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Original article

Multi-Year Assessment of Quality Parameters in Bread Wheat Cultivars under Karacabey Ecological Conditions

Pakize Özlem Kurt *

Department of Park and Garden Plants, Vocational School of Technical Sciences, Bursa Uludag University, Bursa, Türkiye

Abstract

Wheat (*Triticum aestivum* L.) is a strategic cereal crop whose technological quality is strongly influenced by both genetic background and environmental factors. This study aimed to evaluate the quality performance of five bread wheat cultivars grown under the ecological conditions of Karacabey, Bursa, during the 2023 and 2024 production seasons. Field trials were conducted in a randomized complete block design with three replications, and standard agronomic practices were applied. Grain quality traits including protein content, wet and dry gluten, Gluten Index, Zeleny and delayed sedimentation, SDS-sedimentation, Falling Number, hectoliter, and moisture content were determined according to international standard methods (ICC, AACC). Analysis of variance revealed highly significant ($P<0.01$) cultivar effects for most traits across both years, particularly for protein content, gluten strength, sedimentation values, and hectoliter. Environmental variation between years significantly affected protein content, sedimentation values, dry gluten, hectoliter and grain moisture, highlighting the influence of rainfall distribution and temperature patterns during grain filling. However, the year × cultivar interaction was not significant for any trait, indicating stable cultivar performance across years. Among the cultivars, Mihalca and Karatopak consistently exhibited superior technological quality, whereas Lider cultivar showed the lowest performance. These findings emphasize the joint role of genetic potential and climatic variation in shaping wheat quality and suggest that cultivars combining high protein content and strong gluten properties are most suitable for sustainable high-quality wheat production in the Marmara Region under changing climate conditions.

Keywords: Bread Wheat, Quality Traits, Karacabey, Protein Content, Zeleny Sedimentation.

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*** Corresponding author:**

Pakize Ozlem Kurt, Department of Park and Garden Plants, Vocational School of Technical Sciences, Bursa Uludag University, Bursa, Türkiye. Her research interests include the Field crops. Cereal. She lives, worked, and studied in Bursa, Türkiye.
Email: ozlemkurt@uludag.edu.tr

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most widely cultivated cereal crops worldwide, covering approximately 220 million hectares, and serves as a major source of energy and protein in the human diet (Shiferaw et al., 2013). Turkey ranks among the leading countries in wheat production due to its genetic diversity and cultivated area, and the Marmara Region plays a significant role in national wheat cultivation. Within this region, Karacabey district of Bursa province stands out as a favorable area for high-yielding and high-quality wheat production. However, the impacts of climate change, particularly increasing drought and irregular precipitation regimes, have led to pronounced fluctuations in wheat quality parameters (Asseng et al., 2015; Aydogan et al., 2015).

The industrial value of wheat is not determined solely by yield but also by quality characteristics such as protein content, gluten quantity and quality, Zeleny sedimentation value, hectoliter, and Falling Number. In bread wheat, protein concentration and gluten characteristics are critical determinants of flour functionality and end-product quality (Shewry & Hey, 2015). Climatic factors exert substantial influence on these traits: under high temperature and water stress conditions, protein accumulation may increase, while gluten quality may deteriorate. Similarly, irregular rainfall during grain filling can alter the starch–protein balance, negatively affecting the technological properties of flour (Akcura, 2009; Trnka et al., 2014).

Recent studies conducted across different regions of Turkey and internationally have highlighted that ecological variation and inter-annual climatic fluctuations can lead to significant differences in the quality performance of wheat cultivars. In this context, investigating the quality parameters of five different wheat cultivars (Ceyhan-99, Mihalca, Kate A1, Lider, Karatopak) grown during the 2023 and 2024 production seasons in Karacabey, Bursa, is of particular importance for both regional agricultural production and the development of adaptation strategies under climate change. The present study aims to evaluate the influence of genetic background and environmental conditions on wheat quality traits by comparing quality data obtained from two consecutive years.

MATERIALS and METHODS

Experimental Site and Plant Material

The field experiment was conducted during the 2023 and 2024 growing seasons in Karacabey district of Bursa province, Türkiye (40°13′ N, 28°23′ E, 25 m a.s.l.), in a producer's field representing typical regional soil and climatic conditions. The experimental area is located within the Marmara Region, characterized by a Mediterranean climate with increasing inter-annual variability in precipitation and a rising frequency of drought events. Soil samples collected before sowing indicated loamy texture with moderate organic matter and adequate nutrient status (Kurt, 2025).

Five bread wheat (*Triticum aestivum* L.) cultivars (Ceyhan-99, Mihalca, Lider, Kate A1, Karatopak) commonly grown in Türkiye were selected for the study. Seeds were obtained from certified seed sources and sown at the recommended seeding rate for the region (500 seeds m^{-2}). Standard fertilization (120 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1}) was applied in line with regional practices (Yagdı & Kurt, 2013). No disease incidence was observed; therefore, no disease control protocol was applied. Weed control was carried out manually. In the first year, sowing was carried out on 6 November 2022 and harvest on 15 July 2023, whereas in the second year sowing was on 20 November 2023 and harvest 10 July 2024 under ecological conditions in Bursa.

Table 1. Monthly total precipitation and mean temperature in Bursa during the 2022–23 and 2023–24 wheat growing seasons, with long-term (2013–2024) averages for comparison.

	Rainfall (mm)			**Temprature (°C)**		
	2022-23	2023-24	Long Term (2013-2024)	2022-23	2023-24	Long Term (2013-2024)
September	42	40,7	33,08	21.3	22,4	21,2
October	16	23,5	46,9	16.2	16,5	15,9
November	22	21,4	39,3	13.3	12,1	11,9
December	39	20	35,1	10.3	11	8,2
January	25	12,5	34,6	8.3	10,5	7,3
February	77	14,2	30,9	6.5	11	6,8
March	109	10	32,2	10.6	8	5,4
April	122	7	28,1	13.2	22	9,2
May	43	34	45,3	16.9	16	17,5
June	49	0	23,6	22.2	25	23,1
July	8	1,8	12,8	26.6	27	24,1

Monthly precipitation and mean temperature values illustrate the strong inter-annual variation between the two experimental years. The 2022–23 season was markedly wetter (552 mm total rainfall) with relatively moderate temperatures (mean 15.0 °C), especially due to high rainfall in February–April. In contrast, the 2023–24 season was considerably drier, particularly from March to June, coinciding with higher temperatures during grain filling. Compared to the 2013–2024 long-term averages, both years exhibited deviations consistent with ongoing climate variability in the Marmara Region, where irregular precipitation patterns and warmer-than-average conditions have become increasingly common. These climatic differences are reflected in the observed year-to-year variation in wheat quality traits

Experimental Design

The experiment was conducted in a randomized complete block design (RCBD) with three replications, following the experimental approach previously reported for wheat quality evaluations in Bursa conditions. Each plot measured 6.0 m × 1.2 m (7.2 m^2), consisting of 6 rows spaced 20 cm apart. The same layout was used for both years, and border rows were excluded from sampling to minimize

edge effects. For laboratory analyses, the first and sixth rows were excluded, and 10 plants per plot were randomly selected from the inner rows to obtain representative grain samples.

Quality Analysis

Harvested grain samples were cleaned and conditioned to 11% moisture before analysis. Quality traits were determined according to international standard methods (ICC, AACC). The following parameters were measured:

- Grain protein content (%) by near-infrared reflectance spectroscopy (ICC 159).
- Wet and dry gluten (%) and Gluten Index (%) using the Glutomatic system (ICC 137/1, 155).
- Zeleny sedimentation (mL) and delayed sedimentation (mL) (ICC 116/1).
- SDS-sedimentation (mL) following ICC 151.
- Falling Number (s) to assess α-amylase activity (ICC 107/1).
- Hectoliter (kg hL^{-1}) using a standard hectoliter instrument (ICC 123/1).
- Moisture content (%) measured by oven-drying at 105 °C.

Analyses were conducted in triplicate for each plot. Laboratory procedures were adapted from international standards and prior wheat quality studies conducted under Bursa ecological conditions.

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) separately for each year and across combined years, considering year, cultivar, and their interaction as fixed effects. Means were compared using the Least Significant Difference (LSD) test at the 5% probability level. Statistical analyses were performed using JMP Pro 16 (SAS Institute, Cary, NC, USA).

RESULTS and DISCUSSION

According to the single-year ANOVA (Table 2), cultivar effects were highly significant ($P<0.01$) for most technological quality traits—protein content, Gluten Index, Zeleny sedimentation value, delayed sedimentation value, wet and dry gluten, and hectoliter—while a lower but significant effect was detected for grain moisture (*$P<0.05$*). In contrast, cultivar effects on SDS-sedimentation and Falling Number were non-significant, indicating that α-amylase activity (as inferred from Falling Number) was relatively stable across genotypes in 2023 (Seckin, 1970). Replication effects were largely negligible, suggesting an adequate experimental precision. These patterns agree with the view that genetic background is a primary determinant of functional flour properties in bread wheat (e.g., protein concentration and gluten quality), which directly shape end-use performance (Shewry & Hey, 2015).

The strong cultivar separation in sedimentation indices and gluten traits is also consistent with earlier work conducted under Bursa conditions and elsewhere in Türkiye (Ünal, 2002; Bilgin et al., 2016), where Zeleny- and gluten-based metrics captured robust genotypic contrasts in bread-making potential. Mean separations by LSD (Table 5) corroborated the ANOVA results, with cultivars Mihalca and Karatopak forming the superior group for protein/gluten strength indicators, while cultivar Lider consistently ranked lowest—mirroring previous reports on genotype-driven quality differentiation in Turkish germplasm (Kurt & Yağdı, 2013; Vilda et al., 2014).

Table 2. Analysis of variance (ANOVA) for grain quality traits of bread wheat cultivars in Karacabey conditions during the 2023 growing season.

SV	DF	P (%)	GI	ZS (mL)	DS(mL)	WG (%)	DG (%)	Hec. (kg/hl)	MC	SDS (mL)	FN (s)
Cul.	4	29.58**	30.15**	23.40**	38.29**	5.78*	24.30**	16.17**	5.60*	3.39	1.38
Rep.	2	1.04	2.03	0.04	0.29	0.14	0.28	2.74	2.93	4.42	1.89
Error	8	0.074	3.13	1.27	0.80	0.84	0.06	0.65	0.13	1.79	359.3
Tot.	14										

SV: source of variance, DF: degrees of freedom, P: protein, GI: gluten ındex, ZS: zeleny sedimentation value (mL), DS: delayed sedimentation value (mL), WG: wet gluten content (%), DG: dry gluten content (%), Hec: Hectoliter (kg/hl), MC: Moisture content (%) SDS: sedimentation value, FN: Falling Number (%), Cul: Cultivar, Rep:Repeat, Tot: total, *:p<0,05, **: p<0,01

The 2024 analysis (Table 3) reproduced the dominance of cultivar effects for the major quality traits, and again moisture showed a modest yet significant response. Notably, both Zeleny and delayed sedimentation values tended to be higher in 2024 than in 2023, implying more favorable conditions for protein aggregation and gluten development during grain filling. This inter-annual enhancement aligns with multi-environment evidence that rainfall distribution and temperature patterns modulate grain composition and dough functionality (Trnka et al., 2014; Asseng et al., 2015). In our experiment, the generally non-significant replication effect aside from a minor signal in hectoliter indicates that within-field heterogeneity remained limited and that between-year climate variability was the primary environmental driver.

Table 3. Analysis of variance (ANOVA) for grain quality traits of bread wheat cultivars in Karacabey conditions during the 2024 growing season.

SV	DF	P (%)	GI	ZS (mL)	DS (mL)	WG (%)	DG (%)	Hec. (kg/hl)	MC	SDS (mL)	FN (s)
Cul.	4	13.75**	18.90**	9.02**	7.27**	23.21**	20.64**	33.31**	4.32*	0.21	1.96
Rep.	2	0.07	0.56	0.03	0.07	0.65	0.05	4.57*	0.59	2.89	0.16
Error	8	0.129	3.93	5.27	6.60	0.38	0.04	0.48	0.11	1.07	307.9
Tot.	14										

SV: source of variance, DF: degrees of freedom, P: protein, GI: gluten ındex, ZS: zeleny sedimentation value (mL), DS: delayed sedimentation value (mL), WG: wet gluten content (%), DG: dry gluten content (%), Hec: Hectoliter (kg/hl), MC: Moisture content (%) SDS: sedimentation value, FN: Falling Number (%), Cul: Cultivar, Rep:Repeat, Tot: total, *:p<0,05, **: p<0,01

The LSD groupings (Table 6) again placed cultivars Mihalca and Karatopak among the best performers for protein- and gluten-related traits, reinforcing the interpretation that genetic merit for

technological quality can be expressed reliably under Karacabey conditions when seasonal weather is supportive (Öztürk et al., 2009; Mut et al. 2010).

The two-factor ANOVA (Table 4) revealed significant year effects for protein content, sedimentation traits (Zeleny and delayed), dry gluten, hectoliter, and grain moisture, confirming that inter-annual climatic variability influenced absolute quality levels. At the same time, the cultivar effect remained highly significant for nearly all parameters, and the year × cultivar interaction was not significant for any trait. The absence of crossover interactions indicates that cultivar rankings were stable across seasons an important property for selection and recommendation under variable climates. Such stability echoes findings from Turkish and international studies where quality traits showed high genotypic control relative to G×E for ranking (Aktas & Eren, 2014; Kahraman et al. 2021). From a breeding and deployment perspective, the combined analysis suggests that cultivars with strong gluten properties and adequate protein can maintain their relative superiority even when seasonal rainfall/temperature regimes shift (Shiferaw et al., 2013). In our material, Mihalca and Karatopak consistently occupied the top statistical groups across years (Table 7), whereas Lider cultivar persistently clustered at the lower end, underscoring clear genetic contrasts with practical implications for cultivar choice under Marmara conditions.

According to the results of the first year (Table 5), protein content among the cultivars varied between 10.74% in Lider cultivar and 12.50% in Mihalca cultivar. These values fall within the typical range (10–13%) reported for bread wheat cultivars under Bursa conditions (Kurt & Yağdı, 2013). Gluten Index values ranged from 80.67 (Lider cultivar) to 91.33 (Karatopak cultivar), reflecting a generally strong gluten structure. Similar observations were reported by Ünal (2002), who emphasized the importance of gluten strength on bread-making performance.

Zeleny sedimentation values were lowest in Lider cultivar (55.0 mL) and highest in Mihalca cultivar (66.0 mL). This variation is consistent with previous findings under Turkish conditions, where Zeleny values were found to range between 25–41 mL in advanced lines (Kurt & Yağdı, 2013; Guzman et al. 2016) and 32–34 mL in registered cultivars (Akcura, 2009). Wet gluten content varied between 28.60% (Lider) and 32.33% (Mihalca), whereas dry gluten ranged from 9.60% to 11.17%. Hectoliter values ranged between 77.43 and 81.80 kg hL^{-1}, similar to earlier reports indicating 71–79 kg hL^{-1} for bread wheat under Bursa conditions (Aydın et al. 2007). Falling Number values (297.67–331.33 s) were within the acceptable range, comparable to results of Vilda et al. (2014) and Kurt & Yagdı, (2013), who observed values between 250 and 350 s for Turkish cultivars

Table 4. Combined analysis of variance (ANOVA) for grain quality traits of bread wheat cultivars across the 2023 and 2024 growing seasons in Karacabey.

SV	DF	P (%)	GI	ZS (mL)	DS (mL)	WG (%)	DG (%)	Hec. (kg/hl)	MC	SDS (mL)	FN (s)
Year	1	7.4*	3.9	15.2**	20.7**	3.8	10.1**	2.5	9.9**	1.6	0.01
Rep.	4	0.4	1.1	0.03	0.1	0.3	0.18	3.3*	1.7	3.3*	0.9
Cul.	4	37**	45.7**	23.1**	20.4**	21.1**	42.9**	41.9**	9.6**	0.5	1.02
YxC	4	0.1	0.5	0.5	0.6	0.51	2.59	0.4	0.2	1.4	2.4
Error	16	0.1	3.5	3.3	3.9	0.61	0.09	0.6	0.1	1.4	3.4
Tot.	29										

SV: source of variance, DF: degrees of freedom, P: protein, GI: gluten ındex, ZS: zeleny sedimentation value (mL), DS: delayed sedimentation value (mL), WG: wet gluten content (%), DG: dry gluten content (%), H: Hectoliter (kg/hl), MC: Moisture content (%) SDS: sedimentation value, FN: Falling Number (%), Cul: Cultivar, Rep:Repeat, Tot: total, *:p<0,05, **: p<0,01

In the second year (Table 6), protein content was slightly higher than the first year, ranging from 10.86% (Lider) to 12.71% (Mihalca). Similar seasonal differences were also noted by Kurt & Yagdı (2013), highlighting the influence of environmental variation. Gluten Index values varied between 80.67 (Lider) and 94.33 (Mihalca), showing higher averages than the first year. Zeleny sedimentation ranged from 58.0 mL (Lider) to 66.67 mL (Mihalca). Such improvements are likely associated with more favorable climatic conditions during the grain filling period, supporting the findings of Öztürk et al. (2009).

Wet gluten ranged between 29.63% (Lider) and 33.90% (Mihalca), while dry gluten content varied from 9.90% to 11.60%. Hectoliter (78.83–82.30 kg hL^{-1}) were slightly higher than the first year, consistent with the results of Aydogan et al. (2015) and Kahraman et al. (2021). Falling Number values showed wider variation (297–368 s), with the maximum observed in Karatopak cultivar, confirming findings by Kurt & Yağdı (2013) that Falling Number can fluctuate widely (199–487 s) depending on cultivar and year.

Table 5. Mean performance and LSD grouping of bread wheat cultivars for grain quality traits in Karacabey during the 2023 growing season

	Ceyhan-99	Mihalca	Kate A1	Lider	Karatopak
P (%)	11.82 b	12.5 a	11.17 c	10.74 d	12.06 a
GI	87.0 a	91.0 a	83.0 b	80.67 c	91.33 a
ZS. (mL)	61.0 a	66.0 a	57.0 b	55.0 c	62.0 a
DS (mL)	63.33 b	69.67 a	60.67 c	58.33 d	65.0 a
WG (%)	31.4 a	32.33 a	29.97 b	28.6 c	32.17 a
DG (%)	10.53 a	11.17 a	10.17 b	9.6 c	10.8 a
H (kg/hl)	79.67 a	81.53 a	79.17 b	77.43 c	81.8 a
MC (%)	8.86 a	7.95 b	9.0 a	9.26 a	7.91 c
SDS (mL)	11.1 a	12.53 a	11.37 a	10.03 a	12.27 a
FN (s)	326.0 a	331.33 a	306.33 a	297.67 a	312.0 a

P: protein, GI: gluten ındex, ZS: zeleny sedimentation value (mL), DS: delayed sedimentation value (mL), WG: wet gluten content (%), DG: dry gluten content (%), H: Hectoliter (kg/hl), MC: Moisture content (%) SDS: sedimentation value, FN: Falling Number (%)

When data from both years were combined (Table 7), protein content ranged from 10.80% (Lider) to 12.60% (Mihalca). Gluten Index values were lowest in Lider (80.67) and highest in Mihalca (92.67). These results align with previous studies conducted in Bursa, where gluten indices between 47–86% were reported across different genotypes (Kurt & Yağdı, 2013). Sedimentation values varied from 56.5 mL (Lider) to 66.33 mL (Mihalca), consistent with the averages (32–34 mL) reported by Trnka et al. (2014).

Table 6. Mean performance and LSD grouping of bread wheat cultivars for grain quality traits in Karacabey during the 2024 growing season.

	Ceyhan-99	**Mihalca**	**Kate A1**	**Lider**	**Karatopak**
P (%)	12.12 b	12.71 a	11.37 c	10.86 d	12.44 a
GI	88.0 a	94.33 a	84.67 b	80.67 c	93.0 a
ZS. (mL)	64.33 a	66.67 a	60.0 b	58.0 c	66.33 a
DS (mL)	68.0 a	70.33 a	63.0 b	61.33 c	68.67 a
WG (%)	32.2 a	33.9 a	31.0 b	29.63 c	33.07 a
DG (%)	10.6 b	11.6 a	10.37 c	9.9 d	10.97 a
H (kg/hl)	80.6 a	82.2 a	79.87 b	78.83 c	82.3 a
MC (%)	8.36 a	7.85 b	8.54 a	8.82 a	7.81 c
SDS (mL)	11.8 a	13.17 a	11.73 a	10.8 b	13.63 a
FN (s)	312.33 a	350.0 a	320.33 a	297.0 b	368.0 a

P: protein, GI: gluten ındex, ZS: zeleny sedimentation value (mL), DS: delayed sedimentation value (mL), WG: wet gluten content (%), DG: dry gluten content (%), H: Hectoliter (kg/hl), MC: Moisture content (%) SDS: sedimentation value, FN: Falling Number (%)

Hectoliter values across two years remained stable (78.13–82.05 kg hL^{-1}), comparable to the ranges given in earlier Turkish studies (Bilgin et al. 2016; Guzman et al. 2016). Moisture content varied between 7.86% (Karatopak) and 9.04% (Lider). Falling Number values were between 297.33 s (Lider) and 340.67 s (Mihalca), confirming technological stability in most cultivars and agreeing with the results of Mut et al. (2010).

Table 7. Combined mean performance and LSD grouping of bread wheat cultivars for grain quality traits across the 2023 and 2024 growing seasons in Karacabey.

	Ceyhan-99	**Mihalca**	**Kate A1**	**Lider**	**Karatopak**
P (%)	11.97 b	12.6 a	11.27 c	10.8 d	12.25 a
GI	87.5 b	92.67 a	83.83 c	80.67 d	92.17 a
ZS. (mL)	62.67 a	66.33 a	58.5 b	56.5 c	64.17 a
DS (mL)	65.67 a	70.0 a	61.83 b	59.83 c	66.83 a
WG (%)	31.8 a	33.12 a	30.48 b	29.12 c	32.62 a
DG (%)	10.57 c	11.38 a	10.27 d	9.75 e	10.88 b
H (kg/hl)	80.13 b	81.87 a	79.52 c	78.13 d	82.05 a
MC (%)	8.61 a	7.9 b	8.77 a	9.04 a	7.86 c
SDS (mL)	11.45 a	12.85 a	11.55 a	10.42 b	12.95 a
FN (s)	319.17 a	340.67 a	313.33 a	297.33 b	340.0 a

P: protein, GI: gluten ındex, ZS: zeleny sedimentation value (mL), DS: delayed sedimentation value (mL), WG: wet gluten content (%), DG: dry gluten content (%), H: Hectoliter (kg/hl), MC: Moisture content (%) SDS: sedimentation value, FN: Falling Number (%)

Overall, Mihalca and Karatopak cultivars consistently outperformed the others across most quality traits, while Lider exhibited the lowest values. These findings reinforce that both genetic background and environmental conditions jointly shape technological quality in bread wheat, as emphasized by Kurt & Yağdı (2013).

Conclusion

The results of this two-year study conducted in Karacabey, Bursa, revealed significant differences among bread wheat cultivars in terms of technological quality traits. Across both years, protein content, gluten strength, sedimentation values, and hectoliter consistently distinguished the cultivars. Varieties Mihalca and Karatopak cultivars showed superior performance, particularly in protein content, Gluten Index, Zeleny sedimentation, and hectoliter weight, confirming their suitability for bread-making quality under the ecological conditions of the Marmara Region. In contrast, Lider cultivar exhibited the lowest values across most parameters, indicating its limited potential for high-quality wheat production.

Environmental variation between the two years was reflected in the quality traits, with higher protein and sedimentation values observed in 2024, suggesting that rainfall distribution and climatic conditions during grain filling had a positive effect on quality. This highlights the importance of year-to-year climatic variability, especially under conditions of increasing drought and irregular precipitation regimes in Türkiye.

Based on this two-year trial in Karacabey, Mihalca and Karatopak cultivars exhibited superior technological quality and appear as promising candidates for further testing. However, we recommend conducting multi-location trials and economic evaluations before making broader recommendations for the entire Bursa region.

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Conflicts of Interest

The author declares that there are no conflicts of interest related to the publication of this study.

Ethics Approval

This study does not require ethics committee approval as it does not involve any direct application on human or animal subjects.

REFERENCES

AACC International. (2000). *Approved methods of analysis* (11th ed.). St. Paul, MN: AACC International.

Akcura, M. (2009). Genetic variability and interrelationship among grain yield and some quality traits in Turkish winter durum wheat landraces. *Turk J Agric For* 33:547–556.

Aktaş, B., Eren, H., 2014. Bazı ekmeklik buğday (Triticum aestivum L.) çeşitlerinin tane verimi stabilitesi ve kalite özelliklerinin belirlenmesi. Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi, 23(2): 69-76.

Asseng, S., Ewert, F., Martre, P., Rötter, R. P., Lobell, D. B., Cammarano, D., & Zhu, Y. (2015). Rising temperatures reduce global wheat production. *Nature Climate Change, 5*(2), 143–147. https://doi.org/10.1038/nclimate2470

Aydın, N., Bayramoğlu, O.H., Özcan, H., Mut, Z. (2007). Investigation of yield and primary quality characteristics of some bread wheat (Triticum aestivum L.) genotypes. *Anadolu Journal of Agricultural Sciences,* 11(3), 257-263.

Aydoğan, S., Şahin, M., Akçacık, A.G., Hamzaoğlu, S., Taner, S. (2015). Relationships between Farinograph Parameters and Bread Volume, Physicochemical Traits in Bread Wheat Flours. *Jornal of Bahri Dagdas Crop Research*, 3(1): 14-18.

Bilgin, O., C. Guzman, I. Baser, J. Crossa, K.Z. Korkut. (2016). Evaluation of grain yield and quality traits of bread wheat genotypes cultivated in Northwest Turkey. *Crop Sci.,* 56 (1) (2016), pp. 73-84, 10.2135/cropsci2015.03.0148

Guzmán, C., Peña, R. J., & Singh, R. (2016). Wheat quality improvement at CIMMYT and the use of genomic selection on it. *Applied & Translational Genomics, 11*, 3–8. https://doi.org/10.1016/j.atg.2016.10.004

International Association for Cereal Science and Technology. (2000). *Standard methods of the International Association for Cereal Science and Technology*. Vienna, Austria: ICC.

Kahraman, T., Güngör, H., Öztürk, İ., Yüce, İ., & Dumlupınar, Z. (2021). Ekmeklik buğday (Triticum aestivum L.) genotiplerinde genotip ve çevrenin tane verimi ve bazı kalite özellikleri üzerine etkisinin temel bileşen ve GGE biplot analizleri ile değerlendirilmesi. *Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi,* 24(5), 992-1002.

Kurt, P. Ö., & Yağdı, K. (2013). Bazı ileri ekmeklik buğday hatlarında kalite özelliklerinin belirlenmesi. *Uludağ Üniversitesi Ziraat Fakültesi Dergisi, 27*(1), 35–44.

Kurt, P. Ö. (2025). Field-based evaluation of multi-strain PGPR to improve zea mays yield and soil nutrient dynamics in semi-arid of Türkiye. *Sci Rep*. 2;15(1):22553.

Mut Z, Aydin N, Bayramoglu H.O, Ozcan H. (2010). Stability of some quality traits in bread wheat (Triticum aestivum) genotypes. *J Environ Biol*. 31(4):489-95. PMID: 21186725.

Öztürk, A., Çağlar, Ö., & Bulut, S. (2009). Growth and yield response of facultative wheat to winter sowing. *Turkish Journal of Agriculture and Forestry, 33*(1), 1–9. https://doi.org/10.3906/tar-0804-20

Seckin, R. (1970). Buğdayın bileşimi ve kalitesine etki yapan faktorler. *Ankara Universitesi Ziraat Fakultesi Yayınları*. 430 Konferanslar Serisi 8.

Food, 31(2), 63–70. https://doi.org/10.5505/gida.2006.25429

Shewry, P. R., & Hey, S. J. (2015). The contribution of wheat to human diet and health. *Food and Energy Security, 4*(3), 178–202. https://doi.org/10.1002/fes3.64

Shiferaw, B., Smale, M., Braun, H. J., Duveiller, E., Reynolds, M., & Muricho, G. (2013). Crops that feed the world 10: Past successes and future challenges to the role played by wheat in global food security. *Food Security, 5*(3), 291–317. https://doi.org/10.1007/s12571-013-0263-y

Trnka, M., Rötter, R. P., Ruiz-Ramos, M., Kersebaum, K. C., Olesen, J. E., Žalud, Z., & Semenov, M. A. (2014). Adverse weather conditions for European wheat production will become more frequent with climate change. *Nature Climate Change, 4*(7), 637–643. https://doi.org/10.1038/nclimate2242

Ünal, S. (2002). Quality characteristics of Turkish bread wheat (Triticum aestivum L.) genotypes grown under Mediterranean conditions. *Euphytica, 126*(1), 107–113. https://doi.org/10.1023/A:1019619409673

Vida, G., Szunics, L., Veisz, O., Bedo, Z., Lang, L., Arendas, T., Bonis, P., Rakszegi, M. (2014). Effect of genotypic, meteorological and agronomic factors on the gluten index of winter durum wheat. *Euphytica,* 197, 61–71.