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Satyendra Ahirwar
School of Agriculture Science,
Vikrant University, Gwalior,
Madhya Pradesh, India

Hirdesh Kumar
School of Agriculture Science,
Vikrant University, Gwalior,
Madhya Pradesh, India

Jay Prakash Thakur
Professor, School of Natural and
Applied Sciences, Vikrant
University, Gwalior, Madhya
Pradesh, India

Arun Sahu
School of Agriculture Science,
Vikrant University, Gwalior,
Madhya Pradesh, India

Sachin Kumar Singh
School of Agriculture Science,
Vikrant University, Gwalior,
Madhya Pradesh, India

Chandan Singh
School of Agriculture Science,
Vikrant University, Gwalior,
Madhya Pradesh, India

Ajay Shakya
School of Agriculture Science,
Vikrant University, Gwalior,
Madhya Pradesh, India

Corresponding Author:
Satyendra Ahirwar
School of Agriculture Science,
Vikrant University, Gwalior,
Madhya Pradesh, India

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

Satyendra Ahirwar, Hirdesh Kumar, Jay Prakash Thakur, Arun Sahu, Sachin Kumar Singh, Chandan Singh and Ajay Shakya

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Abstract

A field experiment was conducted during the *Rabi* season of 2025–26 at the Agriculture Research and Development Centre, Sakatpura, Vikrant University, Gwalior (Madhya Pradesh), India to evaluate the effect of integrated nutrient management on wheat (*Triticum aestivum* L.). The experiment was laid out in a Randomized Block Design with 11 treatments and three replications using variety HI 1634. Results revealed that all growth, yield attributes and yield parameters were significantly influenced by different nutrient management practices. The treatment involving 100% RDF (120:60:40 NPK) + Vermicompost @ 3 t ha⁻¹ + Azospirillum @ 25 g kg⁻¹ seed recorded the highest plant population, plant height, tillers per plant, spikelets per plant, test weight, grains per spike, grain yield (58.50 q ha⁻¹), straw yield (135.58 q ha⁻¹), biological yield (194.08 q ha⁻¹) and harvest index (43.10%). It was closely followed by treatments with 75% RDF + Vermicompost + Azospirillum and 100% RDF + Vermicompost, while the lowest performance was recorded under the control. The superior performance under integrated nutrient management may be attributed to improved nutrient availability, better soil biological activity, enhanced root growth and efficient nutrient uptake.

Keywords: Wheat, integrated nutrient management, RDF, vermicompost, azospirillum, growth attributes, yield attributes

Introduction

Wheat (*Triticum aestivum* L.) is one of the most widely cultivated cereal crops in the world and a major source of calories and protein for a large population, particularly in countries like India (Kaur *et al.*, 2023) [6]. In India, it plays a crucial role in food security and agricultural economy; however, sustaining its productivity has become increasingly challenging due to continuous nutrient mining, soil degradation and imbalanced fertilizer use under intensive cropping systems (Bhusal, 2025) [1]. Long-term cereal-based rotations with excessive reliance on chemical fertilizers have led to a decline in soil organic carbon, reduced microbial biomass and deterioration of soil physical properties, ultimately affecting soil health and crop productivity (Singh *et al.*, 2024) [14]. In addition, declining nutrient use efficiency, especially nitrogen, has increased production costs and contributed to environmental issues such as nutrient leaching and greenhouse gas emissions (Srivastava & Ngullie, 2009) [16].

Integrated Nutrient Management (INM) has emerged as a sustainable approach to improve soil fertility and enhance crop productivity through the balanced use of chemical fertilizers, organic manures and biofertilizers (Srivastava & Ngullie, 2009) [16]. Organic inputs such as vermicompost improve soil structure, water-holding capacity and organic carbon content, while also enhancing microbial activity and nutrient mineralization (Bhusal, 2025) [1]. Biofertilizers like *Azotobacter* and phosphate-solubilizing bacteria further improve nutrient availability through biological nitrogen fixation and phosphorus solubilization, along with the production of growth-promoting substances that enhance root development and nutrient uptake (Kumar *et al.*, 2022) [8]. The synergistic interaction of these components with inorganic fertilizers ensures a continuous and balanced nutrient supply, leading to improved yield attributes, better grain formation and higher productivity in wheat (Chopra *et al.*, 2025) [12]. Thus, INM not only enhances yield and yield

components but also improves nutrient use efficiency, soil health and economic returns, making it a promising strategy for sustainable wheat production under modern agro-climatic conditions.

Materials and Methods

The experiment was conducted during the *Rabi* season of 2025–26 at the Agriculture Research and Development Centre, Sakatpura, Vikrant University, Gwalior (Madhya Pradesh), India, to evaluate the effect of integrated nutrient management on wheat (*Triticum aestivum* L.). The study was laid out in a Randomized Block Design (RBD) with 11 treatments and three replications, comprising a total of 33 plots. Each plot measured 3×3 m². The wheat variety HI 1634 was used for the investigation under uniform agronomic practices to ensure reliable comparison among treatments. The data recorded on various parameters were analyzed as per Randomized Block Design (RBD) design as suggested by Gomez and Gomez (1984). The results have been interpreted on the basis of 'F' test value and critical difference (CD) was calculated.

The treatment structure included different combinations of recommended dose of fertilizers (RDF), vermicompost and *Azospirillum* to assess their influence on crop performance. The treatments were T₁: 100% RDF (120:60:40 NPK), T₂: 100% RDF + *Azospirillum* (25 g kg⁻¹ seed), T₃: 100% RDF + vermicompost (3 t ha⁻¹), T₄: 75% RDF + *Azospirillum* (25 g kg⁻¹ seed), T₅: 75% RDF + vermicompost (3 t ha⁻¹), T₆: 50% RDF + *Azospirillum* (25 g kg⁻¹ seed) and T₇: 50% RDF + vermicompost (3 t ha⁻¹), along with remaining comparative treatments as per experimental requirement. The study was designed to evaluate the combined and individual effects of inorganic fertilizers, organic manure and biofertilizer on growth, yield and productivity of wheat under agro-climatic conditions of Gwalior region.

Results and Discussion

Growth Attributes

The plant population per plot was significantly influenced by integrated nutrient management treatments. The highest plant population (417.67 plants plot⁻¹) was recorded under 100% RDF (120:60:40 NPK) + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed, followed by 75% RDF + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed (410.00 plants plot⁻¹) and 100% RDF + Vermicompost @ 3 t ha⁻¹ (408.00 plants plot⁻¹), whereas the lowest plant population (375.00 plants plot⁻¹) was observed under the Control treatment. The increased plant population may be attributed to improved soil conditions and better nutrient availability during crop establishment.

Plant height at harvest was significantly affected by the treatments. The maximum plant height (95.73 cm) was recorded under 100% RDF (120:60:40 NPK) + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed, followed by 75% RDF + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed (92.10 cm) and 50% RDF + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed (89.13 cm). The lowest plant height (78.50 cm) was observed under the Control treatment. The greater plant height could be due to balanced nutrient supply and enhanced vegetative growth.

The number of tillers per plant varied significantly among treatments. The highest number of tillers per plant (7.62) was recorded under 100% RDF (120:60:40 NPK) + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed, followed by 75% RDF + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed (7.03) and 100% RDF + Vermicompost @ 3 t ha⁻¹ (6.65), while the lowest value (4.83) was observed under the Control treatment.

Increased tillering may be attributed to improved nutrient uptake and better crop growth.

The number of spikelets per plant was significantly influenced by the treatments. The highest number of spikelets per plant (21.77) was recorded under 100% RDF (120:60:40 NPK) + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed, followed by 75% RDF + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed (20.43) and 50% RDF + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed (19.50), whereas the lowest number (15.50) was observed under the Control treatment. The improvement in spikelet formation may be due to enhanced nutrient availability and better reproductive development.

Test weight differed significantly among the treatments. The maximum test weight (46.83 g) was recorded under 100% RDF (120:60:40 NPK) + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed, followed by 75% RDF + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed (45.22 g) and 100% RDF + Vermicompost @ 3 t ha⁻¹ (44.23 g), while the minimum test weight (36.79 g) was observed under the Control treatment. Higher test weight may be attributed to better grain filling and dry matter accumulation.

The number of grains per spike was significantly affected by integrated nutrient management treatments. The highest number of grains per spike (63.10) was recorded under 100% RDF (120:60:40 NPK) + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed, followed by 75% RDF + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed (59.14) and 100% RDF + Vermicompost @ 3 t ha⁻¹ (55.08), whereas the lowest value (39.03) was observed under the Control treatment. The increased number of grains per spike may be due to improved nutrient supply, which enhanced spike development and grain setting. Similar findings were reported by Kumar *et al.* (2020)^[9] and Patel *et al.* (2018)^[11], who observed improved plant growth and yield attributes under integrated nutrient management due to better nutrient availability and soil conditions. In contrast, Sharma and Singh (2019)^[13] and Verma *et al.* (2021)^[17] reported that some growth parameters like plant population and height are more influenced by seed quality and genetics than fertilizer levels. Similar increases in tillers, spikelets, test weight and grains per spike were also supported by Yadav *et al.* (2017)^[18] and Choudhary *et al.* (2021)^[3], whereas Kaur *et al.* (2019)^[7] and Gupta *et al.* (2018)^[4] noted that environmental and management factors may sometimes limit or weaken these responses.

Yield Attributes

The grain yield was significantly influenced by different integrated nutrient management treatments (Table 4.6 and Fig. 4.6). The highest grain yield (58.50 q ha⁻¹) was recorded under T₈ (100% RDF + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed), followed by T₉ (75% RDF + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed) with 54.74 q ha⁻¹ and T₃ (100% RDF + Vermicompost @ 3 t ha⁻¹) with 52.51 q ha⁻¹. Among the remaining treatments, T₁₀ (50% RDF + Vermicompost @ 3 t ha⁻¹ + *Azospirillum* @ 25 g kg⁻¹ seed) recorded 51.23 q ha⁻¹, T₅ (75% RDF + Vermicompost @ 3 t ha⁻¹) 50.35 q ha⁻¹ and T₂ (100% RDF (120:60:40 NPK) + *Azospirillum* @ 25 g kg⁻¹ seed) 49.76 q ha⁻¹. Moderate grain yield was observed under T₇ (50% RDF + Vermicompost @ 3 t ha⁻¹) with 47.51 q ha⁻¹ and T₁ (100% RDF (120:60:40 NPK)) with 47.23 q ha⁻¹, while T₄ (75% RDF + *Azospirillum* @ 25 g kg⁻¹ seed) recorded 45.30 q ha⁻¹. The lowest grain yield (40.33 q ha⁻¹) was observed under T₆ (50% RDF + *Azospirillum* @ 25 g kg⁻¹ seed), whereas the control treatment T₁₁ (no fertilizer, no organic manure and no biofertilizer) recorded the lowest yield (35.24 q ha⁻¹).

The straw yield also showed significant variation among treatments (Table 4.6 and Fig. 4.6). The highest straw yield (135.58 q ha^{-1}) was recorded under T_8 (100% RDF + Vermicompost @ 3 t ha^{-1} + Azospirillum @ 25 g kg^{-1} seed), followed by T_9 (75% RDF + Vermicompost @ 3 t ha^{-1} + Azospirillum @ 25 g kg^{-1} seed) with 128.17 q ha^{-1} and T_3 (100% RDF + Vermicompost @ 3 t ha^{-1}) with 123.73 q ha^{-1} . Intermediate values were recorded under T_{10} (50% RDF + Vermicompost @ 3 t ha^{-1} + Azospirillum @ 25 g kg^{-1} seed), T_5 (75% RDF + Vermicompost @ 3 t ha^{-1}) and T_2 (100% RDF + Azospirillum @ 25 g kg^{-1} seed). Moderate straw yield was observed under T_7 (50% RDF + Vermicompost @ 3 t ha^{-1}) and T_1 (100% RDF (120:60:40 NPK)), while T_4 recorded 107.08 q ha^{-1} and T_6 (50% RDF + Azospirillum @ 25 g kg^{-1} seed) recorded 96.76 q ha^{-1} . The lowest straw yield (86.54 q ha^{-1}) was recorded under T_{11} (control: no fertilizer, no organic manure and no biofertilizer).

Biological yield followed a similar trend as grain and straw yield. The maximum biological yield (194.08 q ha^{-1}) was recorded under T_8 (100% RDF + Vermicompost @ 3 t ha^{-1} + Azospirillum @ 25 g kg^{-1} seed), followed by T_9 (182.91 q ha^{-1}) and T_3 (176.24 q ha^{-1}). The lowest biological yield (121.78 q ha^{-1}) was observed under T_{11} (control).

Harvest index showed slight variation among treatments. The highest harvest index (43.10%) was recorded under T_8 (100% RDF + Vermicompost @ 3 t ha^{-1} + Azospirillum @ 25 g kg^{-1} seed), followed by T_9 (42.71%) and T_2 (100% RDF (120:60:40 NPK) + Azospirillum @ 25 g kg^{-1} seed) with 42.50%. Treatments

T_3 (100% RDF + Vermicompost @ 3 t ha^{-1}), T_1 (100% RDF), T_5 (75% RDF + Vermicompost @ 3 t ha^{-1}), T_4 (75% RDF + Azospirillum @ 25 g kg^{-1} seed) and T_{10} (50% RDF + Vermicompost @ 3 t ha^{-1} + Azospirillum @ 25 g kg^{-1} seed) showed nearly similar values ranging from 42.34% to 42.43%. The lowest harvest index (40.75%) was recorded under T_{11} (control).

The grain, straw and biological yield were significantly influenced by different integrated nutrient management treatments. The highest grain yield (58.50 q ha^{-1}), straw yield (135.58 q ha^{-1}) and biological yield (194.08 q ha^{-1}) were recorded under T_8 (100% RDF + Vermicompost @ 3 t ha^{-1} + Azospirillum @ 25 g kg^{-1} seed), followed by T_9 and T_3 , whereas the lowest values were observed under the control (T_{11}). Similar findings were reported by Kumar *et al.* (2020) [9], Patel *et al.* (2018) [11] and Choudhary *et al.* (2021) [3], who attributed higher yields to improved nutrient availability, better root development and enhanced photosynthetic activity under integrated nutrient management. In contrast, Sharma and Singh (2019) [13] and Verma *et al.* (2021) [17] reported that yield differences may sometimes be limited due to genetic control and reduced responsiveness at higher fertility levels. Harvest index showed only slight variation among treatments, with the highest value under T_8 (43.10%) and the lowest under T_{11} (40.75%), supporting the findings of Singh *et al.* (2020) [15], while Kaur *et al.* (2019) [7] reported that harvest index is comparatively stable and less influenced by nutrient management practices.

Table 1: Effect of Integrated Nutrient Management on Growth attributes, No. of Spikelets per Plant, Test Weight (g) and No. of Grains per Spike of Wheat

Treatment No.	Treatment Details	Plant Population per Plot	Plant Height at Harvest (cm)	No. of Tillers per Plant	No. of Spikelets per Plant	Test Weight (g)	No. of Grains per Spike
T_1	100% RDF (120:60:40 NPK)	398.33	85.53	5.93	17.83	41.18	49.04
T_2	100% RDF + Azospirillum @ 25 g kg^{-1} seed	401.67	87.27	6.34	18.57	42.77	52.20
T_3	100% RDF + Vermicompost @ 3 t ha^{-1}	408.00	88.57	6.65	19.23	44.23	55.08
T_4	75% RDF + Azospirillum @ 25 g kg^{-1} seed	392.33	86.10	6.03	18.07	40.78	47.05
T_5	75% RDF + Vermicompost @ 3 t ha^{-1}	399.67	87.53	6.40	18.80	43.50	53.12
T_6	50% RDF + Azospirillum @ 25 g kg^{-1} seed	385.00	84.10	5.54	17.23	38.77	43.06
T_7	50% RDF + Vermicompost @ 3 t ha^{-1}	392.33	85.67	5.90	17.87	42.01	50.04
T_8	100% RDF + Vermicompost @ 3 t ha^{-1} + Azospirillum @ 25 g kg^{-1} seed	417.67	95.73	7.62	21.77	46.83	63.10
T_9	75% RDF + Vermicompost @ 3 t ha^{-1} + Azospirillum @ 25 g kg^{-1} seed	410.00	92.10	7.03	20.43	45.22	59.14
T_{10}	50% RDF + Vermicompost @ 3 t ha^{-1} + Azospirillum @ 25 g kg^{-1} seed	397.67	89.13	6.58	19.50	43.77	54.09
T_{11}	Control	375.00	78.50	4.83	15.50	36.79	39.03
SEM $\pm$		2.28	0.46	0.10	0.08	0.09	0.46
CD (P=0.05)		4.42	0.88	0.19	0.16	0.17	0.89

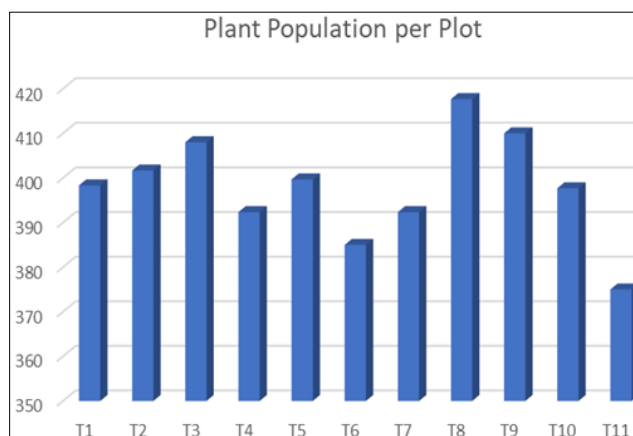


Fig 1: Effect of Integrated Nutrient Management on Plant Population per Plot of Wheat

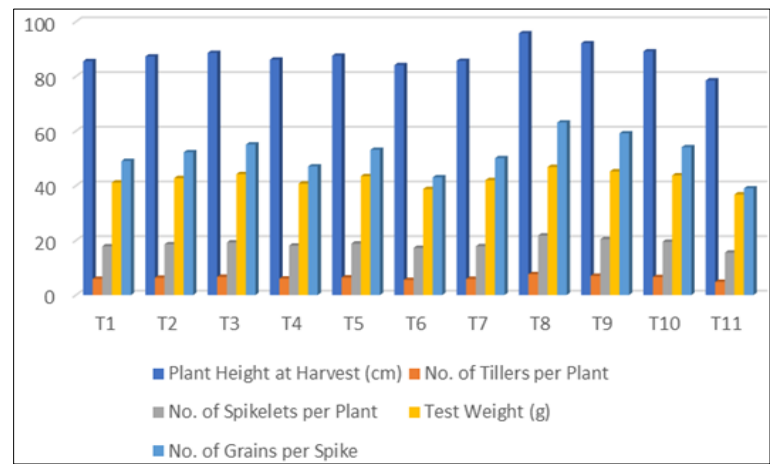


Fig 1: Effect of Integrated Nutrient Management on Growth attributes, No. of Spikelets per Plant, Test Weight (g) and No. of Grains per Spike of Wheat

Table 2: Effect of Integrated Nutrient Management on Yield attributes of Wheat

Treatment No.	Treatment Details	Yield (q/ha)			Harvest Index (%)
		Grain	Straw	Biological	
T ₁	100% RDF (120:60:40 NPK)	47.23	111.47	158.70	42.37
T ₂	100% RDF + Azospirillum @ 25 g kg ⁻¹ seed	49.76	117.10	166.86	42.50
T ₃	100% RDF + Vermicompost @ 3 t ha ⁻¹	52.51	123.73	176.24	42.43
T ₄	75% RDF + Azospirillum @ 25 g kg ⁻¹ seed	45.30	107.08	152.38	42.34
T ₅	75% RDF + Vermicompost @ 3 t ha ⁻¹	50.35	118.83	169.18	42.36
T ₆	50% RDF + Azospirillum @ 25 g kg ⁻¹ seed	40.33	96.76	137.09	41.69
T ₇	50% RDF + Vermicompost @ 3 t ha ⁻¹	47.51	112.67	160.18	42.14
T ₈	100% RDF + Vermicompost @ 3 t ha ⁻¹ + Azospirillum @ 25 g kg ⁻¹ seed	58.50	135.58	194.08	43.10
T ₉	75% RDF + Vermicompost @ 3 t ha ⁻¹ + Azospirillum @ 25 g kg ⁻¹ seed	54.74	128.17	182.91	42.71
T ₁₀	50% RDF + Vermicompost @ 3 t ha ⁻¹ + Azospirillum @ 25 g kg ⁻¹ seed	51.23	121.11	172.34	42.34
T ₁₁	Control	35.24	86.54	121.78	40.75
SEm±		0.27	0.44	0.13	0.13
CD (P=0.05)		0.53	0.86	0.25	0.25

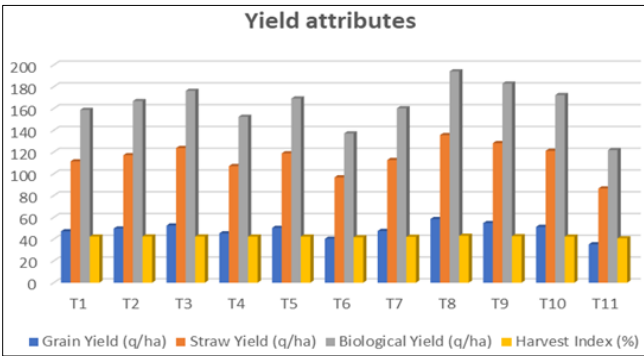


Fig 3: Effect of Integrated Nutrient Management on Yield attributes of Wheat

Conclusion

The study concluded that integrated nutrient management significantly improved the growth, yield attributes and yield of wheat (*Triticum aestivum* L.) under the agro-climatic conditions of Gwalior (M.P.). The treatment involving 100% RDF (120:60:40 NPK) + Vermicompost @ 3 t ha⁻¹ + Azospirillum @ 25 g kg⁻¹ seed recorded the highest plant population (417.67 plants plot⁻¹), plant height (95.73 cm), tillers per plant (7.62), spikelets per plant (21.77), test weight (46.83 g), grains per spike (63.10), grain yield (58.50 q ha⁻¹), straw yield (135.58 q ha⁻¹), biological yield (194.08 q ha⁻¹) and harvest index (43.10%). It was followed by 75% RDF + Vermicompost + Azospirillum and 100% RDF + Vermicompost treatments, while the lowest values were recorded under the control (plant population 375.00, plant

height 78.50 cm, grain yield 35.24 q ha⁻¹, straw yield 86.54 q ha⁻¹ and biological yield 121.78 q ha⁻¹). Hence, it is concluded that integration of inorganic fertilizers with vermicompost and biofertilizer is more effective than sole application of fertilizers, leading to higher productivity, improved yield components, better soil health and sustainable wheat production.

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