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Enhancing fertilizer use efficiency in Wheat (*Triticum aestivum* L.) through integrated nutrient management: A study on economic viability and chemical properties

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Abstract

The current study, "Enhancing Fertilizer Use Efficiency in Wheat (*Triticum aestivum* L.) through Integrated Nutrient Management: A Study on Economic Viability and Chemical Properties," was conducted in 2024–2025 at the Mansarovar Global University Horticulture Research farm in Sehore, Madhya Pradesh. The study used a randomized block design with three replications and twelve hybrids. Twelve hybrids and three replications were used in the randomized block design experiment. The combination of Control, 100% Recommended NPK (150: 75: 60 kg ha⁻¹), 100% Recommended N through Vermicompost, 100% N through FYM, 50% RDF + 50% N through FYM, 50% RDF + 50% N through Vermicompost, 75% RDF + 25% N through FYM, 75% RDF + 25% N through Vermicompost, 50% RDF + 25% N through Vermicompost + 25% through, 50% RDF through Vermicompost + 50% FYM, 75% through FYM + 25% through vermicompost and 75% through vermicompost + 25% through FYM. In order to critically analyze how various treatments affected the crop, 888 parameters related to chemicals, yield parameters, and economics were measured. The representative sample method was used to document the observations of different wheat morphological traits. Three plants were chosen at random from each plot and tagged at each observation. Each replication's treatments were assigned at random. The results showed that, in terms of wheat development and yield, the treatment with 75% vermicompost + 25% FYM was the most appropriate 14 out of all the treatments.

Keywords: Chemical, economic, FYM, vermicompost

Introduction

Wheat (*Triticum aestivum* L.) is the second most important cereal after rice and a staple diet for 40% of the world's population. Over 4.5 billion people in 94 countries get 20% of their protein and 21% of their calories from wheat. Wheat is grown on 215.48 million hectares of land worldwide, producing 731.4 million metric tons with an average productivity of 3390 kg/ha (USDA report, 2019). With an area of 29.65 million hectares and a yield of 99.9 million metric tonnes with an average productivity of 3371 kg/ha (USDA report, 2019), wheat also plays a significant part in food and nutritional security in India. It accounts for about one-third of all food grain production (Tandon, 2000).

By 2050, the current 7.7 billion people on the planet are predicted to increase to 9.7 billion. India currently has the second-highest population (1.3 billion) after China (1.41 billion), and it is predicted to overtake China in around seven years, reaching a peak of 1.7 billion by 2050 (The UN World Population Prospects: 2019 Revision). As a result, wheat is probably going to be essential for maintaining global food security. With 9.75 million hectares, 32.59 million tons produced, and 3100 kg/ha of productivity, Uttar Pradesh is the top wheat-growing state in India (Anonymous, 2021)^[1]. However, compared to Haryana (4 t/ha) and Punjab (4.3 t/ha), the state's wheat productivity is significantly lower. The 2019 Update). Wheat will therefore probably remain essential to maintaining food security worldwide. With an area of 9.75 million hectares, production of 32.59 million tons, and productivity of 3100 kg/ha, Uttar Pradesh is the top wheat-growing state in India (Anonymous, 2021)^[1]. However, compared to Punjab (4.3 t/ha) and

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Haryana (4 t/ha),

The state's wheat productivity is significantly lower. The utilization of organic manure as a renewable source of plant nutrients is becoming more significant due to the ongoing global energy crisis and the skyrocketing cost of chemical fertilizer. In this quest, maintaining soil health and boosting productivity both depend on the right mix of organic and inorganic fertilizer (Bakht *et al.*, 2007) [12].

A sufficient supply of nutrients, particularly nitrogen, is necessary for the growth and yield of wheat, a significant cereal crop (Kumar *et al.*, 2004) [5]. Farm manure application increases soil fertility and reduces soil permeability. The right nutrition and preservation of soil fertility were aided by the application of organic materials either by themselves or in conjunction with inorganic fertilizers.

According to (Hussain *et al.*, 1988) [4], using organic manures improved the effectiveness of chemical fertilizers. It is believed that ongoing chemical fertilizer use is a substantial contributor to both water pollution and the decline of soil health. A balanced application of both organic manures and mineral fertilizers is essential for maintaining high crop and soil productivity and sustainability. In order to preserve the delicate ecosystem and partially or completely replace the usage of expensive inputs like chemical fertilizer, it is imperative to investigate alternative sources.

Chemical fertilizers may be replaced by the useful amendment known as farmyard manures. In addition to improving the quality of the produce, it promotes plant growth and may aid in preventing plant disease. In order to maximize water use, farmyard manure enhances the soil's physical quality and increases its capacity to hold water. By boosting cation exchange capacity and supplying different hormones and organic acids, which are crucial for soil aggregation and beneficial soil microorganisms involved in a variety of biochemical processes and nutrient release, it also enhances the chemical and biological conditions of soil. Combining FYM with inorganic N sources improves soil fertility and boosts wheat yield and financial returns (Sarma *et al.*, 2007) [10].

Farmers are using chemical fertilizer to address the issue of nutrient deficit and boost wheat yield. Nevertheless, small farmers cannot afford to apply chemical fertilizers in an appropriate quantity and proportion due to their high cost. In such circumstances, maintaining soil fertility and crop yield can be greatly aided by the integrated use of chemical and organic fertilizers and manures.

Materials and Methods

In order to determine the best course of action for improved wheat growth and yield, the current study, "Enhancing Fertilizer Use Efficiency in Wheat (*Triticum aestivum* L.) through Integrated Nutrient Management: A Study on Economic Viability and Chemical Properties," will be conducted during the winter of 2024–2025 at the Agriculture Farm and Department of Horticulture, Mansarovar Global University Sehore (Madhya Pradesh), India. Three replications of twelve treatments were used in the Randomized Block Design (R.B.D.) setup of the experiment.

Results and Discussion

Chemical studies

Nitrogen content in grain and straw

Under different treatments over both years, the nitrogen content of straw ranged from 0.22 to 0.62 and that of wheat grain from 1.20 to 1.63. Grain and straw had the highest nitrogen content

during the years when 75% N from vermicompost and 25% N from FYM (T₁₂) were added, whereas the control plot had the lowest nitrogen content.

Nitrogen uptake in grain and straw:

During both years of the experiment, the highest nitrogen uptake in grain was observed when 75% N through vermicompost + 25% N through FYM (T₁₂) was incorporated. Similarly, nitrogen uptake in straw was observed when 75% N through vermicompost + 25% N through FYM (T₁₂), followed by 75% N through FYM + 25% N through vermicompost (T₁₁). Under regulated settings, grain and straw showed the lowest nitrogen uptake.

Phosphorus content in grain and straw

Under various treatments, the phosphorus content in straw ranged from 0.07 to 0.15% and in grain from 0.13 to 0.32%. Higher fertilizer dosages, specifically 75% N through vermicompost + 25% N through FYM (T₁₂), produced the highest phosphorus content in grain and straw, which was statistically comparable to a treatment that added 75% RDF + 25% N through FYM. (T₇) which were considerably better than the remaining therapies when combined. Phosphorus content was lowest in control plots.

Phosphorus uptake by grain and straw

Under various treatments for the corresponding years, phosphorus uptake in grain ranged from 4.40 to 12.70 kg/ha, whereas in straw it ranged from 3.45 to 7.30 kg/ha. During the years, the highest phosphorus uptake in grain was observed when 75% N through vermicompost + 25% N through FYM (T₁₂) was included, followed by 75% N through FYM + 25% N through vermicompost (T₁₁). Similarly, the application of 75% N through vermicompost + 25% N through FYM (T₁₂) resulted in the highest phosphorus uptake in straw, which was superior to the other treatments but on par with the treatment including the addition of 50% RDF + 50% N through vermicompost (T₆) throughout the years. The control plots showed the lowest phosphorus uptake in wheat grain and straw.

Potassium content in grain and straw

Under various treatments, the potassium content in grain ranged from 0.45 to 0.69% and in straw from 0.83 to 0.1. 34%. Higher fertilizer dosages, specifically 75% N through vermicompost + 25% N through FYM (T₁₂), produced the highest potassium content in grain and straw, which was statistically comparable to the treatment that added 75% RDF + 25% N through FYM (T₇), which was significantly better than the other treatments when pooled. The control plots had the lowest potassium content value.

Potassium uptake by grain and straw

Under various treatments for the corresponding years, potassium uptake in grain ranged from 11.9 to 32.70 kg/ha, whereas in straw it ranged from 35.6 to 85.7 kg/ha. During the years, the highest potassium uptake in grain was observed when 75% N through vermicompost + 25% N through FYM (T₁₂) was included, followed by 75% N through FYM + 25% N through vermicompost (T₁₁). Similarly, the application of 75% N through vermicompost + 25% N through FYM (T₁₂) resulted in the highest potassium uptake in straw, which was superior to the other treatments but on par with the treatment including the addition of 50% RDF + 50% N through vermicompost (T₆) throughout the years. Control plots had the lowest potassium uptake in wheat grain and straw.

Protein content in grain (%)

When the crop was fertilized with 75% N through vermicompost + 25% N with FYM (T₁₂), the mean protein content was 10.40%, compared to a mean of 7.35% in the control.

Protein yield (kg/ha)

Protein output ranged from 192.8 to 483.9 kg/ha across all treatments throughout the combined years. The crop that received 75% N from vermicompost and 25% N from FYM (T₁₂) produced the most protein, while the control plot produced the least during the combined years.

Economic Analysis**Cost of cultivation (Rs ha⁻¹)**

The maximum cost of cultivation (Rs. 47947) was calculated using 75% N through vermicompost + 25% N through FYM (T₁₂), followed by 75% Recommended N + 25% N through (T₇) and 100% Recommended NPK T₂. During the examination of pooled years, the control plot had the lowest cultivation cost (Rs. 35089).

Gross return (Rs ha⁻¹)

The gross return of wheat varied significantly depending on the

nutrient management strategy. During the pooling years, crops cultivated in control plots had the lowest gross returns as compared to other fertilizer management strategies. According to data analysis, the application of 75% N through vermicompost + 25% N through FYM (T₁₂) and 75% Recommended N + 25% N through (T₇) during the pooling year had the highest gross return (Rs.128577).

Net returns (Rs. ha⁻¹)

Higher fertilizer dosages, such as 75% N through vermicompost + 25% N through FYM (T₁₂) and 75% Recommended N + 25% N through (T₇), yielded the highest net returns (Rs. 80630) during pooled years, while the control plot yielded the lowest net returns (Rs. 42336).

Benefit: cost ratio

The highest B:C (1.68) was obtained by applying larger fertilizer doses, specifically 75% N through vermicompost + 25% N through FYM (T₁₂), followed by 75% The control plot (1.21) produced the lowest net returns throughout the pooling years, but the recommended N + 25% N through (T₇).

Table 1: Effect of integrated nutrient management on N content (%) and uptake (kg ha⁻¹) in grain and straw of wheat

Symbol	Treatments	N content in grain (%)	N content in straw (%)	N uptake grain (kg ha ⁻¹)	N uptake in straw (kg ha ⁻¹)
T ₁	Control	1.20	0.22	31.7	18.2
T ₂	100% Recommended NPK (150: 75: 60 kg ha ⁻¹)	1.55	0.52	59.7	27.6
T ₃	100% Recommended N through Vermicompost	1.53	0.44	55.2	24.2
T ₄	100% N through FYM	1.44	0.47	58.1	27.5
T ₅	50% RDF + 50% N through FYM	1.38	0.33	44.6	16.7
T ₆	50% RDF + 50% N through Vermicompost	1.58	0.46	62.4	23.3
T ₇	75% RDF + 25% N through FYM	1.50	0.53	65.5	33.0
T ₈	75% RDF + 25% N through Vermicompost	1.46	0.36	46.9	16.6
T ₉	50% RDF + 25% N through Vermicompost + 25% through	1.44	0.41	73.6	18.7
T ₁₀	50% RDF through Vermicompost + 50% FYM	1.49	0.42	63.7	29.6
T ₁₁	75% through FYM + 25% through vermicompost	1.54	0.53	53.5	37.1
T ₁₂	75% through vermicompost + 25% through FYM	1.63	0.62	77.5	56.1
	C.D. (0.05%)	0.006	0.005	0.644	0.572
	SE m (±)	0.002	0.002	0.218	0.194

Table 2: Effect of integrated nutrient management on P content (%) and uptake (kg ha⁻¹) in grain and straw of wheat

Symbol	Treatments	P content in grain (%)	P content in straw (%)	P uptake grain (kg ha ⁻¹)	P uptake in straw (kg ha ⁻¹)
T ₁	Control	0.13	0.07	4.40	3.45
T ₂	100% Recommended NPK (150: 75: 60 kg ha ⁻¹)	0.27	0.12	10.01	6.65
T ₃	100% Recommended N through Vermicompost	0.23	0.10	7.60	5.25
T ₄	100% N through FYM	0.23	0.09	8.50	5.65
T ₅	50% RDF + 50% N through FYM	0.23	0.09	8.40	5.50
T ₆	50% RDF + 50% N through Vermicompost	0.23	0.11	12.35	7.40
T ₇	75% RDF + 25% N through FYM	0.30	0.10	10.50	6.55
T ₈	75% RDF + 25% N through Vermicompost	0.20	0.12	9.95	5.50
T ₉	50% RDF + 25% N through Vermicompost + 25% through	0.21	0.09	8.10	4.90
T ₁₀	50% RDF through Vermicompost + 50% FYM	0.25	0.10	9.70	6.35
T ₁₁	75% through FYM + 25% through vermicompost	0.20	0.11	12.70	5.95
T ₁₂	75% through vermicompost + 25% through FYM	0.32	0.15	14.95	7.45
	C.D. (0.05%)	0.004	0.003	0.140	0.056
	SE m (±)	0.001	0.001	0.048	0.019

Table 3: Effect of integrated nutrient management on K content (%) and uptake (kg ha⁻¹) in grain and straw of wheat

Symbol	Treatments	K content in grain (%)	K content in straw (%)	K uptake grain (kg ha ⁻¹)	K uptake in straw (kg ha ⁻¹)
T ₁	Control	0.45	0.83	11.9	35.6
T ₂	100% Recommended NPK (150: 75: 60 kg ha ⁻¹)	0.61	1.19	25.1	68.8
T ₃	100% Recommended N through Vermicompost	0.56	1.14	20.6	59.3
T ₄	100% N through FYM	0.58	1.11	22.2	62.2
T ₅	50% RDF + 50% N through FYM	0.52	1.02	16.4	50.6
T ₆	50% RDF + 50% N through Vermicompost	0.60	1.17	24.8	67.2
T ₇	75% RDF + 25% N through FYM	0.65	1.24	28.8	76.4
T ₈	75% RDF + 25% N through Vermicompost	0.53	1.04	18.5	54.5
T ₉	50% RDF + 25% N through Vermicompost + 25% through	0.64	1.21	22.6	64.1
T ₁₀	50% RDF through Vermicompost + 50% FYM	0.55	1.07	23.3	63.8
T ₁₁	75% through FYM + 25% through vermicompost	0.57	1.09	19.3	63.0
T ₁₂	75% through vermicompost + 25% through FYM	0.69	1.34	32.7	85.7
	C.D. (0.05%)	0.004	0.007	0.284	0.644
	SE m (±)	0.001	0.002	0.096	0.218

Table 4: Effect of integrated nutrient management protein content (%) and protein yield (kg/ha)

Symbol	Treatments	Quality parameter	
		Protein content (%)	Protein yield (kg/ha)
T ₁	Control	7.35	192.8
T ₂	100% Recommended NPK (150: 75: 60 kg ha ⁻¹)	9.65	399.4
T ₃	100% Recommended N through Vermicompost	9.20	344.5
T ₄	100% N through FYM	9.35	362.2
T ₅	50% RDF + 50% N through FYM	8.45	274.2
T ₆	50% RDF + 50% N through Vermicompost	9.50	391.9
T ₇	75% RDF + 25% N through FYM	9.90	427.5
T ₈	75% RDF + 25% N through Vermicompost	8.50	292.7
T ₉	50% RDF + 25% N through Vermicompost + 25% through	8.65	310.6
T ₁₀	50% RDF through Vermicompost + 50% FYM	9.80	411.9
T ₁₁	75% through FYM + 25% through vermicompost	9.10	334.5
T ₁₂	75% through vermicompost + 25% through FYM	10.40	483.9
	C.D. (0.05%)	0.042	4.016
	SE m (±)	0.014	1.360

Table 5: Effect of integrated nutrient management on cost of cultivation, gross return, net returns and B:C ratio of wheat

Symbol	Treatments	Cost of Cultivation (Rs ha ⁻¹)	Gross Returns (Rs ha ⁻¹)	Net returns (Rs ha ⁻¹)	B:C ratio
T ₁	Control	35089	77425	42336	1.21
T ₂	100% Recommended NPK (150: 75: 60 kg ha ⁻¹)	46586	121391	74805	1.61
T ₃	100% Recommended N through Vermicompost	45176	106265	61089	1.35
T ₄	100% N through FYM	45589	110258	64669	1.42
T ₅	50% RDF + 50% N through FYM	36597	96382	59786	1.64
T ₆	50% RDF + 50% N through Vermicompost	45425	115627	70202	1.54
T ₇	75% RDF + 25% N through FYM	46759	121225	74466	1.59
T ₈	75% RDF + 25% N through Vermicompost	36754	95225	58471	1.59
T ₉	50% RDF + 25% N through Vermicompost + 25% through	37239	105900	68661	1.84
T ₁₀	50% RDF through Vermicompost + 50% FYM	44124	106724	62600	1.42
T ₁₁	75% through FYM + 25% through vermicompost	39389	104374	64985	1.65
T ₁₂	75% through vermicompost + 25% through FYM	47947	128577	80630	1.68
	C.D. (0.05%)	-	705.035	505.260	0.009
	SE m (±)	-	238.847	171.169	0.003

Conclusion

The highest grain yield (46.5 q/ha), net returns (Rs. 80630) and benefit cost ratio 1.68. The crop had higher NPK content in its grain and straw and resulted in higher NPK use efficiency. Accumulating their highest amount soil health as indicated by residual status of nutrient aggregate stability, bulk density, dehydrogenase activity, microbial population (bacteria, fungi, actinomycetes) was also better under the practices.

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