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Effect of integrated nutrient management for sustainable production of wheat (*Triticum aestivum* L.)

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Abstract
The present investigation entitled "Effect of Integrated Nutrient Management for Sustainable Production of Wheat (*Triticum aestivum* L.)" was carried out during the *Rabi* season of 2024-25 at the Agronomy Farm, Faculty of Agriculture and Veterinary Sciences, Mewar University, Chittorgarh (Rajasthan). The experiment aimed to evaluate the impact of integrated nutrient management (INM) on growth, yield, and profitability of wheat cultivation. The study consisted of 10 treatment combinations involving various proportions of recommended doses of fertilizers (RDF), farmyard manure (FYM), vermicompost (VC), and biofertilizer (Azotobacter), laid out in a Randomized Block Design (RBD) with three replications. The results revealed significant variations across treatments for all measured parameters. The treatment T_5 (100% RDF + Azotobacter) consistently outperformed others, recording the highest plant population (434.66 plants/m²), plant height (99.97 cm), number of tillers (430.67), fresh weight (57.27 g), dry weight (19.57 g), leaf area index (13.77), grain weight per spike (1.26 g), and number of grains per spikelet (4.33). Other integrated treatments such as T_7 (50% RDF + 12 t/ha FYM + Azotobacter), T_8 (75% RDF + 2 t/ha VC + Azotobacter), and T_{10} (12 t/ha FYM + 4 t/ha VC + Azotobacter) also exhibited superior performance compared to control. The control treatment (T_1) recorded the lowest values across all parameters, confirming the necessity of nutrient supplementation. The results highlight that the combination of chemical fertilizers with biofertilizers and organic sources significantly enhances wheat growth and productivity. Thus, the application of 100% RDF along with Azotobacter is recommended for achieving optimum growth and yield, while partial RDF substitution with FYM or vermicompost and Azotobacter also presents a viable, eco-friendly alternative for sustainable wheat cultivation.

Keywords: Integrated Nutrient Management (INM), Wheat (*Triticum aestivum* L.), Farmyard Manure (FYM), vermicompost, Azotobacter, growth parameters, yield attributes, soil fertility, Benefit-Cost Ratio (B:C), sustainable agriculture

Introduction
Wheat (*Triticum aestivum* L.), a member of the Poaceae family, is the most widely grown cereal crop globally and is considered the "king of cereals" due to its high nutritional value and staple role in human diets. It contributes nearly 19% to the global caloric intake. In India, wheat cultivation is of paramount importance, supporting nearly half of the country's population and contributing significantly (17.8%) to the national GDP. Wheat is valued for its high content of carbohydrates, proteins, and essential nutrients like niacin and thiamine, with its gluten content making it especially suitable for bread and chapatti production. Northern India, particularly states like Uttar Pradesh, Punjab, and Madhya Pradesh, accounts for around 91% of the country's wheat output. India's wheat production has seen a dramatic rise since the Green Revolution of 1967. The area under cultivation increased from 1.8 million hectares in 1966-67 to over 30 million hectares by 2017-18, with production rising from 11.4 million tonnes to over 98 million tonnes. By 2023-24, production was estimated at 112.18 million tonnes. However, despite being the second-largest wheat producer globally (after China), productivity in some regions like Uttar Pradesh remains below the national average, largely due to delayed sowing and inadequate nutrient management. One of the critical challenges of intensive wheat cultivation is the depletion of soil fertility due to over-reliance on chemical fertilizers. Continuous use of these inputs without replenishing soil organic matter has led to reduced fertilizer use efficiency and potential long-term damage to soil health. Therefore, sustainable

production of wheat requires an integrated nutrient management (INM) approach that combines chemical fertilizers with organic sources such as farmyard manure (FYM), vermicompost, and biofertilizers like Azotobacter. Nitrogen is essential for plant growth, playing a key role in protein synthesis and physiological processes. Phosphorus is vital for energy transfer and cell development, while potassium enhances enzymatic activity, photosynthesis, and stress resistance. The synergistic effect of combining organic and inorganic sources improves plant growth, yield attributes (such as tillers, spikelets, and grain weight), and soil health. FYM, in particular, not only supplies nutrients but also improves soil structure, aeration, water retention, and microbial activity. Research suggests that integrated nutrient applications can delay heading, improve biomass production, and increase harvest index compared to sole applications of either organic or chemical sources. In conclusion, while chemical fertilizers have driven past yield gains, a balanced use of organic manures and biofertilizers is crucial for ensuring long-term productivity and ecological sustainability. Integrated Nutrient Management thus offers a practical solution for enhancing wheat yield, maintaining soil fertility, and improving farmers' economic returns in an environmentally sustainable manner.

Materials and Methods

A field experiment was conducted during the *Rabi* season of winter at the Agronomy Farm, Mewar University, Chittorgarh, Rajasthan.

Experimental material

The experimental material for the present study consisted of Wheat *Triticum aestivum* variety RAJ-3077, a widely cultivated high-yielding variety suitable for the agro-climatic conditions of Rajasthan. The experiment was conducted during the *Rabi* season of 2024-25 at the Agronomy Farm, Department of Agronomy, Faculty of Agriculture and Veterinary Sciences, Mewar University, Gangrar, Chittorgarh, Rajasthan.

Table 1: Treatment Combination

Sr. No.	Dedicated Symbol	Treatment Details
1.	T1	Control
2.	T2	100% RDF
3.	T3	75% RDF
4.	T4	50% RDF
5.	T5	100% RDF + Azotobacter
6.	T6	75% RDF + 6t/hac FYM + Azotobacter
7.	T7	50% RDF + 12t/hac FYM + Azotobacter
8.	T8	75% RDF + 2t/hac VC + Azotobacter
9.	T9	50% RDF + 4t/hac VC + Azotobacter
10.	T10	12t/hac FYM + 4t/hac VC + Azotobacter

Experimental Details

The experiment was laid out in Factorial Randomized Block Design with ten treatments and three replications. The random allocation of treatments was done using statistical table prepared by Fisher and Yates (1963) [9].

Table 2: Experimental Details

Sr. No.	Particulars		Details
1.	Duration	:	*Rabi* 2024-25
2.	Crop	:	Wheat
3.	Variety	:	Raj-3077
4.	Location	:	Agronomy Farm, Department of Agronomy, Faculty of Agriculture and Veterinary Sciences, Mewar University
5.	Experimental Design	:	RBD (Randomized Block Design)
6.	Number of Treatments	:	10
7.	Number of Replications	:	3
8.	Total Number of Plots	:	30
9.	Spacing	:	20 cm (Row)
10.	Gross Plot Size	:	5 m x 3m = 15m^2
11.	Net Plot Size	:	4.2 m x 2.2 m = 9.24m^2
12.	Organic Manure	:	Vermicompost and FYM
13.	RDF	:	120:60:40 (Kg/ha)

Results and Discussion

Physical attributes of different genotypes

The data presented in Table No. 3. clearly reveal that the growth attributes of Wheat were significantly influenced by the foliar application of different levels of Nutrients, FYM and RDF the sub-humid conditions of Southern Rajasthan. The observations recorded at the time of harvest indicated distinct and notable variations among the treatment combinations, thereby reflecting the positive impact of zinc foliar nutrition on the growth performance of Wheat.

Table 3: Growth attributes of Integrated Nutrient Management on Wheat (*Triticum aestivum* L.)

Treatment Code	Treatment Description	Plant Population (m²)	Plant Height (cm)	No. of Tillers	Fresh Weight (g)	Dry Weight (g)	Leaf Area Index	Weight of grain(g) per spike	No. of grains per spikelet
T1	Control	335.33	90.32	397.33	26.33	8.43	7.43	0.52	2.33
T2	100% RDF	344.33	95.12	401.33	41.17	12.77	12.10	0.76	3.00
T3	75% RDF	383.33	96.78	405.33	42.77	13.30	12.43	0.91	3.33
T4	50% RDF	433.33	99.67	427.33	54.13	18.57	13.47	1.22	3.67
T5	100% RDF + Azotobacter	434.66	99.97	430.67	57.27	19.57	13.77	1.26	4.33
T6	75% RDF + 6t/ha FYM + Azotobacter	421.00	97.68	409.67	43.23	14.37	12.53	0.96	3.33
T7	50% RDF + 12t/ha FYM + Azotobacter	423.00	98.57	415.00	44.60	15.57	12.83	1.01	4.33
T8	75% RDF + 2t/ha VC + Azotobacter	425.00	99.20	417.67	45.20	16.43	12.90	1.08	4.00
T9	50% RDF + 4t/ha VC + Azotobacter	426.33	99.42	421.00	47.90	16.87	13.20	1.15	3.67
T10	12t/ha FYM + 4t/ha VC + Azotobacter	428.33	99.58	424.33	50.23	17.13	13.27	1.17	3.67
SE(m) ±		4.261	1.277	6.007	0.543	0.214	0.13	0.013	0.21
C.D		12.758	3.824	17.986	1.625	0.642	0.38	0.028	0.62
C.V		1.820	2.266	2.507	2.076	2.426	1.254	1.135	1.549

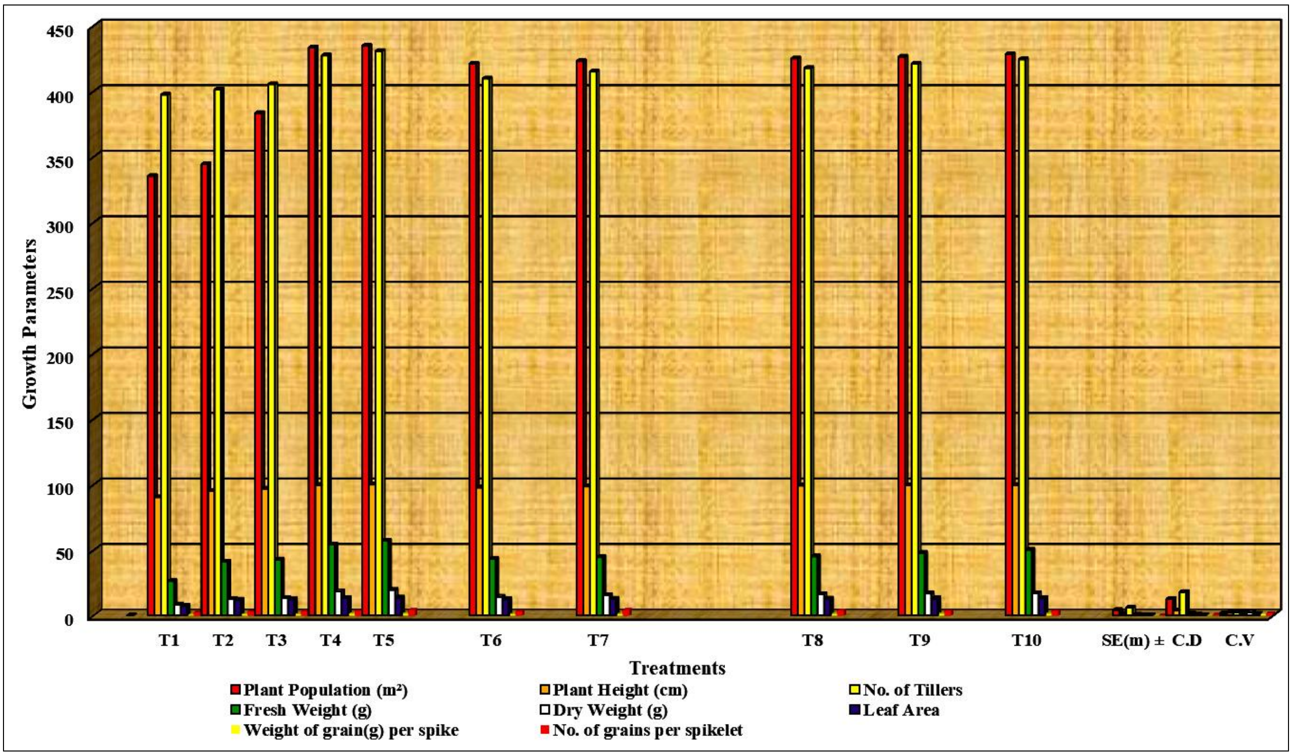

Fig 1: Growth attributes of Integrated Nutrient Management on Wheat (*Triticum aestivum* L.)

A significant variation was observed among the different treatments for all the studied growth and yield attributes of wheat. The plant population ranged from 335.33 plants/m² in the control (T_1) to 434.66 plants/m² in the treatment T_5 (100% RDF + *Azotobacter*), indicating a considerable enhancement due to integrated nutrient application. Plant height was found to be the lowest (90.32 cm) in the control (T_1), whereas the maximum height (99.97 cm) was recorded under T_5, followed closely by T_4, T_7, and T_{10}, all receiving organic amendments and biofertilizer support. The number of tillers followed a similar trend, with the control having the lowest tiller count (397.33), while the maximum tillers (430.67) were produced under T_5.

The fresh and dry biomass accumulation was significantly influenced by treatment variations. The lowest fresh weight (26.33 g) and dry weight (8.43 g) were recorded in the control, whereas the highest values (57.27 g and 19.57 g respectively) were noted in T_5. Treatments involving a combination of RDF, FYM, vermicompost, and *Azotobacter* (T_7 to T_{10}) also recorded relatively high biomass accumulation. Leaf Area Index (LAI), a key indicator of canopy development, varied from 7.43 in control to 13.77 in T_5, highlighting the positive impact of integrated nutrient management.

The weight of grains per spike and the number of grains per spikel*et al*so showed marked differences across treatments. The lowest grain weight per spike (0.52 g) and grains per spikelet (2.33) were recorded under control, while the highest grain weight (1.26 g) was noted under T_5, and the highest number of grains per spikelet (4.33) was observed in both T_5 and T_7. Treatments T_8, T_9, and T_{10} also produced comparable results, indicating that the synergistic effect of reduced RDF levels with organic and biological inputs substantially enhanced reproductive efficiency.

Statistical analysis confirmed that all treatment differences were significant at the 5% level for all parameters. The lowest coefficient of variation was recorded for LAI (1.135%), and the highest was for dry weight (2.426%), indicating high precision and consistency in experimental data. Thus, the treatment T_5 (100% RDF + *Azotobacter*) emerged as the most effective combination for maximizing wheat growth and yield parameters under the given agro-climatic conditions.

Conclusion

The results clearly demonstrate that integrated nutrient management practices significantly influence the growth and yield attributes of wheat. Among all the treatments, T_5 (100% RDF + *Azotobacter*) consistently recorded the highest values for plant population, plant height, number of tillers, biomass accumulation, leaf area index, grain weight per spike, and number of grains per spikelet. This indicates a strong synergistic effect of combining full recommended doses of fertilizers with biofertilizers in enhancing both vegetative and reproductive growth.

However, treatments like T_7 (50% RDF + 12 t/ha FYM + *Azotobacter*), T8 (75% RDF + 2 t/ha vermicompost + *Azotobacter*), and T_{10} (12 t/ha FYM + 4 t/ha vermicompost + *Azotobacter*) also performed comparably well, suggesting that a partial substitution of chemical fertilizers with organic sources and biofertilizers can still maintain high productivity while reducing chemical input load.

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