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Growth and Productivity of Wheat as Influenced by Organic Nutrient Sources in East-central Part of Rajasthan, India

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Authors' contributions

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

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ABSTRACT

A field experiment was conducted to assess the effect of organic nutrient sources and biofertilizers on growth, yield, and economic returns of wheat (*Triticum aestivum* L.). The study involved eight treatments comprising combinations of recommended dose of fertilizers (RDF), farmyard manure

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(FYM), vermicompost, and biofertilizers (*Azotobacter* + phosphate-solubilizing bacteria [PSB]). The experiment was laid out in a randomized complete block design and replicated thrice. The treatments were: T_1 – Control (no fertilizer or manure); T_2 – RDF (150:60:40 kg N:P:K ha^{-1}); T_3 – RDF + 37.5 kg N through FYM (7.5 t ha^{-1}); T_4 – RDF + 37.5 kg N through vermicompost (2.5 t ha^{-1}); T_5 – 112.5 kg N + 60 kg P + 40 kg K + 37.5 kg N through FYM; T_6 – 112.5 kg N + 60 kg P + 40 kg K + 37.5 kg N through vermicompost; T_7 – T_5 + biofertilizers (*Azotobacter* + PSB); and T_8 – T_6 + biofertilizers (*Azotobacter* + PSB). Significant differences were observed among treatments in terms of plant height, dry matter accumulation, tiller number, yield attributes, grain yield, and net returns. The application of 112.5 kg N + 60 kg P + 40 kg K ha^{-1} along with 37.5 kg N through vermicompost and biofertilizers (T_8) resulted in the highest values for growth and yield parameters, significantly surpassing the other treatments. A similar trend was observed with the FYM-based integrated treatment (T_7), indicating that both vermicompost and FYM, when used in combination with biofertilizers, can effectively enhance wheat performance. These results underline the potential of integrated nutrient management strategies in promoting sustainable wheat cultivation.

Keywords: Azotobacter; biofertilizers; climate resilience; integrated nutrient; sustainable.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important staple food crops globally, playing a critical role in ensuring food security and providing livelihoods to millions of farmers. In India, it occupies a prominent position among cereals, ranking second after rice in terms of both area and production. In India, wheat is cultivated in 30.47 million hectares with total production of 106.84 million tonnes with average yield of 3507 kg/ha (DES, 2022). In Rajasthan, wheat is grown in an area of 2.58 million hectares with total production of 9.48 million tonnes with average productivity of 3676 kg/ha (DES, 2022) With an ever-increasing population and shrinking per capita land availability, there is a pressing need to enhance the productivity of wheat through sustainable agricultural practices that ensure long-term soil health, environmental safety, and economic viability.

Conventional agricultural systems heavily rely on chemical fertilizers for high-yielding crop varieties, but their prolonged application can lead to soil degradation, nutrient imbalance, and environmental pollution. The increasing cost and limited availability of chemical inputs pose challenges, especially for resource-poor farmers. As a result, there is growing interest in organic and integrated nutrient management strategies that use locally available organic resources to improve soil fertility, enhance crop productivity, and promote sustainable agriculture (Sharma *et al*., 2024; Rana *et al*., 2025; Prajapati *et al*., 2024; Choudhary *et al*., 2024).

Organic sources of nutrients such as farmyard manure (FYM), vermicompost, biofertilizers, and microbial inoculants like *Azotobacter* and phosphate-solubilizing bacteria (PSB) are gaining increasing attention as viable alternatives or supplements to chemical fertilizers (Shahu *et al*., 2024). These organic amendments not only supply essential macro and micronutrients to crops but also contribute to improving soil physical properties, enhancing microbial biodiversity, increasing nutrient use efficiency, and promoting overall soil health (Naik *et al*., 2024). When applied in appropriate combinations and proportions, organic sources can complement and even partially replace synthetic inputs without compromising crop yields. Farmyard manure (FYM), a traditional and commonly used organic amendment, is a rich source of both macro and micronutrients (Khayat, 2021). It also improves soil structure, water retention, and microbial activity, leading to better root development and nutrient uptake. Vermicompost, produced through the decomposition of organic waste by earthworms, is another highly nutritious and biologically active organic fertilizer (Kumar *et al*., 2018). It contains readily available nutrients, plant growth-promoting hormones, and beneficial microbes that enhance plant growth and yield. Biofertilizers, including nitrogen-fixing bacteria like *Azotobacter* and phosphorus-solubilizing bacteria (PSB), play a significant role in biological nitrogen fixation and solubilization of insoluble phosphates, thereby improving the availability of these nutrients to plants. The use of *Azotobacter*, a free-living nitrogen-fixing bacterium, has been found to increase the nitrogen content in the rhizosphere, stimulate plant growth through the production of phytohormones, and enhance root biomass (Al-

Baldawy *et al*., 2023). Similarly, PSB helps convert insoluble phosphorus compounds into plant-available forms, thereby reducing the dependence on chemical phosphorus fertilizers (Arif *et al*., 2017). These microbial inoculants are environmentally friendly, cost-effective, and capable of improving nutrient uptake and yield when used alone or in combination with organic manures.

In recent years, the concept of integrated nutrient management (INM) has emerged as a holistic approach that combines organic, inorganic, and biological sources of nutrients to optimize plant nutrition and maintain soil fertility on a sustainable basis (Selim, 2020; Sharma *et al*., 2025). Studies have shown that integrating organic and biofertilizer treatments with recommended doses of chemical fertilizers (RDF) can significantly improve growth parameters, yield attributes, and grain quality of wheat. However, the relative effectiveness of different organic sources and their combinations with chemical fertilizers and biofertilizers may vary depending on soil type, agro-climatic conditions, and crop management practices.

Despite a growing body of literature on the benefits of organic and integrated nutrient management in wheat cultivation, there is still a need for location-specific studies that assess the comparative performance of different organic nutrient sources under specific agro-ecological conditions. Such research is crucial to develop practical recommendations for farmers aiming to adopt sustainable nutrient management strategies that ensure both productivity and environmental health.

2. MATERIALS AND METHODS

The field experiment was conducted during the *rabi* season of 2023-24 at the Agronomy Research Farm, School of Agricultural Sciences, Nirwan University, Jaipur, Rajasthan situated at 26º 86'N latitude and 76º 11'E longitude falling under Zone IIIa agro-climatic zone of Rajasthan. The experiment was laid out in a randomized complete block design with eight treatments and three replications (Table 1). The soil of the experimental field was sandy loam in texture and alkaline in reaction (pH 8.2). The soil was deficient in available sulphur (8.1 mg ha^{-1}), low in available nitrogen (128.60 kg ha^{-1}), medium in available phosphorus (19.10 kg ha^{-1}) and available potassium (160.60 kg ha^{-1}). The wheat variety DBW 16 was used with seed rate of 100 kg ha^{-1}. The row to row spacing of 20 cm was maintained. The crop was sown on 19 November 2023. The crop was harvested plot-wise on 24 April 2024. The plant samples for dry matter were taken at 30, 60, 90 DAS and at harvest. The samples were oven dried at 105°C for 72 hours or till the constant weight is achieved. The data obtained was subjected to F-test followed by least significant difference post-hoc test as prescribed by Gomez and Gomez (1984).

Table 1. Details of treatment

S. No.	Treatment	Notation
1.	Control (no fertilizer or manure)	T_1
2.	RDF (150:60:40)	T_2
3.	RDF+ 37.5 kg N through FYM (7.5 t ha^{-1})	T_3
4.	RDF+37.5kg N through vermicompost (2.5 t ha^{-1})	T_4
5.	112.5 kg N + 60 kg P + 40 kg K+37.5kg N through FYM	T_5
6.	112.5 kg N + 60 kg P + 40 kg K+37.5kg N through Vermicompost	T_6
7.	T5 + Bio fertilizer (*Azotobacter* + PSB)	T_7
8.	T6 +Bio fertilizer (*Azotobacter* + PSB)	T_8

3. RESULTS AND DISCUSSION

1. Plant height

The results from the study reveal that the application of organic nutrient sources, particularly in combination with biofertilizers, had a significant impact on plant height of wheat throughout all growth stages (Table 2). Treatment T_7, which included 112.5 kg N + 60 kg P + 40 kg K + 37.5 kg N through FYM along with biofertilizers (*Azotobacter* + PSB), consistently produced the tallest plants at 30 DAS (15.60 cm), 60 DAS (56.10 cm), and 90 DAS (80.56 cm), demonstrating statistically significant superiority over other treatments. Similarly, T_8 (same nutrient regime as T_6 with vermicompost and biofertilizers) also performed significantly similar across stages. This enhanced growth can be attributed to the combined effect of organic manures improving soil structure, water retention, and microbial activity, while biofertilizers enhance nutrient availability through biological nitrogen fixation and phosphorus solubilization, thus promoting better root development and nutrient uptake. Further, the control treatment (T_1), which received no nutrient input, consistently showed the lowest plant height at all stages, indicating the essential role of nutrient management in crop growth.

Table 2. Effect of different organic sources of nutrient on plant height (cm) at different stages of wheat crop

Treatment	Plant height (cm)			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**
T_1	11.60	31.10	52.20	60.20
T_2	12.85	50.30	77.05	94.55
T_3	13.80	51.66	76.22	95.65
T_4	14.42	51.84	76.66	93.56
T_5	14.56	53.58	78.24	91.80
T_6	14.90	54.80	78.54	91.15
T_7	15.60	56.10	80.56	93.94
T_8	15.44	55.98	80.65	92.55
SEm±	**0.49**	**0.49**	**1.74**	**2.59**
CD (P=0.05)	**1.42**	**1.42**	**5.09**	**7.58**

Table 3. Effect of different organic sources of nutrients on dry matter accumulation (g m^{-1} row length) at different stages of wheat crop

Treatment	Dry matter accumulation (g m^{-1} row length)			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**
T_1	17.52	74.28	123.32	153.51
T_2	18.86	75.40	144.42	190.33
T_3	19.06	77.64	151.45	196.35
T_4	20.24	80.36	152.30	199.84
T_5	20.98	83.62	154.64	201.60
T_6	20.40	82.40	166.57	203.97
T_7	21.46	84.32	160.46	208.84
T_8	23.66	86.74	171.28	212.95
SEm±	**0.68**	**0.70**	**2.69**	**3.86**
CD (P=0.05)	**1.99**	**2.08**	**7.86**	**11.55**

2. Dry matter accumulation

The results indicate that the application of organic nutrient sources, particularly in combination with biofertilizers, had a significant impact on dry matter accumulation at all growth stages of wheat (Table 3). Treatment T_8, which included 112.5 kg N + 60 kg P + 40 kg K + 37.5 kg N through vermicompost along with biofertilizers (Azotobacter + PSB), consistently recorded the highest dry matter accumulation at 30 DAS (23.66 g m^{-1}), 60 DAS (86.74 g m^{-1}), 90 DAS (171.28 g m^{-1}), and at harvest (212.95 g m^{-1}), which was significantly at par with T_7 (same nutrient regime as T_5 but with biofertilizers) across all stages. This enhanced dry matter accumulation can be attributed to the combined effect of organic manures improving soil structure, water retention, and microbial activity, while biofertilizers enhance nutrient availability through biological nitrogen fixation and phosphorus solubilization, leading to improved plant metabolism and biomass production. On the other hand, the control treatment (T_1), which received no nutrient input, consistently recorded the lowest dry matter accumulation across all stages of crop. The integration of organic manures and biofertilizers with chemical fertilizers significantly enhanced dry matter accumulation, reflecting better nutrient uptake, photosynthetic efficiency, and overall biomass production throughout the crop cycle.

Table 4. Effect of organic sources of nutrient on number of tillers m^{-1} row length at different stages of wheat crop

Treatment	Number of tillers m^{-1} row length			
	30 DAS	60 DAS	90 DAS	At harvest
T_1	66.62	111.42	97.72	85.41
T_2	67.01	122.35	111.24	99.82
T_3	69.24	124.08	115.78	100.16
T_4	70.18	125.28	116.27	101.48
T_5	71.86	127.14	118.54	102.58
T_6	72.15	128.68	120.46	104.37
T_7	74.96	131.87	124.05	107.85
T_8	75.10	132.34	124.56	108.16
SEm±	**2.36**	**2.38**	**4.16**	**3.88**
CD (P=0.05)	**6.65**	**6.95**	**12.21**	**11.60**

3. Number of tillers

Organic nutrient sources, particularly in combination with biofertilizers, had a significant impact on the number of tillers per meter row length at all growth stages of wheat (Table 4). Treatment T_8, which included 112.5 kg N + 60 kg P + 40 kg K + 37.5 kg N through vermicompost along with biofertilizers (Azotobacter + PSB), consistently recorded the highest number of tillers at 30 DAS (75.10), 60 DAS (132.34), 90 DAS (124.56), and at harvest (108.16), demonstrating statistically significant superiority over other treatments. Similarly, T_7 (same nutrient regime as T_5 but with biofertilizers) also performed well across all stages and was significantly similar to T_8. This enhanced tiller production can be attributed to the combined effect of organic manures improving soil structure, water retention, and microbial activity, while biofertilizers enhance nutrient availability through biological nitrogen fixation and phosphorus solubilization, leading to improved plant growth and tillering capacity. Whereas control treatment (T_1), which received no nutrient input, consistently recorded the lowest number of tillers across all growth stages. The enhanced tiller production observed in treatments incorporating organic manures and biofertilizers can be attributed to improved soil microbial activity, increased nutrient mineralization, and enhanced root proliferation, which collectively promote better nutrient uptake and plant growth (Bhattacharyya *et al*., 2015; Meena *et al*., 2016). Vermicompost and FYM improve soil structure and moisture retention, while biofertilizers like *Azotobacter* and phosphate-solubilizing bacteria (PSB) facilitate biological nitrogen fixation and phosphorus solubilization, leading to enhanced tillering and biomass accumulation (Barooah *et al*., 2019). These synergistic effects contribute to improved crop productivity and sustainability in wheat cultivation.

4. Yield attributes

The application of different organic nutrient sources, especially in combination with biofertilizers, significantly influenced the yield attributes of wheat (Table 5). Treatment T_8, which included 112.5 kg N + 60 kg P + 40 kg K + 37.5 kg N through vermicompost along with biofertilizers (Azotobacter + PSB), consistently recorded the highest values across key yield parameters: effective tillers per meter row length (107.63), spike length (10.64 cm), number of spikelets per spike (14.65), and number of grains per spike (46.71). This demonstrates a statistically significant superiority over other treatments. Similarly, T_7 (same nutrient regime as T_5 but with biofertilizers) also performed well across all parameters, closely following T_8. The observed improvements can be attributed to the synergistic effects of organic manures and biofertilizers. Organic amendments, such as vermicompost and FYM, enhance soil structure, water retention, and microbial activity, while biofertilizers contribute to biological nitrogen fixation and phosphorus solubilization, ultimately leading to better nutrient uptake and improved spike and grain formation. In contrast, the control treatment (T1), which received no fertilizer or manure, consistently recorded the lowest yield attributes, with effective tillers (82.42), spike length (7.21 cm), spikelets per spike (8.76), and grains per spike (33.41), highlighting the critical role of nutrient application in wheat productivity. Integrating organic manures and biofertilizers with chemical fertilizers significantly enhanced wheat yield attributes by improving soil fertility, nutrient availability, and plant growth conditions (Imran 2024). The increased number of spikelets

Table 5. Effect of different organic sources of nutrients on yield attributes of wheat crop

Treatment	Yield attributes			
	Effective Tillers (m^{-1})	Spike length (cm)	Number of spikelets per spike	Number of grains per spike
T_1	82.42	7.21	8.76	33.41
T_2	96.64	8.80	12.25	42.02
T_3	98.13	9.34	13.45	43.32
T_4	100.45	9.54	13.62	43.25
T_5	101.65	10.16	13.94	44.52
T_6	103.12	10.92	14.15	44.91
T_7	105.08	10.36	14.34	44.61
T_8	107.63	10.64	14.65	46.71
SEm±	**2.60**	**0.31**	**0.39**	**0.54**
CD (P=0.05)	**8.30**	**0.82**	**1.15**	**1.78**

and grains per spike observed in treatments incorporating biofertilizers and organic sources can be linked to enhanced root proliferation, increased nutrient mineralization, and improved crop vigour. These findings align with previous studies (Gao *et al*., 2020), reinforcing the benefits of sustainable nutrient management in wheat cultivation (Hafez *et al*., 2021).

5. Yield

The application of organic nutrient sources, particularly in combination with biofertilizers, had a significant impact on grain, straw, and biological yield of wheat (Table 6). Treatment T_8, which included 112.5 kg N + 60 kg P + 40 kg K + 37.5 kg N through vermicompost along with biofertilizers (Azotobacter + PSB), consistently recorded the highest grain yield (45.3 q ha^{-1}), straw yield (57.3 q ha^{-1}), and biological yield (102.6 q ha^{-1}). This demonstrates a statistically significant improvement over other treatments, reflecting enhanced crop productivity due to the synergistic effects of organic manures and biofertilizers. Similarly, T_7 (same nutrient regime as T_5 but with biofertilizers) also performed well across all yield components, recording grain yield (44.5 q ha^{-1}), straw yield (56.7 q ha^{-1}), and biological yield (101.2 q ha^{-1}), showing statistically similar results to T_8. The improved yield can be attributed to the combined effects of organic amendments and biofertilizers, which enhance soil fertility, microbial activity, and nutrient availability through processes like biological nitrogen fixation and phosphorus solubilization. Control treatment (T1), which received no fertilizer or manure, consistently recorded the lowest grain yield (24.8 q ha^{-1}), straw yield (33.4 q ha^{-1}), and biological yield (58.2 q ha^{-1}), emphasizing the importance of nutrient application for higher wheat productivity.

The harvest index showed only minor variations among treatments, with values ranging from 42.2% to 44.2%, suggesting that while organic amendments and biofertilizers significantly enhanced total biomass production, the proportion of grain yield remained relatively stable. These findings align with previous research (Gao *et al*., 2020), reinforcing the benefits of sustainable nutrient management in wheat cultivation (Hafez *et al*., 2021).

Table 6. Effect of different organic sources of nutrients on grain, straw, biological yield (q ha^{-1}) and harvest index (%) of wheat crop

Treatment	Yield (q ha^{-1})			
	Grain	Straw	Biological	Harvest Index (%)
T_1	24.8	33.4	58.2	42.6
T_2	39.2	53.8	93.0	42.2
T_3	41.4	54.1	95.5	43.4
T_4	42.2	55.7	97.9	43.1
T_5	42.8	56.2	99.0	43.2
T_6	43.2	55.7	98.9	43.7
T_7	44.5	56.7	101.2	44.0
T_8	45.3	57.3	102.6	44.2
SEm±	**1.33**	**1.33**	**1.81**	**3.16**
CD (P=0.05)	**3.89**	**3.89**	**5.42**	**NS**

Table 7. Effect of different organic sources of nutrients on cost of cultivation, gross return, net returns and B: C ratio of wheat

Symbol	Cost of cultivation	Gross return	Net return	B: C ratio
T_1	21742	64250	42508	2.96
T_2	27315	102110	74795	3.74
T_3	31065	106345	75280	3.42
T_4	32315	108705	76390	3.36
T_5	30565	110090	79525	3.60
T_6	31815	110555	78740	3.47
T_7	30765	113510	82745	3.69
T_8	32015	115320	83305	3.60
SEm±	**-**	**1016.67**	**726.52**	**0.18**
CD (P=0.05)	**-**	**3020.28**	**2172.68**	**0.52**

6. Economics

The results found that the application of organic nutrient sources, particularly in combination with biofertilizers, had a significant impact on the economic returns of wheat cultivation (Table 7). Treatment T_8, which included 112.5 kg N + 60 kg P + 40 kg K + 37.5 kg N through vermicompost along with biofertilizers (Azotobacter + PSB), recorded the highest gross return (₹115,320 ha^{-1}) and net return (₹83,305 ha^{-1}), demonstrating its economic superiority over other treatments. The benefit-cost (B:C) ratio for T_8 was 3.60, indicating high profitability. Further, the control treatment (T_1), which received no fertilizer or manure, recorded the lowest gross return (₹64,250 ha^{-1}) and net return (₹42,508 ha^{-1}), though it had the lowest cost of cultivation (₹21,742 ha^{-1}). Despite this, its B:C ratio (2.96) was lower than treatments receiving fertilizers and organic inputs, emphasizing the economic disadvantage of not applying nutrients. Among the treatments, RDF (T_2) showed a high B:C ratio (3.74) due to its lower cost of cultivation (₹27,315 ha^{-1}) and substantial yield benefits, making it a cost-effective option. However, treatments integrating FYM, vermicompost, and biofertilizers (T_7 and T_8) provided higher net returns, suggesting that long-term soil health benefits and sustainability advantages outweigh the slightly higher costs of organic amendments. The integration of organic manures and biofertilizers with chemical fertilizers significantly enhanced the economic viability of wheat cultivation by improving yield and profitability.

4. CONCLUSION & FUTURE PROSPECTS

The study results demonstrate that integrating organic nutrient sources with biofertilizers significantly enhances wheat crop performance in terms of plant height, dry matter accumulation, tillering capacity, yield attributes, and overall productivity. Among the treatments, T_8 (112.5 kg N + 60 kg P + 40 kg K + 37.5 kg N through vermicompost with biofertilizers) consistently outperformed others, recording the highest values for growth, yield, and economic returns. Similarly, T_7 (with FYM instead of vermicompost) also exhibited comparable performance. The improved results are attributed to enhanced soil fertility, microbial activity, and nutrient availability facilitated by organic amendments and biofertilizers.

Future research should focus on long-term soil health assessments under different organic and integrated nutrient management practices. Additionally, exploring site-specific nutrient management strategies, climate resilience, and cost-effective organic inputs will be crucial for optimizing sustainable wheat production. Promoting farmer adoption through policy support and awareness programs can further strengthen ecological and economic benefits in wheat cultivation.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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