Yield potential and grain quality of winter wheat varieties and hybrids in the continental climate of Azerbaijan

Parviz Ulker ogly Fatullayev[1,3], *Anatolij Mikhailovich* Spiridonov[2], *Ismayil Bagiyat ogly* Mammadov[1,3], *and Bahruz Surkhay ogly* Bayramov[3]

[1]Institute of Bioresources, Ministry of Science and Education of the Republic of Azerbaijan, Nakhchivan, Azerbaijan
[2]Saint-Petersburg State Agrarian University, Saint Petersburg, Russian Federation
[3]Nakhchivan State University, Nakhchivan, Azerbaijan

Abstract. This study presents a long-term assessment of grain quality indicators in winter wheat varieties and hybrids under the continental climate of the Nakhchivan Autonomous Republic, Azerbaijan. In 2020–2025, a total of 57 durum wheat hybrids, 35 bread wheat hybrids, and 46 varieties were evaluated for yield, 1000 grain weight, crude protein, gluten, test weight, ash content, and vitreousness. Grain yield ranged from 275.2 to 569.0 g/m². Crude protein reached up to 21.5%, gluten up to 54.0%, and vitreousness up to 98.5%. A positive correlation between protein and gluten content was observed. The highest 1000 grain weight (61.8 g) was recorded in the hybrid Yaqut × Alinca-84. Maximum yield (569 g/m²) was found in Alinca-84 × Zatino. The results support practical recommendations for selecting varieties and hybrids adapted to local conditions.

1 Introduction

Winter wheat (*Triticum aestivum* L.) is one of the most important cereal crops worldwide, serving as a staple food for a significant portion of the global population. In Azerbaijan, particularly in the Nakhchivan Autonomous Republic, wheat production plays a crucial role in ensuring food security and supporting the agricultural economy. The region is characterized by a sharply continental climate, with winter temperatures dropping to –20°C and summer temperatures exceeding +40°C, creating challenging conditions for crop production [1-3].

Improving the quality of winter wheat grain is a key objective for breeders and agronomists in the region. Grain quality encompasses multiple traits, including protein and gluten content, gluten quality (assessed by the gluten deformation index, IDK), 1000 grain weight, test weight, vitreousness, and ash content [1, 4]. These parameters determine the technological and baking properties of wheat flour and influence the economic value of the grain [5, 7]. Previous studies have demonstrated that genotype accounts for approximately 27% of yield formation, while resistance to abiotic stresses contributes 19%, and mineral nutrition accounts for 15% [5]. Breeding programs worldwide are increasingly focused on

developing varieties with stable yields and consistent quality under variable environmental conditions [6, 8]. In the Nakhchivan Autonomous Republic, the combination of extreme temperatures, limited precipitation, and specific soil conditions necessitates the development of locally adapted wheat varieties and hybrids with enhanced stress tolerance and superior grain quality.

The objective of this study was to evaluate a wide range of durum and bread wheat hybrids and varieties for yield potential and grain quality parameters under the continental climate conditions of the Nakhchivan Autonomous Republic, and to identify promising genotypes suitable for cultivation in peasant and farmer enterprises.

2 Materials and methods

The study was conducted from 2020 to 2025 at the experimental field of the Institute of Bioresources in Nakhchivan (39°45′ N, 44°45′ E). A total of 57 durum wheat hybrids, 35 bread wheat hybrids, and 46 bread and durum wheat varieties were evaluated under irrigation conditions. Sowing followed international descriptor guidelines with 300 germinating seeds per 1 m². The optimal sowing period for the region, after October 20, was observed. Preceding crops were chickpea (*Cicer arietinum*) and black (clean) fallow. Standard agronomic practices for the region were applied, including irrigation after sowing to ensure uniform emergence.

Quality indicators, including protein, moisture, gluten, and ash content, were determined using a Spectran-119 M analyzer (LOMO Photon Plus) in the laboratory "Grain, Legumes and Industrial Crops". Test weight, 1000 grain weight, and yield were measured using Denver instruments. Weight was determined on analytical scales APX-1502 (max 1500 g, d=0.01 g). Seed vitreousness was assessed using diaphanoscopes DSZ-2 and DSZ-2 with a counter. All analyses were conducted in triplicate, and results were expressed as mean values over the study period. Statistical analysis was performed using analysis of variance (ANOVA), with the least significant difference (LSD) calculated at the 5% significance level.

3 Results and discussion

Significant variability in quality traits was observed among the studied hybrids and varieties. The results for durum wheat hybrids are summarized in Table 1, building upon earlier findings reported for the 2021–2023 period [6].

Table 1. Yield and grain quality indicators of durum wheat hybrids, average for 2020–2025

№	Hybrid	Vitreousness,, %	Crude protein, %	Moisture, %	Gluten, %	Ash elements, %	Test weight, q/l	1000 grain weight, q	Yield, q\m2
Variety *Leucurum* (Alef.) Koern in Koern. Et Wern. (1885)									
1	Tartar-2 X Spelta (red)*	81.7	19.5	9.2	42.3	1.4	808	57.0	472.2
2	Giorgio 12571 X Sharq	78.3	18.3	11.2	46.0	1.3	814	50.0	326.2
3	Mirbashir-50 X Karabakh	75.5	19.9	11.3	51.8	1.3	795	51.2	377.8
4	Sharq X Karabakh	83.2	19.7	12.3	53.8	1.3	782	52.6	564.2
5	Alinca-84 X Bakht	93.0	17.7	11.3	43.5	1.3	793	50.0	344.0
6	Vugar X Bakht	97.0	19.5	10.8	50.8	1.3	836	51.4	503.2

7	Turan X Mirvari*	94.0	19.3	10.5	47.6	1.3	803	54.2	466.8
8	Sharq X Karabakh*	83.5	15.6	12.0	38.7	1.3	796	53.4	295.6
9	Yaqut X Alinca-84	78.0	18.9	11.7	47.9	1.3	798	61.8	466.2
10	Kahraba X Mirbashir-50	79.0	18.9	11.0	48.9	1.3	779	55.6	468.4
11	Giorgio12571 X Mirbashir-50	78.0	20.8	10.2	46.3	1.4	784	53.8	378.6
12	Tartar X Zedoni 3d56*	65.7	17.2	12.4	43.4	1.2	810	53.0	475.8
13	Barakatli-95 X Tartar	76.0	15.8	12.4	40.6	1.2	797	53.2	565.2
14	Spelta (white) X Zedoni 3d56	73.0	16.8	12.4	42.7	1.2	754	49.8	445.2
15	Alinca-84 X Barakatli-95*	70.0	15.7	11.6	40.1	1.3	770	51.6	541.8
16	Turan X Zedoni 3d56	85.0	19.1	10.7	43.6	1.3	774	54.8	412.6
17	Vugar X Alinca-84	79.0	14.8	12.0	38.0	1.3	792	48.4	463.4
Variety *Leucomelan* (Alef.) Koern in Koern. Et Wern. (1885)									
1	Giorgio 12571 X Karabakh*	97.7	18.8	12.0	48.0	1.3	745	51.2	362.0
2	Spelta (red) X Zedoni-3d56*	65.0	20.0	12.1	53.1	1.3	790	47.6	527.4
3	Giorgio 12571 X Karabakh	95.7	20.5	11.2	53.4	1.2	770	45.6	447.0
4	Mirbashir-50 X Giorgio 12571	97.0	20.0	11.1	49.3	1.3	758	47.6	495.0
5	Vugar X Yaqut	88.5	21.3	10.7	49.7	1.3	813	50.2	431.2
6	Mirbashir-50 X Barakat*	95.3	19.1	11.3	49.8	1.3	769	48.2	541.6
7	Yaqut X Qaraqchq-2*	97.4	18.6	11.1	49.5	1.3	791	46.6	483.4
8	Barakatli-95 X Alinca-84	83.7	17.6	11.1	45.6	1.3	767	51.2	528.8
9	Barakatli-95 X Vugar*	76.0	18.8	11.2	47.7	1.4	787	55.2	533.0
10	Tartar-2 X Karolodeskaya*	63.0	19.9	11.6	50.8	1.2	816	53.0	510.0
Variety *Melanopus* (Alef.) Koern in Koern. Et Wern. (1885)									
1	Mirvari X Barakat	72.5	17.9	11.2	48.0	1.3	803	49.0	457.2
2	Kahraba X Mirvari	73.8	14.9	12.9	39.9	1.3	777	48.0	418.6
3	Alinca-84 X Zatino	98.0	18.4	12.1	48.5	1.3	773	53.6	569.0
4	Giorgio 12571 X Mirbashir-50	90.5	17.4	12.1	41.5	1.2	815	53.4	462.0
5	Barakat X Turan	90.7	19.2	10.4	43.5	1.3	845	53.2	275.2
6	Tartar X Turan	79.0	16.6	11.5	38.4	1.3	812	57.2	393.2
Variety *Hordeiforme* (Host) Koern in Koern. Et Wern. (1885)									
1	Vugar X Qaraqchq-2	93.5	14.9	11.9	35.5	1.3	828	51.6	430.4
2	Zedoni-3d56 X Spelta (white)	75.5	17.9	12.0	44.3	1.3	753	49.6	428.8
3	Zedoni-3d56 X Spelta (rid.)*	76.3	19.7	11.2	50.8	1.3	816	50.0	408.4
4	Zatino X Barakatli-95*	78.0	20.2	9.5	42.0	1.4	821	48.0	471.2
5	Bakht X Barakatli-95	80.3	18.4	10.9	41.0	1.3	801	49.0	329.8
6	Yaqut X Bakht	98.5	18.0	11.0	42.7	1.2	824	49.8	531.4
7	Bakht X Yaqut	87.0	15.0	12.1	37.4	1.3	814	49.2	555.0
Variety *Apulicum* Koern.									

1	Zedoni-3d56 X Tartar-2	75.6	18.1	11.6	45.0	1.2	824	50.6	304.6
2	Zedoni-3d56 X Spelta (white)	77.5	16.6	10.7	33.8	1.3	787	50.2	397.0
3	Alinca-84 X Qaraqchq-2*	76.0	16.9	11.9	42.1	1.3	787	53.4	431.2
4	Zedoni-3d56 X Red wheat.	75.0	15.2	12.8	40.1	1.2	798	54.2	446.2
5	Barakatli-95 X Shiraslan-23	76.5	18.8	11.3	49.1	1.3	756	54.2	468.4
Variety *Valenciae* Koern.									
1	Giorgio 12571 X Mirvari	77.7	17.3	11.0	41.5	1.3	846	47.8	370.8
2	Zedoni-3d56 X Spelta red.	75.3	17.3	11.7	43.7	1.3	727	53.4	297.2
3	Mirbashir-50 X Sharq	76.0	15.9	13.2	41.1	1.2	782	52.6	491.0
4	Shiraslan-23 X Vugar	90.8	17.1	11.1	41.2	1.3	777	51.8	398.0
Variety *Serulessens*									
1	Tartar X Karabakh	97.7	15.7	12.2	40.0	1.2	823	52.2	326.8
2	Tartar X Kahraba*	63.5	21.5	9.3	47.2	1.4	797	56.8	523.2
3	Tartar X Karolodeskaya	83.0	16.9	10.7	40.6	1.3	811	50.4	337.4
4	Kahraba X Mirbashir-50	85.7	17.1	11.1	39.1	1.4	821	56.8	478.6
Variety *Erythromelan* Koern in Koern. Et Wern. (1885)									
1	Turan X Giorgio12571	78.2	20.3	11.7	54.0	1.3	783	52.4	327.0
2	Yaqut X Barakatli-95	65.5	16.9	11.8	41.8	1.3	793	50.2	489.2
Variety *Provinciale* (Alef.) Koern in Koern. Et Wern. (1885)									
1	Tartar X Giorgio 12571	73.6	19.4	11.1	41.7	1.3	808	52.8	391.2
Variety *İtalicum* (Alef.) Koern in Koern. Et Wern. (1885)									
1	Vugar X Barakatli-95	83.5	18.3	10.9	45.6	1.4	755	49.6	469.2
	HCP_{05}							2,1	95,4

*Note: * — hybrids with specific characteristics discussed in the text.*

Vitreousness. In the milling and cereal industry, vitreous grain is valued higher than mealy grain. Grain with completely vitreous and dense endosperm produces high flour yields and yields granular flour, which is highly valued in baking and pasta production. Our study showed that vitreousness among durum wheat hybrids ranged from 63% to 98%, with the highest value (98.5%) recorded in Yaqut × Bakht (variety *Hordeiforme*). The average vitreousness across all durum wheat hybrids was 81.36%. Among bread wheat varieties and hybrids, similar variability was observed, with values generally ranging from 60% to 95% depending on genotype and growing conditions [9].

Protein and Gluten Content. Crude protein content in durum wheat hybrids varied between 14.8% and 21.5%, with the maximum observed in Tartar × Kahraba (variety *Serulessens*). The average protein content was 18.15%. Gluten content ranged from 33.8% to 54.0%, peaking in Turan × Giorgio12571 (variety *Erythromelan*), with an average of 44.79%. A positive correlation between protein and gluten content was confirmed in our study, consistent with previous findings [2].

Evaluation of bread wheat varieties revealed protein content ranging from 9.2% to 21.0%, with the highest value recorded in Emil (awned). Gluten content reached 56.8% in the same variety. Among bread wheat hybrids, protein content ranged from 15.1% to 21.6%, with Qobustan × Diomant showing the maximum value (21.6%) and the highest gluten content

(57.5%). These results demonstrate that the region's climatic conditions allow the production of wheat grain with high protein and gluten content, suitable for baking applications [1, 7].

Ash Content and Test Weight. Ash content showed minor variation across all studied materials, averaging 1.29–1.30%. This indicates that mineral nutrition was relatively uniform across the experimental plots and that the studied genotypes did not differ substantially in their mineral accumulation patterns.

Test weight is an important indicator of grain density and overall quality. Among durum wheat hybrids, test weight ranged from 727 to 846 g/l, with the highest value recorded in Giorgio 12571 × Mirvari (variety *Valenciae*). The average test weight was 792.6 g/l. Bread wheat varieties achieved test weights up to 841 g/l, while bread wheat hybrids reached 830 g/l. High test weight values reflect good grain filling and minimal damage from pests or diseases [4, 8].

Thousand Grain Weight. The 1000 grain weight averaged 51.7 g across durum wheat hybrids, with a maximum of 61.8 g in Yaqut × Alinca-84 (variety *Leucurum*). This parameter is important because it reflects grain size and directly influences yield potential. Higher 1000 grain weight values are generally associated with better grain quality and higher flour yields. Our results indicate that the studied hybrids possess favorable grain size characteristics for commercial production [10].

Yield Performance. Yield is the primary economic trait for any crop variety. Among durum wheat hybrids, yield ranged from 275.2 to 569.0 g/m², with an average of 440.7 g/m² (44.07 centners/ha). The highest yield (569 g/m²) was achieved by Alinca-84 × Zatino (variety *Melanopus*), followed by Barakatli-95 × Tartar (565.2 g/m²) and Bakht × Yaqut (555 g/m²). These yields are comparable to or higher than those reported for winter wheat in similar continental climate conditions [4, 5]. The yield potential of bread wheat varieties and hybrids was also substantial, with many entries exceeding 500 g/m² under irrigation. The combination of high yield with desirable quality traits, such as high protein or gluten content, was observed in several genotypes, indicating the possibility of selecting for both productivity and quality simultaneously [6, 11].

Correlations Among Traits. Correlation analysis revealed a positive relationship between protein and gluten content ($r = 0.82$, $p < 0.05$), confirming that selection for higher protein content would likely result in increased gluten content. However, no significant correlation was found between yield and protein content, suggesting that it may be possible to develop high-yielding varieties with good grain quality. Similar results have been reported in other wheat breeding programs [2, 9].

Practical Recommendations. Based on the complex of grain quality indicators, several hybrids and varieties can be recommended for cultivation in the Nakhchivan Autonomous Republic:

- For high protein content: Tartar × Kahraba (durum), Emil (bread wheat variety), Qobustan × Diomant (bread wheat hybrid)
- For high gluten content: Turan × Giorgio12571 (durum), Emil (bread wheat variety), Qobustan × Diomant (bread wheat hybrid)
- For high vitreousness: Yaqut × Bakht (durum)
- For high yield: Alinca-84 × Zatino, Barakatli-95 × Tartar, Bakht × Yaqut (durum)

Farmers and agricultural enterprises should select varieties and hybrids based on their specific end-use requirements, balancing yield potential with quality parameters [8, 11].

4 Conclusions

1. Under irrigation and continental climate conditions, winter wheat hybrids and varieties produced average yields of 440.7 g/m² (44.07 centners/ha) for durum wheat hybrids, with a maximum of 569 g/m² (59.9 centners/ha).

2. Grain with crude protein content up to 21.5% (durum wheat hybrids), 21.0% (bread wheat varieties), and 21.6% (bread wheat hybrids) can be obtained in the region. Gluten content reached 54.0% in durum wheat hybrids, 56.8% in bread wheat varieties, and 57.5% in bread wheat hybrids. A positive correlation between protein and gluten content was confirmed [2].
3. Vitreousness values of 63–98% were recorded across hybrids, with Yaqut × Bakht reaching 98.5%, indicating high suitability for milling applications [9].
4. Grain size, characterized by 1000 grain weight, averaged 51.7 g across durum wheat hybrids, with a maximum of 61.8 g in Yaqut × Alinca-84 [10].
5. Test weight values reached 846 g/l in durum wheat hybrids, 841 g/l in bread wheat varieties, and 830 g/l in bread wheat hybrids, reflecting good grain density [11].
6. Based on the complex of quality traits, hybrids and varieties can be selected for specific end uses, balancing protein and gluten content with yield potential [5, 8]. The genotypes identified in this study represent valuable genetic resources for further breeding efforts and for direct use in agricultural production.

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