International Journal of Plant & Soil Science

Volume 37, Issue 9, Page 680-686, 2025; Article no.IJPSS.144055
ISSN: 2320-7035

Effect of Integrated Nitrogen Management on Growth, Yield and Quality of Wheat (*Triticum aestivum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2025/v37i95744

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/144055

Original Research Article

Received: 08/07/2025
Published: 17/09/2025

ABSTRACT

Field experiment was conducted to evaluate the effect of integrated nitrogen management on growth, yield, and quality of wheat. There were highly significant differences among the treatments for the entire parameters investigated. The plant height varied between 77.19 cm to 105.27 cm, with

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Cite as: *Vaishali Maravi, Shani Kumar, Govind Gupta, Anita Tilwari, Neha Paliwal, Deepak Kher, and Anurag Patel. 2025. "Effect of Integrated Nitrogen Management on Growth, Yield and Quality of Wheat (Triticum Aestivum L.)". International Journal of Plant & Soil Science 37 (9):680–686. https://doi.org/10.9734/ijpss/2025/v37i95744.*

highest values under 100% recommended dose of nitrogen (RDN) using urea. Leaf area index (LAI) was maximum in those treatments that were a combination of inorganic fertilizers with biofertilizers, i.e., (4.92), followed by T7, T2, and T14. Crop growth rate (CGR) was highest in (10.17 g/m²/day), statistically equivalent with T9. Yield traits, 1000-seed weight, straw yield, and grain yield, were also maximum under (42.10 g, 7588.33 kg/ha, and 4943.34 kg/ha, respectively), followed very closely by T9 and T13. As a contrast, protein yield (735.26 kg/ha) and protein content (12.89%) were better in T9 (100% RDN via urea + Azotobacter), wherein the biofertilizer synergistic effect was exhibited. From the results, it is evident that although sole urea application pushed the yield to a maximum, use in conjunction with biofertilizers improved grain quality and efficiency in nitrogen utilization. Therefore, integrated nitrogen management is a sustainable approach to enhance the productivity and nutritional value of wheat.

Keywords: Wheat; INM; biofertilizers; grain yield; protein content.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.), a member of the grass family Poaceae, is the world's second most important staple after rice, contributing nearly one-third of global food grain production. It serves as the primary food for about two billion people (36% of the population) (Mubarak and Singh, 2011). In India, wheat is the second most important cereal crop, with a productivity of 2.98 million tons ha^{-1}, making it a leading contributor to global cereal production.

In 2018–19, wheat was the most widely grown crop, covering 215.45 million ha globally and producing 370.84 million tonnes with an average yield of 3390 kg ha^{-1} (USDA, 2020). It has long been linked with the Green Revolution, food self-sufficiency, and sustained production (Alam et al., 2013). India, the world's second-largest producer after China, cultivates wheat on 29.6 million ha, yielding about 107.59 million tonnes annually with an average productivity of 3508 kg ha^{-1}. Major producing states include Haryana, Uttar Pradesh, Punjab, Rajasthan, Gujarat, Madhya Pradesh, Bihar, and Maharashtra (Sarbaz,et al., 2022).

Worldwide, wheat is grown in two distinct seasons: winter wheat, which matures in 240–300 days in temperate regions (Europe, the United States, and Russia), and spring wheat, which, depending on temperature, matures in 100–150 days. It grows in regions with 300–1130 mm of annual rainfall and below sea level up to 5000 m altitude (Bhardwaj et al., 2010). Temperature has a significant impact on the growth of this long-day, thermo-sensitive crop. 20–22 °Cat sowing, 16–22 °C from tillering to grain filling, and a gradual increase to 40 °C at harvest are ideal conditions (Kumar et al., 2020).

Both humans and animals eat wheat, which is an essential source of nutrition because it contains 8.0-15.0% protein, 60-68% starch, 1.5-2.0% fat, 2.0-2.5% cellulose, and 1.5-2.0% minerals and vitamins (B-complex, E). From sea level to 3658 m, it grows well in a variety of soil types and climates, primarily in the 30°–60° N and 27°–40° S latitudes. Almost every state in India except Kerala grows wheat, with Haryana, Punjab, Madhya Pradesh, and Uttar Pradesh producing the majority of the country's wheat. The growing season is the longest in the Northern Hill Zone and the shortest in the Peninsular Zone (Iqbal et al.,2012).

The majority of cereals lack micronutrients, and their absence in the soil lowers crop yield and plant nutrient concentration, which can result in deficiencies in people and animals and pose health risks to the general public (Bhardwaj et al., 2010). For crops to grow healthily and to ensure food security through the production of nutrient-dense food, adequate soil nutrition is necessary. Chemical fertilizers are essential for increasing food security and yields, but their overuse has sparked worries because of their high costs, detrimental effects on the environment, and potential harm to human health (Nosheen, et al., 2020).

Due to their high cost, small farmers frequently are unable to apply chemical fertilizers in proportionate amounts. Maintaining soil fertility and crop productivity in such circumstances requires combining chemical and organic fertilizers. The most crucial nutrient for yield and quality is nitrogen, but productivity and environmental safety are guaranteed when nitrogen is used in a balanced manner through integrated nitrogen management. By providing vital nutrients, being economical, environmentally friendly, and assisting plants in withstanding stress, biofertilizers further increase productivity (Khan, et al., 2018).

With an unbalanced NPK ratio of 6.92:2.57:1 compared to the advised 4:2:1 (Vermic Survey, 2004–05), nitrogen dominates fertilizer use in India. Wheat productivity has stagnated or declined as a result of this imbalance, as well as soil salinity, waterlogging, micronutrient deficiencies, decreased organic carbon, and dwindling soil microbial populations. Therefore, implementing integrated nutrient management (INM) and increasing the use of organic manures are crucial for sustainable wheat production (Alam et al., 2013).

The demand for premium food made with few chemical inputs is rising along with health consciousness. Neither chemical nor organic sources by themselves can provide nutrients in a balanced way because wheat is a demanding crop that needs careful nutrition. INM ensures effective nutrient use and sustained yields without endangering the agroecosystem by combining inorganic fertilizers with FYM, vermicompost, and biofertilizers. However, for long-term soil health and sustainable wheat productivity, bulky organic manures must be integrated with concentrated sources and managed properly due to their limited availability and low nutrient content (Verma et al., 2015).

2. MATERIALS AND METHODS

A field experiment was conducted at the Research Farm of Sanjeev Agrawal Global Educational University, Bhopal, during the Rabi season of 2024–25 to study the economics of wheat under integrated nitrogen management. The experimental site is located at an altitude of 500 meters above mean sea level, lying between 23.25° North latitude and 77.52° East longitude. The experiment was laid out in a randomized block design with three replications and 16 treatment combinations. i.e. T_1: Control ; T_2: 100% RDN through urea; T_3: 100% RDN through FYM ; T_4: 100% RDN through vermin-compost; T_5: 50% RDN through urea+ 50% RDN through FYM; T_6: 50% RDN through urea+ 50% RDN through vermin-compost; T_7: 25% RDN through urea+ 75% RDN through FYM; T_8: 25% RDN through urea+ 75% RDN through vermin-compost; T_9: 100% RDN through urea + Azotobacter; T_{10}: 100% RDN through FYM + Azotobacter; T_{11} 100% RDN through vermin-compost + Azotobacter; T_{12} 50% RDN through urea+ 50% RDN through FYM + Azotobacter; T_{13} 50% RDN through urea+ 50% RDN through vermin-compost + Azotobacter; T_{14} 25% RDN through urea+ 75% RDN through FYM + Azotobacter; T_{15} 25% RDN through urea+75% RDN through vermin-compost+ Azotobacter and T_{16} Azotobacter. The recommended dose of nitrogen (RDN) was 150 kg/ha. The recommended doses of phosphorus (60 kg/ha), potash (60 kg/ha), and zinc (25 kg/ha) were applied at the time of sowing in all treatments. The data observed on growth and yield trait was Plant height, Leaf area index, Crop growth rate, Number of effective tillers m^{-1}row length, Test weight (g),Grain yield, Straw yield. The wheat variety Annapurna was sown at 120 kg/ha. FYM and vermin-compost were analyzed for available nitrogen and adjusted to supply the required RDN, then broadcast as per treatments. Nitrogen through urea was applied in two splits half before sowing with the full dose of P, K, and Zn, and the remaining half after the first irrigation. All agronomic practices were applied uniformly, with treatments differing only in the rate and source of nitrogen. The statistical analysis of the experimental design was conducted following the methodology of Panse and Sukhatme (1967).

3. RESULTS AND DISCUSSION

The data presented in Table-1 show significant variations among different treatments with respect to plant growth, yield, and quality parameters.

3.1 Plant Height at Harvest (cm)

Plant height varied significantly across treatments, ranging from 77.19 cm (T1) to 105.27 cm (T2). The tallest plants were observed in T2 (105.27 cm), which was statistically at par with T9 (103.73 cm), T13 (102.07 cm), and T6 (100.67 cm). The shortest plants were recorded in T1 (77.19 cm) followed by T16 (82.27 cm). The critical difference (C.D.) at 5% level was 4.13, confirming significant differences (Xin et al., 2018, Chondie, 2015).

3.1.1 Leaf Area Index (LAI)

The LAI ranged from 2.93 (T1) to 4.92 (T10). The maximum LAI was recorded in T10 (4.92), which remained statistically at par with T7 (4.87), T2 (4.80), T14 (4.78), and T3 (4.77). The lowest LAI was observed in T1 (2.93). The C.D. value of 0.21 confirmed significant variation among treatments (Fazilyet al., 2021).

Table 1. Effect of INM for Enhancing Growth and Yield and quality of Wheat

Treatment	Plant Hight at harvest (cm)	LAI	CGR at harvest	1000 seed wt(g)	Straw yield (k / ha)	Grain yield (Kg/ha)	Protein yield (kg/ha)	Protein content (%)
T_1: Control	77.19	2.93	3.83	30.70	6,293.00	3,875.00	384.15	7.32
T_2: 100% RDN through urea	105.27	4.80	10.17	42.10	7,588.33	4,943.34	712.14	12.88
T_3: 100% RDN through FYM	86.70	4.77	6.20	34.50	6,850.00	4,000.00	478.12	12.03
T_4: 100% RDN through vermicompost	89.27	4.65	6.83	35.30	6,678.00	4,145.00	489.12	12.12
T_5: 50% RDN through urea+ 50% RDN through FYM	97.17	3.96	7.78	37.10	6,964.00	4,410.00	527.28	11.75
T_6: 50% RDN through urea+ 50% RDN through vermicompost	100.67	4.53	8.12	38.00	6,734.00	4,450.00	521.16	11.72
T_7: 25% RDN through urea+ 75% RDN through FYM	87.77	4.87	6.27	35.00	6,680.00	4,237.00	330.15	9.81
T_8: 25% RDN through urea+ 75% RDN through vermicompost	88.93	4.45	7.37	35.35	6,543.00	4,322.00	481.33	11.59
T_9: 100% RDN through urea + *Azotobacter*	103.73	4.46	10.14	41.55	7,457.33	4,716.67	735.26	12.89
T_{10}: 100% RDN through FYM +*Azotobacter*	88.43	4.92	6.45	36.10	7,045.00	4,240.00	452.21	11.25
T_{11}: 100% RDN through vermicompost +*Azotobacter*	92.53	4.31	7.37	36.13	7,110.00	4,360.00	481.13	11.15
T_{12}: 50% RDN through urea+ 50% RDN through FYM +Azotobacter	98.20	3.90	7.88	39.45	6,830.00	4,525.00	538.23	11.72
T_{13}: 50% RDN through urea+ 50% RDN through vermicompost +*Azotobacter*	102.07	4.16	8.34	41.53	7,245.00	4,718.00	547.14	11.87
T_{14}: 25% RDN through urea+ 75% RDN through FYM +Azotobacter	86.20	4.78	7.31	37.13	6,758.00	4,325.00	485.90	11.72
T_{15}: 25% RDN through urea+75% RDN through vermicompost + *Azotobacter*	88.10	4.52	7.63	36.53	6,708.00	4,317.00	500.10	11.72
T_{16}: Azotobacter	82.27	4.51	4.12	33.33	6,980.00	4,014.00	431.96	10.50
SEm ±	4.13	0.21	0.32	1.93	303.47	183.89	17.23	0.51
CD at 5%	1.42	0.07	0.11	0.67	104.57	63.36	5.94	0.18

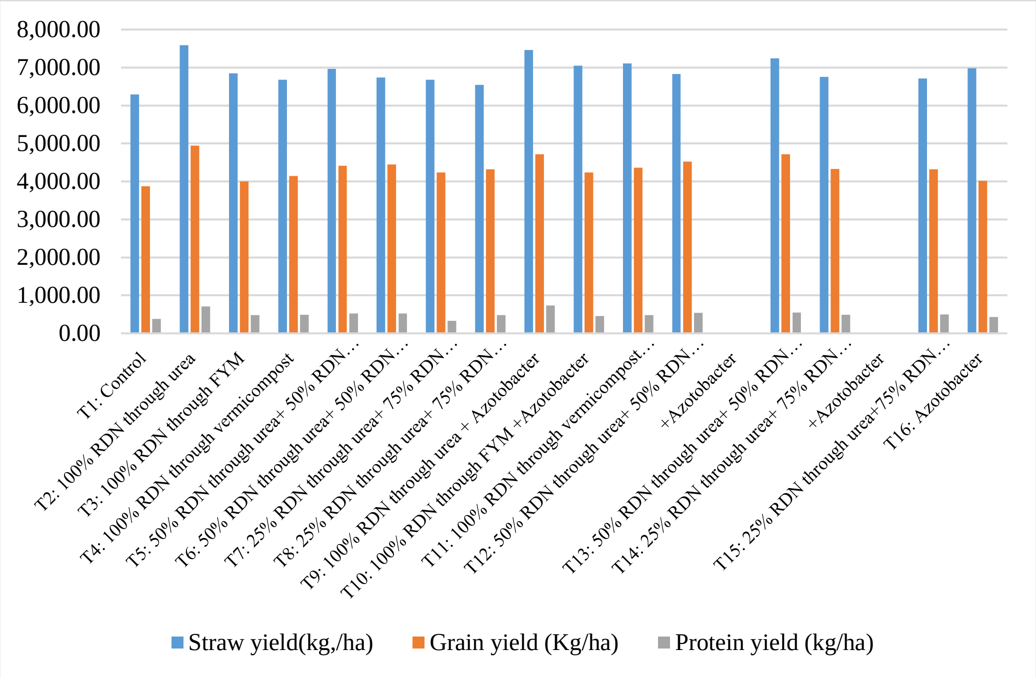

Fig. 1. Effect of INM for Enhancing Growth and Yield and quality of Wheat

3.1.2 Crop growth rate (g/m²/day)

The crop growth rate (CGR) varied between 3.83 (T1) and 10.17 (T2). Significantly higher CGR was observed in T2 (10.17 g/m²/day), which was at par with T9 (10.14 g/m²/day). The lowest CGR was observed in T1 (3.83 g/m²/day), followed by T16 (4.12 g/m²/day) similar finding reported by (Sarwar et al., 2021).

3.1.3 1000-seed weight (g)

The 1000-seed weight ranged from 30.70 g (T1) to 42.10 g (T2). Significantly higher test weight was recorded in T2 (42.10 g), which was statistically comparable with T9 (41.55 g) and T13 (41.53 g). The minimum test weight was recorded in T1 (30.70 g) (Chopra et al., 2016).

3.1.4 Straw yield (kg/ha)

The straw yield ranged from 6293.0 kg/ha (T1) to 7588.33 kg/ha (T2). The highest straw yield was recorded in T2 (7588.33 kg/ha), which was statistically similar to T9 (7457.33 kg/ha) and T13 (7245.0 kg/ha). The lowest straw yield was observed in T1 (6293.0 kg/ha), similar as reported by Zulfiqar et al., 2023).

3.1.5 Grain yield (kg/ha)

The grain yield varied significantly between 3875.0 kg/ha (T1) and 4943.34 kg/ha (T2). The highest grain yield was produced by T2 (4943.34 kg/ha), which was statistically at par with T13 (4718.0 kg/ha) and T9 (4716.67 kg/ha). The lowest yield was recorded in T1 (3875.0 kg/ha) closed finding related to Liu et al., 2024).

3.1.6 Protein yield (kg/ha)

Protein yield ranged from 384.15 kg/ha (T1) to 735.26 kg/ha (T9). The highest protein yield was recorded in T9 (735.26 kg/ha), which was statistically superior to all other treatments. The lowest protein yield was observed in T1 (384.15 kg/ha), (Kaur, et al., 2018).

3.1.7 Protein content (%)

Protein content ranged from 7.32% (T1) to 12.89% (T9). Significantly higher protein content was recorded in T9 (12.89%), which was statistically at par with T2 (12.88%), T4 (12.12%), and T3 (12.03%). The minimum protein content was observed in T1 (7.32%) (Bhardwaj et al., 2021, Iqbal et al., 2012).

3.1.8 Experimental precision

The coefficient of variation (C.V.) ranged from 2.03% (protein yield) to 3.12% (crop growth rate), indicating a high degree of reliability and precision in the experimental findings.

4. CONCLUSION

The present study clearly demonstrated that integrated nitrogen management significantly influenced the growth, yield, and quality of wheat. Treatment T2 consistently performed better for plant height, crop growth rate, test weight, straw yield, and grain yield, establishing its superiority in enhancing overall productivity. Similarly, T9 proved most effective in improving protein yield and protein content, thereby contributing to better nutritional quality of the produce. Treatments T13 and T6 also showed promising results, being statistically comparable with the best treatments in several parameters.

Overall, the results suggest that integrated nitrogen management practices adopted in treatments T2 and T9 are highly effective in enhancing both yield and quality, and could be recommended for wider adoption to improve crop productivity and nutritional value in similar agro-ecological conditions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1. Yes Used ChatGpt for some correction.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/144055