed germination and crop establishment.

In salt-affected soils, factors such as high osmotic pressure, poor aggregation, and surface crusting restrict seedling emergence and growth (Manono *et al.*, 2026) [14]. The addition of organic matter helps alleviate these constraints by improving soil porosity, microbial activity, and permeability, resulting in better plant establishment.

3.2 Yield

3.2.1 Grain Yield

Figure 3 illustrates the effect of organic supplements and inorganic nutrient levels on grain and stover yield of maize. Significantly higher grain yield was recorded with the application of 100% RDF + 2.5 t ha⁻¹ vermicompost + biofertilizer (*Azospirillum*) (59.85 q ha⁻¹), which was statistically at par with 100% RDF + 2.5 t ha⁻¹ FYM + biofertilizer (*Azospirillum*) (55.39 q ha⁻¹). The lowest grain yield was observed under control conditions.

Application of 100% RDF recorded 0.01%, 0.94%, and 10.6% higher grain yield compared to 50% RDF + 5 t ha⁻¹ vermicompost + biofertilizer (*Azospirillum*), 50% RDF + 7.5 t ha⁻¹ FYM + biofertilizer (*Azospirillum*), and 50% RDF alone, respectively. Furthermore, the combined application of 2.5 t ha⁻¹ vermicompost + 2.5 t ha⁻¹ FYM + biofertilizer (*Azospirillum*) resulted in 2.83% and 7.9% higher grain yield compared to the sole application of vermicompost and FYM, respectively.

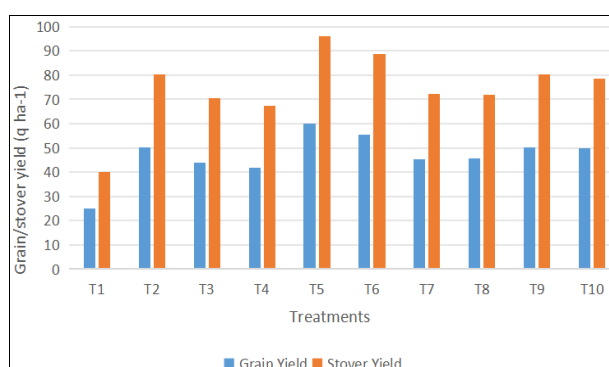


Fig 3: Effect of organic supplements and inorganic nutrient levels on grain and stover yield of maize (q ha⁻¹)

Grain yield is governed by a range of physiological and morphological processes occurring throughout the crop growth cycle (Khan *et al.*, 2008; Fanuel and Gifole, 2013) [9, 7]. The present findings are in agreement with earlier studies by Afe *et al.* and Magda *et al.*, which reported that improved dry matter accumulation and enhanced plant growth under balanced nutrient supply result in higher yield. However, Zhang *et al.* (2018) [26] observed that the addition of organic fertilizers to recommended NPK levels did not significantly increase maize grain yield compared to NPK alone.

3.2.2 Stover yield

Data in Table 2 indicate that stover yield was significantly influenced by organic supplements and inorganic nutrient levels. The highest stover yield was recorded with the application of 100% RDF + 2.5 t ha⁻¹ vermicompost + biofertilizer (*Azospirillum*) (98.26 q ha⁻¹), which was statistically at par with 100% RDF + 2.5 t ha⁻¹ FYM + biofertilizer (*Azospirillum*) (92.32 q ha⁻¹). The lowest stover yield was observed under control.

Application of 100% RDF recorded 0.01%, 2.19%, and 11.98% higher stover yield compared to 50% RDF + 5 t ha⁻¹ vermicompost + biofertilizer (*Azospirillum*), 50% RDF + 7.5 t ha⁻¹ FYM + biofertilizer (*Azospirillum*), and 50% RDF alone, respectively. Furthermore, the combined application of 2.5 t ha⁻¹ vermicompost + 2.5 t ha⁻¹ FYM + biofertilizer (*Azospirillum*) resulted in 2.69% and 7.57% higher stover yield compared to the sole application of vermicompost and FYM, respectively.

The increase in stover yield under integrated nutrient management may be attributed to improved soil physical, chemical, and biological properties, leading to better nutrient availability and biomass accumulation (Guo *et al.*, 2022; Khan *et al.*, 2023) [8, 10]. In contrast, the sole application of inorganic fertilizers resulted in relatively lower yield, possibly due to salinity stress and nutrient imbalance affecting plant growth (Radhakrishnan *et al.*, 2024) [18]. These findings are in agreement with Verma *et al.* (2025) [24], highlighting the effectiveness of combined nutrient sources in enhancing biomass production under salt-affected conditions.

4. Conclusion

The study clearly demonstrates that integrated nutrient management (INM) significantly improves the growth, yield, and yield attributes of maize under saline soil conditions. The combined application of 100% RDF with organic amendments, particularly vermicompost or FYM, along with biofertilizer (*Azospirillum*), resulted in superior plant height, plant population, grain yield, and stover yield compared to the sole application of inorganic fertilizers or control.

The enhanced performance under INM can be attributed to balanced nutrient supply, improved soil physical, chemical, and biological properties, and better nutrient use efficiency. Organic inputs played a crucial role in mitigating the adverse effects of salinity by improving soil structure, moisture retention, and microbial activity. Therefore, the integration of organic and inorganic nutrient sources is a sustainable and effective strategy for enhancing maize productivity and soil health in salt-affected soils. Further long-term studies may help to validate its benefits for sustainable agricultural systems.

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