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Yield Assessment of Bread Wheat (*Triticum Aestivum* L.) under Planned Nitrogen

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Abstract

This research aimed to investigate the influence of various levels of urea as the source of nitrogen on yield and yield-related characteristics such as plant height (PH), spikelet per spike (SPP), spike length (SL), tillers, peduncle length (PL), biomass, spike weight per plant (SWPP), grains per plant (GPP) and spikes per plant (SPP) of wheat cultivars "Aas-2002", "GA-2002" and "Ufaq". This study performed in greenhouse and consisted of six treatments in pots such as (T_0) 0/5 kg, (T_1) 250 mg/5kg, (T_2) 375 mg/5 kg, (T_3) 500mg/5kg, (T_4) 562.5mg /5kg and (T_5) 687.5mg/5 kilograms per pot of nitrogen applied at three different stages of growth (tillering, anthesis, and grain filling) to evaluate their effect on wheat yield. The total amount of N in the given quantity of Urea for T_0, T_1, T_2, T_3, T_4, and T_5 was 0, 115 mg, 172.5 mg, 230 mg, 258.75 mg, and 316.25 mg respectively. Results indicated that yield and yield-related traits responded substantially to the amount of nitrogen, but its excessive concentration shows adverse effects. Nitrogen rate at 262.125 mg/5 kg of urea was more appropriate for Aas-2002 and Ufaq, and maximum yield was obtained at this level. In contrast, the suitable N rate for GA-2002 was 320.125 mg/5 kg giving maximum output. It is concluded that three N-splits are ideal for enhancing bread wheat yield.

1. Introduction

Cereals have been the most common field crop on the planet and are considered a staple food for human beings. The essential indispensable cereal is wheat, which significantly influences global population nutrition (Ciudad-Mulero *et al.,* 2020). As world population is progressively increasing with an estimation of nine billion by 2050 (Hunter *et al.,* 2017). Various approaches can be used to minimize food shortage including crop yield enhancement and more cultivated area of soil (Ray *et al.,* 2012). Wheat (*Triticum aestivum* L.) is considered as the staple food and most important cereal crop in world that can participate in minimizing the food gap (Mandic *et al.,* 2015). Wheat production significantly contributes in whole agriculture system in any country (Rebouh *et al.* 2020). Wheat grain is used for various food items, mainly bread (Shewry *et al.,* 2015). This crop shows high yield potential but globally it shows an average yield of 3.2 t/ha which is very low (FAOSTAT, 2021). Therefore, we can say that globally wheat yield potential exploration is not satisfactory.

Yield gaps in wheat production are significantly influenced by various abiotic stresses, including drought, salinity, temperature extremes, and nutrient deficiencies. Among these, imbalanced plant nutrition is a critical yet often overlooked factor that limits crop productivity. Nitrogen, as a primary macronutrient, plays a pivotal role in plant growth and yield by being a fundamental component of amino acids, proteins, nucleic acids, and chlorophyll. Its availability directly affects photosynthesis, biomass accumulation, and grain formation in wheat. Insufficient or inefficient nitrogen supply can severely reduce wheat productivity, emphasizing

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the need for optimized nitrogen management strategies to minimize yield gaps and enhance sustainable wheat production under abiotic stress conditions.

In agricultural plants, nitrogen (N) plays a crucial role. Various essential processes, including growth and biomass production are closely related to Nitrogen. Crop yield can be effectively enhanced by nitrogen applications as it is necessary nutrient for crops (Guo et. al., 2019). Sufficient nitrogen uptake by plants resulted in better performance and crop output. As nitrogen is the structural element of chlorophyll, nucleic acid, amino acids, ATP, hence are required to accomplish biological activities involving photosynthesis, nitrogen and carbon metabolisms, and protein synthesis (Crawford *et al.,* 2002). Root growth is also improved by nitrogen applications which enhanced the nutrient uptake and its balance, dry mass production. (Ding *et al.,* 2005). Various plant processes including rate of CO_2 absorption, and resistance to environmental problems such as water scarcity are also regulated by the application of nitrogen fertilizer. Nitrogen as compared with other fertilizers plays more effective role for good crop production which shows its necessity for plant production (Chen *et al.,* 2010). Most important nutrient for wheat is nitrogen among the fertilizers as it plays crucial role in quality and grain yield of winter wheat (Wysocki *et al.,* 2007). To attain maximum production and to reduce the negative impact of environment proper N management is necessary in crop production at various growth stages. Nitrogen is the most important nutrient in wheat for plant growth and grain yield improvement (Alexandre *et al.,* 2022). The use of outstanding cultivars and careful nitrogen fertilizer application are obligatory for high wheat yields, as wheat shows sensitivity toward inappropriate nitrogen supply and responsive to nitrogen fertilizer (Alexandre *et al.,* 2022; Fang *et al.,* 2006). Application of nitrogen concentration used to accomplish a marked result, as well as the grain N, roots, straw, and N damages from the root zone, all influence wheat N uptake. The supply of N and other uptake fluctuations is highly changeable due to management constituents such as nitrogen fertilizer, rotation of crops, and environmental components such as climate and diseases. As a result, ensuring soil nitrogen supply and crop nitrogen uptake, long-term farming systems can be improved (Hangs *et al.,* 2013). Information on wheat crop growth performance and variability would help the country's policymakers implement initiate ves for wheat crop production (Seadh *et al.,* 2008). Pakistan produces 131 kilograms of wheat per capita per year, whereas its wheat consumption per capita is the maximum in the world at 118 per capita per year (Abid *et al.,* 2018). The wheat consumption and production balance have accounted for almost 40 percent of the country's imports from foreign markets. As a result, efforts should focus on rising and improving wheat yields to fill the gap between supply and consumption. (Corwin *et al.,* 1996). The principal objective of this study is to improve bread wheat yield by applying various levels of nitrogen at different stages and to find the optimal fertilizer rate wheat growth and development.

2. Materials and Methods

This preliminary study was planned to check the impact of urea as a convenient source of N having various fertilization rates on the yield of different wheat cultivars under controlled environmental conditions.

2.1. Experimental site

The pot experiment was successful in The Islamia University Bahawalpur Baghdad ul Jadeed Campus Punjab, Pakistan, during the 'Rabi" season of 2021-2022. This research area was at 29°22'38.34" N longitude 71° 46'10.13" E latitude and 387 feet above sea level. Potassium (K) and phosphorus (P) were added in the recommended amounts before seeding as calcium super phosphate (15.0% P_2O_5) at the rate of 100 kg/acre and potassium sulphate (48 % K_2O) at the rate of 50 kg/acre, respectively. Additionally, a recommended pesticide solution was used for the prevention of any pest attack.

2.2. Environmental conditions

The climate of the study site was dessert. According to Koppen and Geiger, this climate was coded as BWH. The average annual temperature was 26.1 C (79.0F), and rainfall was around 223 mm, 8.8 inches per year. The soil was alkaline calcareous according to the physicochemical analysis of dirt from the soil and water testing laboratory for research, RARI (Regional Agriculture Research Institute) Bahawalpur.

2.3. Wheat varieties

Bread wheat varieties "Aas-2002", "GA-2002," and "Ufaq" were used for this study and coded as V_1, V_2, and V_3, respectively. The National Agriculture Research Centre provided these varieties (NARC) in Islamabad, Pakistan.

2.4. Sowing time and method

Fifty-four pots (3 varieties × 6 nitrogen treatments × 3 replications) were filled with 5 kg soil in each and tagged with a permanent marker before sowing. Three wheat seeds were grown in each pot at a depth of two centimeters. On December 14, 2021, wheat varieties were seeded. There were three rows of pots in the selected area. Varieties were arranged vertically, and treatments were placed horizontally. Inter-space between the pots at banks was 5cm, and the space between rows was about 10 cm. Irrigation was carried out with the aid of water bottles.

2.5. Fertilizer application

Treatments consisted of six levels of nitrogen fertilizer 'urea', including one control (0, 250 mg, 375 mg, 500 mg, 562.5 mg, and 687.5 mg/5 kg N). The experiment was arranged in a completely randomized design (CRD) with three replications, following a factorial arrangement of varieties and nitrogen treatments. Urea fertilizer was given after making a solution with one liter of water. These treatments were beneficial at three stages. Therefore, the above N concentrations were divided into three doses. First dose of N was given at tillering stage (0, 125 mg, 187.5 mg, 250 mg, 300 mg and 375 mg/5kg). This dosage was applied on February 3, 2022. The second dose of N was given at the anthesis stage (0, 62.5 mg, 125 mg, 187.5 mg, 200 mg, and 250 mg/5 kg) and applied on 9th March 2022. The third dose of N was given at the filling stage on 24th March 2021. Urea at this stage was 62.5 mg for each pot, not for control plants. According to the given treatment, N quantity of urea was 0, 116.5 mg, 174.75 mg, 233 mg, 262.125 mg, and 320.375 mg/5 kg.

2.6. Crop harvesting and threshing

The harvest was completed on April 21, 2022. Harvesting was done when the grains were dried, and straws became golden-yellow in colour. Separate polythene bags were used to keep each variety and treatment. Three days were spent drying the harvested wheat in the sun. After drying, threshing was carried out manually. The observations were recorded on the following parameters: plant height (cm), spikelets per spike, spike length (cm), tillers per plant, peduncle length (cm), biomass per plant (g), spike weight per plant (g), grains per plant, spikes per plant, and yield per plant (g)

2.7. Procedure for recording observations

A measuring tape was used to measure the plant's height and peduncle length. All the data was recorded before harvesting except biomass, grains per plant, yield per plant, and spike weight per plant. Grain per plant, spikes per plant, tillers, and spikelet per spike were recorded by simply counting them. In contrast, after harvesting, spike weight per plant and biomass were calculated using a digital weighing balance. After threshing, grains per plant and yield per plant were calculated.

2.8. Statistical Analysis

Ten traits of three wheat varieties were observed after the application of six treatments under three replications using a factorial completely randomized design (CRD). Data entry was carried out by using Microsoft Excel (2016). Analysis of variance (ANOVA) was performed for the two-way factorial structure (variety × nitrogen treatment) at a significance level of $p < 0.05$. Means were compared using R 3.5.0 software package.

3. Results

Three varieties and six treatments under RCBD showed promising variation in ten traits. Nitrogen treatments cause significant variation in studied traits exhibited by all three varieties.

3.1. Variation Percentage of Studied Traits

3.1.1. Plant Height

The analysis of variance showed that variety, treatment, and the interaction effect of type and treatment were significant at a 5% probability level on plant height. The overall experimental grand mean was noted at 55.46 cm, having a 19.36% coefficient of variance for PH (Table 1).

3.1.2. Spikelet per Spike

The analysis of variance showed that variety and treatment were significant on spikelets per spike at a 5%

Table 1. Variation percentage due to variety (df=2), treatment (df=5), interaction (df=10), and error (df=54) of studied traits obtained with full two-way factorial (3×6) analysis of variance.

Trait	Variety (V)	Treatment (T)	Interaction (V×T)	Error	Grand Mean (GM)
PH (cm)	20.77***	23.24***	6.29ns	49.70	55.46
SPS	26.81***	10.90*	15.77ns	46.53	17.99
SL (cm)	3.89**	68.60***	12.41***	15.10	11.51
Tillers	4.99***	79.38***	7.44***	8.19	8.50
PL (cm)	23.7***	1.6ns	11.5ns	63.2	7.77
Biomass (g)	14.80***	22.94***	27.78***	34.48	10.56
SWPP (g)	8.11***	77.20***	6.47***	8.22	7.43
GPP	10.41**	15.19*	23.60*	50.80	84.81
SPP	2.38*	78.51***	4.80ns	14.32	7.35
YPP (g)	18.92***	61.19***	2.90ns	16.99	3.91

probability level. In contrast, the interaction effect of type and treatment was non-significant. The coefficient of variance was 12.61%, along with a 17.99 grand mean for SPS (Table 1).

3.1.3. Spike Length

Analysis of variance showed that variety, treatment, and the interaction effect of type and treatment were significant on spike length at a 5% probability level. The overall experimental grand mean was calculated at 11.5 cm. The coefficient of variance for spike length was 7.8% (Table 2).

3.1.4. Tillers

The analysis of variance showed that variety, treatment, and the interaction effect of type and treatment were significant on tillers at 5% probability. Overall, the experimental coefficient of variation was determined to be 6.98% with a grand mean of 8.50, according to tillers (Table 2).

3.1.5. Peduncle Length

The analysis of variance showed that the effect of variety was significant, with a 5% probability. In contrast, the impact of treatment and the interaction of type and treatment was non-significant on peduncle length. Overall, the experimental grand mean was 7.77 cm with a 34.01% coefficient of variance for peduncle length. Based on the analysis of variance, the effect of variety, treatment, and interaction of type and treatment were significant biomass at 5% probability. The overall experimental grand mean was 10.56 g having a 31.9% coefficient of variance for biomass (Table 1).

3.1.6. Spike Weight per Plant

The analysis of variance showed that variety, treatment, and the interaction effect of type and treatment were significant at a 5% probability level on spike weight per plant. The grand mean was noted at 7.43 g, along with a 13.97% coefficient of variance for spike weight per plant (SWPP) (Table 1).

3.1.7. Grains per Plant

The analysis of variance showed that variety, treatment, and the interaction effect of type and treatment were significant on grains per plant at a 5% probability level. The overall grand mean was 84.81, with a 49.85% coefficient of variance for grains per plant (GPP) (Table 1).

3.1.8. Spikes per Plant

Analysis of variance showed that variety and treatment were significant at the 5-probability level. In contrast, the interactive effect was non-significant on spikes per plant. The grand mean was 7.35, and the coefficient of variance (CV) was 10.02% for spike per plant (SPP) (Table 1).

3.1.9. Yield per Plant

The analysis of variance showed that variety and treatment were significant at a 5-probability level. In contrast, the interactive effect was non-significant on yield per plant. The grand mean was recorded at 3.91 g, along with a 24.43% coefficient of variance for yield per plant (YPP) (Table 1).

3.2. Air-Wise Multiple Comparison of Means

3.2.1. Plant Height

According to the results of pair-wise multiple comparisons of means, the highest plant height (62.63 cm) was observed by V_2, and the lowest plant height (47.92 cm) was achieved by V_3, While suitable nitrogen fertilization rate for the highest plant height (64.33cm) was 262.125 mg N, and the lowest mean (44.92 cm) of this trait was observed at control (N_0) (Figure 1).

3.2.2. Spikelet per Spike

The mean comparison results show that maximum spikelet per spike (19.5) were found in V_2 and the lowest mean of spikelet per spike (15.958) was obtained in V_1. While the rate of nitrogen fertilization 320.375 mg N yielded maximum spikelet per spike (19.583) and the lowest mean (16.75) of this trait was evaluated at 116.5 mg nitrogen fertilization rate (Figure 1).

3.2.3. Spike Length

The results of pair-wise multiple comparisons revealed that the highest spike length (11.913 cm) was achieved in V_3, and the lowest mean (10.976 cm) of spike length was obtained in V_1. While appropriate nitrogen fertilization rate for the highest spike length (13.271 cm) was 174.75 mg N and the lowest mean (9.042 cm) of this trait was obtained at control (no fertilization) (Figure 1).

3.2.4. Tillers

According to the results of pair-wise multiple comparisons of means, maximum tillers (8.917) were found in V_3 and V_2 obtained the minimum mean of tillers (7.958). While nitrogen fertilization at the rate of 320.375 mg produced the maximum number of tillers (10.5) and the minimum mean (5.583) of this trait was obtained at no nitrogen fertilization (control) (Figure 1).

3.2.5. Peduncle length

The mean comparison results show that V_2 obtained the highest peduncle length (9.75 cm) and the lowest peduncle length (6.637 cm) was achieved in V_1. In contrast, the suitable nitrogen fertilization rate for the highest peduncle length (8.25 cm) was 174.75 mg N. And lowest peduncle length (7.16 cm) was evaluated at 320.375 mg N fertilization rate (Figure 1).

3.2.6. Biomass

The results of pair-wise multiple comparisons show that

V_1 achieved maximum biomass (12.79 g). V_3 obtained minimum biomass (8.125 g). In contrast, maximum biomass (13.542 g) was evaluated at a nitrogen fertilization rate of 174.75 mg. Minimum biomass (6.5 g) was obtained at no nitrogen fertilization (control) (Figure 1).

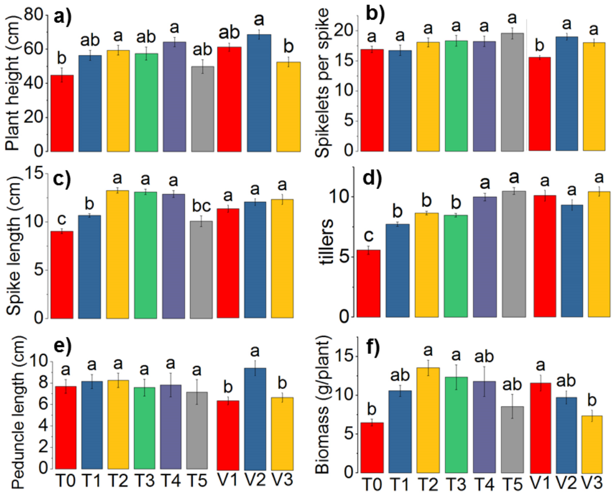

Figure 1. Main effects of nitrogen levels (Factor A) and wheat genotypes (Factor B) on growth traits of bread wheat (Factorial CRD).

3.2.7. Spike weight per plant

According to the mean comparison results, the highest spike weight per plant (8.094 g) was obtained by V_1. And lowest spike weight per plant (6.167 g) was achieved by V_3. In contrast, the suitable nitrogen fertilization rate for the highest spike weight per plant (10.925 g) was 262.125 mg N. And lowest spike weight per plant (3.042 g) was obtained at no fertilization (control) (Figure 2).

3.2.8. Grains per plant

The pair-wise multiple comparisons of mean results show that V_1 obtained maximum grains per plant (105.5). And the minimum grains per plant (64.92) were achieved by V_3. In contrast, entire grains per plant (108.3) were evaluated at a nitrogen fertilization rate of 320.375mg N. And minimum grains per plant (48.42) were obtained at no nitrogen fertilization (Figure 2).

3.2.9. Spikes per plant

According to the results of pair-wise multiple comparisons of means, maximum spikes per plant (7.625) were obtained by V_3. And minimum points per plant (7) were obtained by V_2. In contrast, maximum spikes per plant (9.24) were evaluated at 320.375mg N nitrogen fertilization rate and the minimum points were assessed at no nitrogen fertilization (Figure 2).

3.2.10. Grain Yield per plant

The mean comparison results show that the highest yield per plant (5.025 g) was obtained by V_1. And the lowest yield per plant (2.895 g) was achieved by V_3. In contrast, the suitable nitrogen fertilization rate for the highest yield per plant (5.806 g) was 262.125 mg. and lowest yield per plant was evaluated by no nitrogen fertilization (Figure 2).

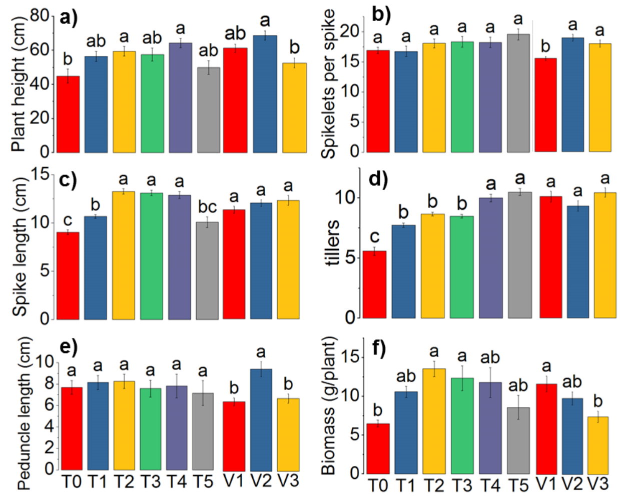

Figure 2. Main effects of nitrogen levels (Factor A) and wheat genotypes (Factor B) on yield traits of bread wheat (Factorial CRD).

4. Discussions

Nitrogen is necessary nutrient in winter wheat required to perform photosynthesis, tillering enhancement and grain protein development. Effective management of nitrogen availability to plant (rate, form, and timing) should be carefully planned to attain goals. Without balanced and adequate supply of nutrients better crop yield cannot be obtained. Maximum crop yield can be obtained by the regulated application of nitrogen because it is the necessary nutrient for crops (Guo *et al.*, 2019). Various studies show that application of nitrogen can enhance crop height (Zhang *et al.*, 2018). Our result for plant height shows that nitrogen (N) fertilizer rates highly significantly ($p<0.05$) affected the PH (Table 2). Increasing nitrogen application increases the protein content of the cells, and as a result, cell size increases. Consequently, the leaf area is enlarged, followed by photosynthetic activity, which ultimately increases PH (Wysocki *et al.,* 2007). The shortest PH (38 cm) was recorded in controlled plants of the variety Ufaq.' Variety 'Aas-2002' gives maximum PH (67 cm) at 262.125mg/5kg. (Table 1). Regulated application of nitrogen can increase the photosynthesis rate as a result more dry matter production and height increment (Liaqut *et al.,* 2003). The number of spikelets per spike showed positive and substantial relation with yield per plant (Table 2). SPS had a significant association with yield, as reported by Ali *et al.,* (2008). Overall, the highest number of spikelets per spike (24) was observed in 'GA-2002' at 320.375 mg/5kg nitrogen application rate.

Contrarily, the lowest number of spikelets per spike (15) was observed at the rate of nitrogen fertilizer application (116.5mg/5kg) by variety 'Aas-2002' (Table 1). These findings were supported by the results of Dogan *et al.,* (2009). Application of nitrogen enhances vegetative growth development by assimilate partitioning towards it (Sun *et al.,* 2019). Overall, the shortest SL (9 cm) was exhibited in unfertilized plants by the variety 'Ufaq' without fertilization. In comparison, the longest SL (15 cm) was also recorded by 'Ufaq' at 262.125mg/5kg rate of N application (Table 1).

One of the yield determining attributes is the production of fertile tillers. Genetic and environmental factors are responsible for tillering potential. More tillers means more spikelets per spike which ultimate resulted in improved production. It is evident from the result that highest tillers was produced by the variety 'Aas-2002' and 'Ufaq,' with maximum nitrogen fertilizer rate (320.375mg/5kg). Higher tillering capacity shown might be due to better cultivar response toward optimum nitrogen fertilization at tillering stage. These results are in line with the findings of Akram *et al.,* (2000) and Liaqat *et al.,* (2003). Similarly significant and positive correlation was found between peduncle length and yield because availability of nutrients during the growth period enhances their functioning and ultimately promote the yield (Abid *et al.,* 2020). Overall, the highest peduncle length (14cm) was attained at the maximum level of fertilizer nitrogen administration (320.375 milligrams per 5 kilograms) by variety 'GA-2002'. On the contrary, the shortest peduncle length (6cm) was recorded by the variety' Aas-2002' at 262.125mg/5kg (Table 1). To moniter the crop growth status and prediction about crop yield, information about crop growth biomass play a key role (Tilly *et al.,* 2015). Above ground mass shown its maximum values with nitrogen application from 'Aas-2002' supplied with N fertilization at 262.125mg/5kg. On the other hand, the lowest total aboveground biomass yield (6g per plant) was obtained from the control plants (Table 1). Spike is also considered as green photosynthesis organ besides leaves which plays an important role in crop yield enhancement (Chen *et al.,* 2019). Highest spike weight per plant is obtained by the application of nitrogen fertilizer as compared with control. Grain weight is correlated with grain yield by determining the rate of grain filling (Liu *et al.,* 2021). It is important to know the physiological changes during the grain filling (Grahmann *et al.,* 2016). A study shows that excessive amounts of nitrogen is used to attain the maximum wheat yield (Lu *et al.,* 2015; Liu *et al.,* 2021). Overall, the lowest number of GPP (40) was recorded by the variety 'Ufaq' without applying N fertilizer. While the highest number of GPP (190) was noted in variety 'GA-2002' at 174.75mg/5kg (Table 1). SPP had a positive correlation with yield per plant (Table 2). Overall, the maximum number of spikes (10) was produced at the highest rate of nitrogen fertilizer (320.375mg/5kg) by both varieties' Aas-2002' and 'Ufaq.' Whereas minimum spikes (4) are observed by 'GA-2002' with no nitrogen application (Table 1). This tendency is consistent with the findings of previous studies by Ahmad *et al.,* (2022). It is proved that if there is more absorption of nitrogen by the plants results in more number of spikes and improved vegetative growth (Nourmohammadi *et al.,* 2010). Maximum grain yield in crop production is the ultimate goal and wheat grain yield was found to be positive link with proper nitrogen application rate (Hawkesford *et al.,* 2014). In the present study, yield per plant ranged from 1g to 8g with different applications of N. Overall, the highest YPP (8g) was obtained in response to the N fertilization application of 262.125mg/5kg by the 'Aas-2002'. These results are in accordance with the following researchers (Gupta *et al.,* 2022; Ghafoor *et al.,* 2021). A combined analysis of variance revealed that bread wheat yield per plant was subjective to the major influences of N fertilizer levels. YPP showed a highly significant positive correlation with the number of spikes per plant (Table 2). Analogous outcomes were found by Okuyama *et al.,* (2004). The present study shows that wheat yield increases by incrementing plant height, spike length, biomass, and grains per plant by applying N at different stages. The higher N levels resulted in higher effective tillers, higher grain weight and higher number of grains and eventually significantly higher grain yield. At the end it was concluded that appropriate nutrient management shows better results for crop improvement than without application. Application of fertilizers at an appropriate level enhances the microbial activity in the soil as a result soil fertility level enhanced and more crop yield resulted (Xin *et al.*, 2017).

5. Conclusion and Policy Recommendations

The outcomes of this research showed that N fertilizer considerably boosted the yield and yield component of bread wheat compared to the control. The N dose of 262.125mg/5kg effectively promoted the grain yield of 'Aas-2002' and 'Ufaq,' while the result of 'GA-2002' was highest at the rate of 320.125mg/5kg. Cantered upon the agronomic traits, 262.125mg/5kg N for 'Aas-2002' and 'Ufaq' and 320.125mg/5kg N for 'GA-2002' was satisfactory to accomplish the highest yield. Consequently, this research considerably pinpoints altered N levels' influence on Pakistan's bread wheat. In addition, these N doses could meritoriously increase the grain yield of bread wheat.

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8. Conflict of Interest

The authors declared no potential conflicts of interest w.r.t this article's research, authorship, and publication.

9. Authors' Contribution

Ayesha Akbar: Field work and data collection, Muhammad Jamil: Planned experiment, incorporation of intellectual content and data analysis, Shazia Parveen: Manuscript write-up, Muhammad Shoaib Shaukat and Muhammad Imran Tipu: Field work and critical revision.

10. SDGs Addressed

This study contributes to SDG 2 (Zero Hunger) by improving wheat yield through optimized nitrogen use, supports SDG 12 (Responsible Consumption and Production) by promoting efficient fertilizer management, and aligns with SDG 13 (Climate Action) by reducing potential nitrogen losses and emissions.

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