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Assessing the Influence of Integrated Nutrient Management on Yield and Economics of Wheat (*Triticum aestivum* L.) in North Indian Plains

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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 during rabi season of 2022-2023 to study the effect of integrated nutrient management on yield and economic sustainability of wheat *(Triticum aestivum L.)* in Uttarakhand at the Agriculture Research Farm, Graphic Era Hill University, Dehradun, Uttarakhand.

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The experiment was conducted in randomized block design and consisted of eight treatments *viz.,* T_1 – Control, T_2 – 100% RDF, T_3- 100% RDF + FYM @ 5t ha^{-1}, T_4- 100 % RDF + VC @ 5t ha^{-1}, T_5- 75% RDF + FYM @ 5t ha^{-1}, T_6- 75% RDF + VC @ 5t ha^{-1}, T_7- 75% RDF + FYM @ 5t ha^{-1} + *Azotobacter*, T_8- 75% RDF + VC @ 5t ha^{-1} + *Azotobacter* with three replications. The wheat variety used for the field experiment was HD-2967 with a seed rate of 100 kg ha^{-1}. Row-row spacing of 20 cm and plant -plant spacing of 10 cm was maintained. Different nutrient sources used were urea, DAP, MOP, FYM, VC and *Azotobacter*. Seed were primed with *Azotobacter* @ 20g kg^{-1} seed as per the treatment. The investigation revealed that, application of 75% RDF + VC @ 5t ha^{-1} + *Azotobacter* (T_8) resulted in significantly higher yield attributes no. of spikes/m^2, spike length (cm), grain/spike, 1000 grain weight (g) over control. The maximum grain yield (50.2 q ha^{-1}) of wheat were obtained with application of 75% RDF + VC @ 5t ha^{-1} + *Azotobacter* (T_8) closely followed by 75% RDF + FYM @ 5t ha^{-1} + *Azotobacter* (T_7). Moreover, straw yield was 85.92% higher over the control. The maximum gross return (₹ 141646.0), and net return (₹ 100045.0) of wheat was obtained with application of 75% RDF + VC @ 5t ha^{-1} + *Azotobacter* (T_8) followed by the 75% RDF + FYM @ 5t ha^{-1} + *Azotobacter* (T_7). The maximum benefit-cost ratio (2.79) was obtained with the application of 75% RDF + FYM @ 5t ha^{-1} + *Azotobacter* (T_7). From the above investigation it can be concluded that 75% RDF + VC @ 5t ha^{-1} + *Azotobacter* is superior to other treatment in improving the productivity and economic returns of wheat.

Keywords: Integrated nutrient management; farmyard manure; vermicompost; azotobacter; gross return; net return and benefit-cost ratio.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is the world's second most crucial cereal crop cultivated as a food source, contributing significantly, with an estimated 30% share, to a nation's food supply [1]. It is known as the 'King of Cereals' because of its leading role in the global food grain trade, its extensive acreage under production, and its magnificent productivity. Wheat plant is a member of the Poaceae family and is a hexaploid. India is the second largest producer of wheat contributing 13.57% of world total production, its share has increased from 0.14% in 2016 to 0.54% in 2020. India produces around 107.59 MT of wheat annually while a major chunk of it goes towards domestic consumption [2]. The adoption of intensive cropping system is seen as a potential solution to meet the food demands of a growing population. However, this approach requires a significant amount of input energy, which not only contributes to environmental pollution but also escalates production costs. Moreover, the manufacturing of synthetic fertilizer, which are a key component of intensive cropping, is highly cost-effective but heavily relies on non-renewable fossil fuels that are currently in short supply. To address the challenges posed by the supply and recent price increase of inorganic fertilizers, there is a need to promote the use of indigenous sources such as farmyard manure (FYM), vermicompost, and bio-fertilizers. These alternatives not only provide essential plant nutrients but also enhance soil biodiversity, leading to improved soil fertility and productivity.

The combined application of both organic and inorganic nitrogen sources enhances field crop production, increased profitability, and contribute to the preservation of soil fertility. To optimize yield and promote soil well-being, it is essential to incorporate organic manure and bio-fertilizers alongside traditional inorganic fertilizers. Notably, the use of bio-fertilizers like Azotobacter in conjunction with other approaches holds significant promise for enhancing wheat productivity, as demonstrated in a study by Kumar and Ahlawat, [3]. By integrating inorganic fertilizers with organic manures and bio-fertilizers, not only can crop productivity be sustained, but also soil health can be improved, and nutrient-use efficiency can be accelerated, as emphasized by Kakraliya et al., [4].

2. MATERIALS AND METHODS

A field experiment was conducted during the rabi season of 2022-2023 using wheat variety HD-2967 at the Agriculture Research Farm, Graphic Era Hill University, Dehradun, Uttarakhand. The experiment consisted of eight treatments which were replicated three times and layout in randomized block design *viz.,* control (T_1), 100% RDF (T_2), 100% RDF + FYM @ 5t ha^{-1} (T_3), 100% RDF + VC @ 5t ha^{-1} (T_4), 75% RDF + FYM @ 5t ha^{-1} (T_5), 75% RDF + VC @ 5t ha^{-1} (T_7), 75% RDF + FYM @ 5t ha^{-1} + *Azotobacter* (T_7), 75% RDF + VC @ 5t ha^{-1} + *Azotobacter* (T_8). In each plot, ten plants were taken randomly from the produce harvested from net plot (2 m × 2 m) for recording yield attributes (spike length, number of spikes m^{-2}, number of grains spike^{-1}), yield (grain, straw and biological yield) and economics (cost of cultivation, gross return, net return and benefit-cost ratio). Benefit-cost ratio was calculated using the following formula:

$$\text{Benefit-cost ratio} = \frac{Net\ return}{Cost\ of\ cultivation}$$

The initial soil samples were collected from the experimental field at 0-15 cm depth. The soil of experimental field was low in organic carbon, medium in available nitrogen, available phosphorus and available potassium with natural soil reaction. The details of soil characteristic are in Table 1.

3. RESULTS AND DISCUSSION

3.1 Yield Attributes

3.1.1 Number of spikes/m^2

Experimental results revealed that different nutrient combinations significantly influence yield attributes of wheat. Application of 75% RDF + VC @ 5t ha^{-1} + *Azotobacter* (T_8) produced maximum number of spikes m^{-2} (323.3/m^2). It was at par with 100% RDF + VC @ 5t ha^{-1} (T_4), 75% RDF + VC @ 5t ha^{-1} (T_6) and 75% RDF + FYM @ 5t ha^{-1} + *Azotobacter* (T_7). It was found to be significantly higher than rest of the treatments. This is possibly due to the role of vermicompost in providing essential nutrients, plant growth hormones, and enzymes. It enhances soil microbial activity that can help in breaking down organic matter, making nutrients more available to wheat plants. Yadav et al. [5] concluded that application of 125% RDF along with vermicompost @ 5t/ha has the potential to increase wheat crop productivity.

Further, it was also observed that the application of 75% RDF + VC @ 5t ha^{-1} + *Azotobacter* (T_8) results is maximum spike length (11.9 cm) which was statistically at par with 75% RDF + FYM @ 5t ha^{-1} + *Azotobacter* (T_7), 100 % RDF + VC @ 5t ha^{-1} (T_4), 100% RDF + FYM @ 5t ha^{-1} (T_3), 75% RDF + FYM @ 5t ha^{-1} (T_5), 75% RDF + VC @ 5t ha^{-1} (T_6) and 100% RDF (T_2). It was found to be significantly higher than control (T_1). The application of organic manure with inorganic fertilizers may have increased the nutrient mineralization and their availability for crop growth. Vermicompost contains essential plant nutrient along with hormones and its integration with chemical fertilizers and *Azotobacter* may have resulted [6] in enhanced yield characters of wheat crop.

Moreover, number of grains/spikes application of 75% RDF + VC @ 5t ha^{-1} + *Azotobacter* (T_8) resulted in maximum number of grains/spike (48/spike) which was statistically at par with 75% RDF + FYM @ 5t ha^{-1} + *Azotobacter* (T_7), 100% RDF + VC @ 5t ha^{-1} (T_4), 75% RDF + FYM @ 5t ha^{-1} (T_5) and 75% RDF + VC @ 5t ha^{-1} (T_6). It was found to be significantly higher than control (T_1), 100% RDF(T_2) and 75% RDF + FYM @ 5t ha^{-1} (T_3). The improvement in number of grains/spikes might be due to enhanced vegetative growth of wheat under the same treatment on account of adequate and prolonged supply of essential nutrients. However, the results do not align with that of Verma et al. [7]. They reported application of 100% RDF resulted in significantly higher number of grains/spikes of wheat.

However, the maximum test weight (1000 seed weight) (39.4 g) was observed under 75% RDF + VC @ 5t ha^{-1} + *Azotobacter* (T_8). It was found to be significantly higher than control (T_1), 100% RDF (T_2), 1005 RDF + FYM @ 5t ha^{-1} (T_3), 75% RDF + FYM @ 5t ha^{-1} (T_5) and 75% RDF + VC @ 5t ha^{-1} (T_6). It may be due to various fertility the highest value of 1000 grain weight was reported by treatment with INM fertilizer at (45g), while the least value was found in control (32g). Ahmed et al. [8] The rise in yield characteristics of wheat could be attributed to better nutrient availability during the crop's development and reproductive stages, which may have supplied more photosynthates from source to sink and enhanced test weight. The findings do not coincide with those of Panigrahi et al. [9] as he obtained maximum test weight under 100 % RDF.

3.2 Yield

The grain and straw yield of wheat varied significantly as a reflection of growth attributes. Maximum grain (50.2 q ha^{-1}) and straw (70.6 q ha^{-1}) yields of wheat were obtained with the application of 75% RDF + VC @ 5t/ha + *Azotobacter* (T_8) which was closely followed by the 75% RDF + FYM @ 5t/ha + *Azotobacter* (T_7) (grain yield 46.9 q ha^{-1} and straw yield 67.0 q ha^{-1}). The significantly difference between these two treatments can be attributed to the nitrogen-fixing capabilities of *Azotobacter*, which ensures a consistent supply of nitrogen to the wheat crop, thereby promoting better growth and increasing yield. These results are consistent with those reported by Kaur et al. [10] also observed higher yields when using a combination of 75% RDF, vermicompost applied at a rate of 2.5 t ha^{-1} and *Azotobacter*. The application of chemical fertilizer in combination with vermicompost and *Azotobacter* had a positive impact on soil structure, increased nutrient availability, and stimulated the growth of beneficial microorganisms. These effects collectively contributed to higher wheat crop yields, as reported by Tiwari et al. [11].

Moreover. As harvest index is a consequence of grain yield and biological yield (120.7 q ha^{-1}) which was followed by application 75% RDF + VC @ 5t ha^{-1} + *Azotobacter* (T_8), the highest harvest index of wheat did not vary significantly under the influence of different treatment. However, application of 75% RDF + VC @ 5t ha^{-1} (T_6) (42.0%) followed by 100% RDF (T_2). The application of vermicompost significantly enriched the soil with both macro and micronutrients, while also adding a substantial amount of organic matter. Furthermore, the presence of *Azotobacter* contributed to the improvement of soil microbial properties, leading to a more efficient utilization of nutrients. In a study by Kumar and Pareek [12] it was found that higher yields were achieved with the application 0f 20t ha^{-1} of FYM and 10t ha^{-1} of vermicompost compared to using 5t/ha of vermicompost alone. Notably, the biological yield increased by 41.50% when a combination of 75% RDF, 5 t ha^{-1} of vermicompost, and Azotobacter(T_8) was applied, as opposed to using 100% RDF (T_2). These findings align with the trends observed in terms of biological yield, as reported by Sharma et al. [13] Devi et al. [14] and Yadav et al. [15]. The observed differences in yield may be attribute to the fact that the control(T_1) recorded a relatively low harvest index of 38.65%. These outcomes are consistent with the research findings of Fazily et al. [16] and Bezboruah and Dutta [17].

3.3 Economic

Any suggestion that aiming to gain acceptance among farmers must be its profitability. The economic viability plays a crucial role in determining the success of any technological advancement.

Table 1. Detail of experimental soil

Character	Value	Method used
pH	7.4	Glass electrode pH meter Jackson, [18]
EC (dS m^{-1})	0.5	Bower and Wilcox [19]
Organic Carbon %	0.42	Walkley and Black method [20]
Available N (kg ha^{-1})	308.2	Alkaline $KMnO_4$ method Subbiah and Asija, [21]
Available P (kg ha^{-1})	48.4	Olsen's phosphorus extraction method Olsen's et al., [22]
Available K (kg ha^{-1})	261.2	Neutral normal ammonium acerate extraction method Hanway and Hiedel, [23]

Table 2. Effect of integrated nutrient management on yield attributes of Wheat

Treatments	Number of spikes m^{-2}	Spike length (cm)	Grain $spike^{-1}$	1000 grain weight (g)
T_1	230.3	9.2	33.0	27.9
T_2	263.3	10.8	43.3	30.8
T_3	272.3	10.9	43.7	34.0
T_4	303.3	11.2	45.0	35.3
T_5	285.3	10.8	44.0	33.6
T_6	297.7	11.0	44.3	34.8
T_7	315.0	11.1	45.7	36.3
T_8	323.3	11.9	48.0	39.4
SEm±	8.7	0.4	1.3	1.4
CD at 5%	26.4	1.2	4.0	4.2

Table 3. Effect of integrated nutrient management on grain yield, straw yield, biological yield and harvest index of Wheat

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index
T_1	27.0	38.3	65.3	41.57
T_2	35.9	49.5	85.3	41.99
T_3	40.8	57.4	98.2	41.56
T_4	43.1	59.9	103.0	41.83
T_5	37.1	52.4	89.5	41.40
T_6	39.5	54.6	94.1	42.00
T_7	46.9	67.0	113.9	41.20
T_8	50.2	70.6	120.7	41.54
SEm±	1.6	2.0	3.4	0.83
CD at 5%	4.9	6.0	10.2	NS

Table 4. Effect of integrated nutrient management on cost of cultivation, gross return, net return and benefit-cost ratio of Wheat

Treatments	Cost of cultivation	Gross return	Net return	Benefit-cost ratio
T_1	25965.00	76426.0	50461.0	1.94
T_2	33595.00	100737.0	67142.0	2.00
T_3	35595.00	115184.3	79589.3	2.24
T_4	42095.00	121249.3	79154.3	1.88
T_5	33931.00	104921.3	70990.3	2.09
T_6	40431.00	110988.5	70557.5	1.75
T_7	34516.00	133039.5	97938.5	2.79
T_8	41016.00	141646.0	100045.0	2.40
SEm±	-	4189.9	4189.9	0.14
CD at 5%	-	12708.8	12831.9	0.44

3.4 Cost of Cultivation

Cost of cultivation of wheat under different treatments are summarized maximum cost of cultivation (₹ 42095.0 ha^{-1}) was estimated for 100% RDF + VC @ 5t ha^{-1} (T_4) followed by ₹ 41016.0 ha^{-1} for 75 % RDF + VC @ 5t/ha + *Azotobacter*(T_8). The cost difference is due to additional cost incurred by application 100% RDF + FYM @ 5t ha^{-1} (T_3). The lowest cost of cultivation amounting to ₹ 25965.0 ha^{-1} was calculated for control as no nutrient sources were incorporated to this treatment.

3.5 Gross Return

Moreover, gross return significantly under the influence of different treatment. However, application of 75% RDF + VC @ 5t/ha + *Azotobacter* (T_8) resulted in maximum gross return (₹141646) which was statistically at par with 75% RDF + FYM @ 5t/ha (T_8). It was found to be significantly higher than control (T_1), 100% RDF (T_2), 100% RDF + FYM @ 5t/ha (T_3), 100% RDF + VC @ 5t/ha (T_4), 75% RDF + FYM @ 5t/ha (T_5) and 75% RDF + VC @ 5t/ha (T_6). Gross return increased by 40.60% with the application of 75% RDF + VC @ 5t/ha + *Azotobacter* (T_8) compared to 100% RDF (T_2). It is due to less cost of cultivation and high yield in the particular treatment. Similar results were reported by Ali et al. [24] and Gudadhe et al. [25].

3.6 Net Return

However, the maximum net return (₹100045) was observed with the application application of 75% RDF + VC @ 5t/ha + *Azotobacter* (T_8) which was statistically at par with 75% RDF + FYM @ 5t/ha + *Azotobacter* (T_7). It was found to be significantly higher than control (T_1), 100% RDF (T_2), 100% RDF + FYM @ 5t/ha (T_3), 100% RDF + VC @ 5t/ha (T_4), 75% RDF + FYM @ 5t/ha (T_5) and 75% RDF + VC @ 5t/ha (T_6). This is due to higher yields in the particular treatments. Rabi et al. [26] reported that integrated application of NPK fertilizers along with vermicompost not only influences production of plant but at the same time also increases net return. Economics net return and benefit-cost ratio increased with supplementation of recommended dose of fertilizer with vermicompost and phosphate solubilizing bacteria.

3.7 Benefit-Cost Ratio

The benefit-cost ratio of wheat varied significantly as a economics. Maximum benefit-cost ratio (2.79%) of wheat were obtained with the application of 75% RDF + FYM @ 5t/ha + *Azotobacter* (T_7) which was closely followed by the 75% RDF + VC @ 5t/ha + *Azotobacter* (T_8) having a B:C ratio 2.40. This may be attributed to higher yield in the treatment compared to other treatments. Tiwari et al*.* [11] reported that the application of 50% RDF + FYM @ 6t/ha + Vermicompost 1.875 t/ha registered higher benefit-cost ratio (0.72) compared to 100 % RDF.

4. CONCLUSION

From the present investigation a conclusion can be drawn that the integrated nutrient management approach has resulted in improved yield attribute, yield and economics of wheat variety HD-2967 has highest yield attributes, yield and economics than the sole use of chemical fertilizer. A maximum value for T_8 was discovered for many character tics, including no. of spikes m^{-2}, spike length (cm), grain spike^{-1}, test weight. Therefore, a fact can be established that combined use of inorganic and organic nutrients can be opted by the farmers for augmenting their crop growth and productivity. This approach will not only sustain the crop growth but also enhance the fertility status of the soil.

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 manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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