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Effect of integrated nutrient management on growth and yield of wheat (*Triticum aestivum* L.) under salt affected soil conditions

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Abstract

A field experiment was conducted during the *rabi* season of 2023-24 at the experimental farm of Galgotias University, Greater Noida, Uttar Pradesh, to evaluate the effect of integrated application of organic and inorganic nutrient sources on the growth and yield of wheat (*Triticum aestivum* L.) under salt-affected soil conditions. The experiment was laid out in a randomized block design with three replications comprising twelve treatments, including combinations of recommended dose of fertilizers (RDF), vermicompost, farmyard manure (FYM), biofertilizer (*Azotobacter*), gypsum, SSP, and zinc sulphate (ZnSO_4). The results revealed that the application of 100% RDF + ZnSO_4 @ 25 kg ha⁻¹ + gypsum @ 20 kg ha⁻¹ recorded significantly higher growth and yield parameters compared to other treatments. This treatment resulted in maximum plant height (53.39 cm at 60 DAS and 88.94 cm at harvest) and plant population (53.03 and 49.45 plants m⁻² at 30 DAS and harvest, respectively). It also produced the highest grain yield (4446 kg ha⁻¹) and stover yield (7088 kg ha⁻¹). The study demonstrates that integrated application of inorganic fertilizers, organic amendments, and biofertilizers enhances crop performance and productivity under saline soil conditions and can be recommended as a sustainable nutrient management strategy for wheat cultivation.

Keywords: Integrated nutrient management, wheat (*Triticum aestivum* L.), salt-affected soil, plant height, plant population, grain yield, vermicompost, farmyard manure, gypsum, zinc sulphate

1. Introduction

Wheat (*Triticum aestivum* L.) is the second most important food crop in India after rice, occupying about 26.7 million hectares and contributing nearly 33.9% of total food grain production. Cereals serve as a major source of energy and nutrition for the global population, particularly in rural areas (Sharma *et al.*, 2024a, b) ^[15]. With the projected increase in wheat demand by 31% by 2050 compared to 2008 levels (Dixon *et al.*, 2009) ^[15], enhancing wheat productivity has become a major agricultural priority. Achieving higher yield and quality largely depends on maintaining optimal soil conditions and efficient nutrient management practices.

Among the various constraints affecting wheat production, soil salinity and sodicity are serious challenges, particularly in arid and semi-arid regions. Salt-affected soils impair plant growth by reducing nutrient availability, disturbing ionic balance, and limiting water uptake, ultimately leading to reduced crop productivity. Therefore, improving soil health and developing effective nutrient management strategies are essential for sustaining wheat production under such adverse conditions.

The continuous and imbalanced use of chemical fertilizers has led to deterioration of soil health, decline in organic matter, and reduced nutrient use efficiency. In recent years, increased emphasis has been placed on the use of organic manures, which improve soil structure, enhance cation exchange capacity, and promote microbial activity, thereby improving nutrient availability. Wheat grains are nutritionally important, containing approximately 12% protein along with essential minerals and carbohydrates (Prasad, 2015).

Integrated nutrient management (INM), involving the combined use of organic and inorganic nutrient sources, has emerged as a sustainable approach to restore soil fertility and enhance crop productivity (Antil *et al.*, 2011; Kumara *et al.*, 2013; Brar *et al.*, 2015) ^[1, 11, 2]. The application of

organic manures such as farmyard manure and vermicompost, along with mineral fertilizers, improves nutrient use efficiency and reduces dependence on chemical inputs, thereby ensuring environmental sustainability (Kaur *et al.*, 2023). Biofertilizers like *Azotobacter* further contribute by fixing atmospheric nitrogen and promoting plant growth through enhanced nutrient availability (Peerzada *et al.*, 2016) [14]. In addition, gypsum plays a crucial role in ameliorating salt-affected soils by improving soil structure and reducing sodicity, while zinc sulphate is essential for enzymatic activities and plant metabolic processes. Despite the proven benefits of integrated nutrient management, limited information is available on the combined application of organic, inorganic, and ameliorative inputs under salt-affected soil conditions in wheat cultivation.

Therefore, the present study was conducted to evaluate the effect of integrated application of organic and inorganic nutrient sources on the growth and yield of wheat under salt-affected soil conditions.

2. Materials and Methods

2.1 Experimental Site and Soil Characteristics

The field experiment was conducted during the Rabi season of 2023–24 at the Experimental Farm, Department of Agriculture, Galgotias University, Greater Noida, Uttar Pradesh, India. 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. The region experiences a semi-arid climate with an average annual rainfall of approximately 748 mm.

The soil of the experimental field was classified as clay loam (Vertisol). Prior to sowing, composite soil samples were collected from 0–15 cm depth and analyzed using standard procedures. The soil had pH 8.2 (1:2.5 soil: water suspension), electrical conductivity (EC) 0.26 dS m⁻¹, organic carbon 0.35%, available nitrogen 213 kg ha⁻¹, available phosphorus 18.5 kg P₂O₅ ha⁻¹, and available potassium 290 kg K₂O ha⁻¹.

2.2 Experimental Design and Treatments

The experiment was laid out in a randomized block design (RBD) with three replications comprising twelve treatments. The treatments included different combinations of recommended dose of fertilizers (RDF), organic manures, biofertilizers, and soil amendments as follows:

T₁: Control (no fertilizer)

T₂: 50% RDF

T₃: 100% RDF

T₄: 75% RDF + FYM @ 5 t ha⁻¹

T₅: 75% RDF + FYM @ 2.5 t ha⁻¹

T₆: 50% RDF + FYM @ 5 t ha⁻¹ + *Azotobacter* @ 20 kg ha⁻¹

T₇: 75% RDF + vermicompost @ 2.5 t ha⁻¹ + gypsum @ 25 kg ha⁻¹

T₈: 50% RDF + vermicompost @ 2.5 t ha⁻¹ + *Azotobacter* @ 20 kg ha⁻¹

T₉: 75% RDF + FYM @ 5 t ha⁻¹ + PSB @ 20 kg ha⁻¹ + ZnSO₄ @ 25 kg ha⁻¹

T₁₀: 75% RDF + vermicompost @ 2.5 t ha⁻¹ + PSB @ 20 kg ha⁻¹ + ZnSO₄ @ 25 kg ha⁻¹

T₁₁: 100% RDF + ZnSO₄ @ 25 kg ha⁻¹ + gypsum @ 20 kg ha⁻¹

T₁₂: FYM @ 10 t ha⁻¹ + vermicompost @ 2.5 t ha⁻¹ + *Azotobacter* @ 20 kg ha⁻¹

2.3 Crop Details and Agronomic Practices

The wheat variety 'DBW-327' was used for the experiment. The crop was sown using recommended agronomic practices for the region. The recommended dose of fertilizers (RDF) comprised

120 kg N, 60 kg P₂O₅, and 40 kg K₂O ha⁻¹.

Urea, single superphosphate (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 nitrogen were applied as basal at the time of sowing. The remaining nitrogen was applied in two equal splits at 20 and 40 days after sowing (DAS). Zinc sulphate and gypsum were applied as per treatment at the time of sowing. The crop was irrigated as per requirement to maintain optimum soil moisture conditions. All other agronomic practices, including weed and pest management, were carried out uniformly across all treatments.

2.4 Observations Recorded

Observations on growth parameters, including plant height and plant population, were recorded at different growth stages (30 DAS and at harvest). Yield parameters such as grain yield and straw yield were recorded at maturity. Grain and straw yields were calculated on a hectare basis after proper drying.

2.5 Statistical Analysis

The experimental data were statistically analyzed using analysis of variance (ANOVA) appropriate for randomized block design as described by standard procedures (Panse & Sukhatme 1985) [12]. The significance of treatment effects was tested at the 5% level of probability ($p = 0.05$). Critical difference (CD) values were calculated to compare treatment means.

3. Results and Discussion

3.1 Growth parameters

3.1.1 Plant Height

Plant height was significantly influenced by different nutrient management treatments at both 60 DAS and at harvest (Fig. 1). The maximum plant height was recorded under T₁₁ (100% RDF + ZnSO₄ @ 25 kg ha⁻¹ + gypsum @ 20 kg ha⁻¹), with values of 53.39 cm at 60 DAS and 88.94 cm at harvest. This treatment was statistically at par with T₁₀ (50.19 cm and 85.0 cm), T₇ (48.80 cm and 82.43 cm), and T₉ (48.70 cm and 81.42 cm), but significantly superior to the control.

At 60 DAS, the application of 100% RDF (T₁₁) resulted in 0.63%, 5.87%, 1.66%, and 5.24% higher plant height compared to 75% RDF + FYM @ 5 t ha⁻¹, 75% RDF + FYM @ 2.5 t ha⁻¹, 50% RDF + FYM @ 5 t ha⁻¹ + *Azotobacter* @ 20 kg ha⁻¹, and 50% RDF + vermicompost @ 2.5 t ha⁻¹ + *Azotobacter* @ 20 kg ha⁻¹, respectively. Similar trends were observed at harvest. Furthermore, the combined application of 50% RDF with FYM @ 10 t ha⁻¹ + vermicompost @ 2.5 t ha⁻¹ + *Azotobacter* @ 20 kg ha⁻¹ resulted in an increase in plant height by 3.8% and 19.78% over the sole application of vermicompost and FYM, respectively.

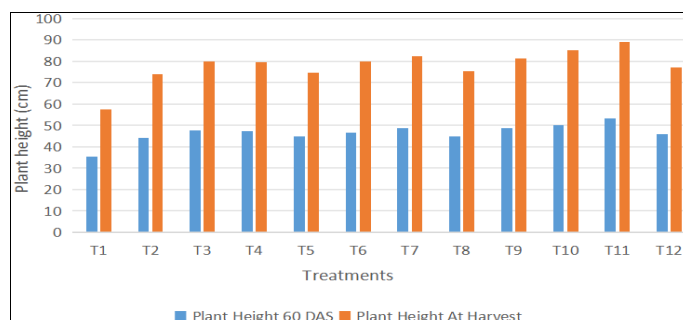


Fig 1: Effect of integrated nutrient management on plant height (cm) of wheat at 60 DAS and at harvest

The increase in plant height under integrated nutrient management may be attributed to improved nutrient availability and uptake, leading to enhanced cell division and elongation. The combined use of organic and inorganic nutrient sources ensures balanced nutrition and sustained nutrient release. Zinc plays an important role in auxin synthesis and enzymatic activity, while gypsum improves soil physical conditions, particularly in salt-affected soils, facilitating better root growth and nutrient absorption. These findings are in agreement with Parveen Gill *et al.* (2018) [13] and Brar *et al.* (2015) [2].

3.1.2 Plant Population

Plant population at 30 DAS and at harvest was significantly influenced by different nutrient management treatments (Fig. 2). The highest plant population was recorded under T₁₁ (100% RDF + ZnSO₄ @ 25 kg ha⁻¹ + gypsum @ 20 kg ha⁻¹), with values of 53.03 plants m⁻² at 30 DAS and 49.45 plants m⁻² at harvest. This treatment was statistically at par with T₁₀ (52.34 and 48.55 plants m⁻²), T₇ (51.23 and 48.75 plants m⁻²), and T₉ (51.87 and 49.89 plants m⁻²), but significantly superior to the control.

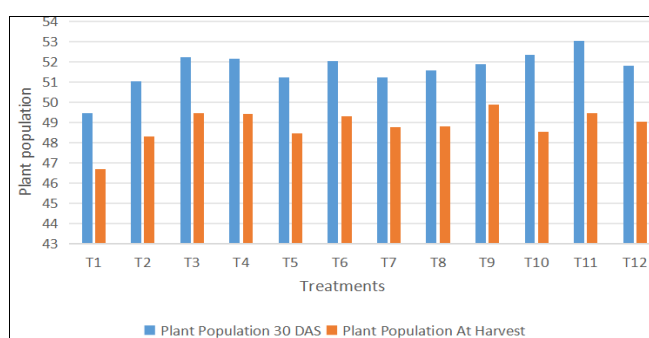


Fig 2: Effect of integrated nutrient management on plant population (plants m⁻²) of wheat at 30 DAS and at harvest

At 30 DAS, the application of 100% RDF (T₁₁) resulted in 0.19%, 1.91%, 0.38%, and 1.26% higher plant population compared to 75% RDF + FYM @ 5 t ha⁻¹, 75% RDF + FYM @ 2.5 t ha⁻¹, 50% RDF + FYM @ 5 t ha⁻¹ + *Azotobacter* @ 20 kg ha⁻¹, and 50% RDF + vermicompost @ 2.5 t ha⁻¹ + *Azotobacter* @ 20 kg ha⁻¹, respectively. Similar trends were observed at harvest. Furthermore, the combined application of 50% RDF with FYM @ 10 t ha⁻¹ + vermicompost @ 2.5 t ha⁻¹ + *Azotobacter* @ 20 kg ha⁻¹ resulted in an increase in plant population by 1.48% and 3.05% over the sole application of vermicompost and FYM, respectively.

The improvement in plant population under integrated nutrient management may be attributed to better seedling establishment and improved soil physical conditions. Organic manures enhance soil structure and moisture retention, while gypsum reduces soil crusting and improves aeration, thereby promoting better germination and plant stand under salt-affected conditions.

3.2 Yield Parameters

3.2.1 Grain Yield

Grain yield was significantly influenced by different nutrient management treatments (Fig. 3). The highest grain yield (4446 kg ha⁻¹) was recorded under T₁₁ (100% RDF + ZnSO₄ @ 25 kg ha⁻¹ + gypsum @ 20 kg ha⁻¹), which was statistically at par with T₁₀ (4387 kg ha⁻¹), but significantly superior to all other treatments including control.

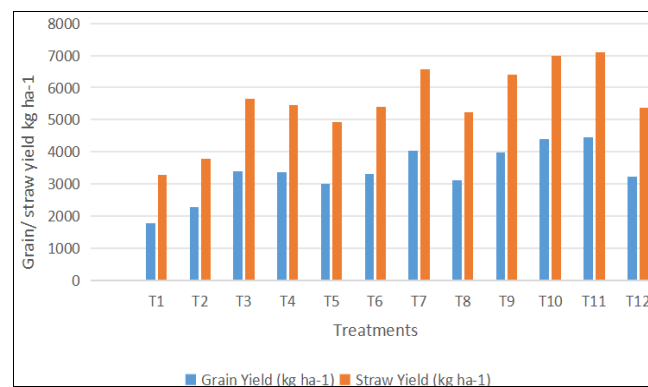


Fig 3: Effect of integrated nutrient management on grain and straw yield (kg ha⁻¹) of wheat

The application of 100% RDF resulted in 0.97%, 11.85%, 2.50%, and 8.62% higher grain yield compared to 75% RDF + FYM @ 5 t ha⁻¹, 75% RDF + FYM @ 2.5 t ha⁻¹, 50% RDF + FYM @ 5 t ha⁻¹ + *Azotobacter* @ 20 kg ha⁻¹, and 50% RDF + vermicompost @ 2.5 t ha⁻¹ + *Azotobacter* @ 20 kg ha⁻¹, respectively. Furthermore, the combined application of 50% RDF with FYM @ 10 t ha⁻¹ + vermicompost @ 2.5 t ha⁻¹ + *Azotobacter* @ 20 kg ha⁻¹ and control resulted in an increase in grain yield by 41.35% and 22.26%, respectively, over the sole application of vermicompost and FYM.

The increase in grain yield under integrated nutrient management may be attributed to balanced nutrient supply, improved soil fertility, and enhanced nutrient use efficiency. The combined use of organic and inorganic nutrient sources ensures both immediate and sustained nutrient availability, leading to improved crop growth and productivity. These findings are in agreement with Khan *et al.* (2008) [9], Fanuel and Gifole (2013) [6], Kaushik *et al.* (2012) [8], and Singh (2017) [16].

3.2.2 Straw Yield

Straw yield was also significantly influenced by different nutrient management treatments (Fig. 3). The highest straw yield (7088 kg ha⁻¹) was recorded under T₁₁, which was statistically at par with T₁₀ and T₉, but significantly superior to the control. The application of 100% RDF resulted in 3.38%, 12.80%, 4.27%, and 7.47% higher straw yield compared to 75% RDF + FYM @ 5 t ha⁻¹, 75% RDF + FYM @ 2.5 t ha⁻¹, 50% RDF + FYM @ 5 t ha⁻¹ + *Azotobacter* @ 20 kg ha⁻¹, and 50% RDF + vermicompost @ 2.5 t ha⁻¹ + *Azotobacter* @ 20 kg ha⁻¹, respectively. Furthermore, the combined application of 50% RDF with FYM @ 10 t ha⁻¹ + vermicompost @ 2.5 t ha⁻¹ + *Azotobacter* @ 20 kg ha⁻¹ and control resulted in an increase in straw yield by 29.63% and 12.93%, respectively, over the sole application of vermicompost and FYM.

Higher straw yield under integrated nutrient management may be attributed to improved vegetative growth due to enhanced nutrient availability and improved soil physical, chemical, and biological properties. Organic amendments increase microbial activity and nutrient mineralization, while gypsum improves soil structure and nutrient uptake. These findings are supported by Guo *et al.* (2022) [17] and Khan *et al.* (2023) [10].

4. Conclusion

The present study demonstrated that integrated nutrient management significantly improved the growth and yield performance of wheat under salt-affected soil conditions. Among the different treatments, the application of 100% RDF along with ZnSO₄ @ 25 kg ha⁻¹ and gypsum @ 20 kg ha⁻¹

proved most effective, recording the highest plant height, plant population, grain yield, and straw yield.

The superior performance of this treatment may be attributed to balanced nutrient supply, improved nutrient use efficiency, and enhanced soil physical conditions under saline environments. The combined application of inorganic fertilizers with soil amendments such as gypsum and micronutrients like zinc played a crucial role in improving crop productivity.

Therefore, the integrated use of chemical fertilizers along with appropriate soil amendments can be recommended as an effective and sustainable nutrient management strategy for enhancing wheat productivity in salt-affected soils.

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