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GENETIC VARIABILITY AND SELECTION CRITERIA IN DURUM WHEAT CULTIVARS AND ADVANCED LINES UNDER RAINFED CONDITIONS

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SUMMARY

The assessment of yield-related and grain quality traits in 27 durum wheat (*Triticum durum* Desf.) cultivars and advanced lines enabled this study to be conducted in 2024 at the Scientific Research Institute of Rainfed Agriculture, Jizzakh Region, Uzbekistan. The results revealed the advanced lines RNS-2023/18 and DNS-2023/16 exhibited superior performance for 1000-kernel weight, hectoliter weight, and relatively stable yield performance compared with the check cultivar Leukurum-3. The cultivar Tilladon and advanced line RNS-2023/18 appeared leading in grain quality due to the highest values in 1000-kernel weight (44.0 g) and hectoliter weight (> 800 g/L). These promising genotypes emerged as recommendable for further breeding programs. A considerable positive association (r = 0.83) was evident between 1000-kernel weight, hectoliter weight, and grain yield, indicating the necessity of prioritizing large and plump grains to ensure the highest productivity in selected genotypes under rainfed conditions.

Keywords: Durum wheat (*T. durum* Desf.), rainfed condition, cultivars and advanced lines, grain yield, 1000-kernel weight, hectoliter weight, correlation analysis

Key findings: The durum wheat (*T. durum* Desf.) advanced lines RNS-2023/18 and DNS-2023/16 significantly outperformed the check cultivar in 1000-kernel weight, grain yield, and hectoliter weight, revealing their adaptability under rainfed conditions. Grain yield emerged as considerably associated with 1000-kernel weight and hectoliter weight, which accounted for the majority of yield variations.

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INTRODUCTION

Durum wheat (*Triticum durum* Desf.) gains enormous prominence for its significant economic contribution and the highest nutritional profile worldwide. Durum wheat provides the fundamental raw material for the food industry, including the production of high-quality pasta, confectionery, and various cereal-based products (Gorbunov *et al.*, 2004). In developed nations, modern breeding programs and the global trade sectors emphasized the productivity and development of cultivars that offer higher grain protein content, better quality, and nutritional benefits essential for human health (Vasilchuk *et al.*, 2010).

Although global durum wheat production reached 31.4 million tons across approximately 14 million hectares in 2023, sustaining this output faces severe challenges with escalating moisture deficits and drought in regional rainfed environments (IGC, 2024). In Uzbekistan, more than 1.2 million hectares were the cultivated areas with cereal crops annually (FAO, 2024), wherein the allocation of 5% of the area was to durum wheat (Zohid, 2022). Nevertheless, the domestic food industry demand is over 400,000 tons of durum wheat annually (Oybek, 2016). The adverse impact of rapid climate change, specifically the global temperature rise, has considerably compromised grain yield and quality traits of durum wheat. Therefore, the primary objective of contemporary breeding programs sought to develop novel cultivars that are early maturing and high yielding with superior quality, while being well-adapted to diverse soil and environmental conditions (Dilmukhammad, 2024).

In this regard, plant height is a critical agronomic trait that significantly influences lodging resistance and harvest index in durum wheat. However, the reduced plant height proved to have an association with better fertilizer response and lodging resistance, while optimal height was crucial for ensuring adequate biomass and photosynthetic capacity (Royo *et al.*, 2007). The 1000-kernel weight serves as a primary indicator of grain size and density, playing a vital role in determining both milling quality and final grain yield. The said trait is under the control of the interaction between genotypes' genetic potential and existing environmental factors during the grain-filling period, particularly heat and drought stress (De-Vita *et al*., 2010). Furthermore, 1000-kernel weight occurred in a positive correlation with semolina yield, proving it as a key selection criterion for the pasta industry (Sissons, 2008).

Grain yield is a polygenic trait resulting from the cumulative effects of yield components, such as spike number, grain number per spike, and grain weight. Therefore, enhancing yield potential while maintaining stability across fluctuating environments remains the paramount objective of durum wheat breeding programs globally (Reynolds *et al*., 2012). Yield performance is heavily dependent on the genotype's ability to adapt to specific agro-climatic conditions and their efficiency in utilizing existing resources (Mohammadi *et al*., 2010). Hence, considering the economic importance of these agronomic attributes, the consequent study aimed to evaluate 27 durum wheat (*T. durum* Desf.) cultivars and advanced lines for yield-related and grain-quality traits and identify superior genotypes for future breeding.

MATERIALS AND METHODS

Plant materials and field experiment

This research on durum wheat (*T. durum* Desf.) began in 2024 at the rainfed fields of the Scientific Research Institute of Rainfed Agriculture, Jizzakh Region, Uzbekistan. In the advanced yield trials, 27 durum wheat cultivars and advanced lines attained selection for evaluation in terms of plant height, 1000-kernel weight, hectoliter weight, and grain yield. The tested genotypes comprised six durum wheat cultivars (Javohir, Marvarid, Yoqut-2014, Billurdon, Kumushdon, and Tilladon), 20 advanced lines, and one check cultivar, Leukurum-3 (Table 1). These cultivars and lines entailed planting in a

randomized complete block design with four replications, and the subplot size was 30 m² (Omonov *et al*., 2004).

Traits measurement

Following the methodology of Udachin (1976), plant height measurement in centimeters (cm) started from the base of the plant to the tip of the spike, using 10 randomly selected plants per durum wheat cultivar and advanced lines. Measurements took place at the full maturity stage from the soil surface to the tip of the spike (excluding awns) on 10 randomly selected plants per plot. Technological quality indicators of the grains incurred evaluation according to established standards. Specifically, measuring 1000-kernel weight followed GOST 12042-80 (2011), while determining hectoliter weight used the PH-1 instrument in accordance with GOST 10840 (2017).

The study conducted supplementary assessments following the VIR (1984) guidelines. The determination of the 1000-kernel weight had two subsamples of 500 seeds counted for each genotype and weighed with a precision of 0.01 g. The variation between replicates remained within 5% of the mean weight to ensure accuracy. The hectoliter weight measurement used a one-liter PH-1 tester. Before testing, the samples, sieved through a 6-mm screen, bore homogenization. Two replicates received analysis, with a maximum permissible weight difference of 5 g.

Meteorological data

During the experimental year (from the sowing of durum wheat in October 2023 to its full maturity in June 2024), the weather had characteristic drought conditions. The annual precipitation was 322.0 mm, which was 40.0 mm below the long-term average. The mean annual air temperature was 9.4 °C, exceeding the long-term average by 1.0 °C. The average relative humidity was 67%. Notably, dry conditions prevailed during the spring and summer months.

Statistical analysis

The analysis of variance (ANOVA) ensued using OriginPro 2025b (v10.2.5.212) to determine the relationships between grain yield, plant height, and grain technological quality traits in various durum wheat (*Triticum durum* Desf.) cultivars and advanced lines. Pearson correlation coefficients underwent calculations to assess the direction of relationships among the agronomic parameters, facilitating the identification of genotypes with the highest productivity potential. The analysis provided quantitative insights into trait interdependencies, contributing to a more refined selection strategy within the breeding program.

RESULTS AND DISCUSSION

Plant height

Plant height has become an important morphological trait in the evaluation of durum wheat (*T. durum* Desf.) genotypes under rainfed conditions. The results revealed significant differences among the durum wheat cultivars and advanced lines for plant height, demonstrating considerable genetic diversity. According to the analysis, the highest values for plant height appeared in the cultivar Tilladon (111.6 cm) and advanced line RNS-2023/27 (109.8 cm) compared with the standard cultivar Leukurum-3 (91.2 cm) (Figure 1). The findings detailed the genotypes' highest capacity for straw biomass production and vigorous vegetative growth under arid conditions. Additionally, the cultivar Kumushdon fell into the group of taller genotypes with a plant height of 104.4 cm. Previous studies disclosed the highest genetic variability for plant height among the wheat lines cultivated in arid regions. This diversity enables breeders to select genotypes that are optimal for grain yield and straw biomass, considering the specific climatic conditions of the region (Mohammadi *et al*., 2010). These observations also agreed with previous

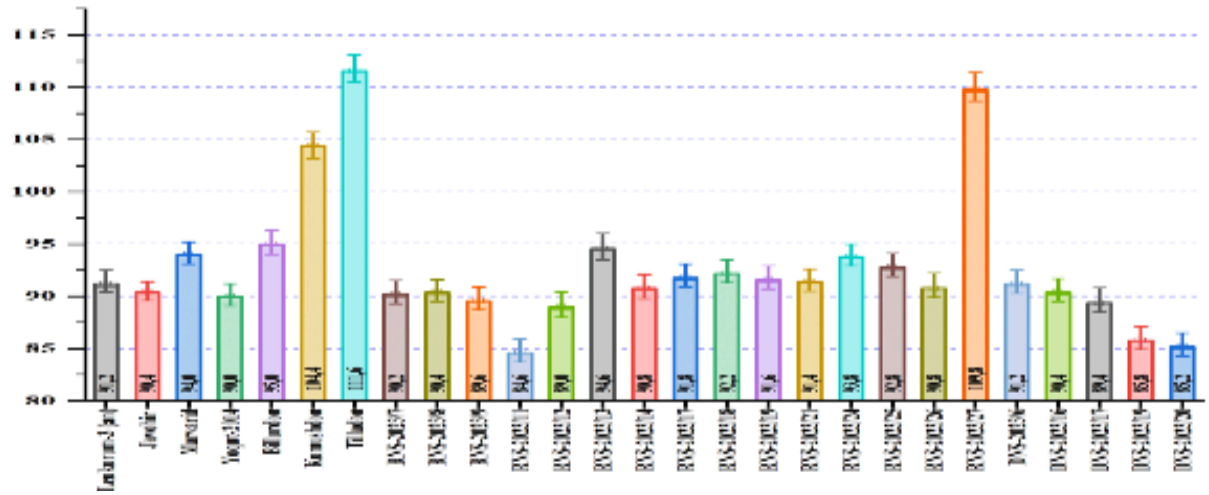

Figure 1. Plant height of durum wheat cultivars and advanced lines in 2024.

findings, which noted that taller durum wheat genotypes often exhibit better adaptation to terminal drought due to their ability to store more stem reserves. Under severe water stress conditions, greater plant height can serve as a buffer to maintain grain filling through remobilization of pre-anthesis assimilates.

In durum wheat breeding, the reduction in plant height emerged to be directly associated with increased lodging resistance and an improved harvest index. According to long-term analyses conducted under Mediterranean climate conditions, the plant height range of 80–100 cm seemed optimal for rainfed environments (Royo *et al*., 2007). Durum wheat cultivars within this plant height range can withstand lodging under adverse weather conditions while maintaining sufficient vegetative biomass for photosynthesis.

In contrast, the durum wheat advanced lines RNS-2023/11 (84.6 cm), DNS-2023/20 (85.2 cm), and DNS-2023/19 (85.8 cm) showed the least plant height, suggesting their highest resistance to lodging. The majority of other cultivars (Javohir, Yoqut-2014, Marvarid, and Billurdon) and lines (RNS-2023/13 and RNS-2023/24) ranged between 90 and 95 cm for plant height. However, the said range tended to be optimal for rainfed conditions, as it considerably facilitates the mechanized harvesting while ensuring resilience against lodging caused by strong winds and precipitation.

Overall, such variation among the genotypes allows breeders to select suitable cultivars for the rainfed regions, catering to grain production purposes. Similar trends have surfaced in previous reports, where semi-dwarf genotypes demonstrated a more favorable harvest index and stable yield across varying rainfed sites. Maintaining an intermediate plant height is a strategic trade-off between lodging prevention and consistent biological yield in drought-prone environments (Mansouri *et al*., 2018).

1000-kernel weight

In durum wheat breeding, thousand-kernel weight is distinct as high heritability, which facilitates effective selection across generations. According to the analysis of variance, the 27 durum wheat cultivars and advanced lines succeeded in their evaluation for 1000-kernel weight under rainfed conditions. The results implied highly significant ($P < 0.0001$) differences among the genotypes for 1000-kernel weight with the highest level of experimental precision (CV = 1.06%). For 1000-kernel weight, the grand mean of the experiment was 39.85 g. A significant number of genotypes exceeded the performance of the standard check cultivar

Table 1. Kernel's technological quality parameters in durum wheat cultivars and advanced lines in 2024.

Cultivars	1000-kernel weight (g)		Hectoliter weight (g/L)	
	Means (g)	Standard Deviation	Means (g/L)	Standard Deviation
Leukurum-3 (check)	38.0	0.39	770.4	3.65
Javohir	38.4	0.43	775.8	3.16
Marvarid	32.8	0.39	745.2	3.92
Yoqut-2014	40.0	0.39	780.6	3.40
Billurdon	40.4	0.43	780.1	3.74
Kumushdon	40.8	0.43	775.9	3.16
Tilladon	44.0	0.47	800.3	4.69
RNS-2023/7	38.4	0.43	775.5	3.74
RNS-2023/8	40.8	0.43	785.7	3.77
RNS-2023/9	38.0	0.39	765.2	4.55
RNS-2023/11	40.0	0.39	780.8	3.56
RNS-2023/12	40.4	0.43	775.4	2.58
RNS-2023/13	40.0	0.39	775.1	3.72
RNS-2023/14	40.0	0.39	775.6	3.54
RNS-2023/17	41.2	0.43	785.3	2.94
RNS-2023/18	44.0	0.47	795.9	4.55
RNS-2023/19	42.0	0.47	785.2	4.55
RNS-2023/21	42.8	0.47	790.5	3.74
RNS-2023/24	36.8	0.39	760.7	3.92
RNS-2023/25	38.0	0.39	775.3	3.74
RNS-2023/26	40.4	0.43	790.1	3.16
RNS-2023/27	43.2	0.47	795.6	3.37
DNS-2023/6	38.4	0.43	760.4	4.55
DNS-2023/16	44.0	0.47	800.8	3.72
DNS-2023/17	38.0	0.39	760.2	3.16
DNS-2023/19	37.2	0.39	770.5	3.74
DNS-2023/20	38.0	0.39	780.9	3.74
Mean Square (Model)	26.19806		679.48718	
Mean Square (Error)	0.17926		14.14815	
Prob>F	<0.0001		<0.0001	
Coeff Var.	0.01062		0.00484	

Leukurum-3, recording only a 1000-kernel weight of 38.0 g (Table 1). Specifically, the cultivar Tilladon and the advanced lines RNS-2023/18 and DNS-2023/16 demonstrated the maximum performance (44.0 g), surpassing the check cultivar by 6.0 g. Numerous studies revealed the 1000-kernel weight served as one of the most critical selection traits for improving grain yield in durum wheat (*T. durum* Desf.) in rainfed and water-scarce environments. Genotypes with larger grains tend to maintain higher yield potential under drought stress conditions, underscoring the necessity of prioritizing this trait in breeding programs (Mohammadi and Amri, 2018).

Furthermore, the advanced lines RNS-2023/27 (43.2 g), RNS-2023/21 (42.8 g), RNS-2023/19 (42.0 g), and RNS-2023/17 (41.2 g), as well as cultivars Kumushdon (40.8 g) and Billurdon (40.4 g), provided superior grain weight compared with the check cultivar Leukurum-3, revealing their highest potential for developing large-grained cultivars suitable for rainfed agriculture. Fellahi *et al*. (2018) reported a considerable positive genotypic correlation between 1000-kernel weight and grain yield under semi-arid conditions. Their results demonstrated that selecting for large-grain genotypes can further improve grain yield and quality traits, such as semolina yield. Moreover, identifying and utilizing lines with a stable 1000-kernel weight has proven highly effective in mitigating adverse effects of terminal drought. Genotypes demonstrating

such traits showed distinction from extended grain-filling durations and improved sink capacity, making them indispensable for sustainable production in arid regions (Pour-Aboughadareh *et al*., 2020).

These results were in close alignment with recent multi-environment trials, which demonstrated that advanced durum wheat lines often exhibit superior grain weight compared with traditional standard cultivars under moisture-deficit conditions. The robust performance of these specific genotypes suggested an enhanced capacity for the remobilization of water-soluble carbohydrates from the stem to the developing grain during post-anthesis stress conditions (Tadesse *et al*., 2019; Karaman, 2020).

Hectoliter weight

For hectoliter weight, the durum wheat cultivars and advanced lines revealed highly significant ($P < 0.0001$) differences, with an exceptionally low coefficient of variation (0.48%), indicating the highest experimental precision. The check cultivar Leukurum-3 gave a recorded hectoliter weight of 770.4 g/L, and a significant number of durum wheat genotypes surpassed this benchmark. Specifically, the advanced line DNS-2023/16 and the cultivar Tilladon exhibited the highest mean values for hectoliter weight (800.8 g/L and 800.3 g/L, respectively), exceeding the check cultivar by 30 g/L (Table 1). Rharrabti *et al*. (2003) emphasized that while environmental factors influence quality traits, the genotypic contribution remains decisive for developing cultivars with stable quality under rainfed conditions.

Furthermore, the superior grain-filling capacity was evident in several advanced lines, such as RNS-2023/18 (795.9 g/L) and RNS-2023/27 (795.6 g/L). This supported the conclusion of Sukumaran *et al*. (2015) that the effective improvement of hectoliter weight can be possible through breeding strategies, thereby enhancing the potential for milling quality under water-limited environments. These superior test weight values revealed efficient starch accumulation and dense endosperm packaging despite terminal drought stress. Maintaining a high hectoliter weight under such adverse conditions confirmed the robust physiological adaptation of these advanced lines, which proved crucial for ensuring maximum semolina extraction rates in the pasta industry (Zecevic *et al*., 2013).

Grain yield

The 27 durum wheat cultivars and advanced lines evaluated under rainfed conditions in 2024 revealed highly significant ($P < 0.0001$) differences for grain yield (Table 2). The coefficient of variation (3.39%) signified the highest experimental precision and reliability of the data. The check cultivar Leukurum-3 produced an average grain yield of 1.4 t/ha, and several durum wheat genotypes remarkably demonstrated superior performance. Specifically, the advanced line RNS-2023/18 provided the topmost yield (1.8 t/ha), surpassing the check cultivar by 0.4 t/ha. Furthermore, the advanced lines RNS-2023/17 (1.8 t/ha), DNS-2023/16 (1.8 t/ha), and RNS-2023/8 (1.8 t/ha), as well as the cultivar Tilladon (1.7 t/ha), showed significantly higher yield potential than the check cultivar Leukurum-3. Such yield advantages over standard checks in arid environments were primarily due to an enhanced harvest index and more efficient water use during the critical grain-filling period (De-Vita *et al*., 2007).

Inversely, the cultivar Marvarid (1.0 t/ha) and the advanced line RNS-2023/24 (1.2 t/ha) exhibited the lowest yields. These results highlighted the exceptional potential of the selected advanced lines, particularly RNS-2023/18 and DNS-2023/16, to maintain the highest productivity under rainfed environments, suggesting their suitability for future release through breeding programs. The superior performance of these specific advanced lines confirmed that targeted selection under moisture-deficit conditions notably improved the partitioning of dry matter to the grain. Assessing the effectiveness of durum wheat breeding under rainfed conditions, Pecetti and Annicchiarico (2013) conducted a comprehensive study in the arid regions of Italy. By comparing landraces with

Table 2. Grain yield of durum wheat cultivars and advanced lines in 2024.

Cultivars and advanced lines	Means (t/ha)	Standard Deviation
Leukurum-3 (check)	1.42	0.02
Javohir	1.54	0.02872
Marvarid	1.06	0.04655
Yoqut-2014	1.56	0.05909
Billurdon	1.59	0.04397
Kumushdon	1.67	0.06055
Tilladon	1.75	0.03266
RNS-2023/7	1.61	0.07719
RNS-2023/8	1.80	0.07455
RNS-2023/9	1.30	0.04655
RNS-2023/11	1.54	0.03317
RNS-2023/12	1.61	0.03317
RNS-2023/13	1.57	0.0943
RNS-2023/14	1.56	0.05909
RNS-2023/17	1.81	0.03317
RNS-2023/18	1.84	0.04397
RNS-2023/19	1.77	0.04787
RNS-2023/21	1.65	0.06055
RNS-2023/24	1.20	0.05447
RNS-2023/25	1.31	0.03317
RNS-2023/26	1.66	0.04397
RNS-2023/27	1.69	0.04573
DNS-2023/6	1.22	0.07932
DNS-2023/16	1.80	0.04655
DNS-2023/17	1.23	0.04787
DNS-2023/19	1.52	0.04787
DNS-2023/20	1.48	0.04787
Mean Square (Model)	0.17626	
Mean Square (Error)	0.00275	
Prob>F	<0.0001	
Coeff Var.	0.03387	

advanced breeding lines, the yield advantage of modern genotypes was not because of an increased adaptability with unfavorable environmental factors, rather to an elevation in yield potential.

Previous studies emphasized that increasing grain number emerged as the main driver of grain yield in wheat, and the stability of individual grain weight plays a crucial role under terminal drought stress conditions in rainfed areas (Slafer *et al*., 2014). Recent multi-environment evaluations further corroborate that the introgression of adaptive traits, such as early vigor and optimal flowering time, was essential to maximize yield potential before the onset of severe terminal drought. Therefore, combining high intrinsic yield capacity with stable yield components remains the most effective strategy for durum wheat improvement under drought-prone agroecosystems (Sallam *et al*., 2019; Bassu *et al*., 2021).

Correlation analysis

The correlation and regression analyses revealed significant associations between the grain yield and grain quality traits in durum wheat (Figure 2). Specifically, grain yield exhibited a robust positive correlation with 1000-kernel weight and hectoliter weight (r = 0.83). The regression analysis detailed that 68%–69% of the variation in grain yield (r^2 = 0.68 and r^2 = 0.69) was due to the variations in these two traits. The results suggested selected genotypes characterized by large and plump grains could be an effective strategy for increasing grain yield in durum

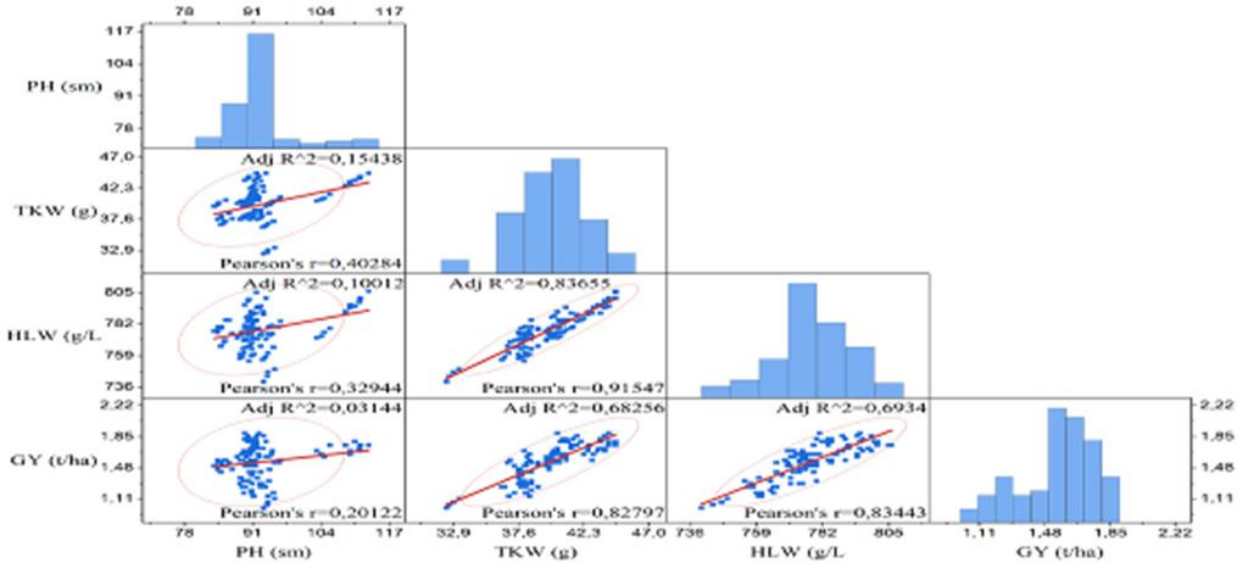

Figure 2. Relationship between plant height, grain quality, and grain yield of durum wheat cultivars and advanced lines. PH = Plant height (sm), TKW = Thousand kernel weight (g), HLW = Hectoliter weight (g/L), and GY = Grain yield (t/ha).

wheat under rainfed conditions. Moreover, the highest positive correlation (r = 0.92) was evident between 1000-kernel weight and hectoliter weight, with a coefficient of determination of r^2 = 0.84, revealing a robust genetic interdependence between these traits.

Contrastingly, the influence of plant height on grain yield occurred to be weak (r = 0.20), with the regression model explaining only 3% of the yield variation (r^2 = 0.03). The results confirmed that under rainfed conditions, plant height was not a decisive factor for yield accumulation. These considerable associations between the grain- and yield-attributing traits were consistent with previous studies in durum wheat, which confirmed that 1000-kernel weight and test weight were the most reliable predictors of grain yield under moisture stress conditions. Therefore, selection for such highly heritable yield components directly enhances the sink capacity and overall productivity in durum wheat under rainfed environments (Mohammadi *et al*., 2012).

The terminal drought stress conditions observed at the end of the growing season, genotypes with a high capacity to remobilize photosynthates from the stem to the grain form larger grains, which directly lead to an increased grain yield (Sio-Se-Mardeh *et al*., 2006). In the correlation analyses conducted under semi-arid conditions, Hannachi *et al*. (2013) reported a nonsignificant relationship between the plant height and grain yield. They attributed this to the tendency of taller plants in rainfed environments to consume excessive moisture to maintain vegetative mass, thereby increasing the risk of depleting soil moisture reserves by the grain-filling stage.

Therefore, the low impact of plant height on grain yield observed in this latest study (r = 0.20) suggested that prioritizing 1000-kernel weight and hectoliter weight in durum wheat breeding for rainfed conditions was the correct strategy. Additionally, extensive evaluations of drought-adaptive traits have shown that minimizing redundant vegetative growth conserves critical soil moisture for the post-anthesis period. Consequently, breeding strategies that favored the highest grain plumpness over excessive plant height ensured the better assimilate partitioning and stable grain yield under severe terminal drought (Garcia-del-Moral *et al*., 2003).

CONCLUSIONS

The presented research evaluated the genetic variability of 27 durum wheat (*T. durum* Desf.) cultivars and advanced lines under rainfed conditions. The advanced lines RNS-2023/18 and DNS-2023/16 demonstrated superior adaptability to water-limited environments, significantly outperforming the check cultivar Leukurum-3 in grain yield, 1000-kernel weight, and hectoliter weight. Correlation and regression analyses established that grain yield received considerable influence from 1000-kernel weight and hectoliter weight rather than plant height. Consequently, prioritizing genotypes characterized by large and plump grains seemed the most effective breeding strategy for rainfed conditions. Combining high productivity with superior grain quality, the advanced lines RNS-2023/18 and DNS-2023/16 emerged as highly recommendable for foundational genetic resources for future breeding programs and cultivation across rainfed regions in Uzbekistan.

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