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DURUM WHEAT (*TRITICUM DURUM* L.) QUALITY PARAMETERS AND THEIR RELATIONSHIP WITH GRAIN YIELD

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SUMMARY

This study aimed to assess the grain quality and yield-related traits of 14 durum wheat (*Triticum durum* L.) cultivars and advanced lines and their trait relationships, carried out from 2019 to 2021 at the Scientific Research Institute of Rainfed Agriculture, Jizzakh Region, Uzbekistan. Key quality parameters determined under laboratory conditions included thousand kernel weight (TKW), hectoliter weight (HLW), kernel vitreousness (KV), grain protein content (GPC), gluten content (GC), and gluten deformation index (GDI). Likewise, an analysis of their correlation with grain yield proceeded. Over a three-year period and based on the results, the advanced lines 2012/7 and 2012/77 exhibited superior grain quality and relatively stable yield performance. Cultivars Kristella, Kurant, and Agat Donsk were outstanding in nutritional and processing quality due to high values in kernel vitreousness, grain protein content, and gluten content. These promising genotypes were favorable for further use in breeding programs. The negative and weak association was evident between grain quality traits and grain yield, indicating the need for genetic balance while considering high quality and productivity in selection.

Keywords: Durum wheat (*T. durum* L.), cultivars, advanced lines, grain quality, yield performance, traits correlation

Key findings: Over a three-year period, the durum wheat (*T. durum* L.) cultivar Mikki-3 and advanced lines 2012/7 and 2012/77 showed a significant yield advantage over the check cultivar Makuz-3. Cultivars Kristella, Kurant, and Agat Donsk emerged superior in nutritional and processing quality. The weak correlation between grain quality and yield suggested a balanced breeding approach is necessary to improve both types of traits collectively.

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INTRODUCTION

Durum wheat holds significant nutritional and economic value worldwide. It serves as an essential raw material in the production of high-quality pasta, confectionery, and grain-based products, as well as being widely used in food industries (Gorbunov *et al.*, 2004). In developed countries and in the global grain trade, durum wheat breeding programs focus on increasing yield and developing new cultivars with enhanced grain protein content, improved quality and digestibility, elevated nutritional values, and ensured safety for human health (Vasilchuk *et al.*, 2010).

Durum wheat, essential for its nutritional and economic worth globally, is an essential raw material in the production of various grain-based products. In 2019, over 17 million hectares of durum wheat underwent cultivation globally, producing a total of 38 million tons, with leading countries that include Canada, Italy, and Turkey (Xynias *et al.*, 2020). Breeding programs in developed countries focus mainly on increasing yield by developing new cultivars with enhanced grain protein content, improved quality, and enriched nutrient contents.

Durum wheat (*T. durum* L.) is a highly cultivated crop in Uzbekistan, alongside common wheat (*T. aestivum* L.). It is popular for high-quality grains and is a key ingredient in numerous confectionery products. In Uzbekistan, over 1.2 million hectares undergo annual cultivation with cereal crops, with approximately 65,000 hectares allocated for durum wheat (Zohid, 2022). However, the national food industry requires more than 400,000 tons of durum wheat grain annually (Oybek, 2016).

With the frequent and ongoing climate change, the global temperature increase (+1.6°C) has negatively affected grain yield and quality-related properties in durum wheat cultivars. Consequently, the development of new, early-maturing, high-yielding, and better-quality durum wheat cultivars well adapted to diverse soil and environmental conditions has become a critical objective in modern breeding programs (Dilmukhammad, 2024).

In durum wheat, kernel vitreousness, grain size, and hardness mainly influence flour yield and its appearance. These traits significantly vary depending on genotypes, environmental conditions, and growing environments (Acar *et al.*, 2019). Moreover, effects on flour color come from multiple factors, including cultivar type, grain protein content, kernel translucency, hardness, shape, size, and the concentration of carotenoids found in the bran layer (Ficco *et al.*, 2014).

Globally, approximately 60% of protein demand hails from cereal and legume crops (Goncharov, 2009). Protein has become a key indicator in assessing the quality of wheat cultivar grains. However, in cereal grains, the protein content receives abiotic and biotic factor influences and, to some extent also, the genetic control, which one cannot disregard in this context (Asplund *et al.*, 2013). The quality of durum wheat grains is largely dependent on their grain protein content, which primarily has the genotypes and environmental conditions determining it, particularly the available nitrogen content in the soil (Gerba *et al.*, 2013). Therefore, from the previous discussion, the presented study aimed to determine the grain quality and yield-related traits of 14 durum wheat (*T. durum* L.) cultivars and advanced lines and their traits' relationships.

MATERIALS AND METHODS

Plant materials and field experiment

The following research on durum wheat (*T. durum* L.) transpired during 2019–2021 at the irrigated fields of the Scientific Research Institute of Rainfed Agriculture, Jizzakh Region, Uzbekistan. In the Advanced Yield Trial plots, 14 durum wheat cultivars and advanced lines entailed selection for evaluation of grain-quality attributes and grain yield. The tested genotypes included durum wheat cultivars (Mingchinor, Istiqbolli, Azeghar-3, Mikki-3, ICAMOR TA04, Kurant, Agat Donsk, and Kristella), advanced lines (299, 576, 586, 2012/7, and 2012/77), and the check cultivar

Table 1. Kernels' technological quality parameters in durum wheat cultivars and advanced lines.

Cultivars	TKW		HLW		KV		GPC		GC		GDI	
	Means (g)	Standard Deviation	Means (g/L)	Standard Deviation	Means (%)	Standard Deviation	Means (%)	Standard Deviation	Means (%)	Standard Deviation	Means (IDK)	Standard Deviation
Mingchinor	45.33	2.10	793.10	14.50	86.24	4.53	16.80	0.20	32.37	0.97	74.77	6.38
Istiqbolli	47.00	1.31	806.10	17.50	85.54	5.02	17.40	0.40	31.40	1.06	80.83	2.11
299	47.87	1.53	805.10	15.27	89.40	4.68	17.40	0.30	30.67	1.81	82.00	5.58
576	43.93	1.37	808.33	13.99	76.99	6.20	14.90	0.60	28.63	1.35	90.37	7.24
586	45.97	1.42	803.73	12.33	85.78	2.92	15.67	1.01	28.23	1.50	88.10	2.92
2012/7	48.13	1.20	810.53	12.91	91.97	4.35	17.70	0.66	33.80	1.55	67.47	3.95
2012/77	46.17	0.80	808.10	11.92	81.66	4.67	15.83	0.35	30.23	2.71	76.23	5.95
Azeghar-3	43.07	0.35	802.33	17.95	80.65	1.44	13.93	0.70	25.77	0.68	100.53	5.42
Mikki-3	45.77	1.63	822.30	12.52	78.50	2.67	14.53	0.50	27.07	1.14	88.90	5.46
ICAMOR TA04	49.47	1.86	807.47	6.59	86.89	3.99	14.90	0.66	26.73	0.87	82.73	4.15
Kurant	44.63	1.10	798.20	1.73	94.63	3.23	17.83	0.76	33.47	1.40	63.63	3.46
Agat Donsk	45.13	1.70	801.27	5.29	89.10	4.68	17.97	0.85	33.93	1.40	64.40	3.70
Kristella	43.90	0.89	794.57	17.08	92.52	2.85	17.87	0.23	33.67	1.52	64.27	4.34
Makuz-3 (check)	45.07	0.42	805.63	13.03	83.53	3.74	15.83	0.72	30.13	1.78	80.87	2.50
Mean Square (Model)	9.66603		156.2181		84.47120		5.92676		23.76434		375.7823	
Mean Square (Error)	1.83643		172.9469		16.77636		0.37690		2.22286		22.52524	
Prob>F	0.00012		0.56038		0.00017		<0.0001		<0.0001		<0.0001	
Coeff Var.	0.02958		0.01634		0.04765		0.03760		0.04899		0.06013	

TKW = Thousand kernel weight (g), HLW = Hectoliter weight (g/L), KV = Kernel vitreousness (%), GPC = Grain protein content (%), GC = Gluten content (%), and GDI = Gluten deformation index (IDK).

(Makuz-3) (Table 1). These cultivars and lines underwent planting using a randomized complete block design with four replications in 25 m² subplots (Omonov *et al.*, 2004).

For durum wheat, the establishment of fertilization rates relied on prior field studies conducted in Uzbekistan. During soil preparation, the application of nitrogen and phosphorus fertilizers had the rate

of 30:90 kg NP ha⁻¹, followed by 75 kg N ha⁻¹ in early spring and an additional dose of 75 kg N ha⁻¹ at the stem elongation phase. Irrigation proceeded according to developmental stages—post-emergence, tillering, stem elongation, and flowering—at the rate of 600–800 m³/ha.

Traits measurement

Assessment of grain technological quality traits used the following standards and instruments: thousand kernel weight (TKW)—GOST 12042-80 (2011), hectoliter weight (HLW)—via PH-1 method, GOST 10840 (2017), kernel vitreousness (KV)—GOST 10987-76 (2009), grain protein content (GPC)—measured using the Perten instrument, gluten content (GC), and gluten deformation index (GDI)—GOST 13586.1-86 (2009).

Additional assessments followed the methodologies of the VIR (1984) manual. For TKW measurement, two subsamples of 500 seeds each from each durum wheat genotype underwent separate weighing with an accuracy of 0.01 g. The difference between replicates did not exceed 5% relative to the average weight, ensuring precision. The HLW determination used a PH-1 model one-liter volume tester. Before measurement, sieving grain samples utilized a 6 mm screen for thorough homogenization. Two replicates gained testing, with the weight difference between them not exceeding 5 g.

The assessment of trait kernel vitreousness under laboratory conditions utilized the DSZ-3 diaphanoscope. For each test, 100 kernels placed into the cassette incurred examination under a light source through a lens. Recording the number of fully translucent, partially translucent, and mealy (non-translucent) kernels continued. The final vitreousness calculation was by summing the number of fully translucent kernels and half the count of partially translucent ones.

Statistical analysis

In determining the relationship between grain yield and grain quality traits among different durum wheat (*T. durum*) cultivars and advanced lines, statistical analyses employed the OriginPro 2025b (v10.2.5.212). Correlation coefficient computations assessed the considerable direction of the associations among the various agronomic parameters, enabling identification of genotypes with high productivity and superior grain quality traits. The analyses provided quantitative insights

into trait interdependencies, contributing to a more refined selection strategy in the said breeding program.

RESULTS AND DISCUSSION

Thousand kernel weight (TKW)

During the three-year period (2019 to 2021), the technological grain quality attributes of 14 durum wheat (*T. durum* L.) cultivars and lines succeeded in their evaluation under laboratory conditions in a competitive varietal trial. The average TKW ranged from 43.1 to 49.5 g (Table 1). The check cultivar Makuz-3 exhibited a 1000-grain weight of 45.1 g. Cultivars and advanced lines, such as Istiqbolli, 299, 2012/7, 2012/77, and ICAMOR TA-04, demonstrated higher TKW weights, surpassing the standard by 1.1 to 4.4 g. Given an extremely low Prob>F value (0.000115), one can conclude considerable significant differences existed among the durum wheat cultivars in terms of TKW. The cultivars 299, Istiqbolli, and ICAMOR TA04 gave the most consistent and superior values for TKW. Additionally, the advanced lines 2012/7 and 576 displayed the highest genetic potential, indicating their suitability as parental forms in future hybridization programs.

In cereal crops, particularly wheat, the thousand kernel weight (TKW) is a critical indicator for determining yield potential, especially under irrigated conditions, where it significantly contributes to yield enhancement (Shevchenko and Korchagin, 2006). According to past studies, in durum wheat the thousand kernel weight (TKW) varies between 37 and 69 g, depending on existing environmental conditions (Collaku and Harrison, 2005). Beyond reflecting the cultivar's genetic traits, this metric provides insight into the environmental conditions prevailing during the grain-filling stage of the crop life.

Hectoliter weight (HLW)

The definition of hectoliter weight (HLW) is the mass of grain per unit volume, typically expressed in grams per liter. A higher HLW

value indicates a greater concentration of valuable nutrients, reflecting well-developed and physiologically mature kernels in durum wheat. Generally, such grains possess a higher proportion of endosperm and a lower proportion of bran, contributing to improved milling performance. The HLW of the studied durum wheat cultivars and lines ranged from 793.1 to 822.3 g/L (Table 1). The check cultivar Makuz-3 demonstrated an HLW of 805.6 g/L. Cultivars and advanced lines, such as 576, 2012/7, 2012/77, and Mikki-3, exhibited HLW values 2.5 to 16.7 g/L higher than the check cultivar. Since $\text{Prob}>F = 0.56$, it indicates the durum wheat cultivars were notable with nonsignificant differences for HLW. However, from a breeding perspective, agronomic differences in this trait remain valuable. Among the genotypes, the cultivar Mikki-3 achieved the highest HLW value (822.3 g/L), denoting a high grain density, which appeared favorable for milling applications. The advanced line 2012/7 displayed the values for thousand kernel weight (TKW) and HLW, recognizing it as a promising candidate genotype for selection. Notably, the cultivar ICAMOR TA04 had the lowest standard deviation ($\text{std. dev.} = 6.52$), indicating stable performance and higher consistency for superior quality traits.

Consequently, HLW can be a critical parameter in determining high-quality durum wheat (Dilmukhammad, 2024). Hectoliter weight, which is the mass of a liter of grain, typically ranges from 700 to 840 g/L for wheat. Hectoliter weight indicates the fullness of the grain and the completion of the synthesis processes of its constituent substances; the fuller the grain, the higher its bulk density (Hossein *et al.*, 2011).

Kernel vitreousness (KV)

Kernel vitreousness is a key quality trait in durum wheat (*T. durum* L.), closely associated with semolina yield and milling performance. The kernel vitreousness levels in the evaluated durum wheat cultivars and advanced lines ranged from 77% to 94.6% (Table 1). The check cultivar Makuz-3 exhibited a kernel

vitreousness value of 83.5%. Compared to the check genotype, cultivars and advanced lines, such as Mingchinor, Istiqbolli, 299, 586, 2012/7, ICAMOR TA-04, Kurant, Agat Donsk, and Kristella, showed 2.0%–11.1% higher values for kernel vitreousness. The significance of differences among the genotypes for kernel vitreousness received confirmation with a low $\text{Prob}>F$ value (0.000168), indicating the differences were highly reliable. The durum wheat cultivars with the highest kernel vitreousness values were Kurant (94.63%), Kristella (92.52%), and 2012/7 (91.98%), identified as stable and promising candidate genotypes for breeding purposes. These genotypes were also suitable for pasta and flour production, offering reduced waste during mechanical grain cleaning.

Kernel vitreousness is a crucial trait, as it has a close association with the technological quality of the grains (Krivchenko *et al.*, 1977). Durum wheat kernels could gain categories such as translucent (fully vitreous endosperm), mealy (fully mealy endosperm), and semi-translucent (partially vitreous or semi-mealy endosperm). According to Sandhu *et al.* (2009), primary determination of kernel vitreousness depends on the density and continuity of the protein matrix within the endosperm of durum wheat (*Triticum turgidum* L. var. *durum*).

Grain protein content (GPC)

The wheat grain protein content plays an essential role in determining its intended utilization for various purposes. The soft wheat typically requires a protein concentration of 14%–15% for bread production, whereas durum wheat used in pasta manufacturing requires a protein content of approximately 17%–18%. The study emphasizes that grain protein content in durum wheat typically exceeds that of bread wheat, often ranging between 13% and 16%, depending on genotypes and the existing environmental conditions. Moreover, the higher molecular weight glutenin subunits (HMW-GS) enhance the dough strength and elasticity, which are the critical parameters in industrial processing.

In this study, the total protein content across 14 durum wheat (*T. durum* L.) cultivars and advanced lines ranged from 13.9% to 18.0% (Table 1). The check cultivar Makuz-3 registered the protein content of 15.8%. Compared with the check genotype, the cultivars and advanced lines, such as Mingchinor, Istiqbolli, 299, 2012/7, Kurant, Agat Donsk, and Kristella, demonstrated higher protein levels by 1.0%–2.2%. Analysis revealed a highly significant difference among the cultivars for protein content, supported by a very low Prob>F value (less than 0.0001). The cultivar Kristella not only showed an elevated protein content, but it also maintained the highest degree of stability, as reflected in its low standard error of mean (SE = 0.13333).

Wheat grain serves as a primary source of plant-based protein for humans, fulfilling up to 50% of daily protein requirements (Kadirov *et al.*, 2015). Durum wheat is widely known for its superior end-use quality, particularly in pasta production, due to its elevated protein content, strong gluten matrix, and high levels of carotenoid pigments. Saini *et al.* (2022) also reported these traits collectively contribute to the desirable cooking and sensory properties of semolina-based products made from the durum wheat.

Gluten content (GC)

The water-insoluble protein fraction of wheat flour forms a cohesive and extensible mass known as gluten, obtained after hydration and allowed to rest. This transformation into an elastic matrix is one of wheat's key advantages in food processing. Increasing gluten content is a primary objective in wheat breeding programs and technological improvement efforts. Gluten content is a principal indicator of grain quality. In this presented study, GC values across the evaluated durum wheat cultivars and lines ranged from 25.8% to 33.9% (Table 1). The check cultivar Makuz-3 showed a gluten content of 30.1%. Cultivars and lines, such as Mingchinor, Istiqbolli, 2012/7, Kurant, Agat Donsk, and Kristella, demonstrated higher gluten content, exceeding the check genotype by 1.3%–3.8%.

In durum wheat (*T. durum* L.), the breeding success often depended on the evaluation of the cultivar's ability to maintain higher gluten levels consistently. Gluten comprises of proteins such as fibrin, casein, and gliadin, which collectively define the nutritional and technological properties of wheat grains. Pasta prepared from durum wheat lines with modified glutenin subunit composition showed the differences in cooked firmness and dough strength, indicating that gluten structure plays a key role in pasta-making quality (Sissons *et al.*, 2014). Genotypes with higher grain protein content and gluten strength had better pasta cooking quality (Kaplan, 2022).

Gluten deformation index (GDI)

Gluten quality assessment further used the gluten deformation index, measured with the IDK-3 instrument. The GDI scale, as divided into three classes, comprised Class I—Good quality (45–75), Class II—Acceptable (20–40/80–100), and Class III—Poor quality (0–15/105–120 and above) (Table 1). The GDI values of the durum wheat cultivars and lines in the competitive variety trial ranged from 63.6 to 100.5. Based on the analysis, six durum wheat genotypes belonged to Class I (good gluten quality), eight genotypes placed in Class II (acceptable quality), and no genotype received Class III (poor quality). The check cultivar Makuz-3 emerged with a GDI value of 80.9. Genotypes classified in Class I for gluten quality included Mingchinor, 2012/7, 2012/77, Kurant, Agat Donsk, and Kristella, and they succeeded in being selected based on their superior gluten elasticity and deformation resistance.

The gluten deformation index is an important trait for the rapid assessment of technological quality in wheat-based products and is widely applicable in breeding programs and industrial processing (Oikonomou *et al.*, 2015). The GDI is one of the key variables for evaluating wheat gluten quality; however, relying solely on elasticity is insufficient, as the deformation index of the extracted gluten does not always accurately reflect its true quality (Shabolkina *et al.*, 2021).

Table 2. Grain yield in durum wheat cultivars and advanced lines during 2019–2021.

Cultivars	2019		2020		2021	
	Means (t/ha)	Standard Deviation	Means (t/ha)	Standard Deviation	Means (t/ha)	Standard Deviation
Mingchinor	6.10	0.16	5.24	0.05909	5.26	0.05909
Istiqbolli	5.54	0.17	5.05	0.1034	4.91	0.18554
299	4.90	0.17	4.19	0.08813	3.98	0.18601
576	5.34	0.30	4.47	0.15457	4.24	0.18699
586	5.45	0.31	4.56	0.15556	4.15	0.13279
2012/7	6.11	0.12	5.60	0.10801	5.49	0.06055
2012/77	5.97	0.10	5.31	0.16663	4.86	0.16681
Azeghar-3	5.37	0.18	4.85	0.14933	4.98	0.16581
Mikki-3	6.57	0.29	5.81	0.18886	5.72	0.11026
ICAMOR TA04	4.63	0.14	4.43	0.20469	4.29	0.1072
Kurant	4.64	0.08	4.56	0.16462	4.28	0.16912
Agat Donsk	4.17	0.09	4.37	0.13772	3.86	0.18679
Kristella	4.13	0.14	4.31	0.21731	3.94	0.14221
Makuz-3 (check)	5.18	0.19	4.64	0.0911	4.39	0.24622
Mean Square (Model)	2.19575		1.03826		1.46394	
Mean Square (Error)	0.03595		0.02221		0.02515	
Prob>F	<0.0001		<0.0001		<0.0001	
Coeff Var.	0.03583		0.03098		0.03451	

Cultivars and line grain yields

In 2019 competitive variety trials, the 14 durum wheat cultivars and advanced breeding lines bore assessment for grain yield. The results showed average yields ranged from 4.1 to 6.6 t/ha (Table 2). The check cultivar Makuz-3 gave a record average grain yield of 5.3 t/ha. Several newly developed breeding lines outperformed the check cultivar. In particular, the genotypes Mikki-3, 2012/77, and 586 were distinct as high-potential genotypes. In 2020, the durum wheat cultivars and lines showed the grain yield ranging from 4.2 to 5.8 t/ha, with Makuz-3 yielding \approx 4.6 t/ha. Notably, the lines 2012/77 (+1.0 t/ha), Mikki-3 (+1.3 t/ha), 2012/7 (+0.7 t/ha), and Azeghar-3 (+0.7 t/ha) demonstrated superior performance compared with the check cultivar. Yield data for 2021 revealed the grain yield range between 3.9 and 5.7 t/ha, with Makuz-3 yielding \approx 4.4 t/ha. Genotypes, such as Azeghar-3 (+0.6 t/ha), 2012/7 (+0.6 t/ha), 2012/77 (+1.1 t/ha), and Mikki-3 (+1.3 t/ha), again exceeded the performance of the check genotype. According to the three-year yield data, the durum wheat

genotypes Mingchinor, Istiqbolli, 2012/7, 2012/77, Azeghar-3, and Mikki-3 showed an advantage of 0.4 to 1.3 t/ha over the check cultivar Makuz-3. Consequently, they became choices as promising sources for further breeding with a focus on higher grain yield.

With current climate change conditions, durum wheat (*T. durum* L.) breeding requires strategic approaches aimed at improving grain yield and ensuring stability. Grains' morphological traits, such as grain size, shape, and 1000-grain weight, are substantially key components of grain yield (De-Vita and Taranto, 2019). Wheat is one of the most widely cultivated cereal crops globally and plays a pivotal role in ensuring food security. In evaluating durum wheat cultivars, yield potential stands out as the leading agronomic trait. The selection process emphasizes not only high productivity but also yield stability across the environments. Achieving higher grain yield is not solely dependent on frequent irrigation and fertilization, but can also be successful by selecting well-adapted cultivars to specific climatic conditions of the target environment (Chosh and Puste, 1997).

Relationship between grain quality traits and grain yield

Based on the three-year (2019–2021) data of the competitive variety trials of 14 durum wheat (*T. durum* L.) cultivars and advanced lines, the analysis served to examine the correlation between technological quality traits and grain yield. The correlation analysis revealed a negative and weak correlation was evident for the traits of grain yield vs. TKW (Pearson's $r = 0.18487$, adjusted $R^2 = 0.01003$). As 1000-grain weight increases, the grain yield tends to decrease; however, this relationship was statistically negligible (Figure 1). This indicates larger kernels do not necessarily guarantee higher grain yield. The traits grain yield vs. HLW (Pearson's $r = -0.49438$, Adjusted $R^2 = 0.00453$) disclosed a moderate negative association, which suggested an increased HLW slightly reduces the grain yield. This may relate to the grain-filling dynamics, as a greater grain number per spike can lead to smaller and less dense grains, sometimes a higher overall grain yield.

The traits grain yield vs. KV (Pearson's $r = -0.32689$, Adjusted $R^2 = 0.0591$) enunciated a weak and negative correlation (Figure 1). As kernel vitreousness increases, the yield declines a bit. Although vitreousness is a key quality indicator in durum wheat, combining high vitreousness with higher grain yield is still a challenge in some durum wheat genotypes. The traits grain yield vs. GPC (Pearson's $r = -0.23844$, Adjusted $R^2 = 0.00967$) exhibited a highly weak and negative correlation, indicating increasing protein content reduces the grain yield. This may be due to the dilution effect in high-yielding cultivars, where synthesized protein distribution is over greater biomass. For the traits grain yield vs. GC (Pearson's $r = -0.18392$, Adjusted $R^2 = 0.01217$), it was the same with protein content; the highly weak and negative correlation was notable, suggesting a higher gluten concentration has a

minor association with lower grain yield. The grain yield vs. GDI (Pearson's $r = -0.19043$, Adjusted $R^2 = 0.0043$) signified an intensely weak and negative correlation, which revealed an increased GDI has a slight correlation with a decreased yield performance.

Correlation refers to the association between two or more quantitative trait values and how the traits influence each other, where the correlation may be positive or negative (Shmoilova, 2002). Determining significant relationships makes it possible to identify the indicators that can be beneficial as selection criteria to increase productivity while improving grain quality (Pravdziva and Shadchyna, 2024).

CONCLUSIONS

The promising research highlighted the crucial and complex relationship between grain quality and yield in durum wheat. The study recommends durum wheat's advanced lines 2012/7 and 2012/77 as the identified excellent parental sources for future breeding programs because of the integration of higher grain yield with desirable technological grain quality traits. A weak and negative correlation emerged between some quality parameters, such as protein and gluten content, and grain yield, which suggested that it is possible to achieve a balance. The analysis revealed a weak and negative correlation between some quality indicators, such as grain protein and gluten content, and yield. This means that when one trait increases, the other slightly decreases. This negative correlation may be in relation to the "dilution effect" in high-yielding cultivars, where the distribution of synthesized protein is over a greater biomass (yield). Therefore, these results emphasize the need for integrated selection criteria in breeding programs to improve the productivity and quality traits simultaneously in durum wheat.

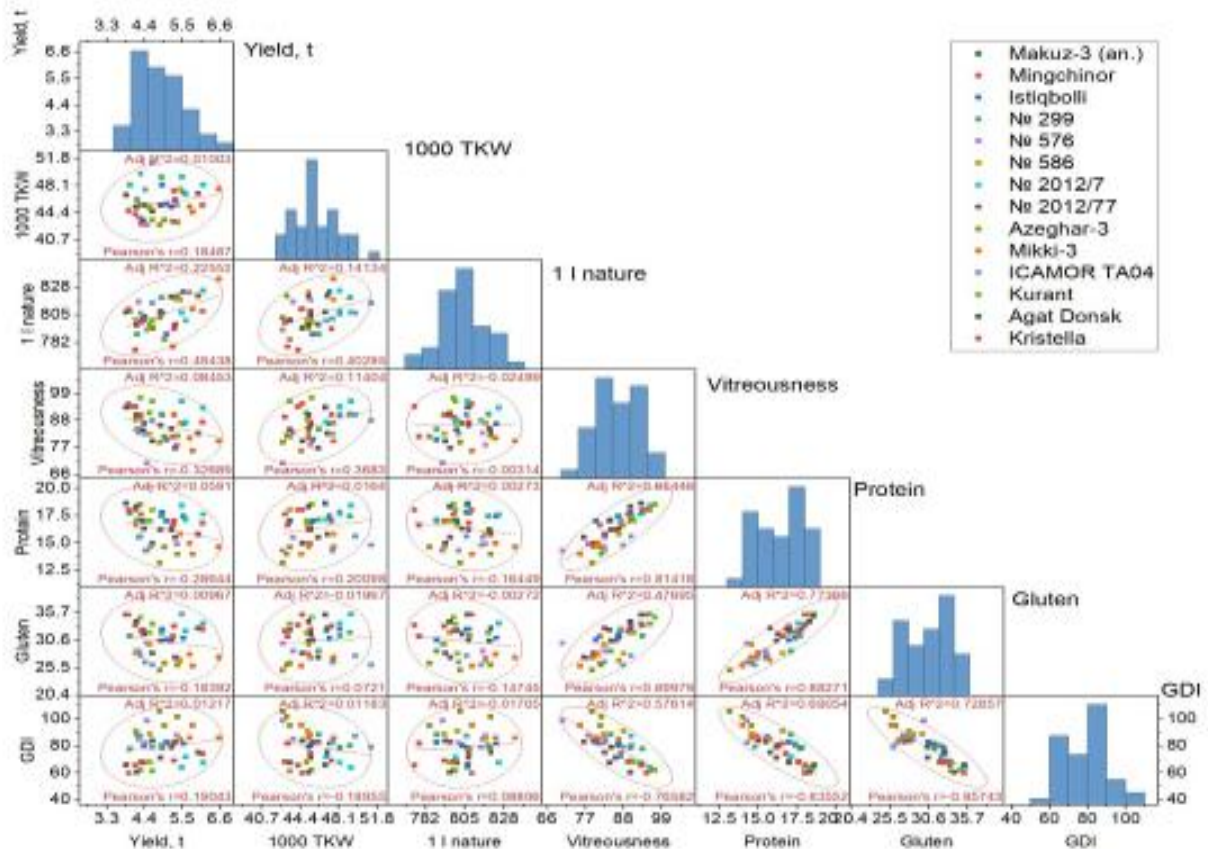


Figure 1. The relationship between grain quality traits and yield performance in durum wheat.

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