

Effect of Seeding Rate on Yield and Yield Components of Wheat

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ABSTRACT

Wheat (*Triticum aestivum* L.) is a major global cereal crop and the principal staple food in Afghanistan. Optimizing seeding rate is essential for improving plant growth, grain yield, and productivity under diverse agro-ecological conditions. This study assessed the effect of seeding rate on wheat yield and yield components during the fall season of 2024 (September–November) at the Research Farm of the Agriculture Faculty, Badakhshan University, Afghanistan. The experiment was conducted under local climatic conditions using a randomized complete block design (RCBD) with three replications. Five seeding rates (80, 100, 120, 140, and 160 kg ha⁻¹) were tested. We applied standard agronomic practices, including land preparation, fertilization with urea and diammonium phosphate, and crop management. Data were collected from randomly selected plants, excluding border rows. Analysis of variance (ANOVA) indicated that seeding rate significantly ($p < 0.05$) influenced all measured yield and yield components. The intermediate rate of 120 kg ha⁻¹ showed the best overall performance, including the highest plant height (93.41 cm), leaf area (4.66), number of tillers per plant (10.69), thousand seed weight (45 g), and grain yield (3.898 t ha⁻¹). Lower rates (80 and 100 kg ha⁻¹) reduced growth and yield, likely due to inadequate plant population, while higher rates (140 and 160 kg ha⁻¹) showed no further improvement and sometimes reduced seed weight due to increased competition. These findings suggest that a seeding rate of 120 kg ha⁻¹ is optimum for maximizing wheat productivity under the agro-ecological conditions of Badakhshan, Afghanistan, and may provide a practical recommendation for wheat growers in similar environments.

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops worldwide, serving as a major staple food for nearly one-third of the global population (Berhanu, 2024; Tehulie & Taminaw, 2021; Zewdie & Hunegnaw, 2020). It provides a significant source of nutrition for both humans and animals (Shewry, 2009), and it is mainly used for local consumption, seed production, and industrial purposes (Tefera, 2013). In addition to being used for food, wheat

residues and other by-products are frequently used to address livestock feed shortages (Tamrat et al., 2022). The global wheat cultivation area is approximately 1.425×10^6 hectares, while total worldwide wheat output is about 9.279×10^6 tons. Consequently, the mean yield is approximately 6.511 tons per hectare (Awad et al., 2022). In addition, global demand is expected to reach roughly 840 million tons of wheat by 2050, compared with the current production level of 642 million tons. Meeting this target will therefore require substantial productivity gains without expanding land or other inputs, through genetic, physiological, and agronomic strategies, especially resource-conserving technologies (Salihi et al., 2024; Sharma et al., 2015).

Wheat constitutes a major component of the Afghan diet, making it essential to maintaining national food security. According to Afghanistan's National Statistics and Information Authority (NSIA), wheat was grown on approximately 2,534,000 hectares of land, including 1,566,000 hectares under irrigated conditions and 968,000 hectares under rainfed systems. Total national wheat production amounted to roughly 4,890,000 metric tons, comprising 4,089,000 metric tons from irrigated wheat and 801,000 metric tons from rainfed wheat. Moreover, the average productivity was about 2.6 metric tons per hectare for irrigated wheat and approximately 0.83 metric tons per hectare for rainfed wheat, yielding an overall national average of about 1.93 metric tons per hectare (Popal, 2024).

Wheat yield responses to seeding density can differ considerably depending on the cultivar and the environmental conditions of the growing region (Otterson et al., 2007). However, many studies indicate that as seeding rate increases, grains per spike tend to decrease, while spikes per square meter and overall grain yield rise (Matsuyama & Ookawa, 2020).

Understanding the seed rate and yield relationship in wheat can facilitate the development of site, season and cultivar-specific recommendations for optimizing seeding rates (Eshete et al., 2021). Afghanistan's climate and soil conditions are well suited for wheat cultivation (Behzad et al., 2021). Optimum seeding rate is one of the most important factors that regulates the ability of crop plants to capture available resources and produce higher grain yields (Fazily, 2021; Iqbal et al., 2020; Lloveras et al., 2004).

Attaining optimal wheat yields requires careful management practices, including appropriate seeding rate, planting timing, irrigation, fertilizer use, weeding, water management, and harvest timing. To achieve higher wheat grain yields with improved quality, it is essential to use the correct seeding rate for various cultivars. Increasing seeding rate may raise production costs without improving grain yield (Behzad & Amani, 2020; Rafique et al., 2010). Previous research on wheat yield responses to seeding rate has largely been conducted under conventional agronomic management conditions, with limited emphasis on systems characterized by excessively high fertility or other intensive management factors (Bastos et al., 2020; Klein, 2020; Lollato et al., 2025). The optimal seed rate can vary significantly depending on several factors, including wheat variety,

environmental conditions, sowing method, and desired plant density (Klein, 2020; Shah et al., 2016).

Afghanistan's northern provinces, including Takhar, Kunduz, Balkh, Jawzjan, and Faryab, are the country's major wheat-producing regions. From 2005 to 2010, wheat contributed an average of 78.5% of Afghanistan's total cereal yield (Ahmadi et al., 2021). In Afghanistan, wheat seeding rates vary between irrigated and rainfed systems, ranging from 110–175 kg ha⁻¹ and 80–100 kg ha⁻¹, respectively (Favre, 2004). Recent studies in Kabul and Khost also showed that seed density affects wheat yield and agronomic traits (Ahmadi et al., 2021). However, seeding recommendations may vary across agro-ecological regions because of unfavorable soil properties, adverse climatic conditions, limited technical knowledge, inadequate irrigation water, and inappropriate fertilizer application rates (Behzad et al., 2021). Therefore, this study aimed to determine the optimum seeding rate to maximize wheat yield under the agro-climatic conditions of Badakhshan, Afghanistan, and to provide a scientifically based recommendation for local wheat production. In this context, the present study aims to;

- Evaluate the Effect of different seeding rates of wheat on yield and components in Badakhshan Province.

METHODS AND MATERIALS

Research Design

The experiment used the following seeding rates (kg ha⁻¹), viz. 80, 100, 120, 140, and 160. The experiment followed a randomized complete block design (RCBD) with three replications.

Experimental site

The field experiment was conducted during the fall season (September-November) of 2024 at the Research Farm of the Faculty of Agriculture, Badakhshan University, Afghanistan. The experimental field consisted of sandy loam to loamy soil with a pH of 8.5. The experimental site had a sandy loam soil texture. Climatic conditions at the experimental site were characterized by average temperatures from May to August in spring, high temperatures from June to September in summer, and average temperatures from November to January, while March was the wettest month.

Land Preparation

The experimental field was prepared using plowing followed by laddering to break clods and level the field. Before sowing, we removed all weeds, stubbles, and crop residues. The entire area was divided into individual unit plots, maintaining the required spacing: 20 cm between rows and 30 cm as a border line. Each plot (bed) had an area of 4.18 m², and the total experimental land area was 100 m². The field was fertilized with urea and diammonium phosphate (DAP) at 105 kg ha⁻¹ and 52 kg ha⁻¹, respectively. Two-thirds of the urea and the

entire amount of DAP were applied during final land preparation, and the remaining urea was applied as a top dressing. Furrows were created using an iron tine, after which seeds were covered with soil. Seeds were sown manually at a depth of 3–4 cm in furrows created using an iron tine, after which seeds were covered with soil. Appropriate care was taken to avoid damaging the seeds. We carried out crop management practices, including weeding and irrigation, throughout the growing season.

Data collection procedure

The crop was harvested upon reaching physiological maturity. Prior to harvesting, five plants were randomly sampled from each plot (excluding border plants), and uprooted for data collection. The harvested plants from each plot were separately bundled, labeled and transported to a clean threshing area. The bundles were sun-dried, manually threshed and the grains were cleaned. Grain and straw weights were recorded for each plot after drying to a constant weight. The grain weight obtained from the sampled plants was incorporated into the respective plot yield and the final grain yield was converted to t ha⁻¹.

Statistics and Data Analysis

Experimental data were statistically evaluated through analysis of variance (ANOVA), followed by the least significant difference (LSD) test for mean comparison among treatments. Total yield was calculated based on area and then converted into kg ha⁻¹. The (DAASTAT) software program was used to complete the statistical analysis.

FINDINGS

Seeding rate significantly affected all measured growth, yield, and yield-component characters (Table 1). Seeding rate significantly influenced plant height. The maximum plant height (93.41 cm) was recorded at 120 kg ha⁻¹. Conversely, lower seeding rates of 80 and 100 kg ha⁻¹, resulted in reduced plant height, most likely due to decreased inter-plant competition and associated changes in stand establishment. In contrast, excessively high seeding rates of 140 and 160 kg ha⁻¹ did not further increase plant height (Table 1, Figure 1).

Table 1. Mean square for the wheat observed parameters

Mean Square								
Plant Height (cm)	Leaf Area (cm ²)	No. of tillers/plant	Spike length	Grain No. per spike	Grain No. per spikelet	No. Spikelet/ Spike	1000 seed Weight (g)	Grain yield (t ha ⁻¹)
0.016	0.262	0.46	0.21	8.24	0.04	0.11	40.2	346169.86
55.92*	0.48*	135.07*	1.75*	93.21*	0.25*	2.09*	102.57*	1907001.83*
10.73	0.11	22.96	0.40	15.98	0.06	0.43	15.86	296400.53
3.77	8.43	14.55	11.10	16.24	9.76	7.145	10.37	17.68

**Significant difference at 1%, *significant difference at 5%, CV: coefficient of variation, df: degrees of freedom

Leaf area index followed a similar pattern, with the highest value (4.66) recorded at 120 kg ha⁻¹. The lowest leaf area (3.58 cm) was obtained at 80 kg ha⁻¹, and differed significantly from the other treatments (Table 2, Figure 2).

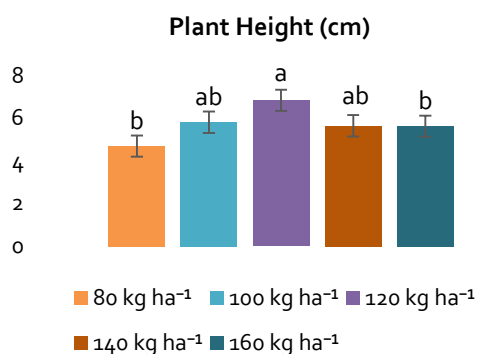


Figure 1. Effect of seeding rate on plant height

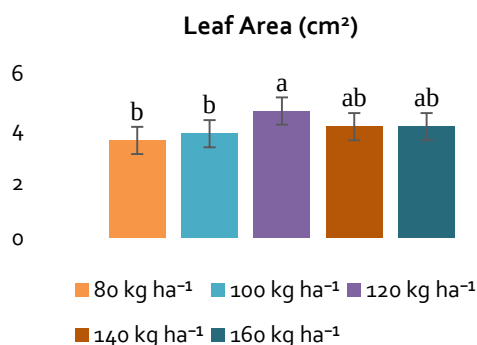


Figure 2. Effect of seeding rate on Leaf area (cm²)

Spike length differed significantly across seeding rates. At a seeding rate of 120 kg ha⁻¹, produced the highest spike length (6.86 cm), and this value was significantly superior to the spike length at 80 and 160 kg ha⁻¹ (4.71 and 5.64 cm, respectively). In contrast, seeding rates of 100 kg ha⁻¹ (5.83 cm) and 140 kg ha⁻¹ (5.66 cm) showed intermediate performance, which suggests their spike lengths were not significantly different from both the top-performing rate of 120 kg ha⁻¹ and the lower-performing rates (80 and 160 kg ha⁻¹) based on the LSD test grouping (Table 2, Figure 4). In Zone 1, the maximum spike length (8.44 cm) was obtained at a seeding rate of 110 kg ha⁻¹, followed closely by 120 kg ha⁻¹, whereas the minimum value was observed at 100 kg ha⁻¹. In Zone 2, the longest spikes (7.30 cm) were recorded at 120 kg ha⁻¹, while the shortest spike length (6.76 cm) occurred at 100 kg ha⁻¹.

Increasing the seeding rate significantly affected the number of tillers per plant (Table 2, Figure 3). The highest number of tillers (10.69) was recorded at 120 kg ha⁻¹, and this value was statistically comparable to those obtained at 100 kg ha⁻¹ (10.29) and 140 kg ha⁻¹ (10.22). In contrast, the lowest number of tillers per plant was observed at 80 kg ha⁻¹ (9.32) and 160 kg ha⁻¹ (9.31).

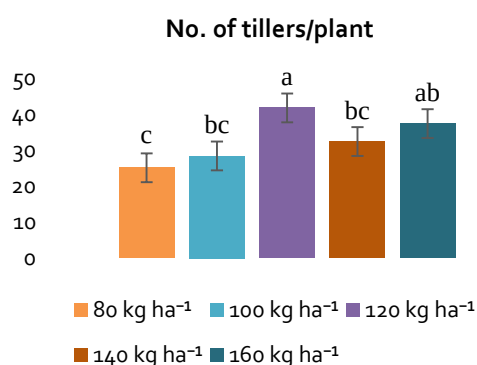


Figure 3. Effect of seeding rate on No. of tillers/plant

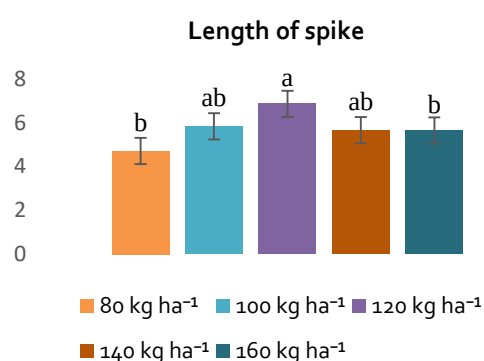


Figure 4. Effect of seeding rate on length of spike

Seeding rate also significantly influenced grain number per spike. The highest grain number per spike (31.08) was recorded at 120 kg ha⁻¹ and did not differ significantly from the values at 140 kg ha⁻¹ (28.23) and 160 kg ha⁻¹ (25.75). Conversely, the lowest grain number per spike was observed at 80 and 100 kg ha⁻¹ (17.41 and 20.58, respectively).

Grain number per spikelet varied significantly. The highest grain number per spikelet (2.98) was recorded at 120 kg ha⁻¹ and was statistically the same as 2.25 at 100 kg ha⁻¹. The minimum number of grains per spikelet was 2.25, 2.33, 2.5, and 2.66 at seeding rates of 100, 140, 160, and 80 kg ha⁻¹, respectively. In addition, the number of spikelets per spike was highest at 140 kg ha⁻¹ (16.50) and decreased to 11.75 at 80 kg ha⁻¹.

Seeding rate had a significant effect on thousand-seed weight. The greatest thousand-seed weight (45 g) was achieved with a seeding rate of 120 kg ha⁻¹, which did not differ significantly from the values obtained at 160 kg ha⁻¹ (41.66 g) and 140 kg ha⁻¹ (40 g). In contrast, the lowest seed weights were observed at lower seeding rates of 80 and 100 kg ha⁻¹ with thousand seed weight values of (35.33 and 30 g, respectively).

Grain yield responded highly significantly to seeding rate. The highest seed yield (3.898 t ha⁻¹) was achieved at 120 kg ha⁻¹, significantly exceeding all other treatments. Although yields at 140 and 160 t ha⁻¹ were relatively high (3.515 and 3.531 t ha⁻¹, respectively), they were statistically similar to each other but lower than the optimum treatment. The lowest yields occurred at 80 and 100 kg ha⁻¹, producing significantly reduced seed yields (2.132.66 and 2.316 t ha⁻¹).

Overall, the LSD values demonstrate that treatment effects were statistically significant for all measured traits at ($p < 0.05$) by seeding rate of 120 kg ha⁻¹. The assignment of distinct grouping letters (a, b, c) provides additional evidence of clear separation among treatments. Furthermore, the relatively low SEM values indicate good experimental precision and support the reliability of the results.

Table 2. Effect of seed rate on yield and yield components of wheat

Seed rate kg/ ha ⁻¹	Plant Height (cm)	Leaf Area (cm ²)	No. of tillers/Plant	Spike length	Grain No. per spike	Grain No. per spikelet	No. Spikelet's/ Spike	1000 seed Weight (g)	Grain yield (t ha ⁻¹)
80	84.5 ^b	3.58 ^b	9.77 ^b	4.71 ^b	17.41 ^c	2.66 ^b	8.56 ^b	30 ^c	2.132 ^b
100	81.91 ^b	3.83 ^b	10.24 ^a	5.83 ^{ab}	20.58 ^{bc}	2.25 ^{ab}	8.32 ^b	35.33 ^{bc}	2.316 ^b
120	93.41 ^a	4.66 ^a	10.32 ^a	6.86 ^a	31.08 ^a	2.98 ^a	10.43 ^a	45 ^a	3.898 ^a
140	86.33 ^b	4.08 ^{ab}	9.94 ^{ab}	5.66 ^{ab}	28.23 ^a	2.33 ^b	9.52 ^{ab}	40 ^{ab}	3.515 ^a
160	88 ^{ab}	4.08 ^{ab}	8.34 ^c	5.64 ^b	25.75 ^{ab}	2.5 ^b	9.29 ^{ab}	41.66 ^{ab}	3.531 ^a
SEM ±	1.89	0.19	0.65	0.36	2.30	0.14	0.38	2.29	314.32
LSD	6.16	0.64	1.23	1.20	7.52	0.46	1.24	7.49	1.03

**Significant difference at 1%, *significant difference at 5%, LSD: least Significant Difference.

DISCUSSION

The findings indicate that higher seeding rates suppressed weed growth by increasing crop density per unit area. The greater plant population enhanced competition for available light, resulting in increased plant elongation as the crop canopy developed. These observations are in agreement with findings reported in previous studies (Ahmadi et al., 2021; Antar and Almashhadany, 2020; Behzad et al., 2021; Behzad & Amani, 2020; Berhanu, 2024; Boru et al., 2022; Hussain et al., 2001; Naveed et al., 2014; Tehulie and Taminaw, 2021), which stated that higher seeding rates e.g., 140 kg ha⁻¹, produced greater plant height (101.25 cm).

Likewise, the shortest plant height (85.75 cm) was observed at the lowest seeding rate of 80 kg ha⁻¹.

The observed variation in leaf area index was consistent with the findings of Shah et al., (2016a), who reported the highest Leaf area index (4.10) at a seeding rate of 120 kg ha⁻¹ and the lowest value (2.76) at 60 kg ha⁻¹. This variation may be associated with differences in vegetative growth duration, as plants established at lower seeding rates may have a longer period of vegetative development than those grown under higher plant densities. The higher spike length at 120 kg ha⁻¹ was due to optimum plant density and reduced competition for light, nutrients, and water, which favored spike development. Ahmadi et al. (2021), Arif (2017), and Naveed et al. reported similar findings.

The findings for the number of tillers are also consistent with those of (Soomro et al., 2009; Tehulie & Taminaw, 2021), who reported that the maximum number of tillers (10.41) occurred at a seed rate of 125 kg ha⁻¹, followed by drilling (10.32) and broadcasting (9.58). They also observed the minimum mean tiller number (8.50) at a seed rate of 175 kg ha⁻¹. This pattern is attributed to differences in plant population density and the resulting tillering behavior.

The results for grains per spike are in agreement with those of (Batoool et al., 2022; Safi et al., 2024; Shah et al., 2016 a; Tigabu & Asfaw, 2016), who found that a seeding rate of 120 kg ha⁻¹ produced more grains per spike (60), whereas a seed rate of 60 kg ha⁻¹ resulted in fewer grains per spike. Overall, higher seeding rates significantly reduced grain number per spike. The higher grains per spikelet under the optimum seeding rate were attributed to balanced plant density and reduced inter-plant competition, which favored spike development. These findings are consistent with (Behzad et al., 2021; Behzad & Amani, 2020; Ullah et al., 2018).

The results conform with (Abouzaytonh, 2020; Berhanu, 2024; Godara & Kumar, 2025; Shah et al., 2011; Shah et al., 2016; Terfa et al., 2020; Twizerimana et al., 2020), who reported that the Maximum 1000-seed weight (41.91 g) was recorded with a seeding rate of 120 kg ha⁻¹.

They also observed that thousand-seed weight declined as the seeding rate increased, with the lowest value (38.30 g) recorded at 60 kg ha⁻¹. The reduction in seed weight at higher seeding rates is attributed to increased inter-plant competition, which limits resources available for grain filling compared with plots sown at lower seeding rates.

The higher grain yield at 120 kg ha⁻¹ was attributed to optimum plant density, which enhanced resource use and yield-component development while minimizing excessive inter-plant competition. The findings align with Anbes et al. (2025), Hameed et al. (2002, 2003), and Shah et al. (2016, who reported maximum grain yield at 120 kg ha⁻¹.

The results confirmed that seeding rate significantly affected wheat growth, yield components, and grain yield, with 120 kg ha⁻¹ producing the best overall performance and identified as the optimum rate under the experimental conditions. However, as the study was conducted at a single location and under one set of environmental conditions, further

research across different locations, seasons, soil conditions, and production environments is recommended to validate this optimum seeding rate.

CONCLUSION

The results indicate that a seeding rate of 120 kg ha⁻¹ produced the highest growth, yield components, and grain yield under the agro-ecological conditions of Badakhshan, Afghanistan. The maximum grain yield (3.898 t ha⁻¹) was obtained at this seeding rate and was significantly higher ($P < 0.05$) than those of the other treatments. Both lower seeding rates (80 and 100 kg ha⁻¹) and higher seeding rates (140 and 160 kg ha⁻¹) occasioned in lower grain yield, likely due to inadequate plant population and increased interplant competition, respectively. These findings highlight the importance of optimizing seeding rate to maximize wheat productivity. However, this study was conducted at a single location during one growing season using one wheat cultivar, which may limit the findings' broader applicability. Therefore, further research should be conducted across different environments, soil types, climatic conditions, and wheat cultivars to validate the optimum seeding rate and enhance its wider applicability for sustainable wheat production.

Author Contributions

- Maqsoodullah Saeedi contributed to manuscript writing, interpretation of the findings, and revision.
- Abdul Shahir Qadiri analyzed the data and contributed to writing and revising the manuscript.
- Abdul Musawer Asim and Sharafatullah Omari contributed to data collection and laboratory work.

All authors critically reviewed the manuscript and approved its final version for submission.

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Conflict of Interest Statement

All authors express no conflict of interest in any part of the research.

Data Availability Statement

All data generated or analyzed during this study are included in the published article. Additional information or data may be made available by the corresponding author upon reasonable request.

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