"Integrated Nutrient Management Enhances Wheat Productivity and Soil Health in Haryana: A Comparative Study of Organic and Chemical Fertilizer Regimes"

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Abstract

Wheat (*Triticum aestivum L.*) is India's most important crop, but its productivity is declining owing to synthetic fertilisers. INM is a programme that aims to increase soil fertility and productivity. To test this hypothesis, the experiment was conducted in randomized block design included 6 treatments across 3 replications as **T1**, 5 t Sesbania green manure /ha (100%), **T2**, 2.5t Sesbania green manure /ha + 50% CDF(chemical fertilizers dose), **T3**, 100% CDF, **T4**, 2.5t Sesbania green manure /ha + 2.5t FYM /ha, **T5**, 5t FYM 1t Vermicompost +10% CDF /ha, **T6**, 2.5t Pollutry Farm Manure + 1t Vermicompost + 2.5t FYM /ha. Among the organic sources, (5 t/ ha FYM + 2.5 t /ha poultry manure + 1 t /ha Vermicompost) was found to be the most economical in terms of productivity, profitability, and sustaining soil fertility. The crop receiving 2.5 t poultry manure /ha along with 75 kg N +16.5 kg P + 31.3 kg K /ha improved yield attributes and yield (5.9 t /ha) as well as nutrient uptake and crop profitability (35090 Rs /ha) over other treatments. The same treatment has shown significant improvement in soil organic carbon, nitrogen, phosphorus and potassium status of soil after the harvest of the crop. The highest benefit and returns (47890 /ha) were recorded with T4 over other treatments. The lowest net returns (19750 /ha) were recorded in treatment T3. Overall, the use of INM can be a sustainable solution to improve crop yield without damaging the soil.

Keywords: INM, FYM, Vermicompost, Poultry manure, Sustainable, organic manures, inorganic fertilizers, nutrient uptake, Wheat (*Triticum aestivum*) yield

Introduction

Integrated nutrient management combines synthetic fertilisers with organic resource materials such as organic manures, green manures, biofertilizers, and other organic compostable materials (Lamlom *et al.*, 2023). Farmers can use IPNS (Integrated Plant Nutrient System), an environmentally benign and economically, socially, and ecologically viable farming method, to increase productivity while preserving soil fertility (Pang *et al.*, 2022; Farid *et al.*, 2023). By promoting the use of on-farm organics, integrated nutrient management reduces the need for fertilizer, which lowers the cost of crop production (Zulfiqar et al., 2023). The right combination of nitrogen fertilizer, organic manure, crop residues, Nitrogen fixation crops such as pulses like, beans, Black gram, other pulses, and oil seeds like soybeans and bio-fertilizers appropriate to the system of land use and ecological, social, and economic conditions are required (Jat et al., 2022). The objective of this strategy for developing INM techniques for various categories is the cropping system rather than a single crop, and the farming system

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rather than a single field. The fundamental idea behind INM is the preservation of soil fertility, improvement of profitability, and sustainable agricultural productivity through the wise and effective use of fertilisers (Jat et al., 2022; Mahmud et al., 2021; UN report, 2022).

Wheat (Triticum aestivum) serves as the primary calorie source among cereals. Cultivated across 44 million hectares of land, it contributes an average yield of 2.37 tonnes per hectare, contributing significantly to the nation's total grain production of 104.32 million tonnes. (Sharma *et al*., 2020; Mahmud et al., 2022). The inherent soil fertility has diminished due to the cultivation of high-yielding dwarf plants responsive to fertilizers, coupled with the excessive application of synthetic fertilizers. (Devi et al., 2021). Nutrient mining and a decrease in the utilisation of organic materials have been blamed for the fall or stagnation in yield. Numerous lengthy studies carried out all throughout India revealed that the constant use of chemical fertilisers was causing a decline in Wheat (Triticum aestivum) output. The objectives of integrated nutrient management are to enhance soil health and maintain elevated levels of productivity and production.

(Zulfiqar et al., 2023; Devi et al., 2021). In Wheat (Triticum aestivum) grown using organics, (Nath et al., 2023) found improved yield and nutrient usage efficiency. Organic nutrient input at peak absorption time additionally supplies micronutrients, modifies soil physical behaviour, and boosts the effectiveness of applied nutrients (Bharati *et al*., 2017; Kumar et al., 2017). According to reports, combining organic and inorganic fertilisers can help maintain ambitious productivity targets in addition to providing the crop with the nutrients, it needs (Kumar *et al*.,2017). While soil fertilizer aims to restore the fertility of the soil, crop fertilisation refers to the application of fertiliser by the needs of the crop (Sharma *et al*., 2020).

METHODOLOGY

The field experiment was carried out at a farm located in Dujana village in Jhajjar during the rabi season of 2022 and 2023, using Wheat (Triticum aestivum) as the test crop. The experimental site was situated at coordinates 28.688027 N latitude and 76.636683 E longitude, at an average altitude of 220 meters above sea level. Throughout the experiment, the temperature ranged from 15.6°C to 32.6°C, while the relative humidity ranged from 81% to 85%. The experimental design employed was a randomized block design with three replications and six treatments. These treatments included various sources of organic manures and inorganic fertilizers, as follows:

Treatment 1 (T1): 5 tonnes of Sesbania green manure per hectare (100%)

Treatment 2 (T2): 2.5 tonnes of Sesbania green manure per hectare + 50% of the chemical fertilizers dose (CDF)

Treatment 3 (T3): 100% of the CDF

Treatment 4 (T4): 2.5 tonnes of Sesbania green manure per hectare + 2.5 tonnes of Farm Yard Manure (FYM) per hectare

Treatment 5 (T5): 5 tonnes of FYM + 1 tonne of Vermicompost per hectare + 10% of the CDF

Treatment 6 (T6): 2.5 tonnes of Poultry Farm Manure + 1 tonne of Vermicompost + 2.5 tonnes of FYM per hectare.

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RESULT

Growth attributes

Diverse sources of organic manure and inorganic fertilizers had a positive impact on the growth and yield of Wheat. The crop received increased nutrient levels from both organic and inorganic sources, resulting in enhanced growth and yield. Among the various nutrient management practices, treatment T4, which involved the application of 2.5 tonnes of Poultry Farm Manure, 1 tonne of Vermicompost, and 2.5 tonnes of Farm Yard Manure per hectare, recorded the tallest plants (110.24 cm), the highest number of effective tillers (14.1), a grain yield of 5.09 tonnes per hectare, and a straw yield of 8.91 tonnes per hectare. On the other hand, the lowest growth and yield of Wheat were observed in treatment T5, which utilized 5 tonnes of Farm Yard Manure, 1 tonne of Vermicompost, and 10% of the chemical fertilizers dose per hectare. However, among the organic sources, the addition of 1 tonne of Vermicompost per hectare led to increased crop growth but had a negative impact on yield, possibly due to suboptimal nutrient management. This observation aligns with the findings of Singh and Kumar (2014). The higher yield associated with increasing fertilizer levels can be attributed to the greater nutrient input into the soil, which is consistent with the results reported by Yadav and Meena (2014). The beneficial effect of integrated nutrient management, combining both inorganic fertilizers and organic manures, on enhanced crop growth and yield, has also been documented by Kumar et al. (2008) and Ahmed et al. (2014).

Table 1. Effects of different INM treatments on the growth and yield of Wheat (Triticum aestivum)

Treatments	*Plant height (cm)*	*No. Of tillers*	*Grain yield (t/ha)*	*Straw yield (t/ha)*
T1, 5 t Sesbania green manure /ha (100%)	92.41	11	2.6	4.1
T2 , 2.5t Sesbania green manure /ha + 50% CDF	96.71	11.6	2.01	3.2
T3, 100% CDF	109.32	12	1.9	6.9
T4, 2.5t Pollutry Farm Manure + 1t Vermicompost + 2.5t FYM /ha	110.24	14.1	5.09	8.9
T5, 5t FYM 1t Vermicompost +10% CDF /ha	101.70	13.7	1.9	2.9
T6 2.5t Sesbania green manure /ha + 2.5t FYM /ha	94.30	8.9	3.9	3.1
Control	62.7	11	0.7	2.4

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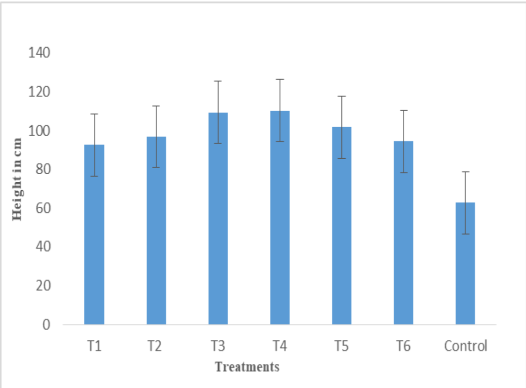
S.E±	**±16**	**±1.76**	**±1.46**	**±2.44**



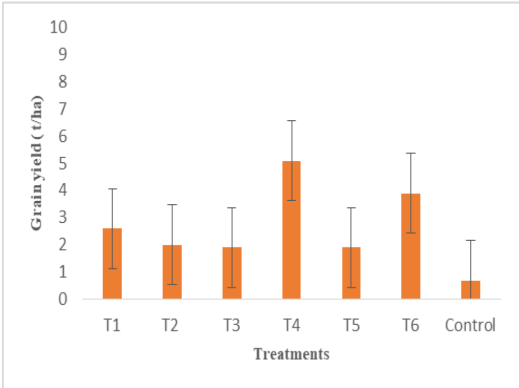
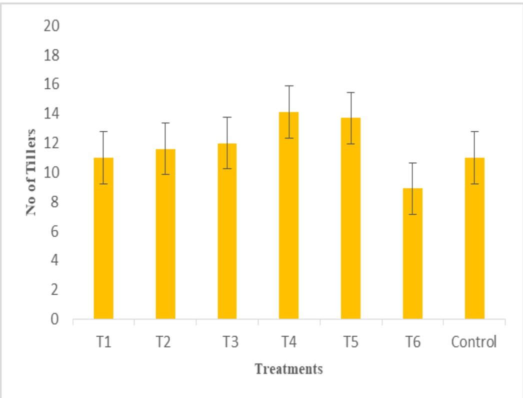


Fig. a. Showing height in cm of plant in different treatments **Fig. b**. Showing grain yield in ton/ha of plant in different treatments



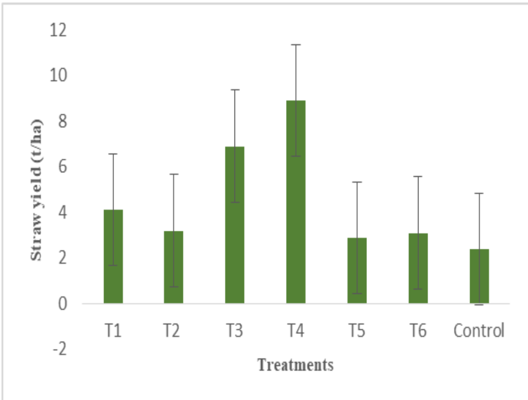


Fig. c. Showing the number of tillers in different treatments **Fig. d.** Showing straw yield in different treatments

The above figures demonstrate the effect of different treatments of Integrated Nutrient Management (INM) on the growth of plant height, as shown in figure (a), the highest growth of the plant was seen in T4 (110.24 cm), which might be due to the significant amount of vermicompost in the contrast of poultry manure. As we see the Figure (b), the highest tillers were seen in treatment T4 as compared to the rest of the different treatments.

Figure (c & d) shows the yield of grain and straw, where T4 showed the maximum yield of grain (5.09 ton/ha) and straw yield (8.9 ton/ha) as compared to another alternative hypothesis. The finding of Singh and Kumar (2014) also showed that a significant amount of fertilizer (FYM, Vermicompost and Poultry farm manure) can be beneficial for the growth and yield of Wheat (Triticum aestivum). The term INM plays an important role in reducing the contamination in soil due to excessive use of synthetic fertilizers.

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Table 2. NPK uptake (Kg/ha) by Wheat (*Triticum aestivum)* grain and straw

Treatments	*Nitrogen (Kg/ha)*		*Phosphorus (Kg/ha)*		*Potassium (kg/ha)*	
	Grain	Straw	Grain	Straw	Grain	Straw
T1	15.9	17.2	5.9	3.2	7.4	32.7
T2	30.1	32.9	11.9	7.9	18.9	91.4
T3	52.4	48.3	16.5	12.9	24.7	112.9
T4	65.9	52.4	21.1	16.4	27.9	130.2
T5	43.2	38.4	13.5	8.5	21.4	104.9
T6	24.1	26.2	8.4	5.2	11.9	104.7
Control	10.1	8.7	3.4	2.9	6.3	22.9
S.E±	**±20.21**	**±15.91**	**±6.16**	**±5.02**	**±8.51**	**±41.30**

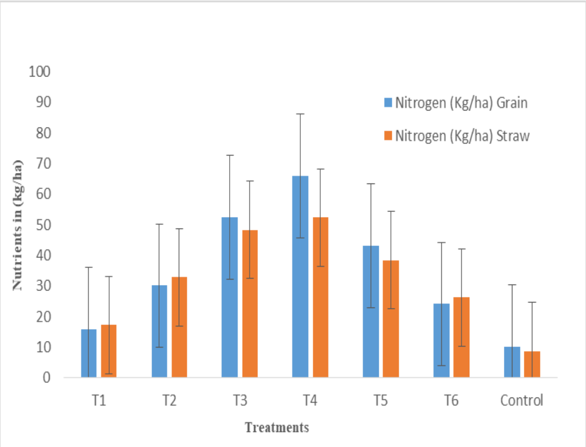

Fig. e. N uptake by grain and straw

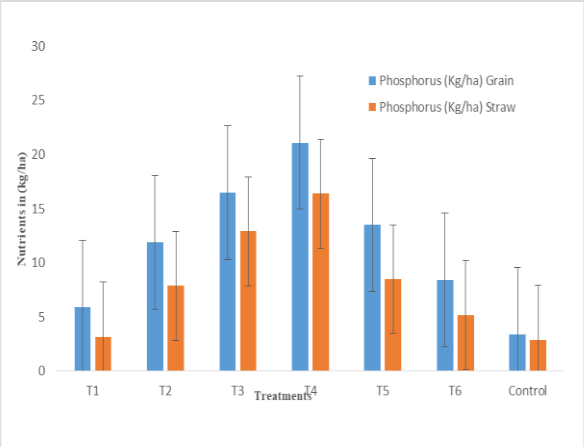

Fig. f. P uptake by grain and straw

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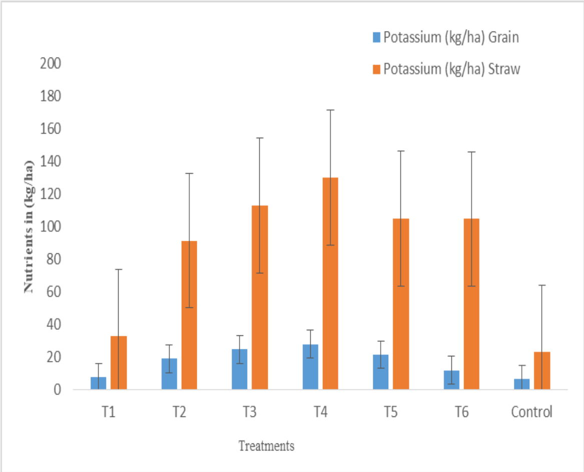

Fig. e. K uptake by grain and straw

Figure (e) shows that the uptake of Nitrogen in grains and straw was optimum in treatment T4 where Nitrogen (65.9 kg/ha) and in straw (16.4 kg/ha). In figure (f), Potassium uptake was 27.9 kg/ha in grains and straw uptake was 130.2 kg/ha. The result of uptaking the nutrients significantly proves that Integrated Nutrient Management can help in the reclamation of soil fertility in the future prospective. Similar results can be seen in the finding of (Pandey *et al*., 2007).

Table 3. Organic carbon, Available N, P and K in the soil after harvesting

Treatments	*Organic Carbon (g/kg)*	*Available N (kg/ha)*	*Available P (kg/ha)*	*Available K (kg/ha)*
T1	6.2	152.1	21.4	59.3
T2	7.1	168.9	25.9	63.9
T3	8.0	181.3	31.2	91.7
T4	8.2	192.7	33.1	93.1
T5	7.3	171.4	27.7	68.1
T6	6.9	165.3	23.2	61.4
C	4.3	63.2	11.3	23.4
S.E±	**±1.31**	**±43.01**	**±7.25**	**±23.39**

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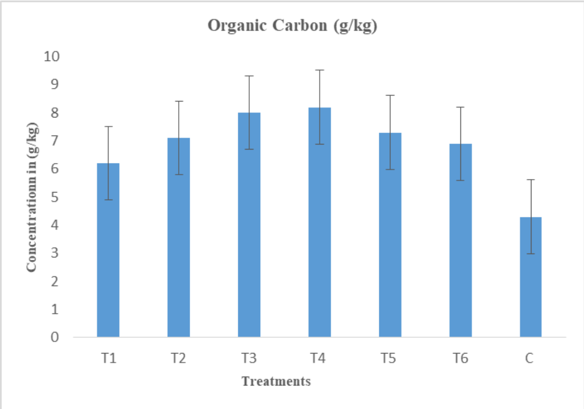


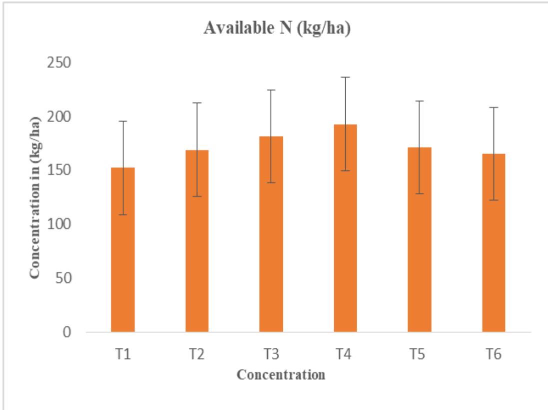
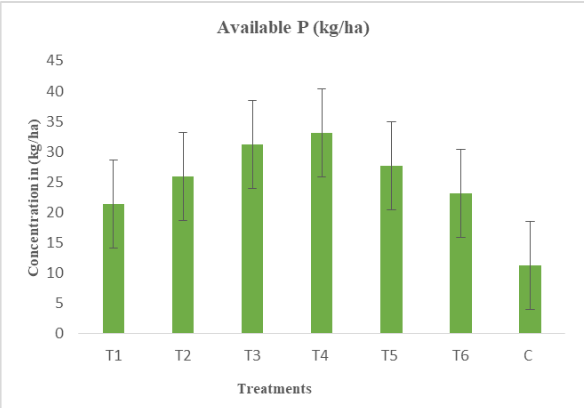


Fig. f. Status of OC in post-harvest soil of different treatments

Fig. g. Status of N in post-harvest soil of different treatments



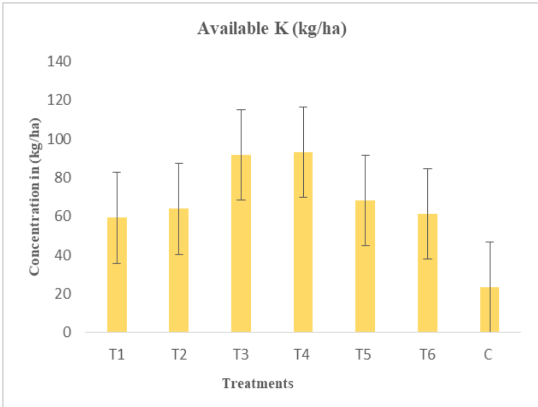


Fig. h. Status of P in post-harvest soil of different treatments

Fig. i. Status of K in post-harvest soil of different treatments

In fig. h, i, and j showed the availability of essential nutrients of soil nutrients after the harvesting of Wheat (Triticum aestivum) in different treatments, where T4 shows the optimum nutrients (Organic Carbon, Nitrogen, Phosphorus and Potassium) availability as (OC 8.2 g/kg, N 192.7 kg/ha^{-1}, P 33.1 kg/ha^{-1} and K 93.1 kg/ha^{-1}). Nutrient deficiency can be seen in T1, which might be due to improper nutrients provided to the soil.

Table 4. Economic status of the crop

Treatments	Gross retrun	Net retrun
T1	27970	10980
T2	50810	19860
T3	19750	8761
T4	47890	35090
T5	52000	31037
T6	41090	34712
Mean/Average	**44490**	**25448.5**

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Dhainsa at a rate of 1 rupee per kilogram, Farm Yard Manure (FYM) at 2 rupees per kilogram, Vermicompost (V.C) at 8 rupees per kilogram, and Poultry Manure (PM) at 2 rupees per kilogram were the provided organic materials. Additionally, 123 kilograms of Urea fertilizer, priced at 1230 rupees, 2437 rupees for Single Super Phosphate (SSP), and 601 rupees for Muriate of Potash (MOP) were the inorganic fertilizers used, resulting in a total cost of 4268 rupees.

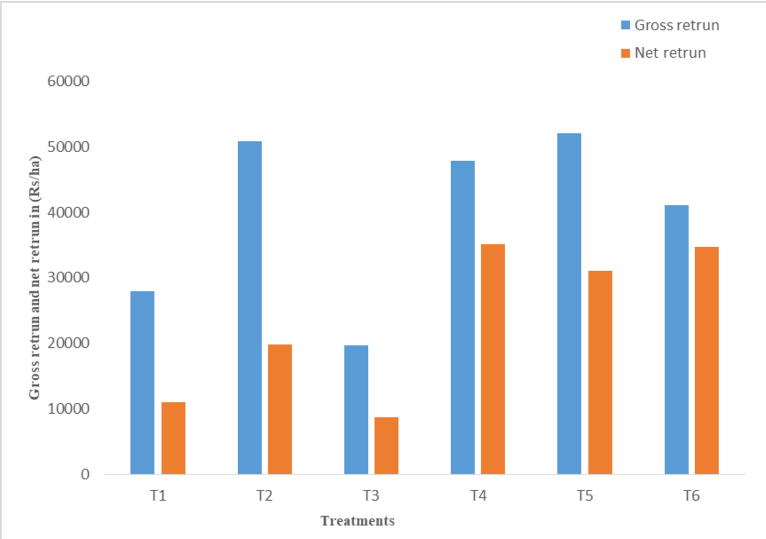

Fig. k. Economic analysis of crop

The treatment T3 gave the minimum benefit due to improper management of nutrients supplied to the soil, where the gross return was(19750 Rs/ha^{-1}). In the recommended treatment of this study, T4 showed the maximum net return of the crop was seen (35090 Rs/ha).

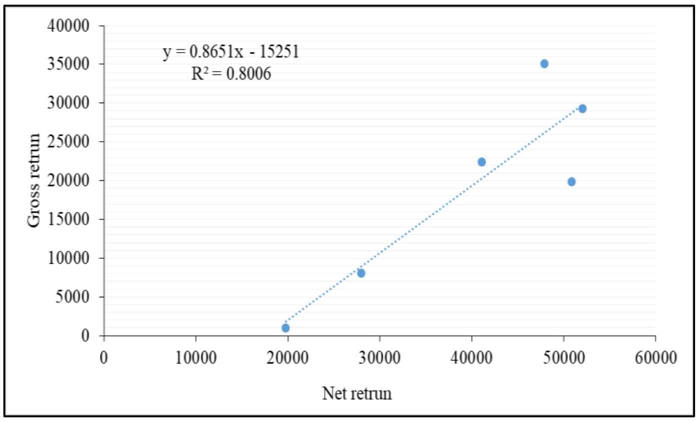

Fig. L. Corelation in gross retrun and net retrun

A correlation coefficient of 0.8006 indicates a strong linear relationship between gross return and net return in the context of wheat crop production. This value suggests that 80% of the variability in net returns can be explained by changes in gross returns. In other words, as gross returns from wheat crop production increase or decrease, there is a robust tendency for net returns to follow suit. Such a high correlation signifies that gross returns are a significant predictor of net returns, which can be crucial information for farmers and agricultural stakeholders when making financial decisions related to wheat crop cultivation. However, it's

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important to remember that correlation does not imply causation, and additional factors and variables may also influence net returns in this agricultural context.

Conclusion

In conclusion, the study conducted on the effects of different Integrated Nutrient Management (INM) treatments on wheat crops has provided valuable insights into optimizing crop growth, yield, and soil fertility. Several key findings can be summarized:

Nutrient Management: The use of both organic and inorganic sources of nutrients positively influences crop growth and yield. The treatment T4, which involved a combination of poultry farm manure, vermicompost, and farmyard manure, emerged as the most effective in terms of plant height, effective tillers, grain yield, and straw yield for wheat, T4 showed significant improvements in plant height, tiller number, grain yield, and straw yield.

Organic vs. Inorganic: While organic sources like vermicompost had a positive impact on plant growth, it was noted that improper management of nutrients could affect yield. Therefore, a balanced combination of organic and inorganic sources, as demonstrated in T4, appeared to be the most effective approach.

Nutrient Uptake: Nutrient uptake analysis revealed that treatment T4 had the highest nitrogen and potassium uptake for wheat. This indicates that the integrated approach to nutrient management significantly improved the nutrient content in the crops.

Soil Fertility: Post-harvest soil analysis showed that T4 maintained the highest levels of organic carbon, available nitrogen, phosphorus, and potassium. This suggests that the integrated nutrient management approach not only benefits crop yield but also contributes to long-term soil fertility and health.

Economic Benefits: The economic analysis demonstrated that T4 was the most financially rewarding treatment, resulting in the highest net return. This underscores the practical value of implementing integrated nutrient management practices in agricultural systems.

In summary, the study highlights the importance of adopting an integrated nutrient management strategy that combines organic and inorganic sources of nutrients to optimize crop growth, yield, and soil fertility. Properly managed INM practices, as exemplified by treatment T4, can lead to higher agricultural productivity and economic benefits while also promoting sustainable and environmentally friendly farming practices. These findings can serve as a valuable guide for farmers and agricultural practitioners seeking to enhance crop production and soil health.

DATA AVAILABILITY STATEMENT

All data generated or analysed in the present study have been included, and are available within this article.

CONFLICT OF INTEREST STATEMENT

Authors certify that the authors are not affiliated with or involved with any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this paper.

ETHICAL APPROVAL

Not Applicable

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AUTHORS' CONTRIBUTION

Wazir Singh: Execution of the sampling/analysis work, writing original draft

Vikram Mor: Supervision, Conception and design of the work, Data correction, Proofreading

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