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Evaluation of Wheat Varieties under Different Sowing Dates in Irrigated Arid Regions

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Abstract

Wheat (Triticum aestivum L.) is Afghanistan's principal staple crop, yet national production remains insufficient to meet demand. In Farah province, irrigated wheat yields are constrained by climatic variability and suboptimal agronomic practices. In such arid irrigated areas, identifying suitable sowing dates and adapted varieties is essential for improving productivity. This study evaluated the effects of sowing date and variety on yield performance under irrigated arid conditions during the 2022–23 season in Qala-Mohammad Jan village, Farah province, Afghanistan. A factorial experiment in a randomized complete block design included three sowing dates (Oct 23, Nov 11, and Dec 1) and three varieties (Mazar-99, Darulaman-07, and Chont No.1), with three replications. Data were recorded on yield components, grain and straw yield, harvest index, and economic returns. Data were analysed using analysis of variance (ANOVA), and treatment means were compared using the LSD test at the 5% significance level. Sowing on Nov 11 significantly improved effective tillers, spike length, grains per spike, thousand-grain weight, grain yield, harvest index, and net income. Darulaman-07 variety outperformed other varieties across all parameters. Combining mid-November sowing with Darulaman-07 is recommended to enhance wheat productivity in Afghanistan's irrigated arid regions.

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Introduction

Wheat (Triticum aestivum L.) ranks among the most significant cereal crops cultivated worldwide, and this includes Afghanistan. As a principal food crop, wheat is essential for maintaining national food security. In Afghanistan, it accounts for roughly 32% of all cultivated land and is found in every province, thriving at altitudes between 2,000 and 3,500 meters above sea level. Planting usually starts in September or October and may continue into March or

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April, influenced by climate conditions, while harvesting takes place from April to May, extending through August and September (MAIL, 2024). Afghanistan extensively grows both irrigated and rainfed wheat, with flatbread called "Nan" being a fundamental part of the Afghan diet. The nation has one of the highest per capita wheat consumption rates in the world, estimated at around 180 kg per person each year (Poole et al., 2018).

Nevertheless, domestic production fails to satisfy national needs. The 2024 wheat production report from the Ministry of Agriculture, Irrigation and Livestock reveals that Afghanistan cultivated 2.12 million hectares of wheat, including 1.38 million hectares under irrigation and 736,000 hectares relying on rainwater. Irrigated wheat achieves much higher yields, yet the total output (4.83 million metric tons) does not meet the projected national requirement of 6.82 million metric tons, resulting in an annual deficit of roughly 2 million metric tons (MAIL, 2024). This shortfall is typically addressed through international humanitarian food assistance and costly imports from nations like Kazakhstan, Russia, Uzbekistan, and India, with expenses reaching approximately 600–700 million USD each year.

Wheat production in Afghanistan, particularly rainfed varieties, heavily depends on climatic factors, especially the necessity for timely rainfall. Moreover, crop yields are affected by practices related to integrated pest management, disease control, crop rotation, and the adoption of advanced seed varieties. However, ongoing issues such as recurring droughts, sudden floods, and the lack of modern farming technologies continue to hinder wheat productivity significantly. The reported average yield for irrigated wheat in 2024 was 2.98 t ha^{-1}, while rainfed wheat yielded a mere 0.96 t ha^{-1} (MAIL, 2024). Major obstacles to achieving higher yields include diseases such as rusts and smuts, grain rot, and water scarcity. Data shows that Afghanistan is still far from achieving self-sufficiency in wheat production.

Among these factors, sowing date and varietal selection play a critical role in determining wheat growth, development, and final productivity. Among its provinces, Farah is particularly important for wheat cultivation. Due to limited rainfall, wheat farming in Farah is predominantly reliant on irrigation. In 2024, the total wheat production in Farah province was about 313,568 metric tons, with an average productivity of 2.9 t ha^{-1}, which met local consumption requirements while producing an excess of more than 100,000 metric tons. The province ranks just behind Helmand and Kandahar in terms of area dedicated to irrigated wheat cultivation (MAIL, 2024).

Although wheat is crucial, productivity is highly variable across different regions. Research conducted by CIMMYT (International Maize and Wheat Improvement Center) across 11 agroecological zones in Afghanistan reported yields of 3.58-5.97 t ha^{-1} for improved wheat varieties (Sharma et al., 2021). This indicates substantial potential to increase productivity through improved agronomic practices—particularly optimal sowing times and the selection of high-yielding varieties. In light of recent climate change trends, ongoing droughts, rising temperatures, and diminishing water resources, reassessing current crop management practices is essential.

Given wheat's strategic role in Afghanistan and Farah's vital contribution to national wheat production, developing site-specific agronomic guidance for optimal sowing dates and appropriate varieties is crucial. However, there is limited scientific information on the optimal sowing date and wheat variety for irrigated arid conditions in Farah province. This research was conducted to assess the impact of various sowing dates on yield attributes and grain yield of three wheat varieties under irrigated conditions in Farah province.

Although farmers in this area use a range of sowing dates (mainly in November and December) and a combination of local and improved varieties, there is a lack of comprehensive scientific information to help them choose optimal practices. The timing of sowing plays a crucial role in wheat growth and productivity, as it affects the crop's exposure to temperature, rainfall, pests, and diseases (Rawson, 1993). Late or improper sowing and unsuitable varietal selection can result in yield reductions and higher production costs, diminishing farmers' enthusiasm for wheat farming and increasing their dependence on imports.

Furthermore, different wheat varieties exhibit varying physiological and morphological adaptations to heat and water stress, including leaf thickness, leaf area, growth duration, and plant height. It is important to identify the varieties most compatible with the environmental conditions in Farah province.

Given the dominance of traditional farming methods in Farah, limited access to modern agricultural technologies, declining groundwater resources, and insufficient knowledge of optimal sowing dates and varieties, wheat farmers in the area face significant productivity challenges. Their seasonal hard work often results in diminished profits due to lower yields.

Therefore, this study was conducted to address the existing knowledge gap by evaluating the effects of different sowing dates and wheat varieties on yield and economic performance of wheat under irrigated arid conditions in Farah province. The findings from this research are anticipated to facilitate informed decision-making for farmers, extension agents, and policymakers, promote a culture of agricultural inquiry, and ultimately enhance food security and farmer incomes in the region.

Methods and Materials

A field study was conducted during the cropping season (October-May) of 2022-23 in Qala-Mohammad Jan village, situated in Farah province, Afghanistan. The experimental plots exhibited a consistent topography along with uniform soil fertility, making them suitable for wheat cultivation. The research was conducted in a randomized complete block design (factorial-RCBD), featuring three sowing dates (Oct 23, Nov 11, and Dec 1) as factor A, and three wheat varieties (*Mazar 99*, *Darulaman-07*, and *Chont No.1*) as factor B, with each combination replicated three times. Thus, the experiment included 9 treatment combinations (3 sowing dates × 3 varieties) and a total of 27 experimental plots. Prior to sowing, composite soil samples were collected from the experimental field at 0–30 cm depth and analyzed for physicochemical properties. The soil exhibited a pH of 7.6 and an electrical conductivity of 0.675 dS m^{-1}. Organic carbon content was 0.36%, while available nitrogen, phosphorus, and potassium contents were 78.6, 8.6, and 161.2 kg ha^{-1}, respectively. Based on textural analysis, the soil was classified as clay loam.

All wheat varieties were sown at the same time, with 20-day intervals, at a row spacing of 20 cm and a seed rate of 100 kg ha^{-1}. Irrigation was applied immediately after sowing, again 21 days after sowing, and subsequently every 12 days across all plots. Each wheat variety received the recommended nitrogen and phosphorus dose of 125 kg ha^{-1} through inorganic fertilizers: di-ammonium phosphate (black fertilizer) applied at sowing, and urea (white fertilizer) applied in two equal splits—at tillering and at flowering. To control weeds, hand weeding was performed 35 days after sowing, and the herbicide Clodinafop-propargyl + Metsulfuron-methyl (Super-topic 80%) was applied to manage both broad-leaved and narrow-leaved weeds. Harvesting was carried out from the net plot area of 5.5 square meters, with the total weight of grain and straw measured and expressed in kg ha^{-1}. All agronomic practices were consistently applied across all treatments. Data on yield attributes, such as the number of effective tillers per square meter, were collected from five rows per plot at harvest.

Ten spikes were randomly chosen for measurement from the sampling area, with their length measured from the base to the tip of the panicle. The total number of grains from these spikes was threshed, cleaned, and counted to establish the average number of grains per ear. A sample of one thousand grains was collected from the produce of each plot, counted, and weighed in grams. For grain yield, the net plot area was harvested, sun-dried for 3-4 days, then threshed and cleaned. The resulting grain was weighed and reported in kg ha^{-1}. The total biological yield (grain plus straw) was documented, and the straw yield was computed by deducting the grain yield from the biological yield, also expressed in kg ha^{-1}. The Harvest Index (HI) was calculated to assess the effectiveness of dry matter partitioning towards grain production. It was expressed as a percentage by dividing the grain yield by the biological yield and multiplying the result by 100. The costs of various operations were estimated based on the year's market prices for inputs, and the total cost per hectare was determined by summing all expenses associated with each treatment. Gross returns were calculated by multiplying total grain and straw yields by the relevant market prices, with net returns determined by subtracting total cultivation costs from gross returns. The market prices for wheat grain and straw were established at Afghani 30,000 per ton and Afghani 2,700 per ton, respectively.

The collected data were analyzed using STAR statistical software. Analysis of variance (ANOVA) was performed for all measured variables, and the significance of treatment effects was evaluated at the 5% probability level. Treatment means were compared using the Least Significant Difference (LSD) test, and interaction effects were interpreted only when the ANOVA indicated significant differences.

Findings

Yield Attributes

The date of sowing significantly influenced yield attributes of wheat, including the number of effective tillers per square meter, spike length, grains per spike, and 1000-grain weight at harvest (Table 1 and Figure 1).

Table 1: *Comparison of the average yield attributes of wheat under different sowing dates and varieties*

Treatment combinations	At harvest			
	Number of effective tillers (m^2)	Spike length (cm)	No. of grains per spike	1000-grain weight (g)
Factor(A) Sowing Date				
Oct 23	722.22b	9.67b	47.56b	46.72b
Nov 11	773.33a	10.28a	57.22a	49.30a
Dec 1	646.67c	9.05c	43.67c	44.11c
Factor(B) Variety				
Mazar-99	661.11c	9.05c	45.67c	44.97c
Darulaman-07	767.78a	10.44a	53.67a	48.52a
Chont No. 1	713.33b	9.50b	49.11b	46.64b
(A×B)Interaction	s	s	s	s

Means followed by the same letter within a column are not significantly different at the 5 % probability level.

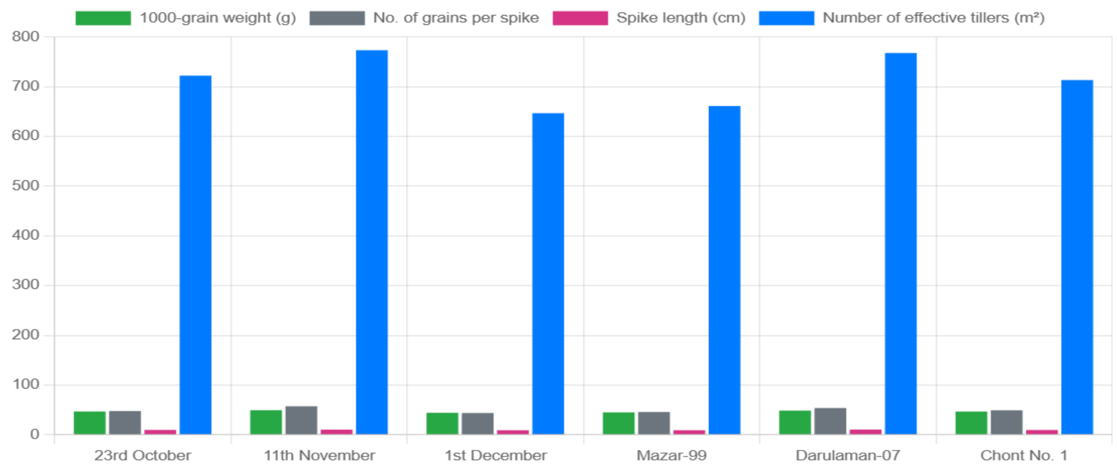

Figure 1. *Comparison of the average yield attributes of wheat under different sowing dates and varieties*

Sowing date of Nov 11 (20th Aqrab) recorded significantly the highest values for these characteristics, followed by Oct 23 (1st Aqrab). Conversely, Dec 1 (10th Qaws) sowing date recorded significantly lower values for effective tillers per square meter, spike length, grains per spike, and 1000-grain weight. Differences among varieties also demonstrated a notable impact on yield attributes, including the number of effective tillers per square meter, spike length, number of grains per spike, and thousand-grain weight at harvest. The *Darulaman-07* variety consistently recorded the highest measurements for all these characteristics, followed by the Chont No. 1 variety, while the Mazar-99 variety exhibited the lowest measurements.

The interaction of sowing date and variety showed significant effects on spike length, effective tillers, 1000-grain weight, and grains per spike (Tables 2 and 3).

Table 2: *Interaction of sowing dates and varieties on fertile tillers and spike length*

Variety	Sowing Date					
	Number of effective tillers (m^2)			Spike length (cm)		
	Oct 23	Nov 11	Dec 1	Oct 23	Nov 11	Dec 1
Mazar-99	663.33d	723.33bc	596.67e	9.00f	9.83cd	8.32g
Darulaman-07	786.67b	843.33a	673.33d	10.50b	10.83a	10.00c
Chont No. 1	716.67bc	753.33b	670.00d	9.50e	10.17c	8.83f

Means followed by the same letter within a column are not significantly different at the 5 % probability level.

Table 3: *Interaction of sowing dates and varieties on grains per spike and 1000-grain weight*

Variety	Sowing Date					
	No. of grains per spike			1000-grain weight (g)		
	Oct 23	Nov 11	Dec 1	Oct 23	Nov 11	1st December
Mazar-99	45.00e	50.00c	42.00f	44.17ef	48.07bcd	42.67f
Darulaman-07	50.00c	65.00a	46.00e	49.33b	51.40a	44.83e
Chont No. 1	47.67d	56.67b	43.00f	46.67d	48.43bc	44.83e

Means followed by the same letter within a column are not significantly different at the 5 % probability level.

Darulaman-07 variety sown on Nov 11 produced the longest spikes (10.83 cm), the highest number of effective tillers (843.33 m^2), the heaviest 1000-grain weight (51.40 g), and the greatest number of grains per spike (65.00), all of which were statistically superior to other treatment combinations. In contrast, the *Mazar-99* variety sown on Dec 1 recorded the lowest values across these traits, with spike length of 8.32 cm, effective tillers of 596.67 m^2, 1000-grain weight of 42.67 g, and grains per spike of 42.00. These results clearly demonstrate that the *Darulaman-07* variety, when planted at the optimal sowing date, had greater tillering, spike development, grain filling, and kernel development, which collectively contributed to its superior yield performance.

Grain and Straw Yield

The timing of sowing had a considerable impact on both grain and straw yields following harvest (Table 4). The sowing date of Nov 11 (20^{th} Aqrab) yielded significantly the highest amounts of grain and straw yields, while Oct 23 (1^{st} Aqrab) followed closely behind. In contrast, Dec 1 (10^{th} Qaws) sowing date exhibited significantly the lowest yields for both measurements. Varietal differences also demonstrated a significant impact on both grain and straw yield. The *Darulaman-07* variety yielded the highest amounts of grain and straw yields, with the *Chont No. 1* variety following in performance, while the *Mazar-99* variety produced the lowest yields.

Harvest Index

The harvest index (HI) of wheat was notably influenced by the timing of sowing (Table 4 and Figure 2).

Table 4: *Comparison of the mean wheat yield across various sowing dates and varieties*

After harvest			
Treatment combinations	Grain yield (kg ha⁻¹)	Straw yield (kg ha⁻¹)	Harvest Index (%)
Factor(A) Sowing Date			
Oct 23	5548.28b	7205.56b	43.49b
Nov 11	6061.11a	7666.11a	44.15a
Dec 1	5030.00c	6709.89c	42.83c
Factor(B) Variety			
Mazar-99	5178.28c	6798.78c	43.21a
Darulaman-07	5872.22a	7542.22a	43.74a
Chont No. 1	5588.89b	7240.56b	43.53a
)A×B(Interaction	s	s	ns

Means followed by the same letter within a column are not significantly different at the 5 % probability level.

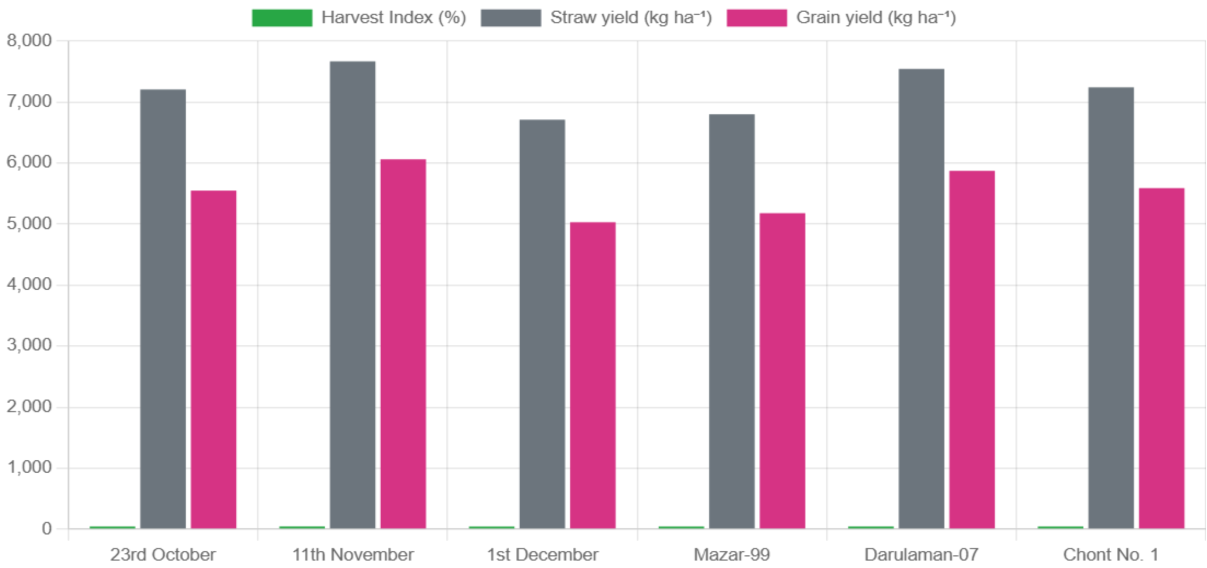

Figure 2. *Comparison of the mean wheat yield across various sowing dates and varieties*

The interaction between sowing dates and varieties significantly influenced grain and straw yield (Table 5). The highest grain yield (6500.00 kg ha⁻¹) and straw yield (8133.33 kg ha⁻¹) were obtained from *Darulaman-07* variety sown on Nov 11, which was statistically superior to all other treatment combinations. Conversely, the *Mazar-99* variety planted on Dec 1 gave the lowest grain yield (4806.67 kg ha⁻¹) and straw yield (6493.00 kg ha⁻¹). These results confirm that timely sowing on Nov 11 enabled the Darulaman-07 variety to exploit favorable climatic conditions, resulting in enhanced biomass accumulation and better partitioning of assimilates toward grain production.

Table 5: *Interaction effect of sowing dates and varieties on wheat grain and straw yields*

Variety	Sowing Date					
	Grain yield (kg ha⁻¹)			Straw yield (kg ha⁻¹)		
	Oct 23	Nov 11	Dec 1	Oct 23	Nov 11	Dec 1
Mazar-99	5144.85de	5583.33c	4806.67ef	6773.33ef	7130.00cd	6493.00gh
Darulaman-07	5800.00c	6500.00a	5316.67d	7473.33b	8133.33a	7020.00de
Chont No. 1	5700.00c	6100.00b	4966.67e	7370.00bc	7735.00b	6616.67fg

Means followed by the same letter within a column are not significantly different at the 5 % probability level.

Significantly, the highest harvest index was observed for the Nov 11 (20th Aqrab) sowing date, with the Oct 23 (1st Aqrab) date following closely behind. Conversely, Dec 1 (10th Qaws) sowing date resulted in significantly lower harvest index, highlighting the substantial impact of environmental factors on this characteristic. On the other hand, varieties failed to significantly affect the wheat harvest index.

Economic Evaluation

Among the different sowing dates, the sowing on Nov 11 (20th Aqrab) yielded the highest net income, followed by the sowing on Oct 23 (1st Aqrab). Conversely, the sowing date of Dec 1 (10th Qaws) resulted in the lowest net income (Table 6 and Figure 3).

Table 6: *Comparison of the economic performance of wheat across different sowing dates and varieties*

Treatment combinations	After Harvest			
	Cost of Cultivation (AFN ha⁻¹)	Gross Returns (AFN ha⁻¹)	Net Returns (AFN ha⁻¹)	B: C ratio
Factor(A) Sowing Date				
Oct 23	50100a	185903.412b	135803.412b	2.710b
Nov 11	50100a	202531.797a	152431.797a	3.042a
Dec 1	50100a	169016.703c	118916.703c	2.373c
Factor(B) Variety				
Mazar-99	50100a	173705.106c	123605.106c	2.467c
Darulaman-07	50100a	196530.594a	146430.594a	2.922a
Chont No. 1	50100a	187216.212b	137116.212b	2.736b

Means followed by the same letter within a column are not significantly different at the 5 % probability level.

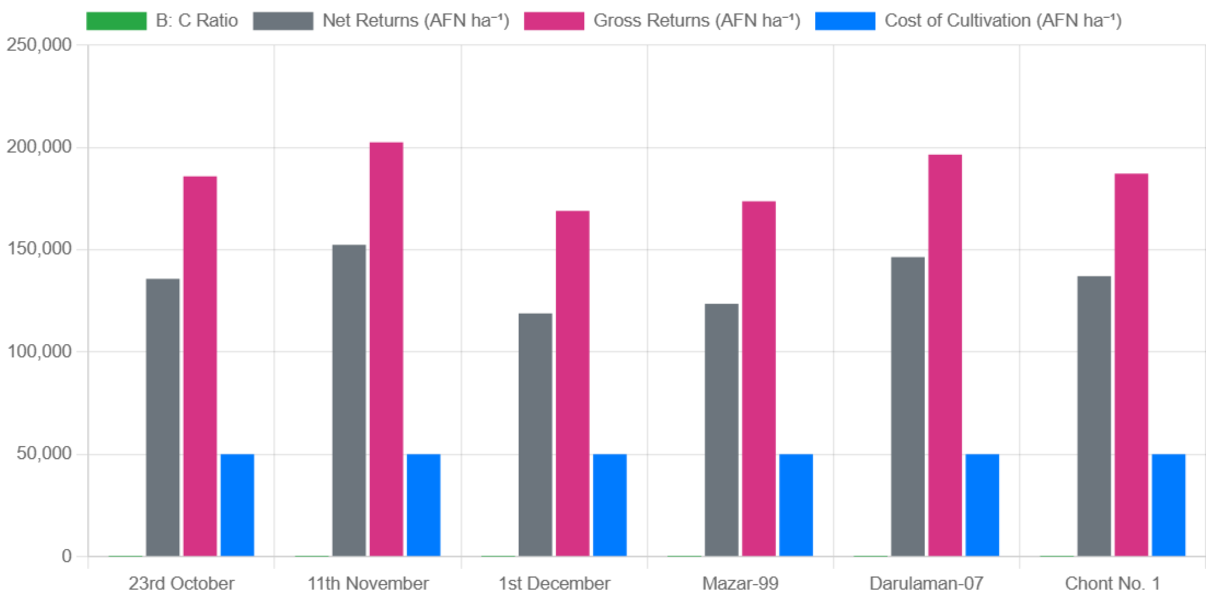

Figure 3. *Comparison of the economic performance of wheat across different sowing dates and varieties*

A similar pattern was observed in the benefit-cost ratios for these sowing dates, with the peak benefit-cost ratio noted on Nov 11, then Oct 23, and the least on Dec 1. Among wheat varieties, Darulaman-07 achieved the highest net income, followed by Chont No. 1, while Mazar-99 produced the lowest net income. A comparable trend was noticed in the benefit-cost ratios among these varieties.

Discussion

The improved yield attributes observed with 11th November sowing can be attributed to the longer growing season, which allowed for greater solar radiation interception and enhanced tillering. Additionally, this timing provided optimal environmental conditions for spike and grain development, resulting in more grains per spike and increased 1000-grain weight. In contrast, 1st December sowing limited the vegetative phase, resulting in fewer effective tillers and shorter spikes.

The reduced grains per spike and lower 1000-grain weight in the 1st December sowing were likely due to a shortened grain filling period and exposure to higher temperatures during grain development, which accelerated maturity and led to shriveled grains. These findings align with studies by Ikram et al. (2025), Nikzad et al. (2025), Entz and Fowler (1991), and Kalateh Arabi et al. (2011), which reported similar effects of late sowing on grain-filling and yield attributes.

Regarding varietal effects, the superior performance of Darulaman-07 across all measured traits reflects its genetic potential to produce more fertile tillers, longer spikes, and heavier grains, reinforcing its adaptability and productivity in the given environment. This is consistent with findings from Ghanbari et al. (2012), Sarlak and Alavi Fazel (2020), Asakareh Nejad and Lak (2016), Baygi et al. (2018), Abdrabbo et al. (2016), Yousefi Moghaddam et al. (2018), Bobomirzayev and Tursunov (2022), Ayeneh et al. (2002), and Kalateh Arabi et al. (2010).

The enhanced performance observed on Nov 11 compared to Oct 23 can be linked to the plants' ability to withstand early cold stress and to a decreased risk of bird predation on the plant seeds.

Furthermore, this sowing date promoted greater dry matter accumulation, more tillers, and improved yield characteristics, resulting in higher yields.

The advantages of the 11th November sowing date compared to Dec 1 were primarily due to having enough time for the crop to progress through its various growth stages. Conversely, earlier sowing can lead to overgrowth before winter temperatures arrive, increasing the risk of winter damage. This is particularly concerning when root and crown development coincide with freezing soil temperatures, which can adversely affect spring growth (Yousefi et al., 2018).

The superior performance of the Darulaman-07 variety may be attributed to its increased dry matter production per square meter, higher number of tillers, and greater weight of a thousand grains at harvest when compared to the other two varieties. Additionally, genetic diversity among varieties contributes to the variations observed in grain and straw yields.

These findings regarding grain and straw yield are consistent with previous studies by Ghanbari et al. (2012), Sarlak and Alavi Fazel (2020), Asakareh Nejad and Lak (2016), Baygi et al. (2018), Abdrabbo et al. (2016), Yousefi Moghaddam et al. (2018), Bobomirzayev and Tursunov (2022), Ayeneh et al. (2002), and Kalateh Arabi et al. (2010).

It can be inferred that temperature, the length of day, and late sowing significantly reduced the harvest index. Nevertheless, the wheat varieties examined did not demonstrate significant variations in harvest index, indicating that genotype did not markedly affect this trait under the experimental conditions. The harvest index relates to both economic yield (grain yield) and biological yield (total aboveground biomass). It exhibits a positive correlation with economic yield and a negative one with biological yield. In this study, the harvest index was more strongly affected by economic yield than by sowing date, as treatments that led to higher grain yields also showed higher harvest index values. These results align with prior research conducted by Ghanbari et al. (2012), Sarlak and Alavi Fazel (2020), and Asakareh Nejad and Lak (2016).

The higher profitability of the Darulaman-07 variety may be attributed to its superior grain and straw yield potential, improved tillering capacity, higher number of grains per spike, and greater 1000-grain weight compared with the other varieties. These attributes enhanced biological yield, thereby increasing marketable grain output. Since economic returns are directly associated with yield performance, the superiority of the Darulaman-07 variety in yield traits translated into an advantage in financial metrics. These results align with the findings reported by Bachhao et al. (2018).

Conclusion

This year-long field study in Farah province, Afghanistan, showed that planting date and wheat cultivar significantly affect yield attributes, grain and straw yields, harvest index, and economic returns of irrigated wheat. Late sowing on Dec 1 (10^{th} Qaws) caused major declines due to shortened growth, poor tillering, and weak grain filling, while early sowing on Oct 23 (1^{st} Aqrab) also gave lower results because of excessive vegetative growth and stress vulnerability. The best performance was consistently achieved with Nov 11 (20^{th} Aqrab) sowing, which provided an optimal balance between vegetative and reproductive growth, resulting in higher tillers, spike length, grain weight, yield, and income. Among cultivars, Darulaman-07 outperformed Chont No. 1 and Mazar-99, showing superior tillering, dry matter production, grain weight, and the highest benefit-cost ratio. Interaction effects confirmed that the Darulaman-07 variety was best across all sowing dates. The study concludes that Nov 11 sowing with the Darulaman-07 variety maximizes wheat productivity and profitability, supporting food security and reducing wheat imports. However, further multi-year research is needed to validate these results under different climatic conditions.

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Authors Contributions

Kazem Nikzad designed and performed the experiment and contributed to the data management. The drafted manuscript was revised by Abdul Wasi Amiri, M. Yousef Jami, and Akhil Bharti. All authors provided approval for publication of the manuscript.

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