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Effect of integrated nutrient management on growth, yield attributes and yield of wheat (*Triticum aestivum* L.)

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Abstract

Integrated nutrient management (INM) is a sustainable approach for improving crop productivity, nutrient use efficiency and soil fertility through the judicious integration of mineral fertilizers, organic nutrient sources and biofertilizers. A field experiment was conducted during the Rabi season of 2025–26 at the Agronomy Research Farm, GD Goenka University, Sohna, Gurugram, Haryana, India, to evaluate the effect of integrated nutrient management practices on growth, yield attributes and yield of wheat (*Triticum aestivum* L.). The experiment was laid out in a Randomized Block Design (RBD) with three replications comprising nine nutrient management treatments involving recommended dose of fertilizers (RDF), farmyard manure (FYM), neem cake, vermicompost, phosphate-solubilizing bacteria (PSB), bio stimulant (Sagarika) and an untreated control. The results revealed that integrated nutrient management substantially improved growth and yield performance of wheat compared with the untreated control. Among the treatments, 50% RDF + 50% Neem cake + PSB (T₈) recorded the highest plant height (94.88 cm), leaf area index (3.56), dry matter accumulation (1325.45 g m⁻¹ row length), crop growth rate (3.27 g m⁻² day⁻¹) and relative growth rate (0.0003 g g⁻¹ day⁻¹). T₈ also recorded the highest number of effective tillers (106.94 m⁻¹ row length), spike length (12.92 cm), grains per spike (48.25) and test weight (41.11 g). Similarly, the highest grain yield (59.73 q ha⁻¹), straw yield (70.74 q ha⁻¹) and biological yield (130.47 q ha⁻¹) were recorded under T₈, while harvest index showed a comparatively narrow variation among treatments and was numerically highest under 100% RDF (T₂). The improved performance under integrated nutrient management may be attributed to the balanced and sustained supply of nutrients, enhanced nutrient availability, improved soil biological activity and better nutrient use efficiency. The findings indicate that 50% RDF + 50% Neem cake + PSB was the most promising treatment for improving growth, yield attributes and yield of wheat under the agro-climatic conditions of Haryana.

Keywords: Wheat, integrated nutrient management, neem cake, phosphate-solubilizing bacteria, growth attributes, grain yield, yield attributes

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in the world and serves as a staple food for more than one-third of the global population. It contributes substantially to global food and nutritional security by supplying nearly 20% of the calories and protein consumed worldwide. In India, wheat is the second most important food grain after rice and plays a vital role in ensuring food security and supporting the agricultural economy. During the 2024–25 cropping season, wheat occupied approximately 32.8 million hectares with a production of about 113.3 million tonnes and an average productivity of 3.56 t ha⁻¹, making India the second-largest wheat producer after China (USDA, 2024) [31]. Despite remarkable progress in wheat production over recent decades, sustaining higher productivity remains a major challenge due to declining soil fertility, nutrient imbalances and increasing production costs.

The continuous cultivation of wheat under intensive cropping systems has resulted in the depletion of essential soil nutrients and deterioration of soil health. The indiscriminate use of chemical fertilizers, particularly the excessive application of nitrogen with inadequate phosphorus, potassium and micronutrients, has reduced nutrient use efficiency and adversely affected soil productivity (Pathak *et al.*, 2003; Hussain *et al.*, 2016 and Ernst *et al.*, 2020) [6, 9, 21]. Such nutrient imbalances not only limit crop growth and yield but also contribute to environmental concerns through nutrient losses, greenhouse gas emissions and degradation of soil biological activity.

Therefore, developing nutrient management strategies that enhance crop productivity while maintaining soil health has become an important priority for sustainable wheat production. In view of rising fertilizer prices and the environmental consequences of imbalanced fertilizer use, fertilizer recommendations based on soil test values, residual nutrient effects and targeted yields have become increasingly important and imperative (Prasad, 2009) [23].

Integrated Nutrient Management (INM) has emerged as an effective approach for improving crop productivity through the combined use of inorganic fertilizers, organic manures and biological nutrient sources. The integration of these nutrient sources ensures a balanced and continuous supply of plant nutrients, improves nutrient use efficiency and enhances soil physical, chemical and biological properties (Roy *et al.*, 2006) [25]. Organic amendments such as farmyard manure (FYM) improve soil organic carbon, aggregation, moisture retention and microbial activity, while inorganic fertilizers provide readily available nutrients during critical growth stages. Their complementary use has been reported to improve root development, dry matter accumulation, tillering, yield attributes and grain yield compared with the sole application of chemical fertilizers (Manna *et al.*, 2005; Bhattacharyya *et al.*, 2012 and Mahajan *et al.*, 2008) [3, 15, 16]. Moreover, INM contributes to long-term soil fertility by increasing nutrient availability, reducing nutrient losses and promoting sustainable crop production systems.

The combined application of organic and inorganic fertilizers has been shown to influence growth and yield attributes of wheat, including delayed days to 50 per cent heading, increased plant height, higher leaf area index, grain yield and yield components compared to the sole application of either organic or inorganic sources (Manna *et al.*, 2005) [16].

Several studies have demonstrated the positive influence of integrated nutrient management on wheat growth and productivity; however, the response of wheat to different combinations of nutrient sources varies with soil type, climatic conditions and crop management practices. Consequently, region-specific evaluation of integrated nutrient management strategies is essential for identifying nutrient combinations that maximize productivity while improving resource-use efficiency. Information on the comparative performance of different integrated nutrient management practices under the agro-climatic conditions of Haryana remains limited, particularly with respect to their influence on wheat growth, yield attributes and grain yield.

Biofertilizers such as *Azotobacter* and *Azospirillum*, either alone or in combination, have shown considerable potential in enhancing wheat productivity (Kumar and Ahlawat, 2004) [14]. This highlights the need for conjunctive use of inorganic fertilizers, organic manures, crop residues and biofertilizers through an integrated plant nutrient supply system. Timely fertilizer application using appropriate methods is equally crucial for sustainable nutrient management (Devi *et al.*, 2011) [4].

Seaweed-based bio stimulants such as Z++ (IFFCO Sagarika) are organic soil conditioners derived from red and brown algae and are enriched with nutrients like sulphur, calcium, zinc and boron. These bio stimulants enhance plant metabolic activity, stimulate beneficial rhizosphere microorganisms and promote root growth, tillering, nutrient uptake and seed development. They also improve tolerance to abiotic stresses such as drought and temperature extremes. Seaweed extracts have been reported to enhance seed germination, plant growth, yield and stress resistance across cereals, pulses, vegetables and horticultural crops (Khan *et al.*, 2009) [12].

The integrated plant nutrition system (IPNS) emphasizes the conjunctive use of chemical fertilizers, organic manures and biological sources to alleviate nutrient deficiencies and enhance nutrient use efficiency. Integrated nutrient management (INM) offers a flexible approach to reduce reliance on chemical fertilizers while improving their efficiency, farm profitability and soil health. Fertilizers, organic manures and biofertilizers constitute the major components of INM. No single nutrient source can fulfil the entire nutrient requirement of crops under modern intensive agriculture; therefore, nutrients must be supplied in an integrated manner through economically viable, socially acceptable and ecologically sound management practices. The integrated use of organic and inorganic fertilizers has been reported to significantly enhance root and shoot dry matter accumulation compared to sole application of inorganic fertilizers.

Keeping these considerations in view, the present investigation entitled “Effect of Integrated Nutrient Management on Growth, Yield Attributes and Yield of Wheat (*Triticum aestivum* L.)” was conducted during the Rabi season of 2025–26 at the Agronomy Research Farm, GD Goenka University, Sohna, Gurugram, Haryana. The study aimed to evaluate the effect of different integrated nutrient management treatments on the growth, yield attributes and yield of wheat and to identify an efficient nutrient management strategy for enhancing wheat productivity under the prevailing agro-climatic conditions.

Materials and Methods

A field experiment was conducted during the Rabi season of 2025–26 at the Agronomy Research Farm, School of Agricultural Sciences, GD Goenka University, Sohna, Gurugram, Haryana, India. The experimental site is located at 28°15' N latitude and 77°04' E longitude with an altitude of approximately 220 m above mean sea level. The region experiences a humid subtropical climate with semi-arid characteristics, characterized by hot summers and cool winters. During the crop-growing season, the weather remained favourable for wheat cultivation. Before sowing, composite soil samples (0–15 cm depth) were collected from the experimental field and analysed using standard laboratory procedures. The experimental soil was silty loam in texture, slightly alkaline (pH 8.4), low in organic carbon (0.37%) and available nitrogen (168.0 kg ha⁻¹), medium in available phosphorus (16.9 kg ha⁻¹) and high in available potassium (280.8 kg ha⁻¹). The experiment was laid out in a Randomized Block Design (RBD) with three replications. Nine nutrient management treatments consisting of different combinations of recommended dose of fertilizers (RDF), farmyard manure (FYM), neem cake, vermicompost, phosphate-solubilizing bacteria (PSB) and seaweed-based bio stimulant (Sagarika) were evaluated. The treatments were: T₁: Control, T₂: 100% RDF (120:60:40 kg N:P₂O₅: K₂O ha⁻¹), T₃: 100% Organic Manure (50% FYM + 50% Neem cake), T₄: 50% RDF + 50% FYM + PSB, T₅: 75% RDF + 25% FYM + PSB, T₆: 50% RDF + 50% Vermicompost + Sagarika (1 L ha⁻¹), T₇: 75% RDF + 25% Neem cake, T₈: 50% RDF + 50% Neem cake + PSB, T₉: 75% RDF + 25% Neem cake + PSB. Wheat variety HD-2851 was sown on 25 November 2025 using a seed rate of 100 kg ha⁻¹ with a row spacing of 20 cm. The recommended dose of fertilizers (120:60:40 kg N:P₂O₅: K₂O ha⁻¹) was supplied through urea, diammonium phosphate (DAP) and muriate of potash (MOP). Full doses of phosphorus and potassium together with half of the nitrogen were applied as basal, while the remaining nitrogen was top-dressed in two equal splits at the first and second irrigations. Farmyard manure, vermicompost and neem cake were incorporated into the soil 15

days before sowing according to the respective treatments. PSB and the seaweed-based bio stimulant (Sagarika) were applied as per treatment specifications. Standard agronomic practices, including irrigation, weed management and plant protection measures, were followed uniformly in all plots throughout the crop growth period. Five representative plants were randomly selected from each plot for recording growth observations. Plant height, leaf area index, dry matter accumulation, crop growth rate, relative growth rate and the number of effective tillers were recorded at different growth stages. At harvest, spike length, grains per spike, test weight, grain yield, straw yield, biological yield and harvest index were determined following standard procedures. The experimental data were subjected to analysis of variance (ANOVA) appropriate for a Randomized Block Design following the procedure described by Panse and Sukhatme (1957 & 1967)^[19, 20]. Treatment means were compared using the critical difference (CD) test at the 5% level of significance wherever the F-test indicated significant differences among treatments.

Result and Discussion

Integrated nutrient management treatments influenced the growth attributes of wheat, as presented in Table 1. Plant height at harvest varied from 70.54 to 94.88 cm, with the maximum plant height recorded under T₈ (50% RDF + 50% Neem cake + PSB), followed by T₅ (75% RDF + 25% FYM + PSB) and T₆ (50% RDF + 50% Vermicompost + Bio stimulant [Sagarika @1 L ha⁻¹]), with values of 91.40 and 86.62 cm, respectively. The minimum plant height (70.54 cm) was recorded under the untreated control (T₁). Based on the critical difference, T₈ was statistically at par with T₅, indicating a comparable response of these integrated nutrient management treatments. Leaf area index followed a similar trend, with the highest value under T₈ (3.56), closely followed by T₅ (3.54) and T₆ (3.33), whereas the lowest LAI (2.39) was recorded in T₁. Dry matter accumulation was also maximum under T₈ (1325.45 g m⁻¹ row length), followed by T₅ (1296.30 g m⁻¹ row length) and T₆ (1288.47 g m⁻¹ row length), while the control recorded the lowest value (977.01 g m⁻¹ row length). Similarly, the highest crop growth rate (3.27 g m⁻² day⁻¹) was observed under T₈, followed by T₅ (2.91 g m⁻² day⁻¹), whereas the relative growth rate was numerically highest under T₅ and T₈ (0.0003 g g⁻¹ day⁻¹). Overall, the integrated nutrient management treatments promoted greater vegetative growth and biomass production than the control. The beneficial response of organic nutrient sources may be associated with their supply of macro- and micronutrients and biologically active compounds, together with improvement in soil microbial activity and nutrient cycling. Organic manures can improve soil fertility through the addition of organic matter and humic substances, which favour root development and provide a suitable environment for plant growth (Pong and Laty, 2000)^[22]. Farmyard manure enhances plant growth through both direct and indirect mechanisms by supplying essential plant nutrients, organic matter and humic substances formed during decomposition (Ali *et al.*, 2021, Noreen and Noreen, 2014)^[1]. In addition, the incorporation of organic manures promotes microbial proliferation and increases the activity of important soil enzymes, thereby enhancing nutrient transformation and availability to plants (Knapp *et al.*, 2010)^[13]. The yield attributes of wheat were markedly improved under integrated nutrient management treatments (Table 2). The number of effective tillers ranged from 71.96 to 106.94 m⁻¹ row length, with the maximum value recorded under T₈ (106.94 m⁻¹ row length), followed by T₅ (106.17 m⁻¹ row length) and T₆ (103.29 m⁻¹ row length), whereas the control (T₁) recorded the minimum

number of effective tillers (71.96 m⁻¹ row length). The difference between T₈ and T₅ was smaller than the critical difference, indicating that these treatments were statistically at par. Spike length was also highest under T₈ (12.92 cm), followed by T₅ (11.64 cm) and T₆ (11.33 cm), while the minimum spike length (6.34 cm) was recorded under T₁. Similarly, T₈ produced the maximum number of grains per spike (48.25), followed by T₅ (45.00) and T₆ (44.23), whereas the minimum value (31.13 grains spike⁻¹) was observed under the control. Test weight was highest under T₈ (41.11 g), followed by T₅ (40.81 g) and T₆ (40.79 g), while the control recorded the lowest test weight (32.20 g). These results indicate that balanced nutrient availability under integrated nutrient management favoured tiller formation, spike development and grain filling. The beneficial effects of FYM, neem cake, biofertilizers and other organic nutrient sources may be attributed to their capacity to provide nutrients progressively and to improve the soil environment, thereby supporting cell division, cell enlargement, meristematic activity, photosynthesis and water uptake. The combined application of organic and inorganic nutrient sources also helps maintain a more balanced nutrient supply during crop growth (Sekar, 2003; Sharma *et al.*, 2013)^[26, 27].

The application of integrated nutrient management also resulted in considerable improvement in grain, straw and biological yield of wheat (Table 3). Grain yield ranged from 26.49 to 59.73 q ha⁻¹. The highest grain yield was recorded under T₈ (59.73 q ha⁻¹), followed by T₅ (56.25 q ha⁻¹), T₆ (54.90 q ha⁻¹) and T₉ (53.89 q ha⁻¹), whereas the untreated control (T₁) recorded the lowest grain yield (26.49 q ha⁻¹). The difference between T₈ and T₅ was less than the critical difference, indicating that these treatments were statistically comparable, while T₈ remained clearly superior to the control. Straw yield followed a similar pattern, with the maximum value under T₈ (70.74 q ha⁻¹), followed by T₅ (68.73 q ha⁻¹) and T₆ (66.83 q ha⁻¹), compared with 32.82 q ha⁻¹ under T₁. Consequently, biological yield was also highest under T₈ (130.47 q ha⁻¹), followed by T₅ (124.98 q ha⁻¹) and T₆ (121.73 q ha⁻¹), while the lowest biological yield (59.32 q ha⁻¹) was recorded under the control. Harvest index showed relatively narrow variation among the treatments, ranging from 44.71 to 46.36%, with the highest numerical value under T₂ (100% RDF), indicating that the response of harvest index was less pronounced than that of grain, straw and biological yield. The higher productivity under integrated nutrient management, particularly T₈, may be attributed to improved nutrient availability and utilization, greater vegetative growth and better development of yield-attributing characters. Organic nutrient sources such as FYM and neem cake can provide nutrients through mineralization and contribute to favourable soil physical conditions, including improved aggregation, water retention, aeration and root development (Hendrix *et al.*, 1994; Martens *et al.*, 1992)^[8, 17]. The formation of stable humus-colloidal complexes and the comparatively higher nutrient content of organic sources may further enhance nutrient availability and soil productivity (Singh *et al.*, 2024; Ali *et al.*, 2025; Singh *et al.*, 2011; Reddy *et al.*, 2006; Singh and Shrivastava, 1970; Dhaka *et al.*, 2012)^[2, 5, 24, 28, 29, 30]. Similar improvements in yield components and grain and straw yields of wheat following FYM application have been reported by Gupta and Sharma (2007)^[7]. The present findings are also in agreement with Singh *et al.* (2011)^[28] and Ali *et al.* (2025)^[2], who reported beneficial effects of integrated organic and inorganic nutrient management on soil fertility, nutrient use efficiency and crop productivity.

Table 1: Effect of integrated nutrient management on growth of wheat (*Triticum aestivum* L.)

Treatments	Plant height (cm)	Leaf Area Index (LAI)	Dry Matter (g/m. r. l.)	Crop growth rate (CGR) (g m ⁻² day ⁻¹)	Relative Growth Rate (RGR) (g g ⁻¹ day ⁻¹)
T ₁	70.54	2.39	977.01	2.07	0.0002
T ₂	70.80	2.75	1103.56	2.43	0.0002
T ₃	71.16	2.91	1140.52	2.57	0.0002
T ₄	76.43	3.29	1234.08	2.67	0.0002
T ₅	91.40	3.54	1296.30	2.91	0.0003
T ₆	86.62	3.33	1288.47	2.80	0.0002
T ₇	75.92	2.97	1160.36	2.60	0.0002
T ₈	94.88	3.56	1325.45	3.27	0.0003
T ₉	85.34	3.30	1252.35	2.77	0.0002
SE(m) ±	2.71	0.11	23.48	0.11	0.00003
CD (P=0.05)	8.12	0.34	70.39	0.33	0.00007

T₁: Control, T₂: 100% RDF (120:60:40 kg N:P₂O₅: K₂O ha⁻¹), T₃: 100% Organic Manure (50% FYM + 50% Neem cake), T₄: 50% RDF + 50% FYM + PSB, T₅: 75% RDF + 25% FYM + PSB, T₆: 50% RDF + 50% Vermicompost + Sagarika (1 L ha⁻¹), T₇: 75% RDF + 25% Neem cake, T₈: 50% RDF + 50% Neem cake + PSB, T₉: 75% RDF + 25% Neem cake + PSB.

#CD = Critical Difference at P ≤ 0.05; SE(m) = Standard Error of Mean.

Table 2: Effect of integrated nutrient management on yield attributes of wheat (*Triticum aestivum* L.) at harvest

Treatments	No. of effective tillers (m. r. l)	Spike Length (cm)	No. of grains spike ⁻¹	Test Weight (g)
T ₁	71.96	6.34	31.13	32.20
T ₂	81.52	8.29	38.45	38.59
T ₃	83.92	8.68	40.23	40.29
T ₄	95.22	9.83	43.33	40.56
T ₅	106.17	11.64	45.00	40.81
T ₆	103.29	11.33	44.23	40.79
T ₇	88.98	9.02	42.80	40.41
T ₈	106.94	12.92	48.25	41.11
T ₉	97.57	10.13	44.13	40.74
SE(m) ±	1.61	0.55	1.36	0.66
CD (P=0.05)	4.82	2.03	4.97	2.42

T₁: Control, T₂: 100% RDF (120:60:40 kg N:P₂O₅: K₂O ha⁻¹), T₃: 100% Organic Manure (50% FYM + 50% Neem cake), T₄: 50% RDF + 50% FYM + PSB, T₅: 75% RDF + 25% FYM + PSB, T₆: 50% RDF + 50% Vermicompost + Sagarika (1 L ha⁻¹), T₇: 75% RDF + 25% Neem cake, T₈: 50% RDF + 50% Neem cake + PSB, T₉: 75% RDF + 25% Neem cake + PSB.

#CD = Critical Difference at P ≤ 0.05; SE(m) = Standard Error of Mean.

Table 3: Effect of integrated nutrient management on yield of wheat (*Triticum aestivum* L.) at harvest

Treatments	Grain Yield (q ha ⁻¹)	Straw Yield (q ha ⁻¹)	Biological Yield (q ha ⁻¹)	Harvest index (%)
T ₁	26.49	32.82	59.32	44.71
T ₂	38.57	44.73	83.30	46.36
T ₃	45.52	54.33	99.85	45.55
T ₄	52.33	62.04	114.37	45.72
T ₅	56.25	68.73	124.98	44.99
T ₆	54.90	66.83	121.73	45.09
T ₇	49.00	57.90	106.90	45.96
T ₈	59.73	70.74	130.47	45.78
T ₉	53.89	65.07	118.96	45.32
SE(m) ±	1.87	2.33	3.02	1.46
CD (P=0.05)	5.62	6.98	9.05	4.37

T₁: Control, T₂: 100% RDF (120:60:40 kg N:P₂O₅: K₂O ha⁻¹), T₃: 100% Organic Manure (50% FYM + 50% Neem cake), T₄: 50% RDF + 50% FYM + PSB, T₅: 75% RDF + 25% FYM + PSB, T₆: 50% RDF + 50% Vermicompost + Sagarika (1 L ha⁻¹), T₇: 75% RDF + 25% Neem cake, T₈: 50% RDF + 50% Neem cake + PSB, T₉: 75% RDF + 25% Neem cake + PSB.

#CD = Critical Difference at P ≤ 0.05; SE(m) = Standard Error of Mean.

Citations Requiring Manual Verification

The following in-text citations could not be confidently matched to a single reference in the References list and require manual verification:

- (Jain, 2012) – Introduction section. Two references in the list share this exact author and year (10. Jain P., Trends in Biosciences, 2012 and 11. Jain P., Journal of Science and Research, 2012). Please confirm which one this citation refers to.
- Noreen and Noreen, 2014 (within the bracket "(Ali *et al.*, 2021, Noreen and Noreen, 2014)") – Result and Discussion

section. Reference 18 (Noreen F, Noreen S.) in the list does not specify a publication year (listed as "International [journal information incomplete]"), so the year 2014 in the citation could not be verified against it.

Conclusion

The present investigation demonstrated that integrated nutrient management substantially improved the growth, yield attributes and yield of wheat compared with the untreated control. Among the nine nutrient management treatments, T₈ (50% RDF + 50% Neem cake + PSB) consistently recorded the highest values of

plant height, leaf area index, dry matter accumulation, crop growth rate, effective tillers, spike length, grains per spike, test weight, grain yield, straw yield and biological yield. The highest grain yield of 59.73 q ha⁻¹ under T₈ was statistically comparable with T₅ (56.25 q ha⁻¹), but clearly higher than the untreated control (26.49 q ha⁻¹). Harvest index showed comparatively little variation and was numerically highest under T₂ (100% RDF). The superior performance of T₈ may be attributed to the complementary effects of mineral fertilizer, neem cake and phosphate-solubilizing bacteria, which together can provide a balanced and sustained nutrient supply, improve nutrient availability and support favourable soil biological and rhizospheric conditions. Therefore, under the agro-climatic conditions of Haryana, 50% RDF + 50% Neem cake + PSB emerged as the most promising treatment for enhancing wheat growth, yield attributes and productivity and may be considered a suitable integrated nutrient management strategy for improving nutrient use efficiency and crop performance.

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