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Integrated Effect of Synthetic Fertilizers and Bio-Inoculant on Growth, Yield Attributes and Yield of Wheat (*Triticum aestivum* L.)

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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

During the Rabi season of 2021-22, a field trial was carried out in micro plots within the 'pot culture house' at the Department of Soil Science & Agricultural Chemistry, Chandra Shekhar Azad University of Agriculture and Technology in Kanpur. The study involved nine treatment combinations arranged in a randomized block design with three replications, aiming to assess the impact of nitrogen (N), phosphorus (P), potassium (K), and Azotobacter on the wheat variety K-1317. Based on the findings obtained from the study, it can be deduced that concerning the growth parameters maximum plant height is 77.51 cm, maximum number of tillers plant-1 is 6.00 were associated with the treatment T6 [125 % RDF + Azotobacter]. Similarly, among the yield components and productivity parameters maximum values in relation to length of ear (12.75 cm), number of grain ear-1 (57.67), fresh weight plant-1 (156.24 g), dry weight plant-1 (25.25 g), grain yield (52.00 q ha-1), straw yield (65.80 q ha-1) and biological yield (101.96 q ha-1) were also found in the treatment T6 [125 % RDF + Azotobacter]. While the minimum value of growth, yield attributes and yield parameters were also found under the treatment T1 [Control].

Keywords: Azotobacter; dry weight; fresh weight; plant height; tillers; yield.

1. INTRODUCTION

Wheat, the "king of cereals," is a staple food grain cereal crop grown globally, with India being the second largest producer. It has higher nutritional value and is used for animal feed and soil health. The chemical composition of wheat kernels includes starch, protein, water, cellulose, fat, sugar, and mineral matter.

India has been categorized into six zones dedicated to wheat cultivation, taking into account diverse agro-climatic and agro-ecological conditions. The common bread wheat (*Triticum aestivum* L.) accounts for more than 90 % of total wheat area, with macaroni wheat accounting for 10 % (*Triticum durum* L.). In the country, emmer wheat (*Triticum dicoccum* L.) is grown on a very small scale. Wheat is annual plant of Graminae family which belongs to genus Triticum (18 spps). Wheat is primarily grown in three regions of Uttar Pradesh: Eastern, Western, and Northern Uttar Pradesh. Eastern UP is the largest wheat growing region of the above three, with more than 52 lakh hectares of land under wheat cultivation. Traditionally, wheat is cultivated within intensive cropping systems, wherein there is widespread utilization of inorganic fertilizers, with a specific emphasis on NPK fertilizers [1].

Wheat cultivation spans 122 countries, encompassing a total land area of 214 million hectares and yielding approximately 772.64 million tons in 2020. In India, wheat is cultivated across roughly 30.5 million hectares, resulting in a total production of 107.2 million metric tons and a standard productivity of 31.13 quintals per hectare. Uttar Pradesh stands out as the leading wheat-producing state in the country, with an expansive area of 9.2 million hectares contributing to a production of 34.18 million tons and a productivity of 31.15 quintals per hectare. Notably, the wheat cultivation area has expanded from 12 million hectares in 1966-67 to 31.13 million hectares in 2016-17.

This essential nutrient serves diverse functions in plant metabolism, contributing to structural components in molecules like nucleic acids and proteins. It plays a crucial role in processes such as energy transfer, respiration, glycolysis, carbohydrate metabolism, redox reactions, enzyme activation/inactivation, membrane synthesis and stability, as well as in nitrogen fixation [2]. Nitrogen is a key structural component of the cell. As a result, it has been regarded as the most important nutrient for the development of plant life, which would be impossible without it. In its absence, crop growth is greatly slowed, and the foliage turns yellowish, causing grain shriveling for ultimately, lower crop yield and also chlorophyll and carbohydrate assimilation are significantly reduced. Consequently, a decline in crop yield occurs due to suboptimal flowering and premature development, indicating that enhancing nutrient use efficiency can be achieved through a balanced application of nitrogen (N), phosphorus (P), and potassium (K) fertilizers, coupled with judicious utilization of organic manures in wheat systems. Phosphorus, being the second most crucial essential nutrient for crop production after nitrogen (Venkatesh *et al.,* 2020), plays a vital role as a component in DNA and RNA, carrying genetic information essential for protein synthesis. Beyond its agricultural significance, phosphorus is also of utmost importance to human beings, contributing to the growth and repair of body cells and tissues. Potassium, recognized as a pivotal plant nutrient, lacks specific binding to particular plant compounds, allowing it to move freely within the plant and participate in various physiological functions. The deficiency of potassium can consequently lead to a decrease in crop yield, compromise quality, and impact overall profitability [3].

Nitrogen deficiency is a notable characteristic of Indian soil. It has been extensively noted that the efficiency of nitrogen utilization is only around 30-37 %, with the remaining percentage being lost through processes such as volatilization, denitrification, and leaching. Nitrogen, Phosphorus, and Potassium are significantly playing the role for wheat yield and quality. In India, facing the problem is compounded by unbalanced fertilizer use, which has resulted in an increase in the NPK ratio from 6:2.5:1 in 2004 to 8.5:2.9:1 in 2010, compared to the optimum ratio of 4:2:1. The majority of India's soils are deficient, but excessive N use fails to produce long-term sustainable yield. Achieving a balance between crop nutrient requirements and soil nutrient reserves is critical for maintaining higher yields and soil fertility, preventing environmental contamination, and long-term agricultural production. Crops efficiently use N fertilizer in general, more than half of the N applied is not assimilated by plants (Dobermann and Cassman, [4] and this is a potential source of pollution. Furthermore, global cereal production per unit of applied N is decreasing, this trend indicates a higher economic and environmental cost per unit of food produced. Cereal crops remove 60-70 kg of initial plant nutrients per ton of grain on average [5].

Crop yield declines have been observed all over the world as a result of the continued use of inorganic fertilizer. As a result, there is a growing need to integrate nutrient supply with organic sources in order to restore soil health. Bio fertilizers are an economically appealing and sound way of reducing external input while improving the quality and quantity of internal resources. These are microorganisms that use biological processes to mobilize nutrients from non-usable pools. Beneficial microbes include N fixers, which may be able to save 25-30 % of inorganic nutrient sources while also providing environmental safety. Among non-symbiotic diazotroph, the name free living (*Azotobacter chroococcum*) is well known for its broad-spectrum utility for various types of crops. Azotobacter proliferation in soil or rhizosphere is influenced by ecological and Agro climatic factors such as fertility level, moisture, temperature, pH, carbon content, plant type, and nature of plant exudates, which determine the compatibility of (*Azotobacter chroococcum*) stain in terms of its survival and efficiency to benefit the crop plant. Beside nitrogen fixation, the bacterium has been found to synthesize plant growth promoting substances like auxins, gibberellins and cytokinin.

2. MATERIALS AND METHODS

2.1 Experimental Site

The study took place in the winter (Rabi) season of 2021-22 at the Student’s Instructional Farm, located within C.S.A. University of Agriculture and Technology in Kanpur Nagar, Uttar Pradesh. The experimental field was appropriately levelled and received irrigation from a tube well. Positioned in the western-northern sector of Kanpur city, the university's main campus hosts the farm, situated within the sub-tropical zone of the fifth agroclimatic zone

2.2 Edaphic Condition

The experimental site featured well-drained soil with consistent and level topography. The soil in the experimental field originated from alluvium, possessed a sandy loam texture, and exhibited a slightly alkaline pH of 7.7. The electrical conductivity measured 0.38 dSm^{-1}, following the same soil-to-water suspension method as per Jackson [6]. Organic carbon content in the soil was determined as 0.42 percent, employing the rapid titration method by Walkley and Black [7]. Soil analysis revealed an available nitrogen content of 253 kg ha^{-1} (using the Alkaline permanganate method by Subbiah and Asija in [8] , available phosphorus as sodium bicarbonate extractable P at 14.3 kg ha^{-1} (determined by Olsen's calorimetric method, Olsen *et al.,* [9], and available potassium at 154.7 kg ha^{-1} (analyzed through the Flame photometer method by Hanwey and Heidel in [10].

2.3 Crop Husbandry

The experimental field underwent pre-sowing irrigation (Paleva) with the aim of achieving optimal moisture conditions for facilitating robust germination. Following proper soil tilth, a single ploughing was conducted using a tractor-drawn mouldboard plough, succeeded by two cultivator ploughings. The recommended amounts of Nitrogen, Phosphorus, and Potassium were administered through Urea, DAP, and MOP at the rates of 120:60:40 kg ha-1, respectively. Azotobacter inoculant, sourced from the Department of Microbiology at Chandra Shekhar Azad University of Agriculture & Technology in Kanpur, was applied through seed treatment. This involved creating a slurry of the biofertilizer, pouring it onto the seeds, thoroughly mixing, and subsequently drying the treated seeds in the shade before immediate sowing.

2.4 Detail of Treatments and Design

A randomized block design with three replications was employed to implement nine different nutrient management practices involving inorganic fertilizers (Urea, DAP, and MOP). The treatments, along with their respective symbols, included Control (T_1), 125 % recommended dose of fertilizer (RDF) (T_2), 100 % RDF (with a composition of 120:60:40 NPK, T_3), 75% RDF (T_4), 50 % RDF (T_5), 125 % RDF with *Azotobacter* (T_6), 100 % RDF with *Azotobacter* (T_7), 75 % RDF with *Azotobacter* (T_8), and 50 % RDF with *Azotobacter* (T_9).

2.5 Harvesting and Threshing

The crop was harvested when it reached maturity and subsequently sun-dried. Each plot's yield was bundled separately and weighed. After the drying process, the harvest underwent manual threshing.

2.6 Experimental Parameters

2.6.1 Grain yield (q ha^{-1})

Following the weighing of bundles within each respective net plot, the crop was subjected to threshing using a tractor thresher. The grain yield was then measured in kilograms per plot and converted to quintals per hectare (q ha^{-1}) based on the net plot area. The final step involved converting the grain yield per plot to quintals per hectare using a designated conversion factor.

2.6.2 Straw yield (q ha^{-1})

To determine the straw yield in kilograms per plot, the grain yield of each plot was deducted from the bundle weight. Subsequently, the straw yield was converted into quintals per hectare (q ha^{-1}) based on the net plot area, enabling the recording of straw yield in quintals per hectare.

2.7 Statistical Analysis

The information pertaining to various traits examined throughout the investigation was subjected to statistical analysis using a randomized block design. In cases where there were significant differences among treatments (as determined by the "F" test), critical differences were calculated at a probability level of five percent. The statistical analysis of the study's data followed the methods recommended by Gomez and Gomez in [11].

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Data pertaining to growth parameters mainly plant height (cm) and number of tillers per plant, was clearly revealed in Table 1; the average plant height at 90 DAS (cm) and number of tillers per plant of wheat were affected by different doses of NPK and azotobacter. The plant height at 90 DAS (days after sowing) and the number of tillers per plant of wheat were significantly increased over control. The maximum plant height (77.51 cm) and number of tillers per plant (6.0) of wheat were recorded in T_6 [125 % RDF + *Azotobacter*], followed by T_7 [100 % RDF + *Azotobacter*] with the value 73.23 cm and 5.67 and the minimum plant height (51.71 cm) and number of tillers per plant (2.67) were recorded in control. The consequences of the current investigation are additionally in concurrence with the investigation of Tiwari *et al.,* [5] , Verma *et al.,* [12] and Choudhary *et al.,* [13].

3.2 Yield Components

The average number of grain ear^{-1}, length of ear, fresh weight and dry weight of the wheat plant affected by different doses of NPK and azotobacter, as presented in Table 2, reveals that the number of grain ear^{-1}, length of ear, fresh weight and dry weight of the wheat plant were significantly increased over control. The maximum number of grains (57.67), length of ear (12.75 cm), fresh weight (156.24 g) and dry weight (25.25 g) of wheat were recorded in treatment T_6 [125 % RDF + *Azotobacter*] followed by treatment T_7 [100 % RDF + *Azotobacter*] with the value 54, 12.43 cm, 139.30 g and 22.52 g respectively, and the minimum number of grains (28.33), length of ear (7.25 cm), fresh weight (75.19 cm) and dry weight (12.15 g) of wheat was recorded in control. The results of the present investigation are also in agreement with the findings of Kumar *et al.,* [14] Verma *et al.,* [15] and Patyal *et al.,* [16]

3.3 Productivity Parameters

It was observed that the application of different doses of NPK and azotobacter enhanced the grain yield, straw yield and biological yield of wheat significantly over those present in Table 3. Maximum grain yield (52.00 q ha^{-1}), straw yield (65.80 q ha^{-1}) and biological yield (117.80 q ha^{-1}) were recorded under the treatment T_6 [125 % RDF + *Azotobacter*] followed by treatment T_7 [100 % RDF + *Azotobacter*] with the value 46.33, 55.63 and 101.96 q ha^{-1} and minimum grain (25.33 q ha^{-1}), straw yield (29.80 q ha^{-1}) and biological yield (55.13 q ha^{-1}) of wheat were recorded in control. These findings are further supported by the findings of Sirohiya *et al.,* [17] and Tiwari *et al.,* [18-21].

Table 1. Effect of different treatment combinations on growth parameters of wheat

S. No	Treatment Details	Plant height (cm)	No. of tiller $plant^{-1}$
1	**T_1 –** Control	51.71	2.67
2	**T_2-**125 % RDF	67.35	5.33
3	**T_3 -**100 % RDF	64.38	4.67
4	**T_4 -**75 % RDF	62.76	4.00
5	**T_5 -**50 % RDF	59.92	3.67
6	**T_6** -125 % RDF +Azotobacter	77.51	6.00
7	**T_7** -100 % RDF + Azotobacter	73.23	5.67
8	**T_8 -**75 % RDF + Azotobacter	69.58	5.47
9	**T_9 -**50 % RDF + Azotobacter	63.36	4.72
SEm ±		1.530	0.408
CD at 5%		4.62	1.23

Table 2. Effect of different treatment combinations on yield components of wheat

S. No	Treatment Details	Length of ear (cm)	Number of grain ear^{-1}	Fresh weight of plant (g)	Fresh weightof plant (g)
1	**T_1 -** Control	7.25	28.33	75.19	12.15
2	**T_2-**125 % RDF	9.51	47.00	98.66	15.94
3	**T_3 -**100 % RDF	9.41	45.67	97.69	15.78
4	**T_4 -**75 % RDF	8.65	43.33	89.72	14.50
5	**T_5 -**50 % RDF	8.10	40.67	83.99	13.57
6	**T_6** -125 % RDF +Azotobacter	12.75	57.67	156.24	25.25
7	**T_7** -100 % RDF + Azotobacter	12.43	54.00	139.30	22.52
8	**T_8 -**75 % RDF + Azotobacter	11.80	50.00	127.49	20.60
9	**T_9 -**50 % RDF + Azotobacter	9.95	46.33	103.65	16.75
SEm ±		0.291	1.110	3.4733	0.495
CD at 5%		0.837	3.34	10.41	1.49

Table 3. Effect of different treatment combinations on productivity parameters of wheat

S. No	Treatment Details	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})
1	**T_1 –** Control	25.33	31.66	56.99
2	**T_2-**125 % RDF	43.00	49.29	92.29
3	**T_3 -**100 % RDF	40.00	44.00	84.00
4	**T_4 -**75 % RDF	37.33	43.30	80.63
5	**T_5 -**50 % RDF	35.00	38.15	73.15
6	**T_6** -125 % RDF +Azotobacter	52.00	65.80	117.80
7	**T_7** -100 % RDF + Azotobacter	46.33	55.63	101.96
8	**T_8 -**75 % RDF + Azotobacter	43.67	50.46	94.13
9	**T_9 -**50 % RDF + Azotobacter	38.68	46.46	85.14
SEm ±		1.023	1.254	2.501
CD at 5%		3.76	3.92	7.57

4. CONCLUSION

The findings from the experiment revealed excellence in terms of growth parameters, yield components, and productivity parameters, including grain yield (q ha^{-1}), straw yield (q ha^{-1}), and biological yield (q ha^{-1}). The application of the treatment combination involving 125 % recommended dose of fertilizer (RDF) along with *Azotobacter* in the soil resulted in the highest values for growth parameters, yield components, and overall productivity of the wheat crop when compared to all other treatments.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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