Indus Journal of Agriculture and Biology (IJAB)

Volume 3, Number 1, 2024, Pages 30 – 35

Journal Home Page

https://journals.airsd.org/index.php/ijab

The Role of Nitrogen Fertilization in Improving Wheat Crop Yields

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ARTICLE INFO

Article History:

Received:	April	25, 2024
Revised:	May	10,2024
Accepted:	May	25,2024
Available Online:	June	30,2024

Keywords:

Wheat genotypes, Fertilization rates, Nitrogen efficiency, Grain quality, Yield components, Sustainable agriculture

ABSTRACT

A field study was conducted during the 2021-22 growing season to evaluate the effects of different nitrogen levels (0, 40, 80, and 120 kg N ha⁻¹) on the performance of two wheat genotypes, Galaxyand AZRC-Dera. The study meticulously gathered detailed data on various growth and yield parameters, which were then rigorously analyzed. The findings revealed that AZRC-Dera consistently outperformed Galaxyacross several key metrics. Throughout the crop growth cycle, AZRC-Dera produced notably taller plants, a trend that was significantly enhanced by incremental nitrogen application. The application of nitrogen at 120 kg ha⁻¹ was particularly effective, resulting in substantial increases in both the number of tillers and fertile tillers per plant in AZRC-Dera. Furthermore, the grain yield of AZRC-Dera was markedly higher compared to Galaxy, underscoring the genotype's superior responsiveness to nitrogen fertilization. The study conclusively demonstrated that each incremental addition of nitrogen fertilizer had a positive impact on the growth and productivity of the wheat cultivars under investigation. AZRC-Dera, in particular, exhibited notable superiority in several growth and yield parameters, making it a promising candidate for achieving higher wheat productivity through optimized nitrogen management. The research highlights the critical role of nitrogen fertilization in enhancing wheat growth and yield, with AZRC-Dera showing significant advantages in terms of plant height, tiller production, and grain yield. These findings provide valuable insights for agronomic practices aimed at maximizing wheat productivity.

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is a crucial global cereal crop, ranking third in significance after maize and rice, and contributes approximately 30% to the world's total cereal production, highlighting its essential role in global food security [1]. In Pakistan, wheat is a staple food, occupying about 37% of the total cultivated land area and significantly contributing to agriculture with nearly a 14% share. Despite its importance, there is a notable yield gap, particularly evident during the 2022-23 period when wheat was cultivated on 11 million hectares, yielding 26.767 million tons [2]. Bridging this yield gap is crucial for enhancing productivity per unit area.

Intensive agriculture and the introduction of new, more productive wheat genotypes have led to significant nitrogen depletion in the soil. However, crops show a positive response to added nitrogen, underscoring its critical role [3]. Nitrogen is vital for plant metabolism, particularly in protein synthesis and chlorophyll production. Adequate nitrogen supply boosts photosynthetic activity, promotes strong vegetative growth, and imparts a deep green color, influencing carbohydrate utilization.

Recent studies highlight the benefits of nitrogen application at specific growth stages for cereals such as maize, wheat, sorghum, and barley. Fertilization with nitrogen, especially after silking or grain filling, is crucial for maximizing grain yields [4]. High-yielding varieties generally exhibit increased yield components with elevated nitrogen levels [5]. Therefore, the judicious use of nitrogenous fertilizers is essential for achieving farm profitability while minimizing environmental pollution.

This study aims to address the discrepancy between the beneficial effects of fertilizer usage on wheat and the variable responses of different wheat types to fertilizers. Conducted in the agro-ecological settings of DI Khan, the primary objective is to determine the optimal nitrogen fertilizer dosage for wheat growth under these specific conditions. By exploring the intricate relationship between nitrogen, wheat cultivars, and agro-ecological dynamics, this study seeks to provide insights that enhance wheat productivity and promote sustainable agricultural resource management. The subsequent sections will detail the methodology, results, and discussions to unravel the complexities of nitrogen application in optimizing wheat yield in the unique context of DI Khan.

MATERIALS AND METHODS

Experimental Setup

This investigation was conducted at the Research Area of the Arid Zone Research Center, DI Khan, aiming to examine the impact of varying nitrogen levels (0, 40, 80, and 120 kg ha^{-1}) on two wheat genotypes: Galaxyand AZRC-Dera. The soil in the experimental field was well-prepared, featuring 0.45% organic matter (OM), 0.029% nitrogen, 9 ppm available phosphorus, and 120 ppm exchangeable potassium, creating a conducive environment for wheat growth.

The experimental design followed a Randomized Complete Block (RCB) Design with a factorial arrangement and four replications. Each treatment was assigned to plots measuring 1.4 m by 4 m. Sowing was carried out using single-row hand drills, with a row spacing of 30 cm. A basal application of 60 kg ha^{-1} P_2O_5 and 50 kg ha^{-1} K_2O, along with one-third of the nitrogen dose, was done at sowing. The remaining nitrogen was split into two equal parts: one-third was applied at the first irrigation, and the rest at the second irrigation. This method ensured a steady supply of nitrogen throughout the critical growth stages of the wheat plants.

Data Collection and Analysis

Comprehensive data were meticulously recorded for various parameters, including the number of plants, tillers, fertile tillers per unit area, straw yield, and grain yield per hectare. The statistical analysis was performed using the "Statistix 8.1" software. Differences among treatment means were evaluated using the Least Significant Difference (LSD) test at a 5% probability level, following the methodology outlined by Lee *et al*. [6].

Soil Preparation

The soil preparation involved several steps to ensure optimal growing conditions. Initially, the field was plowed to a depth of 15-20 cm, followed by harrowing to break down soil clumps. The final step was leveling to ensure uniformity across the experimental plots.

Sowing Procedure

The sowing was performed using a precise single-row hand drill method to maintain consistent row spacing. The seeding rate was adjusted to ensure optimal plant density, enhancing the reliability of the growth and yield measurements.

Nutrient Management

The application of a basal dose of phosphorus (P_2O_5) and potassium (K_2O) was done to meet the initial nutrient requirements of the wheat plants. The nitrogen application strategy, divided into three stages, aimed to match the nitrogen availability with the plant's growth stages, maximizing nutrient uptake efficiency and promoting healthy development.

Irrigation Management

Irrigation scheduling was based on the critical growth stages of wheat, ensuring adequate moisture availability. The timing and quantity of water applied were carefully monitored to avoid water stress and ensure uniform growth across all plots.

Pest and Weed Control

Integrated pest management practices were employed to control pests and diseases. Regular monitoring was conducted to identify and manage pest infestations promptly. Weed control was achieved through a combination of mechanical weeding and the application of pre-emergence herbicides.

Statistical Analysis

The experimental data were analyzed using the "Statistix 8.1" software. Analysis of variance (ANOVA) was conducted to determine the significance of the treatments. The LSD test at a 5% probability level was used to compare the means of different treatments. This rigorous statistical approach ensured that the observed differences in growth and yield parameters were attributable to the varying nitrogen levels and not to random variation.

RESULTS AND DISCUSSION

The primary objective of this study is to maximize wheat yields through genomic and ecological manipulations. Germination, a critical indicator of plant growth, plays a pivotal role in achieving this goal. This study focuses on the wheat cultivars Galaxy and AZRC-Dera, evaluating their response to different nitrogen levels.

Germination and Stand Establishment

Cultivar AZRC-Dera exhibited significantly higher germination rates throughout the crop growth period, underscoring its genetic superiority. The observed differences in sprouting counts among the cultivars can be attributed to heritable variations. These findings are consistent with Ju *et al*. [7], who highlighted the differential response of wheat varieties to nitrogen levels. Notably, nitrogen application at rates of 40, 80 and 120 kg ha^{-1} resulted in significantly more plants compared to the zero nitrogen treatment. The highest nitrogen rate (120 kg ha^{-1}) consistently produced the greatest number of plants, indicating the positive impact of nitrogen on germination and early crop establishment.

Table 1. *Quantity of plants m^{-2} as influenced by the fertilization of N at various dates*

Treatments	**December 20**		**January 30**		**April 05**	
N application Kg ha^{-1}	**Galaxy**	**AZRC-Dera**	**Galaxy**	**AZRC-Dera**	**Galaxy**	**AZRC-Dera**
0	129.4 e	142.4 d	143.4 f	157.1 f	166.2 d	168.4 d
40	175.3 bc	181.4 b	178.9 e	194.3 d	265.1 b	271.3 b
80	166.5 c	155.3 c	231.3 c	249.7 b	248.3 c	291.0 a
120	194.1 a	204.2 a	256.1 b	274.2 a	257.1 bc	305.9 a
LSD	13.94		13.98		15.11	

Tiller Production and Fertile Tillers

Tiller production, a key determinant of stand density, is influenced by both genetic factors and external environmental conditions. Cultivar AZRC-Dera demonstrated a superior ability to produce tillers throughout the crop growth period compared to Galaxy ($P < 0.01$). Nitrogen application significantly influenced tiller production, with higher rates resulting in an increased number of tillers. The nitrogen rate of 120 kg ha^{-1} resulted in the highest tiller count, further supporting the positive correlation between nitrogen application and tiller development [8,9]. Fertile tillers, which are crucial for grain yield, were significantly more abundant in AZRC-Dera than in Galaxy ($P < 0.01$). Nitrogen application, particularly at rates of 40, 80 and 120 kg ha^{-1}, significantly increased the number of fertile tillers. The highest nitrogen rate (120 kg ha^{-1}) resulted in the maximum number of fertile tillers, indicating a positive impact on reproductive potential.

Table 2. *Number of tillers and fertile tillers m^{-2} as influenced by the application of nitrogen at various rates*

Treatments	**No. of Tillers (m^{-2})**		**No. of Fertile Tillers (m^{-2})**	
N application (Kg ha^{-1})	**Galaxy**	**AZRC-Dera**	**Galaxy**	**AZRC-Dera**
0	208.3 f	209.6 f	169.2 g	189.5 f
40	279.6 e	342.9 d	274.1 e	338.0 d
80	371.7 c	416.2 b	352.9 c	411.8 b
120	461.4 a	481.1 a	482.6 a	489.4 a
LSD	23.42		18.72	

Grain Yield and Straw Yield

The ultimate goal in crop production is to maximize profitable yield. Cultivar AZRC-Dera achieved significantly higher grain yields (4.64 tons ha^{-1}) compared to Galaxy ($P < 0.01$). Nitrogen application at rates of 40, 80 and 120 kg ha^{-1} significantly increased grain yields, with the highest nitrogen rate producing the maximum grain yield (4.64 tons ha^{-1}). This aligns with previous research that highlights the positive influence of nitrogen on wheat growth and development [10,11]. Furthermore, cultivar AZRC-Dera exhibited a significantly higher straw yield (9.32 tons ha^{-1}) compared to Galaxy ($p < 0.01$). Nitrogen application, particularly at rates of 40, 80 and 120 kg ha^{-1}, significantly increased straw yields. The highest nitrogen rate (120 kg ha^{-1}) resulted in the maximum straw yield (9.32 tons ha^{-1}). This suggests that nitrogen use boosts vegetative growth, delays senescence, and increases overall biological yield.

Table 3. *Grain and Straw yields as influenced by application of nitrogen at various rates*

Treatments	**Grain Yield (Tons ha^{-1})**		**Straw Yield (Tons ha^{-1})**	
N application (Kg ha^{-1})	**Galaxy**	**AZRC-Dera**	**Galaxy**	**AZRC-Dera**
0	2.69 e	2.71 e	7.12 e	7.56 d
40	3.25 d	3.69 c	7.61 d	8.13 c
80	4.23 b	4.31 b	8.15 c	8.78 b
120	4.24 b	4.64 a	8.51 bc	9.32 a
LSD	0.31		0.37	

CONCLUSION

The importance of nitrogen fertilization in maximizing the growth and yield of the wheat cultivars Galaxy and AZRC-Dera is highlighted by this study. Comparing cultivar AZRC-Dera to Galaxy, the latter consistently performed lesser across important growth characteristics including as germination rate, tiller production, fertile tillers, grain yield, and straw yield. The highest increases in plant growth and production were obtained from the administration of nitrogen, namely at a rate of 120 kg ha^{-1}. These findings demonstrate how managing nitrogen levels and genetic potential work together to increase wheat yields. The study offers insightful advice for maximizing wheat yield, highlighting the necessity of cultivar selection and targeted nitrogen administration for long-term agricultural success.

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