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Comparative Evaluation of Yield and Agronomic Traits of Four Winter Wheat (*Triticum aestivum* L.) Varieties under the Agro-Climatic Conditions of Char Asiab District, Kabul, Afghanistan

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ABSTRACT: Winter wheat (*Triticum aestivum* L.) is a staple cereal crops that provides income and support the livelihoods of local farmers of Afghanistan, while also playing a vital role in food security. It is a major source of carbohydrates and proteins for human consumption, while its straw is commonly used as livestock feed in Afghanistan. yet productivity remains below potential due to limited availability of locally adapted improved varieties. This study evaluated the agronomic performance, yield, and yield-related traits of four winter wheat varieties (Sohla 02, Sohla 018, Chont, and local variety Riza Gul) under irrigated conditions in Char Asiab District, Kabul, during the 2024–2025 growing season. Using a Randomized Complete Block Design with three replications, the data was analyzed with Statistical Tools for Agricultural Research (STAR 2.0.1) software. significant varietal differences were observed for most traits. Result showed that Sohla 018 produced the highest grain yield (4,866.67 kg ha^{-1}), 1000-grain weight (44.36 g), and grains per spike (51.11). While Sohla 02 showed superior vegetative growth, this did not translate to higher yield. The findings identify Sohla 018 as the most suitable variety for cultivation in Char Asiab District, with potential to improve wheat productivity and contribute to food security in Afghanistan.

KEYWORDS: agronomic traits, irrigated conditions, grain yield, variety evaluation, winter wheat.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the world's most important cereal crops, serving as a primary source of calories, protein, and essential nutrients for billions of people. It plays a fundamental role in global food security and agricultural sustainability due to its wide adaptability to diverse climatic conditions and its economic importance in both developed and developing countries (Sharma et al., 2014; Pardey, P. G., 2011; Zakharova & Zakharov, 2024). Improving wheat productivity remains essential to meet the increasing global demand for food under the combined pressures of population growth and climate change (Tadesse et al., 2017; Poole et al., 2022).

In Afghanistan, wheat is the principal staple crop and occupies the largest proportion of cultivated agricultural land. It contributes substantially to national food security, rural livelihoods, and household income. Nevertheless, average wheat productivity remains below the global average because of recurrent drought, limited availability of certified seed, suboptimal agronomic practices, soil fertility constraints, and increasing climatic variability (Sharma & Nang, 2018; FAO, 2015; MAIL, 2019; Raoufi & Attayee, 2020). Improving wheat production is therefore one of the major priorities for ensuring sustainable agricultural development in the country.

Winter wheat is generally better adapted to regions with cold winters because it is sown in autumn, undergoes vernalization during the winter period, and resumes vigorous growth in spring. Compared with spring wheat, winter wheat often produces higher grain yields due to its longer growing season, improved utilization of winter and early spring soil moisture, and greater biomass accumulation, provided that suitable environmental conditions are available (Tadesse et al., 2017; Poole et al., 2022).

In Afghanistan, irrigation plays a vital role in wheat production because rainfall is highly variable and insufficient to meet crop water requirements throughout the growing season. Most wheat-growing areas depend on supplemental or full irrigation to ensure adequate soil moisture during critical growth stages, particularly tillering, stem elongation, heading, and grain filling. Therefore, evaluating winter wheat varieties under irrigated conditions is essential for identifying varieties with superior agronomic performance and yield potential under the agro-climatic conditions of the country (FAO, 2015; MAIL, 2019).

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The productivity of wheat is determined by the interaction between genotype, environment, and crop management practices. Agronomic traits such as tillering ability, spike characteristics, grain number, and thousand-grain weight are major contributors to final grain yield and vary considerably among varieties grown under different agro-ecological conditions (Harasim & Wesołowski, 2016; Akram, 2011; Poltoretskyi et al., 2020). Consequently, evaluating varietal performance under local conditions is essential for identifying stable, high-yielding, and well-adapted varieties.

Several studies conducted in Afghanistan have demonstrated significant differences among wheat varieties n terms of growth, yield, and adaptation. Improved varieties generally outperform local varieties because of their wide adaptability to diverse production environments (Osmani et al., 2020; Taliman et al., 2016; Salari et al., 2015; Turabi et al., 2024; Lateifi & Amani, 2024). Likewise, research conducted in other countries has confirmed that varietal selection is one of the most effective strategies for increasing wheat productivity under changing environmental conditions (Bisht et al., 2017; Tursunov et al., 2024; Iwańska et al., 2020).

Despite the importance of wheat production in Kabul Province, limited information is available regarding the comparative performance of improved winter wheat varieties under the irrigated agro-climatic conditions of Char Asiab District, Kabul, Afghanistan. Consequently, farmers and agricultural extension services lack locally generated evidence to identify the most suitable varieties and develop evidence-based recommendations for improving wheat productivity under these conditions.

Therefore, the present study was conducted to evaluate and compare the performance of four winter wheat varieties by assessing key agronomic and yield-related traits, including plant height, number of tillers per plant, number of nodes per plant, spike length, number of grains per spike, thousand-grain weight, and grain yield under the irrigated agro-climatic conditions of Char Asiab District, Kabul, Afghanistan. The findings are expected to identify high-performing and locally adapted varieties, providing scientific evidence to support variety selection, increase wheat productivity, improve farm income, and enhance food security in Afghanistan.

METHODS AND MATERIALS

Study Area

The field experiment was conducted during the 2024–2025 winter growing season in Char Asiab District, Kabul Province, Afghanistan (34.395064° N, 69.160145° E), at an elevation of approximately 1,790 m above sea level. The study area has a semi-arid continental climate characterized by cold winters and warm, dry summers, making it suitable for winter wheat cultivation. Most annual precipitation occurs between November and April, while rainfall during late spring and summer is limited. Consequently, wheat production depends largely on supplemental irrigation during critical growth stages. The average annual temperature ranges from approximately 25 °C to 30 °C, and the average annual rainfall is about 70 mm. The previous crop grown in the experimental field was maize. The experimental soil was classified as a loam to sandy loam, with a pH of 7.5 and an organic matter content of 1.2%. Crop growth and development were monitored throughout the growing season, from seedling emergence to physiological maturity.

Experimental Materials and Design

Four winter wheat (Triticum aestivum L.) varieties were evaluated: Sohla 02 (T1), Sohla 018 (T2), Chont (T3), and the local variety Riza Gul (T4). Certified seeds of the improved varieties were obtained from two reliable sources: the Kabul Directorate of Agriculture irrigation and livestock (DAIL) and the Logar Brothers Agriculture Seed production Company, both of which supply certified wheat seed for agricultural production in Afghanistan. Uniform, healthy, and high-quality seed was used to ensure satisfactory crop establishment.

The experiment was arranged in a Randomized Complete Block Design (RCBD) with four treatments and three replications. Each experimental plot measured 2 m × 2 m (4 m²). The four varieties were randomly assigned within each replication to minimize experimental error.

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Table 1. Experimental Layout of the Randomized Complete Block Design (RCBD) for Four Winter wheat varieties.

NORTH

WEST							EAST
	Replication I	Main-Irrigation canal	P1	P2	P3	P4	
			T2	T4	T1	T3	
			Sub-Irrigation canal				
	Replication II		P1	P2	P3	P4	
			T3	T1	T4	T2	
			Sub-Irrigation canal				
	Replication III		P1	P2	P3	P4	
			T4	T3	T2	T1	

SOUTH

Note: Main and sub-irrigation canals shown in the layout represent the water distribution channels used for irrigation management and were not considered as experimental units or treatments. P1–P4 indicate plot positions within each replication, while T1–T4 represent the treatment codes assigned to the four wheat varieties

Crop Management

Seeds were sown on 10 November 2024 using the row planting method with a row spacing of 20–25 cm and a sowing depth of 5–7 cm. The seed rate was 120 kg ha^{-1}. Before sowing, diammonium phosphate (DAP) fertilizer was uniformly applied as a basal fertilizer at a rate of 100 kg ha^{-1}. All experimental plots received the same agronomic management practices, including land preparation, irrigation, fertilizer application, weed control, and other field operations, to ensure that varietal performance was evaluated under uniform growing conditions. Irrigation water was supplied from a well, and A total of five irrigations were applied throughout the growing season, with particular attention given to maintaining sufficient soil moisture during critical growth stages, including tillering, stem elongation, booting, heading, flowering, grain filling, and physiological maturity. Weed control was carried out mechanically throughout the growing season to minimize weed competition. The crop was harvested manually by hand at physiological maturity in June 2025, and all plots were harvested using the same procedure for consistent evaluation of yield and yield-related traits.

Data Collection

Data were collected from five randomly selected plants in the central rows of each plot to minimize border effects. Agronomic and yield-related traits were measured at appropriate growth stages of winter wheat. During the vegetative growth stage, plant height (cm), number of nodes per plant, and fertile tillers per plant were recorded. Plant height (cm) was measured from the ground surface to the tip of the flag leaf, while leaf length was measured from the ligule to the leaf tip. At the heading and grain development stages, spike length (cm) and grains per spike were determined, with grain number counted only from the main spike. Thousand-grain weight (g) was measured after physiological maturity using the drying method. At harvest, grain yield (kg ha^{-1}), straw (kg ha^{-1}), and biological yields (kg ha^{-1}), were determined from the net harvested area of each plot, excluding border rows. Biological yield was calculated as the total dry weight of above-ground biomass, grain yield as the weight of clean grains after threshing, and straw yield as the difference between biological yield and grain yield.

Statistical Analysis

The collected data were subjected to analysis of variance (ANOVA) using a Randomized Complete Block Design (RCBD) to determine the significance of differences among wheat varieties. Before performing ANOVA, the assumptions of normality and homogeneity of variance were checked to ensure the validity of the statistical analysis. Treatment means were compared using the Least Significant Difference (LSD) test at the 5% probability level. The LSD test was selected because it provides a suitable and sensitive method for comparing treatment means when the number of treatments is limited and the experiment is conducted under a controlled design such as RCBD. All statistical analyses were performed using the Statistical Tool for Agricultural Research (STAR) software developed by the International Rice Research Institute (IRRI) (IRRI, 2014). Differences among treatments were considered statistically significant when $P \leq 0.05$.

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RESULTS

The analysis of variance (ANOVA) revealed significant differences among the four winter wheat varieties for most agronomic and yield-related traits (Tables 2 and 3). Significant varietal effects ($P \leq 0.05$) were observed for node number per plant, tillers per plant, leaves per plant, spikes per plant, grains per spike, spikelets per spike, 1000-grain weight, grain yield, straw yield, and biological yield. However, plant height, leaf length, spike length, and harvest index were not significantly affected by varietal differences.

Among the evaluated varieties, Sohla 018 (T2) recorded the highest grain yield (4,866.67 kg ha^{-1}), followed by Sohla 02 (T1) (3,516.67 kg ha^{-1}), whereas the local variety Riza Gul (T4) produced the lowest grain yield (2,883.33 kg ha^{-1}) (Table 2). Sohla 018 also achieved the highest values for grains per spike (51.11), 1000-grain weight (44.36 g), straw yield (6,466.67 kg ha^{-1}), biological yield (11,333.33 kg ha^{-1}), and harvest index (42.78%), indicating superior overall agronomic performance.

For vegetative growth traits, Sohla 02 (T1) produced the highest number of tillers (6.00 $plant^{-1}$), leaves (29.67 $plant^{-1}$), and spikes (7.00 $plant^{-1}$), while Chont (T3) recorded the highest node number (4.66 $plant^{-1}$) and spikelets per spike (17.66). Although Sohla 018 and Chont produced relatively taller plants and longer spikes than the remaining varieties, these differences were not statistically significant (Table 1).

Overall, the results demonstrate considerable genetic variation among the tested winter wheat varieties and identify Sohla 018 (T2) as the highest-yielding and best-performing variety under the irrigated agro-climatic conditions of Char Asiab District, Kabul.

Table 2. Mean comparison of growth and agronomic traits of four winter wheat varieties

Treatment	Plant Height (cm)	Node $plant^{-1}$	Leaf Length (cm)	Tillers $plant^{-1}$	Leaves $plant^{-1}$	Spikes $plant^{-1}$	Spike Length (cm)
T1 – Sohla 02	66.77	3.66	17.02	6	29.67	7	8.55
T2 – Sohla 018	78.99	3.55	18.23	5	25.33	5.67	9.55
T3 – Chont	72.33	4.66	18.27	4.67	21.67	5	9.55
T4 – Local variety (Riza Gul)	77.66	3.55	14.95	3.33	18	4	7.99
F-test	NS (P = 0.1621)	* (P = 0.0262)	NS (P = 0.1017)	** (P = 0.0061)	** (P = 0.0094)	* (P = 0.0210)	NS (P = 0.0778)
CV (%)	8.36	9.49	8.72	11.64	11.55	15.07	7.72
LSD (0.05)	-	0.7317	-	1.1044	5.4613	1.6313	-

NS = not significant; * = significant at $P \leq 0.05$; ** = highly significant at $P \leq 0.01$. LSD = Least Significant Difference; CV = coefficient of variation.

Table 3. Mean comparison of yield and yield components of four winter wheat varieties

Treatment	Grains $spike^{-1}$	Spikelets $spike^{-1}$	1000-Grain Weight (g)	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Biological Yield (kg ha^{-1})	Harvest Index (%)
T1 – Sohla 02	43.39	16.11	39.69	3516.67	5466.67	8983.33	39.14
T2 – Sohla 018	51.11	15.88	44.36	4866.67	6466.67	11333.33	42.78
T3 – Chont	37.50	17.66	40.37	2933.33	4800.00	7733.33	37.91
T4 – Local variety (Riza Gul)	45.44	15.44	35.39	2883.33	5233.33	8116.67	35.52

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F-test	* (P = 0.0328)	* (P = 0.0180)	** (P = 0.0006)	** (P = 0.0062)	* (P = 0.0144)	** (P = 0.0021)	NS (P = 0.1763)
CV (%)	9.09	3.72	2.95	13.08	7.68	7.30	8.88
LSD (0.05)	8.0558	1.2111	2.3528	927.8808	843.0444	1319.5943	-

NS = not significant; * = significant at P ≤ 0.05; ** = highly significant at P ≤ 0.01. LSD = Least Significant Difference; CV = coefficient of variation.

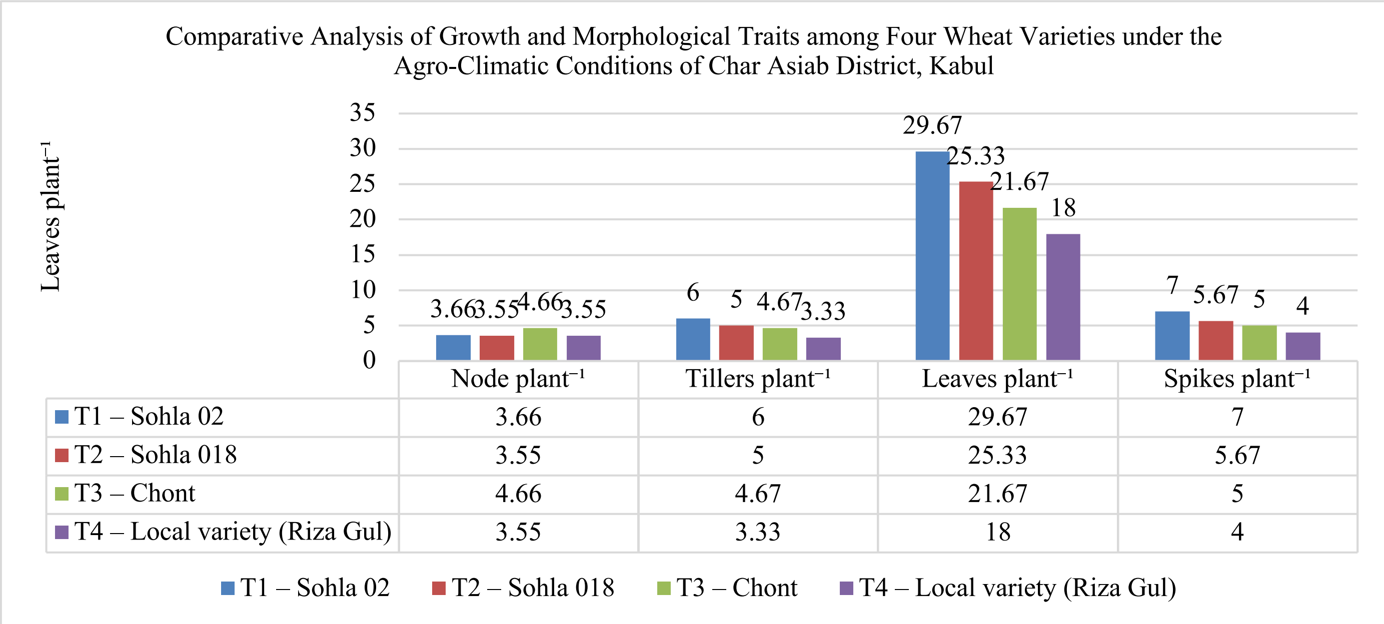

Figure 1. Growth and Agronomic Performance of Four Winter Wheat Varieties under the Agro-Climatic Conditions of Char Asiab District, Kabul

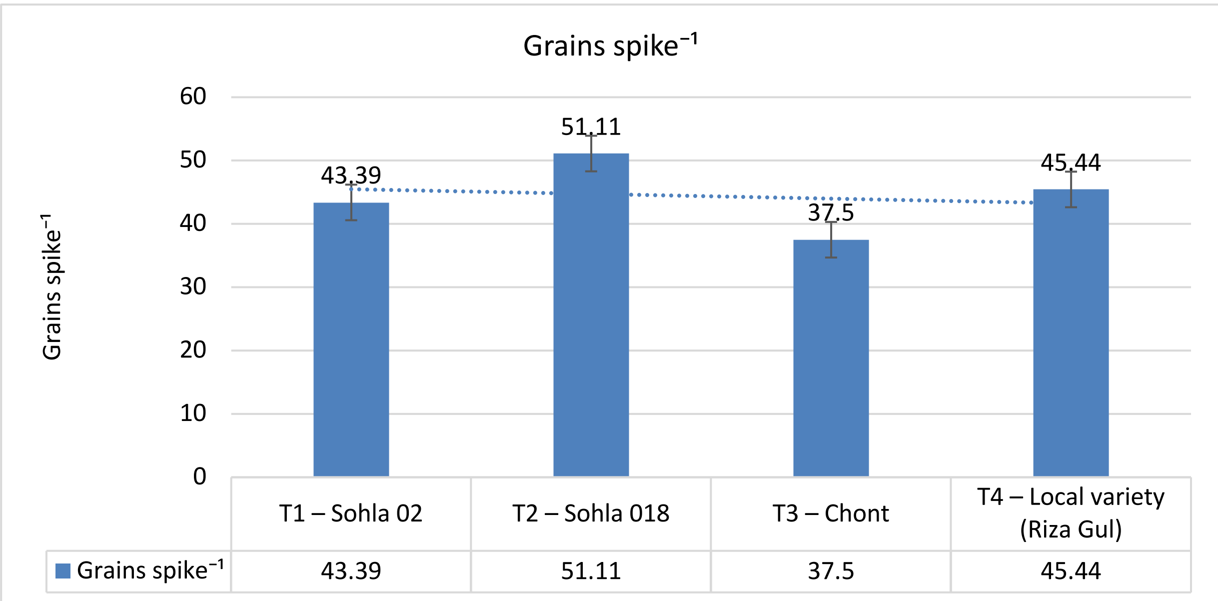

Figure 2. Grains spike⁻¹ of Four Winter Wheat Varieties under the Agro-Climatic Conditions of Char Asiab District, Kabul

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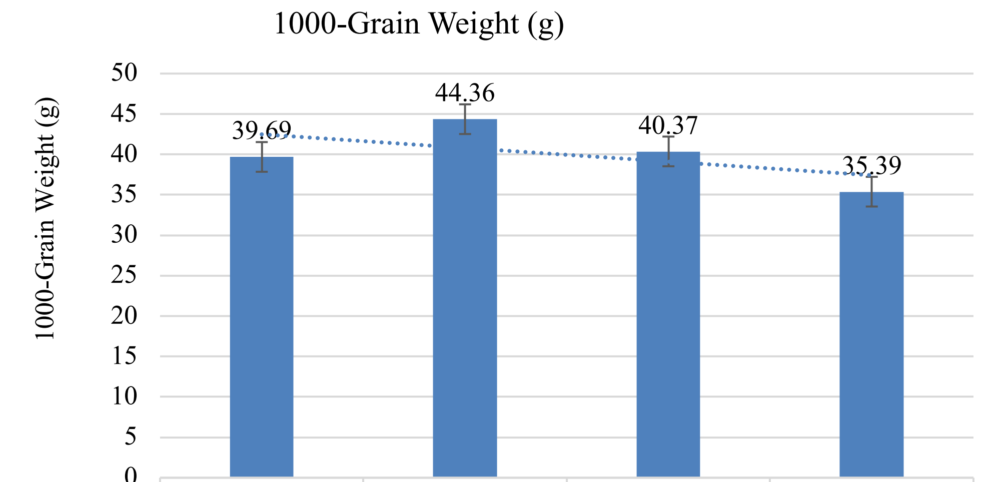
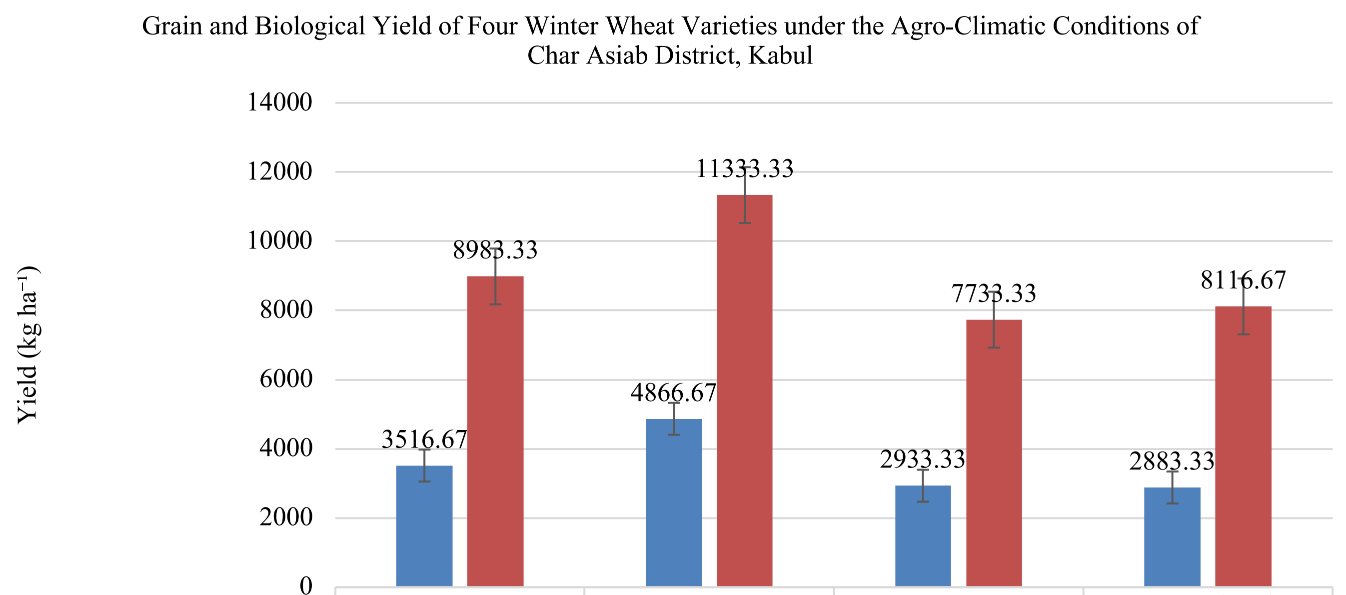


	T1 – Sohla 02	T2 – Sohla 018	T3 – Chont	T4 – Local variety (Riza Gul)
1000-Grain Weight (g)	39.69	44.36	40.37	35.39

Figure 3. 1000-Grain Weight (g) of Four Winter Wheat Varieties under the Agro-Climatic Conditions of Char Asiab District, Kabul



	T1 – Sohla 02	T2 – Sohla 018	T3 – Chont	T4 – Local variety (Riza Gul)
Grain Yield (kg ha^{-1})	3516.67	4866.67	2933.33	2883.33
Biological Yield (kg ha^{-1})	8983.33	11333.33	7733.33	8116.67

Figure 4. Grain and Biological Yield of Four Winter Wheat Varieties under the Agro-Climatic Conditions of Char Asiab District, Kabul

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DISCUSSION

This study demonstrated significant varietal differences in several agronomic and yield-related traits of winter wheat under the irrigated agro-climatic conditions of Char Asiab District, Kabul. These findings indicate that varietal performance was strongly influenced by genetic characteristics and their interaction with local environmental conditions, resulting in differences in growth, biomass production, and grain yield. Similar observations were reported by Harasim and Wesołowski (2016), who emphasized that wheat productivity is determined by the combined contribution of multiple yield components rather than by a single agronomic trait.

Among the evaluated varieties, Sohla 018 consistently outperformed the other tested varieties by producing the highest grain yield, grains per spike, thousand-grain weight, straw yield, and biological yield. The superior performance of Sohla 018 may be associated with its better adaptation to the environmental conditions of the study area and its greater efficiency in converting assimilates into grain production. Similar findings have been reported under Afghan conditions, where wheat productivity is strongly influenced by genetic potential and agro-climatic adaptation. Turabi et al. (2024) demonstrated that improved wheat varieties such as Wahdat 0.15 and Elham 0.15 exhibited superior growth and yield performance under the environmental conditions of Maidan Wardak. Likewise, Osmani et al. (2020) identified significant variation among wheat varieties grown in Kabul and recommended high-performing adapted varieties. Furthermore, Lateifi and Amani (2024) emphasized that grain yield is determined by the combined contribution of important yield components, including grains per spike, spikes per unit area, and thousand-grain weight, which supports the findings of the present study.

The significant differences observed in tillers per plant, spikes per plant, grains per spike, and thousand-grain weight indicate that these traits contributed substantially to variation in final grain yield among the tested varieties. Previous studies have identified these characteristics as major determinants of wheat productivity (Akram, 2011; Bisht et al., 2017; Poltoretskyi et al., 2020). Although Sohla 02 produced the highest number of tillers, leaves, and spikes per plant, its grain yield remained lower than that of Sohla 018. This indicates that greater vegetative growth alone does not necessarily result in higher grain yield. Yield formation depends on an effective source–sink relationship, including the capacity of the plant to produce assimilates and efficiently transfer them to developing grains. Therefore, the higher yield of Sohla 018 may be associated with improved grain filling efficiency and more effective assimilating partitioning toward grain production. Similarly, although Chont recorded the highest number of spikelets per spike, this advantage did not result in increased grain yield, possibly due to differences in grain formation, grain filling efficiency, and thousand-grain weight. These findings suggest that balanced development among yield components is more important than a single yield-related trait for achieving higher productivity.

The local Riza Gul showed lower grain yield compared with the improved varieties, indicating limited yield potential under the irrigated conditions of Char Asiab District. However, local varieties may possess valuable characteristics such as environmental adaptation, yield stability, or specific grain quality traits that were not evaluated in the present study. Therefore, further investigations including grain quality parameters and stability assessments are required to fully characterize the potential value of local wheat varieties.

In contrast, plant height, leaf length, spike length, and harvest index did not show significant differences among the tested varieties, indicating that these traits were relatively stable under the environmental conditions of the study. Similar findings have been reported by Raza et al. (2015), Hussain et al. (2018), and Ullah et al. (2023), who observed limited variation in some morphological traits among adapted wheat varieties grown under comparable environmental and management conditions. The harvest index values recorded in the present study ranged from 35.52% to 42.78%, which falls within the range commonly reported for wheat grown under semi-arid environments. The higher harvest index of Sohla 018 indicates its greater efficiency in partitioning assimilates toward grain production compared with the other tested varieties. Variation in harvest index among varieties may be associated with differences in biomass accumulation, grain filling capacity, and genetic adaptation to local agro-climatic conditions. However, the non-significant differences among varieties suggest that biomass partitioning efficiency was relatively similar under the conditions of this study.

The non-significant effect of replication on the evaluated traits indicates that environmental variation among experimental blocks was relatively low and did not substantially influence varietal performance. The absence of significant replication effects suggests that the RCBD design effectively controlled field variability and allowed reliable comparison among wheat varieties. No significant interaction between varieties and replications was observed, indicating that the differences among varieties were mainly associated with genetic variation rather than variation among experimental blocks.

Correlation analysis was not included in the present study because the primary objective was to evaluate and compare the agronomic performance and yield potential of four winter wheat varieties under RCBD conditions. However, future studies involving a larger number of genotypes, multiple locations, and different growing seasons should consider correlation analysis to better understand the relationships among yield components and identify traits strongly associated with grain yield improvement.

This study was conducted at a single location and during one growing season using a limited number of wheat varieties. Therefore, additional multi-location and multi-year evaluations involving a wider range of genotypes are recommended to confirm the stability and adaptability of promising varieties under diverse agro-climatic conditions. From a practical perspective, the superior performance of Sohla 018 indicates its potential for improving wheat productivity in the study area. However, successful farmer adoption depends on factors such as availability and affordability of certified seeds, farmer awareness, access to extension services, and local production conditions.

Overall, the findings demonstrate that Sohla 018 (T2) possesses superior agronomic performance and yield potential under the irrigated agro-climatic conditions of Char Asiab District. The selection of well-adapted and high-yielding wheat varieties represents an effective strategy for improving wheat productivity and supporting sustainable production in Kabul Province. These conclusions are consistent with recent studies emphasizing the importance of improved varieties, climate adaptation, and appropriate agronomic management practices for enhancing wheat production and food security (Poole et al., 2022; Raoufi & Attayee, 2020; Soofizada et al., 2023; Tadesse et al., 2017).

CONCLUSION

This research evaluated the agronomic performance and yield potential of four winter wheat (Triticum aestivum L.) varieties, including Sohla 02 (T1), Sohla 018 (T2), Chont (T3), and Riza Gul (T4), under the irrigated agro-climatic conditions of Char Asiab District, Kabul, Afghanistan. The results demonstrated significant varietal differences for most agronomic and yield-related traits, confirming the importance of selecting well-adapted varieties to improve wheat productivity under local environmental conditions.

Among the evaluated varieties, Sohla 018 (T2) consistently showed superior performance by producing the highest grain yield, grains per spike, thousand-grain weight, straw yield, and biological yield. Although Sohla 02 (T1) and Chont (T3) showed better performance in some vegetative and morphological characteristics, these advantages did not result in higher grain yield. The local variety Riza Gul (T4) showed comparatively lower performance for most evaluated traits.

Based on this single-season evaluation, Sohla 018 demonstrated promising yield potential and adaptation under the irrigated conditions of Char Asiab District. Its higher grain yield was mainly associated with improved yield components, particularly grains per spike and thousand-grain weight, indicating better source–sink balance. However, multi-location and multi-season studies involving additional varieties are recommended to confirm yield stability and genotype × environment interactions before making broader regional recommendations. The adoption of improved and locally adapted wheat varieties, together with appropriate agronomic management, can contribute to increased wheat productivity and food security in Afghanistan.

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