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Influence of nitrogen levels and inoculation of biofertilizers on yield and economics of wheat

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Abstract

A field experiment was conducted during Rabi 2022 at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh, to study the influence of different nitrogen levels and biofertilizer inoculation on wheat. The experiment was laid out in a Randomized Block Design (RBD) with 10 treatments and three replications, comprising 50%, 75%, and 100% nitrogen levels combined with Azotobacter and/or Azospirillum seed inoculation, along with an RDF control.

The results revealed that, among the all treatments, T₃ (100% N - 150kg/ha + Azotobacter 10 g+ Azospirillum 10 g/kg seed) proved superior recording which is the highest plant height (85.0 cm), tillers/hill (8.2), effective tillers/hill (6.03), grains/spike (50.06), grain yield (4.96 t/ha), and straw yield (7.0 t/ha). The same treatment also resulted in the maximum economic returns, with a gross return of Rs1,09,120/ha, net return of Rs 71,770/ha and a B:C ratio of 1.92.

Keywords: Wheat, nitrogen, bio-fertilizers, azotobacter, azospirillum, yield and economics

Introduction

One of the most widely grown grains in the world is wheat (*Triticum aestivum* L.). It is the third most significant cereal in the world due to its plentiful end product manufacturing, nutritious diversity, and protein-to-carbohydrate ratio. In 2022, there were 221.84 million hectares of wheat cultivation worldwide, with a total production of 779.33 million metric tons and a yield per hectare of 3.51 metric tons. This is an increase in production of around 0.57 percent over the previous year. China leads the production scale for 2022, followed by the United States, Australia, Russia, India, the European Union, and so on (Global Market Analysis, FAS, USDA, 2023) [17]. Approximately 304.47 lakh hectares are planted with wheat in India (GOI, 2022) [7]. India produces about 111.32 million tons of wheat annually. Major wheat-producing states include Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, and Rajasthan, with Uttar Pradesh ranking first in production. During 2022–23, Uttar Pradesh produced around 11.27 million tonnes of wheat. Wheat is traded more globally than all other crops put together. India's wheat is becoming more and more popular worldwide (APEDA, 2022) [1].

Nitrogen is one of the elements of the chlorophyll molecule that propels a crop's growth and output. Nitrogen is particularly important throughout the wheat crop's reproductive period, which subsequently exhibits noticeable fluctuations in grain output. Wheat protein content rises with nitrogen fertilization (Robinson *et al.*, 1979) [16], improving grain quality and vigor. According to Kelley (1995) [12], applying nitrogen later in the season is more successful than applying it earlier. In other words, applying nitrogen close to anthesis increases grain protein content more effectively than applying it earlier (Wuest and Cassman, 1992). Wheat grain yield is mainly determined by the number of kernels and their weight per unit area. Nitrogen plays a vital role in grain filling by promoting leaf area development and increasing dry matter accumulation through greater interception of solar radiation (Green, 1984) [8]. Grain weight is largely controlled by genetic factors, although environmental conditions during the grain-filling period can significantly influence its expression (Kausar *et al.*, 1993) [10].

Biofertilizers are formulations of beneficial microorganisms that improve plant growth and soil fertility through nitrogen fixation, nutrient solubilization, growth hormone production, and disease

suppression. They include bacteria, fungi, and cyanobacteria (AICRP, 2018) ^[2]. Among bacterial biofertilizers, Azotobacter and Azospirillum are highly effective in enhancing wheat growth and yield.

Azotobacter is a free-living, nitrogen-fixing bacterium that contributes roughly 10–20 kg N ha⁻¹ per cropping season to the rhizosphere of a variety of crops, including wheat, maize, rice, sorghum, sugarcane, and cotton (Jadav *et al.*, 1987). Apart from fixing nitrogen, it also produces a number of growth-promoting substances, including auxins, gibberellins, nicotinic acid, B vitamins, and biotin, which promote plant growth and root development (Rao, 1978). According to Narula and Gupta (1986) ^[14], it also releases ammonia into the rhizosphere, which improves the availability and uptake of nutrients by plants.

Azospirillum is a well-known rhizobacterium that fosters plant growth by forming an associative bond with plant roots. Through biological nitrogen fixation and phytohormone production, it improves crop growth in both field and greenhouse settings, leading to increased root growth and plant vigor.

Materials and Methods

The experiment was conducted during the Rabi season of 2022–23 at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh, to evaluate the influence of different nitrogen levels and biofertilizer inoculation on the growth and yield of wheat. The experimental field had a sandy loam soil with a nearly neutral reaction (pH 7.8), low organic carbon (0.62%), available nitrogen (225 kg ha⁻¹), phosphorus (38.2 kg ha⁻¹), potassium (240.7 kg ha⁻¹), and zinc (2.32 mg kg⁻¹). The experiment was laid out in a Randomized Block Design (RBD) comprising 10 treatments and three replications. The treatments consisted of three nitrogen levels (100%, 75%, and 50% of the recommended dose) in combination with Azotobacter and/or Azospirillum seed inoculation. The treatment details were: T₁–100% N (150 kg ha⁻¹) + Azotobacter @ 20 g kg⁻¹ seed, T₂–100% N + Azospirillum @ 20 g kg⁻¹ seed, T₃–100% N + Azotobacter @ 10 g kg⁻¹ seed + Azospirillum @ 10 g kg⁻¹ seed, T₄–75% N (112.5 kg ha⁻¹) + Azotobacter @ 20 g kg⁻¹ seed, T₅–75% N + Azospirillum @ 20 g kg⁻¹ seed, T₆–75% N + Azotobacter @ 10 g kg⁻¹ seed + Azospirillum @ 10 g kg⁻¹ seed, T₇–50% N (75 kg ha⁻¹) + Azotobacter @ 20 g kg⁻¹ seed, T₈–50% N + Azospirillum @ 20 g kg⁻¹ seed, T₉–50% N + Azotobacter @ 20 g kg⁻¹ seed + Azospirillum @ 20 g kg⁻¹ seed, and T₁₀:Control (RDF- 150:60:40 kg/ha).

Growth parameters such as plant height, number of tillers hill⁻¹, and plant dry weight, along with yield attributes including effective tillers hill⁻¹, grains spike⁻¹, grain yield, and straw yield, were recorded at harvest from randomly selected plants in each plot.

Results and Discussion

Post-Harvest Observations on Yield Parameters

The data regarding yield attributes and yield of wheat are summarized in the table 1.

Number of effective tillers/hills

Treatment 3, which applied 100% N-150 kg/ha + Azotobacter 10 g + Azospirillum 10 g/kg seed, showed a significantly higher number of effective tillers/hill (6.03). Nonetheless, the treatment 1 which is 100% N-150 kg/ha + Azotobacter 20 g/kg seed, Treatment 5 which is 75%N -112.5 kg/ha + Azospirillum @ 20 g/kg seed were statistically equivalent to the 100%N -150kg/ha + Azotobacter @10 g + Azospirillum @10 g/kg seed) 100% N-150 kg/ha + Azotobacter 10 g/kg seed (T₃).

More tillers were produced as a result of the improved early

vegetative development in terms of larger leaf area, dry matter accumulation, and robust root systems, which in turn greatly boosted the number of effective tillers. Devi *et al.* (2011) ^[6], found similar results. According to (Avivi and Feldman, 1982) ^[4], an increase in the number of effective tillers per hectare following the application of biofertilizer may be attributed to the microorganisms' enhanced production of plant hormones or the roots' response to microbial colonization.

Number of grains/spikes

The largest number of grains/spike (50.06 t/ha) was observed with the application of 100% N-150 kg/ha + Azotobacter 10 g + Azospirillum 10 g/kg seed (Treatment 3). Nonetheless, the 50% N -75 kg/ha+ Azotobacter @10 g+Azospirillum@10 g/kg seed (T₉) were statistically equivalent to Treatment 03.

Higher nitrogen dosages result in the formation of more spikelet, which causes a notable rise in the number of grains or spikes. Bhatta *et al.* (2020) ^[5] found similar results. Similar to this, an increase in grains or spikes may result from the simultaneous application of Azospirillum and Azotobacter bacteria, which fix nitrogen in the soil and aid in the synthesis of protein, carbohydrates, starch, and other assimilates by plants. Amit Kumar and Urmila (2018) ^[3] discovered similar results.

Grain Yield (t/ha)

In treatment 3 with the application of 100% N - 150kg/ha + Azotobacter 10 g + Azospirillum 10 g/kg seed was recorded significantly higher grain yield (4.96 t/ha) However, treatment 2 which is 100% N- 150 kg/ha + Azospirillum 20 g/kg seed was statistically at par with the treatment 3.

Grain output may have increased as a result of enhanced photosynthetic activity, increased vegetative growth, and improved yield qualities brought about by higher nitrogen application. According to Pandey *et al.* (2018) ^[15], similar outcomes have been noted. According to Kaur *et al.* (2018) ^[11], the improvement in yield characteristics and yield by biofertilizer may be due to the production of additional plant hormones (auxin, cytokinin, gibberellin, etc.) by the specific microbes or by the root in response to the microbial population.

Straw yield (t/ha)

Significantly higher straw yield (7.00 t/ha) was recorded in treatment 3 with the application of 100% N - 150kg/ha + Azotobacter 10 g + Azospirillum 10 g/kg seed. However, treatment 6 with 75% N -112.5 kg/ha+ Azotobacter 10 g + Azospirillum 10 g/kg seed was statistically at par with the treatment 3.

The application of biofertilizer enhanced wheat straw yields as well as growth and yield-attributing traits, according to Kaur *et al.* (2018) ^[11]. Higher plant height, the quantity of green leaves on each hill, and the production of dry matter all improved straw output, according to Bhatta *et al.* (2020) ^[5]. Thus, vegetative growth determines straw yield.

Test weight (g)

Treatment 3 showed a higher test weight (40.03 g) when 100% N-150 kg/ha + Azotobacter @10 g + Azospirillum @10 g/kg seed was applied. Despite this, the treatments did not significantly differ from one another.

Harvest Index (%)

The treatment 3 which is application of 100% N-150 kg/ha + Azotobacter 10 g + Azospirillum 10 g/kg seed produced the highest harvest index (41.48%). Despite this, the treatments did not significantly differ from one another.

Table 1: Influence of Nitrogen levels and inoculation of Biofertilizers on yield and yield attributes of Wheat

S No	Treatments	Number of effective Tillers/hill	Number of grains/ spikes	Test Weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index (%)
1.	100% N- 150 kg/ha + Azotobacter 20 g/kg seed	6.03	47.05	38.07	4.63	6.65	41.01
2.	100% N-150kg/ha + Azospirillum 20 g/kg seed	6.00	48.03	37.04	4.73	6.75	41.18
3.	100% N - 150kg/ha + Azotobacter 10 g + Azospirillum 10 g/kg seed	6.03	50.06	40.03	4.96	7.00	41.48
4.	75% N- 112.5 kg/ha + Azotobacter 20 g/kg seed	5.07	50.04	39.08	4.44	6.51	40.55
5.	75% N -112.5 kg/ha + Azospirillum 20 g/kg seed	6.03	47.07	36.03	4.51	6.59	40.67
6.	75% N -112.5 kg/ha+ Azotobacter 10 g + Azospirillum 10 g/kg seed	6.00	48.03	36.00	4.60	6.96	39.77
7.	50% N- 75 kg/ha + Azotobacter 20 g/kg seed	5.03	49.05	39.00	4.24	6.29	40.27
8.	50% N -75 kg/ha + Azospirillum 20 g/kg seed	5.07	48.03	37.06	4.26	6.31	40.30
9.	50% N - 75 kg/ha+ Azotobacter 10 g + Azospirillum 10 g/kg seed	5.06	49.03	39.03	4.33	6.42	40.28
10.	Control (150-60-40 NPK kg/ha)	5.03	47.01	38.03	3.96	5.99	39.80
	F-test	S	S	NS	S	S	NS
	S Em ($\pm$)	0.14	0.34	0.30	0.09	0.11	0.33
	CD at 5%	0.41	0.12	--	0.28	0.33	--

Economics Analysis

Table 2 displayed the information on cultivation costs, gross returns, net returns, and the B:C ratio as affected by various treatments.

Cost of cultivation (INR/ha)

When compared to other treatments, treatment 3, which applied 100% N-150 kg/ha + Azotobacter 10 g + Azospirillum 10 g/kg seed, had the highest cultivation cost (37,350.04 INR/ha).

Gross Returns (INR/ha)

Compared to other treatments, treatment number 3 which is application of 100% N-150 kg/ha + Azotobacter 10 g + Azospirillum 10 g/kg seed yielded the highest gross return (Rs. 1,09,120.00/ha) and treatment 10 which is N:P: K (150-60-40) kg/ha Control produced the lowest gross returns (Rs.

84,150.00/ha).

Net Returns (INR/ha)

Treatment 3, consisting of 100% N - 150kg/ha + Azotobacter 10 g + Azospirillum 10 g/kg seed recorded the maximum net returns of Rs. 71,770/ha among all the treatments. whereas minimum was recorded with treatment 10, N:P:K (150-60-40) kg/ha Control, (Rs. 50,270.00/ha).

Benefit Cost Ratio (B: C)

The highest benefit-cost ratio (1.92) was recorded under the treatment 3 with the application of 100% N - 150kg/ha + Azotobacter 10 g + Azospirillum 10 g/kg seed. However, treatment 10 which was NPK (150-60-40) kg/ha Control, had a lower benefit cost ratio (1.36).

Table 2: Influence of Nitrogen levels and inoculation of Biofertilizers on Economics of Wheat

S. No.	Treatments	Total cost of cultivation (INR/ha)	Gross Returns (INR/ha)	Net Returns (INR/ha)	B:C ratio
1	100% N- 150 kg/ha + Azotobacter 20 g/kg seed	37,348.04	98,387.50	64,510.00	1.73
2	100% N-150kg/ha + Azospirillum 20 g/kg seed	37,348.04	1,00,513.00	66,710.00	1.79
3	100% N - 150kg/ha + Azotobacter 10 g+ Azospirillum 10 g/kg seed	37,350.04	1,09,120.00	71,770.00	1.92
4	75% N- 112.5 kg/ha + Azotobacter 20 g/kg seed	36,725.04	94,350.00	60,955.00	1.66
5	75% N -112.5 kg/ha + Azospirillum 20 g/kg seed	36,725.04	95,837.50	62,495.00	1.70
6	75% N -112.5 kg/ha+ Azotobacter 10 g+ Azospirillum 10 g/kg seed	36,725.04	97,750.00	64,475.00	1.76
7	50% N- 75 kg/ha + Azotobacter 20 g/kg seed	36,100.04	90,100.00	57,180.00	1.58
8	50% N - 75 kg/ha + Azospirillum 20 g/kg seed	36,100.04	90,525.00	57,620.00	1.60
9	50% N - 75 kg/ha+ Azotobacter 10 g+ Azospirillum 10 g/kg seed	36,100.04	92,012.50	59,160.00	1.64
10	Control (150-60-40 NPK kg/ha)	36,850.04	84,150.00	50,270.00	1.36

Summary

The present investigation titled “Influence of Nitrogen Levels and Inoculation of Biofertilizers on Growth and Yield of Wheat” was carried out at the Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P).

The results indicated that the combined application of 100% N - 150kg/ha + Azotobacter 10 g/kg seed along with Azospirillum 10 g/kg seed in Treatment 3 resulted in superior yield attributes and economic analysis, recording the effective tillers per hill (6.03), grains per spike (50.06), grain yield (4.96 t/ha), and straw yield (7.00 t/ha).

Higher gross returns (INR 1,09,120.00), net returns (INR 71,770.00) and B: C ratio (1.92) were also recorded with the application of 100% N - 150kg/ha + Azotobacter10 g + Azospirillum 10 g/kg seed (Treatment-3).

Treatment 3, consisting of 100% N - 150kg/ha + Azotobacter10 g + Azospirillum 10 g/kg seed resulted in the highest gross returns (₹109,120.00 ha⁻¹), net returns (₹71,770.00 ha⁻¹), and benefit-cost ratio (1.92) in wheat crop.

Conclusion

The results of the present investigation indicate that the 100% N 150kg/ha along with Azotobacter 10 g/kg seed and Azospirillum 10 g/kg (Treatment 3) was the most effective treatment, recording superior growth parameters, yield attributes, grain and straw yields, and economic returns. Hence, this treatment can be considered a viable option for improving wheat productivity and farm profitability under the prevailing conditions of the study.

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