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Evaluation of the Effect of Urea Fertilizer on Wheat Growth and Yield under Saline Soil Conditions

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ABSTRACT

Wheat (*Triticum aestivum* L.) is a staple food crop in Afghanistan, but its production is severely affected by soil salinity, especially in arid and semi-arid regions. This study aimed to evaluate the effect of different levels of urea fertilizer on wheat growth and yield under saline soil conditions in Balkh Province. The experiment was conducted in 2023 –2024 at the research farm of the Faculty of Agriculture, Balkh University, using a Randomized Complete Block Design (RCBD) with four replications and six treatments (0, 50, 100, 150, 200, and 250 kg/ha of urea). Standard soil analysis was conducted before planting, and irrigation was applied in five stages during the growing period. Growth parameters, including days to heading, plant height, spike height, tiller number per plant, 1000-grain weight, and grain yield, were recorded. Results revealed that urea application significantly improved most growth and yield attributes. The highest grain yield (2316.8 kg/ha) was obtained with 250 kg/ha (T1),

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followed by 200 kg/ha (T2); both treatments significantly outperformed as compared with the control. Plant height, spike height, and number of tillers also increased with higher urea levels. Statistical analysis demonstrated significant differences at 5% levels among treatments. The study concludes that moderate to high levels of urea (200–250 kg/ha) can enhance wheat performance under saline conditions, improving both vegetative growth and final grain yield of wheat. These findings support targeted nitrogen management to increase productivity in salt-affected soils.

Keywords: Growth, Salinity, Urea, Wheat, Yield.

1. INTRODUCTION

اَلْحَمْدُ لِلّٰهِ رَبِّ العَالَمِينَ وَالصَّلَاةُ وَالسَّلَامُ عَلى سَيِدِالْمُرْسَلِينَ وَعَلَى اٰلِهِ وَصَحْبِهِ اَجْمَعِينَ.

Wheat (*Triticum aestivum* L.) is a principal cereal crop in Afghanistan, cultivated by thousands of farmers, particularly in northern provinces like Balkh, where it plays a vital role in food security and rural income (FAO, 2021). However, productivity has been severely constrained by increasing soil salinity due to poor irrigation practices, high evapotranspiration, and inadequate drainage (Shahid *et al*., 2018). Salinity negatively impacts plant growth, nutrient uptake, and grain yield of wheat, with nitrogen availability being particularly sensitive under salt stress conditions (Munns & Tester, 2008). Urea is the most commonly used nitrogen fertilizer in Afghanistan; however, its efficiency in saline soils is inconsistent, often resulting in economic losses and reduced crop performance (Alam *et al.*, 2013).

Previous research in other regions has shown that adjusting nitrogen levels can improve plant tolerance to salinity and enhance grain yield (Ali *et al.*, 2019; Abdulghafar *et al*., 2020). However, there is a lack of localized studies evaluating optimal urea application rates under saline conditions in Afghanistan. This research addresses that gap by testing six levels of urea in a saline field environment in Balkh Province during the 2023–2024 growing season. The aim is to determine the most effective nitrogen level for maximizing wheat productivity under salt stress, providing evidence-based recommendations for Afghan farmers. Soil salinity is a growing concern in agricultural areas, particularly in arid and semi-arid regions, including large parts of northern Afghanistan. It affects over 20% of the world’s irrigated lands and continues to expand due to climate change and poor land management (Rengasamy, 2010). In saline soils, excessive sodium ions interfere with plant water uptake, disrupt ionic balance, and cause nutrient deficiencies, particularly nitrogen

(Grattan & Grieve, 1999). Wheat, being moderately salt-sensitive, shows reduced tillering, plant height, spike formation, and grain filling under such stress (Zhu *et al.*, 2025).

Nitrogen, especially in the form of urea, is essential for protein synthesis and vegetative growth. However, salinity alters nitrogen metabolism in plants, reduces microbial nitrification, and can lead to losses through volatilization and leaching (Li *et al.*, 2011). Studies have shown that proper nitrogen management can alleviate salinity stress to a certain extent. For example, Ashraf *et al*., (2018) reported that wheat yield improved significantly with 150–200 kg/ha of urea under moderate salinity in Pakistan. Similarly, Zörb *et al*., (2019) demonstrated that nitrogen improves osmotic adjustment and photosynthesis under salt stress.

Despite this, most of these studies are region-specific and may not apply to Afghanistan's unique agro-ecological and socio-economic conditions. Thus, localized research is crucial for optimizing nitrogen fertilization strategies for wheat grown in the saline soils of Balkh. This study aims to provide such targeted insight.

Given the urgent need to enhance wheat productivity in salt-affected areas of Afghanistan, this study was designed to investigate the effect of different urea fertilizer levels on the growth and yield of wheat under saline soil conditions in Balkh Province. The primary objective is to identify the optimal rate of nitrogen application (via urea) that maximizes crop performance while remaining economically viable and environmentally sustainable. The significance of this research lies in its potential to offer practical, localized fertilization recommendations for farmers dealing with saline soils, an increasingly common problem due to over-irrigation, poor drainage, and rising groundwater salinity. By analyzing key agronomic traits such as plant height, number of tillers, spike height, 1000 grain weight, and overall yield under varying urea treatments, the study seeks to clarify how nitrogen availability interacts with salinity stress.

The research is guided by the central question: How does the application of different levels of urea fertilizer affect wheat growth and yield under saline soil conditions in Balkh Province It is hypothesized that moderate to high urea application (150–250 kg/ha) will significantly enhance plant development and grain yield compared to lower levels or no fertilizer, even in saline environments. To test this, a field experiment was conducted at the research farm of the Faculty of Agriculture, Balkh University, during the 2023–2024 growing season, using a Randomized Complete Block Design (RCBD) with four replications and six treatments

(0, 50, 100, 150, 200, and 250 kg/ha of urea). Key agronomic parameters such as plant height, spike length, number of tillers, 1000-grain weight, and final yield were measured.

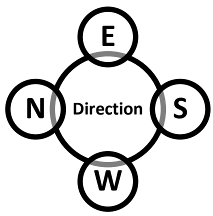
Background literature highlights the complexity of plant nutrient uptake under salinity stress, as excessive salt can inhibit nitrogen assimilation and reduce fertilizer use efficiency (Khan *et al.*, 2021; Shrivastava & Kumar, 2015). By building on such studies, this research addresses the local knowledge gap regarding effective nitrogen management in Afghanistan's saline soils and contributes to improving wheat productivity in marginal lands.

2. MATERIALS AND METHODS

2.1. Research Design

The study employed an experimental research design to evaluate the effects of different urea fertilizer levels on wheat growth and yield under saline soil conditions. This design was chosen because it allows for the controlled manipulation of the independent variable (urea fertilizer levels) to directly observe its impact on dependent variables such as growth parameters and yield, providing reliable cause-and-effect conclusions. The sample size consisted of 24 experimental plots, each measuring 7.85 m², laid out over a total area of 300 m² at the research farm of the Faculty of Agriculture, Balkh University. The experiment was arranged in a Randomized Complete Block Design (RCBD) with six treatments (urea levels: 0, 50, 100, 150, 200, and 250 kg/ha) and four replications per treatment.

The independent variable in this experiment was the amount of urea fertilizer applied, with six treatment levels: 0 (control), 50, 100, 150, 200, and 250 kg per hectare. The dependent variables included wheat growth parameters such as days to heading, plant height, spike height, number of tillers per plant, 1000-grain weight, and final grain yield per hectare. Controlled variables were soil type, salinity level, irrigation timing and method, wheat variety, and environmental conditions to minimize external influences. The urea fertilizer levels were manipulated by applying specified doses divided into three stages: at sowing, tillering, and heading. This systematic manipulation ensured consistent treatment across experimental plots. The experiment was laid out as a Randomized Complete Block Design (RCBD) with four replications to control for spatial variability in the field. This design allowed for random allocation of treatments to plots within each block, ensuring unbiased comparison between treatment effects.

<table>
<tr><th colspan="7">Experimental Research Layout</th><th>Reps</th></tr>
<tr><td rowspan="4"></td><td>T2</td><td>T4</td><td>T6</td><td>T3</td><td>T1</td><td>T5</td><td>R4</td></tr>
<tr><td>T3</td><td>T2</td><td>T5</td><td>T4</td><td>T6</td><td>T1</td><td>R3</td></tr>
<tr><td>T2</td><td>T5</td><td>T6</td><td>T3</td><td>T4</td><td>T1</td><td>R2</td></tr>
<tr><td>T3</td><td>T5</td><td>T6</td><td>T2</td><td>T1</td><td>T4</td><td>R1</td></tr>
</table>

Fegure 1: Shows the research layout, which has 6 treatments and 4 replications.

2.2. Population and Sample

The research was conducted on wheat (*Triticum aestivum*. L) Plants, specifically a local variety known as Mawri, widely cultivated in Balkh Province, Afghanistan. Since the study is agronomic in nature and the participants refer to experimental plots and biological samples of the wheat crop. Soil samples were also randomly collected from the study site before planting to analyze initial soil conditions, including salinity levels, pH, texture, and nutrient content. The sampling method used was random sampling to ensure representativeness of the experimental area and reduce spatial bias.

2.3. Procedure and Data Collection:

In this agronomic field experiment, the data collection relied on standard agronomic measurement tools and laboratory instruments rather than surveys or questionnaires. The following instruments and procedures were used to collect quantitative data on soil properties and wheat performance indicators:

1. Soil Analysis Instruments & Results

- PH Meter: To determine the soil's acidity/alkalinity.
- Electrical Conductivity (EC) Meter: For measuring soil salinity levels.
- Spectrophotometer & Flame Photometer: Used for nutrient analysis, including nitrogen (N), phosphorus (P), potassium (K), sulfur (S), and calcium carbonate ($CaCO_3$).
- Soil Texture Analysis (Hydrometer method): To classify soil texture.
- The collected soil sample from the experimental site showed a slightly alkaline pH of 8.08 and electrical conductivity (EC) of 1.34 dS/m, indicating moderate salinity. The irrigation water used had an

EC of 3.56 dS/m, which may negatively affect plant growth under saline conditions. The organic matter content was low (0.9%), reflecting poor soil fertility. The soil was classified as silt in texture.

- **Soil nutrients:**
  - Calcium carbonate ($CaCO_3$): 13.63% (relatively high)
  - Available nitrogen (N): 17.6 ppm
  - Available phosphorus (P): 47.4 ppm (good level)
  - Available potassium (K): 146 ppm (adequate)

These characteristics suggest that the soil provides moderately favorable to weak conditions for wheat cultivation under salinity stress. Thus, nitrogen application (urea) can play a significant role in improving plant growth and yield in such conditions.

2. Data Measurement Tools

- Meter Scale & Measuring Tape: For determining plant height and spike height (in cm).
- Manual Counting: For the number of tillers per plant (randomly sampling five sub-sections per plot).
- Precision Weighing Scale: For measuring 1000-grain weight (in grams) and grain yield (kg/ha).
- Hand Tools: Marker, hoe, and sickle for planting and harvesting operations.

3. Scoring and Data Recording

- Observations were recorded manually in pre-designed data collection sheets.
- Each trait (e.g., plant height, number of tillers, yield) was averaged across replicates and subjected to statistical analysis.

2.4. Procedure and Data Collection

The experiment was conducted in the 2023–2024 cropping season at the research farm of the Faculty of Agriculture, Balkh University, using a Randomized Complete Block Design (RCBD) with six urea fertilizer levels (0–250 kg/ha) and four replications. Before sowing, composite soil samples were collected randomly and analyzed in the soil laboratory to assess texture, pH, EC, and major nutrients using standard methods. The field was divided into 24 plots (7.85 m^2 each), and wheat was manually sown in rows 15 cm apart at a depth of 3 cm using the local Mawri variety. Urea was applied in three splits: at sowing, tillering, and heading stages. Surface irrigation was carried out at five critical growth stages. Weed control was done manually throughout the season.

Data collection included tiller number, plant height, spike height, days to heading, 1000-grain weight, and grain yield. All measurements were taken from five randomly selected samples per plot. Grain yield was calculated per hectare, and 1000-grain weight was determined by doubling the weight of 500 counted seeds.

Figure 1: Shows 24 plots of the experiment at the agricultural research farm of Balkh University.

2.5. Data Analysis Methods

The collected agronomic data were statistically analyzed using the Analysis of Variance (ANOVA) method based on the principles described by Sundaraj *et al.*, (1972). This approach was used to evaluate the effects of different levels of urea fertilizer on the growth and yield characteristics of wheat. The ANOVA test helped determine the significance of treatment differences within the Randomized Complete Block Design (RCBD) framework. When significant differences were observed, mean comparisons were conducted using Least Significant Difference (LSD) at the 5% level of significance to assess treatment effects more precisely.

3. RESULTS

The application of different urea fertilizer levels had a significant effect on most wheat growth and yield parameters under saline soil conditions. According to the ANOVA results, statistically significant differences at both the 1% and 5% levels were observed among treatments for days to heading, plant height, spike height, tiller number per m^2, 1000-grain weight, and grain yield.

The highest grain yield (2316.8 kg/ha) was recorded in the T1 treatment (250 kg/ha urea), followed closely by T2 (200 kg/ha) with 2309.8 kg/ha,

both significantly outperforming the control (T6 = 2085.0 kg/ha). Plant height and spike height were also highest in T1 (60.2 cm and 5.59 cm, respectively), showing the positive correlation between nitrogen availability and vegetative growth. The number of tillers/plant was greatest in T1 (5.3) and T2 (5.0), while the control showed the lowest tillering (3.8).
The LSD and CV values confirm acceptable variability and reliability across the replications. Treatments T1 and T2 demonstrated superior performance across most parameters, indicating that urea application at 200–250 kg/ha is optimal for wheat production under saline conditions.

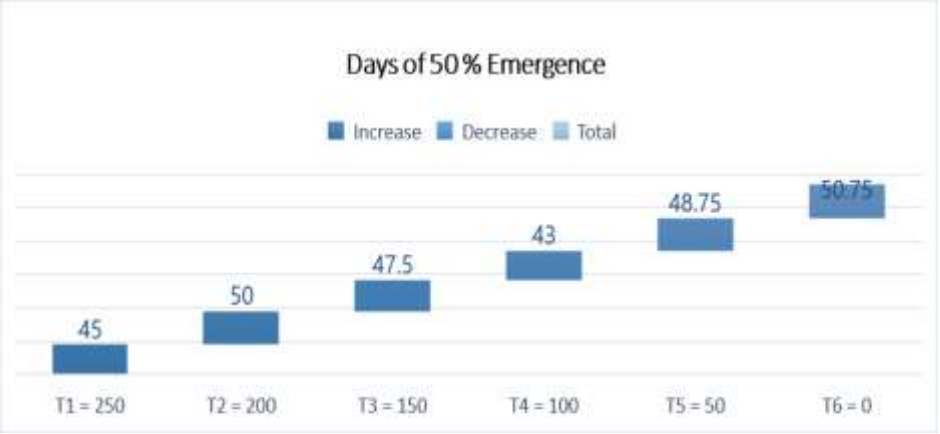
Table 2: Shows the general results of parameters under different levels of urea.

Treatments	*Days of 50% Germenation*	*plant % stand*	*Days to heading*	*Plant height (cm)*	*Spike height (cm)*	*No. of tillers/plant*	*۱۰۰۰ Grain weight(gr)*	*Yield kg/ha*
T1 = 250	45	84.58	145.5	60.2	5.59	5.3	40.8	2316.8
T2 = 200	50	77.36	146.25	57.25	5.35	5.0	39. 5	2309.8
T3 = 150	47.5	81.32	145.50	55.75	5.62	4.8	39.3	2300
T4 = 100	43	81.52	150.25	52.25	4.92	4.0	39.0	2287.5
T5 = 50	48.75	79.73	149.5	53	5.17	4.3	39.5	2237.5
T6 = 0	50.75	78.61	151.25	49	4.85	3.8	38.8	2085
FC	3.31 *	1.55 ns	5.80 *	5.84 *	3.86 *	3.71*	4.02*	13.014 *
FT 5%	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
LSD	2.48	6.15	1.62	2.48	0.32	0.31	1.173	54.309
CV %	6.94	5.07	1.45	6.032	8.07	13.66	2.853	10.119

Days of 50% Emergence

According to the statistical analysis, the influence of different levels of urea fertilizer on the number of days to 50% emergence was found to be significant at the 5% probability level. The application of urea notably affected the germination period of wheat under saline soil conditions. Specifically, increasing the levels of urea fertilizer led to a reduction in the number of days required to reach 50% emergence.
The most favorable result was recorded in Treatment T1 (250 kg/ha urea), where 50% emergence was achieved in 45 days, indicating accelerated germination. Conversely, the control treatment T6 (0 kg/ha urea) showed delayed germination, with 50% emergence occurring after an average of 50.75 days. These findings suggest that the application of higher urea

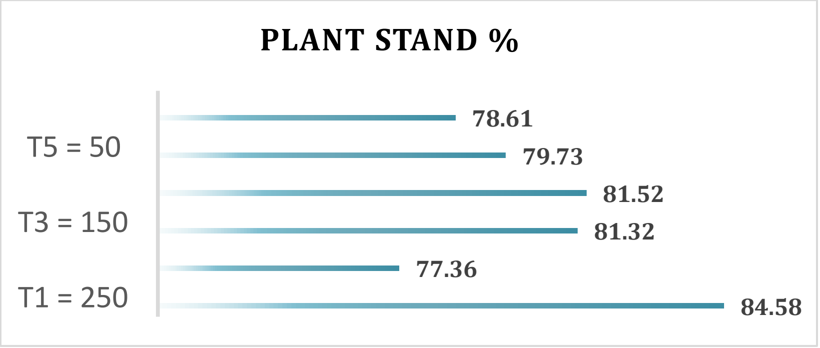
levels can significantly enhance the speed of germination in wheat grown under salinity stress.



Graph 1: Shows the days of 50% emergence in different levels of urea.

Plant Stand %

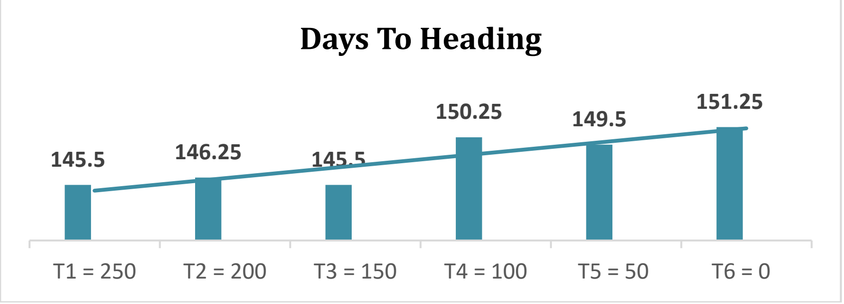
The application of different levels of urea fertilizer influenced the plant stand percentage of wheat. The highest stand percentage was recorded in Treatment T1 (250 kg/ha) with 84.58%, indicating improved seedling establishment. This was followed by T4 (100 kg/ha) with 81.52%, T3 (150 kg/ha) with 81.32%, T5 (50 kg/ha) with 79.73%, T6 (control) with 78.61%, and T2 (200 kg/ha) with the lowest value of 77.36% among the treatments with fertilizer. However, according to the analysis of variance (ANOVA), the differences among treatments for stand percentage were not statistically significant at the 5% probability level, suggesting that urea levels did not have a strong or consistent effect on this particular trait under the experimental conditions.



Graph 2: Shows plant stand % in different levels of urea.

Days to Heading

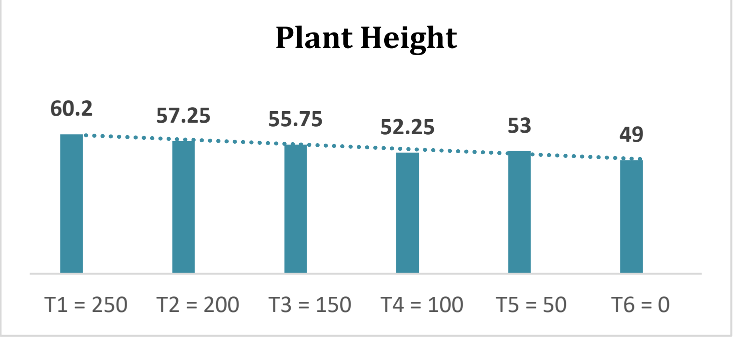
The application of different urea fertilizer levels showed varied effects on days to heading. Higher urea rates accelerated spike emergence. T1 (250 kg/ha) showed the earliest heading at an average of 145.5 days, while T4 (100 kg/ha) and T6 (control) had the latest heading at 150.25 and 151.25 days, respectively. ANOVA results indicated that these differences were statistically significant at the 5% level, confirming the effect of urea on heading time.



Graph 3: Shows days to heading in different levels of urea.

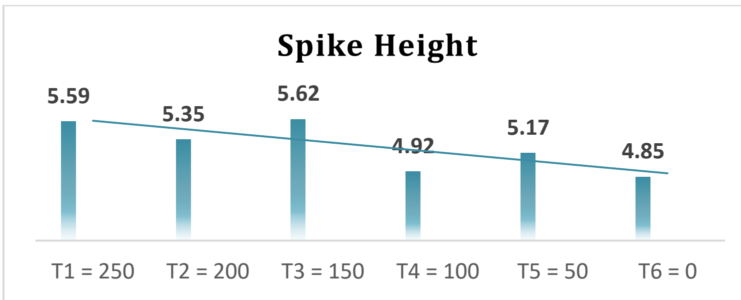
Plant Height

Increasing the levels of urea fertilizer led to an improvement in plant height. The tallest plants were recorded in T1 (250 kg/ha) with an average height of 60.2 cm, followed by T2 (57.25 cm), T3 (55.75 cm), T5 (53 cm), T4 (52.25 cm), and the shortest in T6 (control) with 49 cm. Statistical analysis showed that the differences in plant height among treatments were significant at the 5% level, indicating that urea positively influenced vegetative growth.



Graph 4: Shows plant height in different levels of urea**Spike Height**

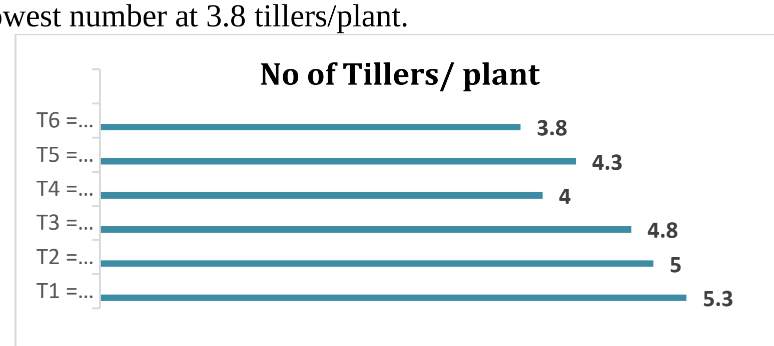
Different levels of urea fertilizer had notable effects on spike height. As the amount of urea increased, spike length also improved. The highest spike height was observed in T1 (250 kg/ha) with an average of 5.59 cm, followed by other treatments, while the lowest values were recorded in T4 (100 kg/ha) at 4.92 cm and T6 (control) at 4.85 cm. Statistical analysis confirmed that the differences in spike height among treatments were significant at the 5% level, indicating a positive correlation between urea application and spike development.



Graph 5: Shows spike height in different levels of urea.

No. of Tillers/plant

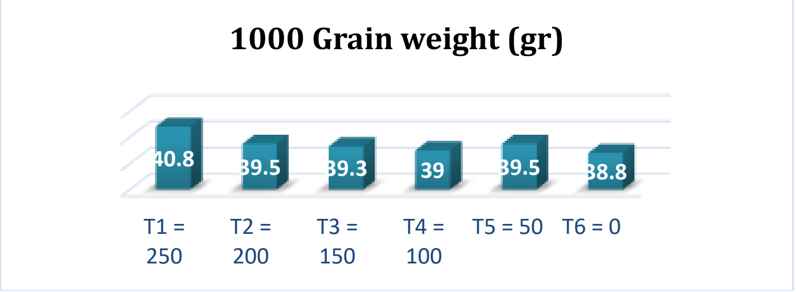
According to the results of the analysis of variance, the effects of different urea fertilizer levels on the number of tillers per plant were statistically significant at the 5% level. The treatment with 250 kg/ha urea (T1) produced the highest number of tillers, with an average of 5.3 tillers/plant. This was followed by T2 (200 kg/ha) with 5.0 tillers/plant, T3 (150 kg/ha) with 4.8 tillers/plant, T5 (50 kg/ha) with 4.3 tillers/plant, T4 (100 kg/ha) with 4.0 tillers/plant, and the control treatment T6 (0 kg/ha), which had the lowest number at 3.8 tillers/plant.



Graph 6: Shows no of tillers/plant in different levels of urea.

1000 Grain Weight

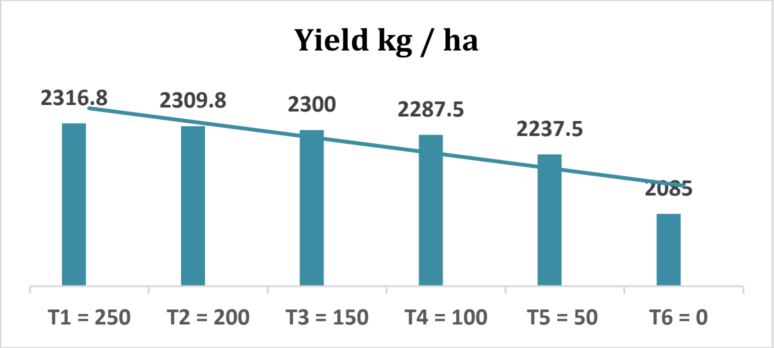
The mean comparison results showed that the highest 1000-grain weight was recorded in treatments T1 (250 kg/ha) and T2 (200 kg/ha), with average weights of 40.8 g and 39.5 g, respectively. Additionally, T5 (50 kg/ha) also showed a positive effect, recording an average weight of 39.5 g. Treatments T3 (150 kg/ha) and T4 (100 kg/ha) followed with 39.3 g and 39.0 g, respectively, while the control treatment T6 (0 kg/ha) had the lowest 1000-grain weight at 38.8 g. According to the analysis of variance, the differences in 1000-grain weight among the treatments were statistically significant at the 5% level.



Graph 7: Shows 1000 grain weight (gr) in different levels of urea.

Yield kg/ha

According to the analysis of variance results, the effects of urea fertilizer on wheat yield were significant at the 5% probability level. As the amount of fertilizer increased, the wheat yield also increased, mainly due to the higher 1000-grain weight at higher urea application rates. Among all treatments, the highest yield was recorded in T1 (250 kg/ha of urea), followed by T2 (200 kg/ha), T3 (150 kg/ha), T4 (100 kg/ha), and T5 (50 kg/ha), with the lowest yield observed in the control treatment T6 (0 kg/ha). The grain yields per hectare were as follows: T1 (2316.8 kg), T2 (2309.8 kg), T3 (2300 kg), T4 (2287.5 kg), T5 (2237.5 kg), and T6 (2085 kg).



Graph 8: Shows the yield kg/ha in different levels of urea.

Overall, the results clearly demonstrate that increasing levels of urea fertilizer positively influenced most growth and yield parameters of wheat under saline soil conditions. Higher urea application significantly improved emergence rate, plant height, spike height, tiller number, 1000-grain weight, and final grain yield. The treatment with 250 kg/ha urea consistently outperformed all others, indicating that moderate to high levels of nitrogen can effectively mitigate the adverse effects of salinity and enhance wheat productivity in affected soils.

4. DISCUSSION

The study aimed to assess the impact of different urea fertilizer levels on wheat growth and yield in saline soils of Balkh Province. The findings revealed that increasing urea levels led to notable improvements in most agronomic traits, including earlier emergence and heading, taller plants and spikes, a higher number of tillers per plant, greater 1000-grain weight, and significantly higher grain yields. The best performance was consistently observed in the T1 treatment (250 kg/ha urea), while the control treatment (T6) had the lowest values across all parameters. These results suggest that higher nitrogen input can partially counteract the negative effects of salinity on wheat performance, supporting the research objective of identifying effective fertilization strategies for salt-affected soils.

A notable finding in this study is that soil and water salinity significantly affected certain plant traits, particularly plant height. This indicates that, alongside fertilizer management, environmental factors such as salinity play a crucial role in the growth and development of the crop. Therefore, these factors should be carefully considered in agricultural practices and future research to optimize crop performance under varying environmental conditions.

The results of this study align with several previous investigations that have highlighted the positive role of nitrogen fertilization, particularly urea, in mitigating salinity stress and improving wheat performance. For instance, Munns and Tester (2008) explained that nitrogen supply enhances osmotic adjustment and promotes growth in salt-affected conditions, which is consistent with the increased plant height, tiller number, and grain yield observed in the current study at higher urea levels (200-250 kg/ha). Similarly, Khan *et al.*, (2021) reported that moderate to high nitrogen application significantly improved yield components under saline irrigation, closely matching our finding that T1 and T2 treatments produced the highest yields.

Moreover, Zhu et al. (2022) found that nitrogen enhances photosynthesis and grain filling in wheat under salinity, supporting our results on increased 1000-grain weight in higher urea treatments. However, some studies, such as Li et al. (2011), have warned that excessive nitrogen under high salinity may lead to leaching or luxury consumption, which was not observed in our field results, possibly due to balanced irrigation and soil management. Consistent with Ali *et al.*, (2019) and Zhang *et al*. (2025), our results show that increasing urea application rates significantly enhances key growth parameters such as emergence rate, stand percentage, plant height, spike height, and grain weight, ultimately improving yield under saline conditions. This supports the understanding that nitrogen not only promotes vegetative growth but also facilitates better reproductive development, which is often inhibited by salt stress.

These results further reinforce the significance of site-specific nutrient management in saline environments. According to Shrivastava and Kumar (2015), salinity interferes with nutrient uptake, particularly nitrogen, making efficient nitrogen management crucial. In our study, incremental urea application improved vegetative and reproductive traits, supporting this theory. For example, the tiller number per plant and spike height increased progressively with higher nitrogen rates, consistent with Ali *et al.* (2019), who found nitrogen enhances tillering and spike development under stress. Additionally, the relatively minor differences in stand percentage and emergence times among treatments compared to some earlier studies (e.g., Munns & Gillham, 2015) highlight the influence of regional climatic factors and genotype variability. This reinforces the idea that while nitrogen fertilization is broadly beneficial, its optimal application rates may vary depending on local agro-ecological contexts.

However, some contrasts exist. Unlike reports by Ramasamy (2010) and

Munns & Tester (2008), where excessive nitrogen under high salinity sometimes resulted in decreased yields due to nutrient imbalances or ammonia volatilization, this study did not observe a yield decline at the highest urea rate (250 kg/ha). This divergence may be attributed to the moderate salinity levels (EC 1.34 dS/m) and sufficient organic matter content, which likely improved nitrogen use efficiency and reduced nutrient losses. It suggests that local soil and environmental conditions can influence nitrogen's effectiveness, underscoring the importance of tailored nutrient management strategies.

This study offers valuable insights into the effects of different urea fertilizer levels on wheat growth and yield under saline soil conditions, highlighting the optimal fertilizer rates for enhancing crop performance. One of the strengths of the research lies in its comprehensive evaluation of multiple growth parameters and yield components, which provides a detailed understanding of how nitrogen application interacts with salinity stress. The use of ANOVA for statistical analysis further strengthens the reliability of the findings.

However, some limitations should be acknowledged. The study was conducted under specific soil and climatic conditions, which may limit the generalizability of the results to other regions with different salinity levels or environmental factors. Additionally, the experiment focused primarily on short-term effects within a single growing season, so long-term impacts of urea application under saline conditions remain unexplored. The study also did not investigate potential environmental risks, such as nitrogen leaching or ammonia volatilization, associated with high fertilizer use.

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5. CONCLUSION

This study systematically evaluated the impact of varying levels of urea fertilizer on multiple growth parameters and yield components of wheat. The findings indicate that urea application significantly enhances key agronomic traits, including emergence percentage, plant height, and spike length, number of tillers per plant, 1000-grain weight, and overall grain yield. Among the treatments, the highest urea rate of 250 kg/ha consistently delivered superior performance, suggesting its potential as an optimal fertilizer level for maximizing wheat productivity under the given experimental conditions. However, the study also highlights the importance of balanced fertilizer use to prevent excessive application, which could lead to environmental concerns or diminishing returns. While the results contribute valuable insights for improving wheat cultivation practices, the study's limitations include the focus on a single growing season and location. Therefore, future research should expand to multi-seasonal and multi-locational trials and assess long-term soil health and economic viability to develop comprehensive fertilizer recommendations that ensure sustainable agricultural production. It is recommended that farmers consider adopting the optimal urea levels identified in this study while monitoring soil conditions to optimize wheat yield effectively.

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