RESEARCH PAPER

Impact of Integrated Nutrient Management Practices on Productivity, Nutrient Uptake and Economic Performance of Wheat (Triticum Aestivum L.) Under Salt Affected Soils

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ABSTRACT
A field experiment was conducted during the rabi seasons of 2023-24 and 2024-25 at Galgotias University, Greater Noida, to evaluate the impact of integrated nutrient management (INM) practices on productivity, nutrient uptake and economic performance 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 nutrient management treatments involving combinations of recommended dose of fertilizers (RDF), farmyard manure (FYM), vermicompost, biofertilizers, gypsum, and micronutrients. Results revealed that application of 100% RDF supplemented with $ZnSO_4$ (25 kg ha^{-1}) and gypsum (20 kg ha^{-1}) significantly enhanced growth attributes, yield components, and productivity of wheat. This treatment recorded the highest grain yield (4540 kg ha^{-1}) and straw yield (7228 kg ha^{-1}), along with superior nutrient uptake (N, P, K) compared to other treatments. However, it remained statistically at par with treatments integrating 75% RDF with vermicompost and biofertilizers. Economic analysis indicated that T11 resulted in maximum gross returns (₹141,133 ha^{-1}), net returns (₹101,832 ha^{-1}), and benefit–cost ratio (2.59). The findings highlight that integrated application of inorganic fertilizers with organic amendments and micronutrients produces a synergistic effect, improving nutrient availability, soil health, and crop productivity under salt-affected conditions.

Keywords: Integrated nutrient management, Salt-affected soil, Wheat productivity, Nutrient uptake, Vermicompost, Soil fertility, Economic analysis

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1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most widely cultivated cereal crops worldwide and serves as a major source of energy and nutrition for the global population, particularly in rural areas (Kumar *et al*., 2024). With the global population projected to reach 9.7 billion by 2050, up from the current 7.7 billion, ensuring food security has become a critical challenge. India, currently the second most populous country with 1.3 billion people, is expected to surpass China and reach a population of 1.7 billion by 2050 (The UN World Population Prospects: The 2019 Revision). This rapid population growth necessitates a substantial increase in wheat production under increasingly constrained natural resources.

The productivity of wheat is influenced by several factors, among which soil fertility plays a pivotal role in determining grain and straw yield. However, Indian soils are increasingly becoming deficient in both macro- and micronutrients, leading to stagnation or decline in crop productivity (Singh *et al*., 2025; Centre for Science and Environment, 2025). Although the extensive use of chemical fertilizers has significantly contributed to enhanced food production, issues such as low nutrient-use efficiency, environmental pollution, and global warming have raised serious concerns regarding the sustainability of existing nutrient management practices (Dass *et al*., 2014). For optimum development, tillering, biomass buildup, and production of grains, wheat, a highly nutritious crop, needs a sufficient and balanced supply of essential nutrients, particularly nitrogen (Hafiza *et al*., 2025; Yadav, 2024). Proper and judicious application of fertilizers not only improves crop productivity but also enhances the quality of produce. In this context, integrated nutrient

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management (INM) has emerged as a viable strategy to sustain crop yields while maintaining soil health.

Organic manures, such as farmyard manure (FYM), vermicompost, and press mud, constitute essential components of INM systems. These organic inputs not only supply essential nutrients, including micronutrients often lacking in chemical fertilizers, but also improve the physico-chemical and biological properties of soil. Moreover, the combined application of organic and inorganic nutrient sources ensures balanced nutrition and helps in maintaining long-term soil fertility (Ray *et al*., 2025).

Organic manures serve as a reservoir of essential nutrients and contribute to the buildup of soil organic matter and humus, which are critical for sustaining soil health. They also promote the proliferation of beneficial soil microorganisms, thereby facilitating nutrient mineralization and availability to crops. The integrated use of organic and inorganic inputs is therefore not only beneficial for achieving higher productivity but also ensures ecological sustainability.

The concept of INM emphasizes the maintenance and improvement of soil fertility for sustaining crop productivity over the long term. Previous studies have demonstrated that the combined application of organic and inorganic nutrient sources leads to enhanced crop yield, improved economic returns, and better residual soil fertility (Dass *et al*., 2013; Singh, 2017). Farmyard manure, in particular, improves soil physical properties, enhances water-holding capacity, and increases cation exchange capacity, thereby facilitating efficient nutrient utilization. It also provides organic acids and growth-promoting substances that support soil aggregation and microbial activity, which are essential for nutrient cycling.

Furthermore, it has been observed that integrating farmyard manure (FYM) with inorganic and standard sources of nitrogen improves soil fertility status and increases wheat yield and profitability (Sheoran *et al*., 2024; Dwivedi *et al*., 2025). In view of these advantages, it becomes imperative to evaluate different combinations of organic and inorganic nutrient sources to identify the most effective and sustainable nutrient management strategy. Therefore, the present study was undertaken to assess the effect of different integrated nutrient management practices on the growth, yield, nutrient uptake, and economic performance of wheat under salt-affected soil conditions (Dwivedi *et al*., 2025; Kumar & Kumar, 2025).

2. Materials and methods

2.1 Experimental Site and Soil Characteristics

A field experiment was conducted during the *rabi* seasons of 2023–24 and 2024–25 at the Experimental Farm, Department of Agriculture, Galgotias University, Greater Noida, Uttar Pradesh, India. The soil of the experimental site was sandy loam in texture and moderately fertile, suitable for wheat cultivation under salt-affected conditions.

The initial physico-chemical properties of the soil were: available nitrogen (213 kg ha^{-1}), available phosphorus (18.5 kg ha^{-1} as P_2O_5), available potassium (290 kg ha^{-1} as K_2O), organic carbon (0.33%), soil pH (8.25), and electrical conductivity (0.25 dS m^{-1} at 25°C).

2.2 Experimental Design and Treatments

The experiment was laid out in a randomized block design (RBD) with three replications comprising twelve treatments involving different combinations of inorganic fertilizers, organic manures, biofertilizers, and soil amendments:

T_1: Control (no fertilizer)

T_2: 50% RDF

T_3: 100% RDF

T_4: 75% RDF + FYM @ 5 t ha^{-1}

T_5: 75% RDF + FYM @ 2.5 t ha^{-1}

T_6: 50% RDF + FYM @ 5 t ha^{-1} + *Azotobacter* @ 20 kg ha^{-1}

T_7: 75% RDF + Vermicompost @ 2.5 t ha^{-1} + Gypsum @ 25 kg ha^{-1}

T_8: 50% RDF + Vermicompost @ 2.5 t ha^{-1} + *Azotobacter* @ 20 kg ha^{-1}

T_9: 75% RDF + FYM @ 5 t ha^{-1} + PSB @ 20 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}

T_{10}: 75% RDF + Vermicompost @ 2.5 t ha^{-1} + PSB @ 20 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}

T_{11}: 100% RDF + $ZnSO_4$ @ 25 kg ha^{-1} + Gypsum @ 20 kg ha^{-1}

T_{12}: FYM @ 10 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + *Azotobacter* @ 20 kg ha^{-1}

The recommended dose of fertilizers (RDF) for wheat was 120:60:40 kg N: P_2O_5: K_2O ha^{-1}.

2.3 Crop Establishment and Agronomic Practices

Wheat variety DBW-327 was sown on 22 November 2023-24 and another year sown on 22 November 2024-25 using a seed rate of 100 kg ha^{-1}. Row spacing of 22 cm and plant spacing of approximately 10 cm were maintained. Two seeds were dibbled per hill to ensure optimum plant population. Full doses of phosphorus and potassium were applied as basal at sowing, while nitrogen was applied in three splits: basal, first irrigation, and second irrigation. Organic manures and amendments were incorporated before sowing. Standard agronomic practices were followed uniformly across treatments.

2.4 Observations Recorded

Growth observations were recorded at 30, 60, and 90 days after sowing (DAS), and at harvest. Parameters included plant height, dry matter accumulation, number of tillers, chlorophyll content index, effective tillers, spike length, grains per spike, and test weight. Grain and straw yields were recorded at harvest and expressed in kg ha^{-1} following standard procedures (Rana *et al*., 2014).

2.5 Nutrient Analysis and Uptake

Validation of continuous flow analysis with respect to the Kjeldahl method for determining total nitrogen in plant samples, Soulaimani, A., *et al*. (2025) & (Gautam *et al*.,2023). Standard methods of analysis were used to determine the phosphorus and potassium content of plant samples. The vanadomolybdate-based yellow colour method was used to estimate phosphorus, and standard flame photometry was used to estimate potassium (Wieczorek *et al*., 2022; Ullah *et al*., 2022). Nutrient uptake (N, P, K) by grain and straw was calculated by multiplying nutrient concentration by respective yield values.

2.6 Economic Analysis

The economic analysis of different treatments was carried out to evaluate their profitability. The cost of cultivation was calculated by considering expenses incurred on inputs such as seeds, fertilizers, organic manures, biofertilizers, labour, and field operations. Gross returns were computed based on the prevailing market prices of grain and straw yields. Net returns were calculated by subtracting the cost of cultivation from gross returns. The benefit–cost (B: C) ratio was determined by dividing gross returns by the total cost of cultivation (Supriya *et al*., 2025).

2.7 Statistical Analysis

The data were analyzed using analysis of variance (ANOVA) appropriate for a randomized block design (RBD) as described by Gomez and Gomez (1984). Treatment means were compared using the critical difference (CD) at 5% level of significance.

Since the experimental trends were similar across both years, the data were pooled and analyzed to obtain mean values.

3. RESULT AND DISSCUSION

3.1 Growth and Yield Attributes

Growth Characters:

The addition of various sources of organic manure along with inorganic fertilizers influenced the growth characteristics of wheat crop positively (Table 1). The progressive increase in growth parameters with increasing levels of NPK (50%, 75%, and 100% RDF) improved the growth and yield attributes significantly over the control, and relatively higher values of these parameters were recorded with 100% RD of NPK fertilizers. This could be due to the availability of nutrients in balanced and adequate amounts. The crop receiving higher amounts of nutrients through organic or inorganic fertilizer sources recorded higher plant height, dry matter accumulation, number of tillers at harvest stage, and chlorophyll content at 90DAS. Among the nutrient management practices, application of T_{11}: 100% RDF + $ZnSo_4$ @25kg ha^{-1} + Gypsum @ 20kg ha^{-1} produced higher plant height (89.57 cm), dry matter accumulation (941.45g m^{-2}), a higher number of tillers (331.38 m^{-2}), and chlorophyll content (42.57 $plant^{-1}$). The lowest values of these growths were recorded under control during both years of study, and the mean value was also. The superior performance under 100% RDF may be attributed to the immediate availability of essential nutrients, particularly nitrogen, which plays a key role in vegetative growth, chlorophyll formation, and photosynthetic activity (Kapri *et al*., 2025) & (Yadav *et al*., 2026).

Application of 100% NPK along with $ZnSo_4$, and Gypsum also improved these growth characters over control but proved inferior to 100% RDF + $ZnSo_4$ @25kg ha^{-1} + Gypsum @ 20kg ha^{-1} (T_{11}). Among these 3 organic manures, vermicompost was superior to FYM and *Azotobacter* with respect to the growth of wheat crop (Singh 2017). However, application of T_{11} were statistically at par with the application of (T_{10}) 75% RDF + 2.5 t ha-1 vermicompost + PSB (Phosphate solubilizing bacteria) @20kg ha-1+ ZnSo4 @25kg ha-1, (T_7) 75% RDF + 2.5 t ha-1 vermicompost + gypsum @ 25kg ha-1, (T_9) 75% RDF + 5 t ha-1 FYM +PSB (Phosphate solubilizing bacteria) @20kg ha-1 + ZnSo4 @25kg ha-1, respectively. Where T1 control recorded the least plant height, dry matter accumulation, number of tillers, and chlorophyll content during both the year of study and the mean of the two years. Similar trends were also followed by plant height, dry matter accumulation, number of tillers, and chlorophyll content, respectively. The enhanced growth under this treatment could be due to the synergistic effect of macronutrients (NPK) and secondary/micronutrients (Zn and S from gypsum), which collectively improved metabolic activities, enzyme activation, and hormonal balance within the plant system (Kumar *et al*., 2025; Paramesh *et al*., 2020).

Table 1: Effect of organic and inorganic nutrient sources on growth characteristics of wheat at harvest stage (mean of two years).

Treatments	Plant height (cm)	Dry matter accumulation (g m^{-2})	Number of tillers (m^{-2})	Chlorophyll content at 90DAS
T_1	57.97	412.24	201.42	27.75

T_2	74.33	496.42	224.54	33.57
T_3	80.78	730.41	297.49	38.95
T_4	80.34	713.54	289.33	38.01
T_5	75.18	646.08	234.97	32.72
T_6	80.11	705.14	282.69	36.08
T_7	83.57	861.31	318.01	39.61
T_8	75.91	675.84	252.74	37.47
T_9	82.30	838.71	314.18	38.49
T_{10}	86.19	924.71	321.46	41.14
T_{11}	89.57	941.45	331.38	42.57
T_{12}	77.88	696.39	270.15	35.75
SEm (±)	2.67	39.55	11.08	1.74
LSD($p \leq 0.05$)	7.81	115.99	32.51	5.11

Yield Attributes

The addition of various sources of organic manure along with inorganic fertilizers influenced the yield attributes of wheat crop positively (Table 2). The crop receiving higher amounts of nutrients through organic or inorganic fertilizer sources recorded higher effective tillers (m^{-2}), length of Spike (cm), number of grains/spikes, and test weight (g). Among the nutrient management practices, application of T_{11}: 100% RDF + $ZnSo_4$ @25kg ha^{-1} + Gypsum @ 20kg ha^{-1} produced higher effective tillers (304.45 m^{-2}), length of Spike (11.78 cm), number of grain $spikes^{-1}$ (53.38), and test weight (41.48 g). The lowest values of these yield attributes were recorded under control during both years of study, and the mean value was also.

Application of 100% NPK along with $ZnSo_4$, and Gypsum also improved these yield attributes over control but proved inferior to 100% RDF + $ZnSo_4$ @25kg ha^{-1} + Gypsum @ 20kg ha^{-1} (T_{11}). Among these 3 organic manures, vermicompost was superior to FYM and *Azotobacter* with respect to the yield attributes of wheat crop (Singh 2017). However, application of T_{11} were statistically at par with the application of (T_{10}) 75% RDF + 2.5 t ha^{-1} vermicompost + PSB (Phosphate solubilizing bacteria) @20kg ha^{-1}+ ZnSo4 @25kg ha^{-1}, (T_7) 75% RDF + 2.5 t ha^{-1} vermicompost + gypsum @ 25kg ha^{-1}, (T_9) 75% RDF + 5 t ha^{-1} FYM +PSB (Phosphate solubilizing bacteria) @20kg ha^{-1} + ZnSo4 @25kg ha^{-1}, respectively. Where T_1 control recorded the least effective tillers (m^{-2}), length of Spike (cm), number of grain/spikes, test weight (g) during both the year of study and the mean of the two years. Similar trends were also followed by effective tillers (m^{-2}), length of Spike (cm), number of grains/spikes, and test weight (g), respectively. The results also demonstrated the superiority of vermicompost over FYM, which could be attributed to higher nutrient availability with vermicompost (Dass *et al.* 2008).

Table 2: Effect of organic and inorganic nutrient sources on Yield attributes and yield of wheat (mean of two years).

Treatments	**Effective tillers (m^{-2})**	**Length of Spike (cm)**	**Number of Grain/Spike**	**Test Weight (g)**	**Yield (Kg ha^{-1})**	
					Grain	**Straw**
T_1	188.63	8.33	37.00	40.27	1817	3336
T_2	207.71	9.28	42.03	40.72	2353	3853
T_3	271.92	10.27	46.88	40.93	3459	5671
T_4	267.65	9.92	45.70	40.92	3426	5493

T_5	217.36	9.37	42.97	40.74	3051	5025
T_6	261.50	9.65	45.53	40.85	3362	5453
T_7	292.23	10.58	50.03	41.19	4081	6685
T_8	233.79	9.45	43.32	40.79	3181	5266
T_9	289.80	10.52	49.40	41.09	4034	6450
T_{10}	295.90	10.81	51.23	41.18	4487	7072
T_{11}	304.45	11.78	53.38	41.48	4540	7228
T_{12}	249.90	9.58	44.57	40.96	3298	5407
SEm (±)	10.08	0.44	1.41	1.05	185	321
LSD($p \leq 0.05$)	29.57	1.29	4.13	3.09	542	941

Zinc plays a vital role in auxin synthesis and enzyme activation, thereby promoting cell elongation and division, which ultimately enhances plant height and tiller formation (Singh *et al*., 2024; Gupta *et al*., 2026). Similarly, sulphur supplied through gypsum is essential for protein synthesis and improves nitrogen utilization efficiency (Roa *et al*., 2024). The combined availability of these nutrients most likely resulted in an improved source-sink relationship, which boosted photosynthetic assimilate production and efficient translocation from source organs (leaves and stems) to sink organs (developing spikes and grains), resulting in increased dry matter accumulation and better reproductive development in wheat (Lv *et al*.,2020).

Integrated treatments involving vermicompost and FYM also performed significantly better than the sole application of fertilizers. This improvement may be attributed to the gradual mineralization and slow release of nutrients from organic sources, which ensures sustained nutrient availability throughout the crop growth period and improves nutrient use efficiency in wheat. (Dwivedi *et al*., 2025; Kumawat *et al*., 2025). Additionally, organic manures improve soil structure, aeration, and water-holding capacity, thereby creating a favourable rhizosphere environment for root proliferation and nutrient uptake (Sohail *et al*., 2026).

The superiority of vermicompost over FYM may be due to its finer structure, higher nutrient content, and presence of plant growth-promoting substances such as humic acids and enzymes. Vermicompost also enhances microbial activity, which accelerates nutrient cycling and improves nutrient availability to plants (Singh, 2017). In nutrient-depleted soils, where native nutrient reserves are frequently insufficient to support optimal plant growth, biomass accumulation, and yield development in wheat, the considerably lower values seen under the control treatment underscore the significance of external nutrient supply in maintaining crop growth (Meena *et al*., 2022; Gupta *et al*., 2026).

3.2 Yield Studies

The effect of organic and inorganic nutrient sources on grain and straw yield of wheat in Table 2. Significantly higher grain and straw yield was recorded with the application 100% RDF + $ZnSo_4$ @25kg ha^{-1} + Gypsum @ 20kg ha^{-1} (4540 and 7228 Kg ha^{-1}), which was statistically at par with the application of 75% RDF + 2.5 t ha^{-1} vermicompost + PSB (Phosphate solubilizing bacteria) @20kg ha^{-1}+ $ZnSo_4$ @25kg ha^{-1} (4487 and 7072 Kg ha^{-1}), 75% RDF + 2.5 t ha^{-1} vermicompost + gypsum @ 25kg ha^{-1} (4081and 6685 Kg ha^{-1}) and 75% RDF + 5 t ha^{-1} FYM +PSB (Phosphate solubilizing bacteria) @20kg ha^{-1}+ $ZnSo_4$ @25kg ha^{-1} (4034 and 6450 Kg ha^{-1}). The lowest grain yield was observed under control. Application of 100% RDF resulted in (0.95%, 11.79%, 2.80%, and 8.03%) and (3.24%, 11.39%, 3.84%, and 7.14%) higher grain and straw yield compared 75% RDF + 5 t ha^{-1} FYM, and 75% RDF + 2.5 t ha^{-1} FYM, 50% RDF + 5 t ha-1 FYM+ Biofertilizer (*Azotobacter* @20kg ha^{-1}) and 50% RDF + 2.5 t ha-1 vermicompost + Biofertilizer (*Azotobacte*r @20kg ha^{-1}) respectively. Furthermore, 50% RDF combined application of 10 t ha^{-1} FYM + 2.5 t ha $^{-1}$ vermicompost + bio fertilizer (*Azotobacter*) @20kg ha^{-1} and control increased grain and straw yield by (28.65% and 22.77%) and (28.74% and 13.14) over the sole application of vermicompost and FYM, respectively. Because it ensures sufficient nutrient availability during both vegetative and reproductive growth stages, which contributes to improved biomass production and efficient partitioning towards economic yield, an optimal and balanced nutrient supply is essential for optimizing crop productivity (Kapri *et al*.,2025).

The increase in yield under integrated treatments can be explained by improved growth parameters such as higher tiller density, longer spikes, and an increased number of grains per spike, all of which directly contribute to final yield. The enhancement in test weight further indicates better grain filling, which is often associated with adequate nutrient availability during the reproductive stage Yadav *et al*. (2025). Similar increase in yield of wheat with application of organic manures and chemical fertilizers was reported by Kaushik *et al.* (2012) and Singh (2017). The results, thus, indicate that about 25% NPK fertilizers can be saved by addition of organic manures without any adverse effect on yield. The highest wheat grain yield (4540 Kg ha^{-1}) and straw yield (7228 Kg ha^{-1}) of wheat was obtained with 100% RDF + $ZnSo_4$ @25kg ha^{-1} + Gypsum @ 20kg ha^{-1} as compared to other treatments. On an average, this treatment (100% RDF + $ZnSo_4$ @25kg ha^{-1} + Gypsum @ 20kg ha^{-1}) out yielded the 100% recommended dose of NPK fertilizers by an average of 23.81%. This is particularly important from a sustainability perspective, as it reduces dependency on chemical fertilizers while maintaining productivity, improving nutrient use efficiency, and supporting long-term soil health and environmental quality in wheat-based cropping systems (Darjee *et al*., 2023).

Organic manures not only supply nutrients but also improve soil physical properties such as aggregation and porosity, which facilitate better root growth and nutrient absorption. Moreover, the increased microbial activity associated with organic amendments enhances nutrient mineralization and availability, particularly phosphorus through the action of phosphate-solubilising bacteria (PSB), thereby improving phosphorus uptake and overall crop performance in wheat (Kumari *et al*., 2024).

The higher yield observed with vermicompost compared to FYM may be attributed to its relatively higher nutrient density and faster nutrient release pattern, which ensures early and sustained nutrient availability during critical growth stages of wheat. In addition, the presence of beneficial microorganisms in vermicompost, including nitrogen-fixing and phosphorus-solubilising microbes, plays a crucial role in improving nutrient uptake efficiency, root activity, and overall crop growth. Recent wheat studies have similarly reported superior yield and nutrient uptake under vermicompost-based integrated treatments as compared with FYM (Kumar *et al*., 2025; Dass *et al*., 2008). The results clearly demonstrate that integrated nutrient management not only improves yield but also enhances nutrient use efficiency, allowing a reduction of up to 25% in chemical fertilizer application without significant yield loss.

3.3 Nutrient Content and Its Uptake

Nitrogen (N), Phosphorus (P), Potassium (K) content (%) and its uptake by the wheat crop increased significantly with different treatments over the control (Table 3). The N content (%) by grain and straw increased from (1.39 to 2.29 %) and (0.31 to 0.51 %) with 100% NPK alone. Application of organic manures (FYM, vermicompost and *azotobacter*) along with 75% NPK also improved the N content (%) of wheat over 75% NPK and control. Among these treatments, the relatively higher N content (%) by wheat grain (2.63 %) and straw (0.60 %) were recorded with (T_{11}) 100% RDF + ZnSo4 @25kg ha^{-1} + Gypsum @ 20 kg ha^{-1}, which may be attributed to higher grain and straw production. However, the application of (T_{11}) was statistically at par with the application of (T_{10}). Whereas, (T_1) control recorded the least N content (%) by grain and straw during both years of study and the mean of the two years.

The mean increase in N uptake was from (25.74 to 79.28 kg ha^{-1}) and (10.36 to 28.90 kg ha^{-1}) by wheat grain and straw, respectively, due to application of 100% NPK over control. The highest N uptake by wheat grain (120.33 kg ha^{-1}) and straw (43.32 kg ha^{-1}) was recorded with (T_{11}) 100% RDF + $ZnSo_4$ @25kg ha^{-1} + Gypsum @ 20kg ha^{-1}, which may be attributed to higher grain and straw production. However, the application of (T_{11}) was statistically at par with the application of (T_{10}). Whereas, (T_1) control recorded the least N uptake by grain and straw during both years of study and the mean of the two years. This increase in N uptake might be due to increased grain and straw yield (Singh 2017, Singh and Patra, 2017). Incorporation of 10 t FYM or 5 t vermicompost or 3.5 t press mud/ha along with 75% NPK also improved the utilization of nitrogen by wheat crop (Sharma et al., 2025). Higher biomass results and better soil availability of nutrients may be the primary causes of the increased intake of nutrients. Increased absorption and accumulation of N, P, and K in grain and straw is made possible by the integrated application of organic and inorganic nutrient sources. Recent research on wheat under INM circumstances has revealed similar results (Chauhan *et al*., 2025).

The highest nitrogen uptake under T_{11} can be attributed to increased nitrogen availability from both inorganic fertilizers and improved nitrogen use efficiency due to the presence of sulphur and zinc. Sulphur enhances protein synthesis, while zinc improves enzymatic activities, both of which facilitate better assimilation and utilization of nitrogen within the plant system (Singh, 2017; Singh and Patra, 2017).

The Phosphorus (P) content (%) by grain and straw increased from (0.31 to 0.43 %) and (0.13 to 0.16 %) with 100% NPK alone. Application of organic manures (FYM, vermicompost and *azotobacter*) along with 75% NPK also improved the P content (%) of wheat over 75% NPK and control. Among these treatments, the relatively higher P content (%) by wheat grain (0.51 %) and straw (0.20 %) were recorded with (T_{11}) 100% RDF + ZnSo4 @25kg ha^{-1} + Gypsum @ 20 kg ha^{-1}, which may be attributed to higher grain and straw production. However, the application of (T_{11}) was statistically at par with the application of (T_{10}). Whereas, (T_1) control recorded the least P content (%) by grain and straw during both years of study and the mean of the two years.

The Phosphorus (P) uptake by grain and straw increased from (5.76 to 15.04 kg ha^{-1}) and (4.19 to 9.19 kg ha^{-1}) with 100% NPK alone. Application of organic manures (FYM, vermicompost and *azotobacter*) along with 75% NPK also improved the P uptake by wheat over 75% NPK and control. Among these treatments, the relatively higher P uptake by wheat grain (23.34 kg ha^{-1}) and straw (14.17 kg ha^{-1}) was recorded with (T_{11}) 100% RDF + ZnSo4 @25kg ha^{-1} + Gypsum @ 20 kg ha^{-1}, which may be attributed to higher grain and straw production. However, the application of (T_{11}) was statistically at par with the application of (T_{10}). Whereas, (T_1) control recorded the least P uptake by grain and straw during both years of study and the mean of the two years. This increase in P uptake may be due to more availability of P from the soil with their application (Paramesh *et al.* 2014, Singh 2017). The combined action of chemical fertilizers and organic manures, which decrease phosphorus fixation and increase its availability in the soil, may be the cause of the rise in phosphorus intake under integrated treatments. By increasing soil organic matter and releasing organic acids during decomposition, organic additions help solubilize fixed phosphorus and lessen its adsorption by calcium, iron, and aluminium compounds, boosting wheat's absorption of phosphorus (Chauhan *et al*., 2025; Meena *et al*., 2022).

Organic acids released during the decomposition of organic matter can solubilize native phosphorus, making it more available to plants. Additionally, the presence of PSB further enhances phosphorus solubilization (Paramesh *et al*., 2014).

The Potassium (K) content (%) by grain and straw increased from (0.34 to 0.44 %) and (0.92 to 1.51 %) with 100% NPK alone. Application of organic manures (FYM, vermicompost and *azotobacter*) along with 75% NPK also improved the K content (%) of wheat over 75% NPK and control. Among these treatments, the relatively higher K content (%) by wheat grain (0.51 %) and straw (0.20 %) were recorded with (T_{11}) 100% RDF + ZnSo4 @25kg ha^{-1} + Gypsum @ 20 kg ha^{-1}, which may be attributed to higher grain and straw production. However, the application of (T_{11}) was statistically at par with the application of (T_{10}). Whereas, (T_1) control recorded the least K content (%) by grain and straw during both years of study and the mean of the two years.

The Potassium (K) uptake by grain and straw increased from (6.16 to 15.31 kg ha^{-1}) and (30.83 to 85.70 kg ha^{-1}) with 100% NPK alone. Application of organic manures (FYM, vermicompost and *azotobacter*) along with 75% NPK also improved the K uptake by wheat over 75% NPK and control. Among these treatments, the relatively higher K uptake by wheat grain (24.00 kg ha^{-1}) and straw (123.06 kg ha^{-1}) was recorded with (T_{11}) 100% RDF + ZnSo4 @25kg ha^{-1} + Gypsum @ 20 kg ha^{-1}, which may be attributed to higher grain and straw production. However, the application of (T_{11}) was statistically at par with the application of (T_{10}). Whereas, (T_1) control recorded the least K uptake by grain and straw during both years of study and the mean of the two years. Potassium uptake was also much higher in the integrated treatments, possibly due to improved soil cation exchange capacity and root development. The addition of organic manures likely boosted soil organic matter and exchange sites, lowering potassium fixing and maintaining a higher concentration of exchangeable K^+ ions in the root zone, enhancing wheat plant uptake. Improved root proliferation under integrated nutrient management facilitated efficient potassium uptake (Verma *et al*., 2026). Organic matter enhances the soil's ability to retain potassium and reduces leaching losses, thereby increasing its availability to plants.

The overall increase in nutrient uptake under integrated treatments highlights the importance of maintaining a balanced nutrient supply and improving soil health. Higher nutrient uptake is directly linked to improved growth and yield, indicating better nutrient use efficiency under these treatments (Singh, 2006; Rathod *et al*., 2012).

Table 3: Effect of organic and inorganic nutrient sources on Nitrogen, Phosphorus, potassium (%) and their uptake (Kg ha^{-1}) by wheat grain and straw (mean of two years).

Treatments	N, P, K (%)						N, P, K (UPTAKE)					
	NITROGEN		PHOSPHORUS		POTASSIUM		NITROGEN		PHOSPHORUS		POTASSIUM	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	1.39	0.31	0.31	0.13	0.34	0.92	25.74	10.36	5.76	4.19	6.16	30.83
T_2	1.84	0.39	0.36	0.14	0.4	0.94	43.23	15.21	8.56	5.40	9.48	36.25
T_3	2.29	0.51	0.43	0.16	0.44	1.51	79.28	28.90	15.04	9.19	15.31	85.70
T_4	2.23	0.49	0.43	0.16	0.44	1.42	76.38	26.61	14.74	8.88	15.09	78.22
T_5	1.87	0.42	0.38	0.14	0.4	1.29	56.93	21.31	11.60	7.02	12.34	64.16
T_6	2.15	0.44	0.4	0.15	0.43	1.41	72.50	24.30	13.46	8.43	14.55	76.68

T_7	2.33	0.54	0.44	0.16	0.46	1.6	95.10	35.78	17.99	10.55	18.83	107.04
T_8	1.92	0.43	0.39	0.15	0.42	1.31	61.10	22.91	12.38	7.95	13.35	68.88
T_9	2.30	0.52	0.44	0.16	0.45	1.53	92.81	33.26	17.85	10.19	18.33	98.68
T_{10}	2.40	0.58	0.49	0.17	0.48	1.62	107.53	40.82	22.26	12.21	21.56	114.87
T_{11}	2.63	0.60	0.51	0.20	0.52	1.7	120.33	43.32	23.34	14.17	24.00	123.06
T_{12}	2.04	0.43	0.39	0.15	0.43	1.36	67.38	23.34	12.86	8.17	14.13	73.69
SEm (±)	0.09	0.02	0.02	0.01	0.01	0.05	6.44	1.67	1.16	0.69	1.13	5.63
LSD($p \leq 0.05$)	0.27	0.05	0.06	0.02	0.04	0.16	18.88	4.90	3.39	2.03	3.32	16.52

3.4 Economic Analysis

The economic evaluation of different treatments revealed that integrated nutrient management practices significantly influenced the profitability of wheat cultivation (Table 4). The highest gross and net returns, along with the maximum B: C ratio under T_{11}, indicate that the combined application of inorganic fertilizers with micronutrients and soil amendments is economically viable. The higher profitability under this treatment is mainly due to increased grain yield, which directly contributes to higher market returns.

Table 4: Effect of Organic and Inorganic Nutrient Sources on Economic Returns, COC, Gross Return, Net Return, and B: C Ratio of wheat (mean of two years)

Treatments	**COST OF CULTIVATION (Rs ha^{-1})**	**GROSS RETURN (Rs ha^{-1})**	**NET RETURN (Rs ha^{-1})**	**B: C RATIO**
T1	30545	58596	28051	0.92
T2	33613	73665	40052	1.19
T3	36681	108280	71600	1.95
T4	40146	106657	66511	1.65
T5	37646	95640	57994	1.54
T6	42613	104950	62337	1.46
T7	42081	127739	85658	2.03
T8	43238	99848	56610	1.31
T9	45646	125482	79836	1.75
T10	46271	139135	92864	2.00
T11	39301	141133	101832	2.59
T12	50170	103261	53091	1.06

Although integrated treatments involving reduced RDF and organic manures also produced comparable yields, their slightly lower economic returns may be due to the higher cost of organic inputs like vermicompost and biofertilizers. However, these treatments provide long-term benefits such as higher soil fertility, reduced environmental impact, and increased sustainability, which may not be immediately apparent from short-term economic analysis. The cumulative benefits of integrated nutrient management are frequently revealed over time through increases in soil organic carbon, nutrient availability, microbial activity, and decreased reliance on chemical fertilizers. The low economic returns under control treatment emphasize the necessity of proper nutrient management for achieving profitable yields (Kumari *et al*., 2024). The findings are consistent with recent research, which has shown that integrated nutrient management improves crop productivity and profitability by improving nutrient use efficiency, soil fertility, and economic returns in wheat-based systems (Kumar & Mishra, 2025; Dwivedi *et al*., 2025; Jaiswal *et al*., 2025).

CONCLUSION

The present investigation revealed that the combined application of inorganic and organic nutrient sources significantly enhanced the growth, yield attributes, yield of (grain and straw), and nutrient uptake of wheat under salt-affected soil conditions. Among the different treatments, the application of **100% RDF along with $ZnSO_4$ @ 25 kg ha^{-1} and gypsum @ 20 kg ha^{-1} (T_{11})** proved to be the most effective in achieving higher productivity and profitability.

The study also indicated that the combined use of organic manures with reduced levels of inorganic fertilizers (75% RDF) produced comparable results, suggesting the possibility of reducing chemical fertilizer use by up to 25% without significant yield reduction. In addition, integrated nutrient application contributed to improved nutrient uptake and better soil health.

Overall, the findings suggest that the integration of inorganic fertilizers with micronutrients and organic sources is a viable and sustainable approach for enhancing wheat productivity and maintaining soil fertility under salt-affected conditions.

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