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Assessment of Yield Performance and Stability of Winter Barley (*Hordeum vulgare* L.) Genotypes under Rainfed Conditions of Central Anatolia and Transition Regions

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ABSTRACT

Barley (*Hordeum vulgare* L.) is one of the most important agricultural crops in Türkiye. It is imperative to increase the grain yield of barley to meet the growing demand. One of the most important ways to do this is to develop high-yielding cultivars with good adaptation to varying environmental conditions. In breeding studies, the performance of candidate lines should be determined through multiple yield trials. In this study, eighteen advanced barley lines with six check cultivars were planted in nine locations under rainfed conditions of Central Anatolia and transitional regions in the 2019-2020 growing season. In addition to the yield performance of the genotypes, their yield stability in nine locations was also determined. According to the result of the study, the highest and lowest-yielding locations were Konya and Afyonkarahisar, respectively. This study revealed Sayım 40 had higher grain yield potential in Central Anatolia. Additionally, advanced line G23 was identified as the most promising feed barley genotype yielding approximately 3959 kg/ha across nine locations in the Central and transitional ecological zones of Anatolia.

Keywords: Barley, grain yield, multi-location trials

Introduction

Barley (*Hordeum vulgare* L.), one of the world's earliest crops, was cultivated in the Fertile Crescent 10500 years ago (Saisho and Purugganan, 2007). Today, barley is grown worldwide in both highly productive agricultural areas and harsh environments where cultivation is a challenge. In recent years, global barley grain production has reached approximately 150 million tons (FAOSTAT, 2023). Barley is traded worldwide and is of great economic importance for both feeding livestock and producing malting beverages (Newton et al., 2011).

Türkiye, one of the world's major barley-producing countries, produces about 8.5 million tons of barley grain on 3.2 million hectares of agricultural land (TSI 2023). In Türkiye, barley production is predominantly sustained in dryland areas, and the grain yield is highly impacted by the amount and distribution of annual rainfall throughout the growing season (Tokgöz 1997). In such areas, it is necessary to develop new varieties that are resistant to biotic and abiotic stress factors. Across diverse environmental conditions, conducting multi-location trials to assess the genotypic performances of the plant materials holds crucial importance for a breeding scheme (Lee et al., 2023).

The selection of high-yielding and stable genotypes is an unsubstituted strategy for developing new cultivars in rainfed conditions across various sub agro-ecologic zones. The ability of candidate genotypes to adapt to multi-environments increases their effectiveness (Becker and Leon, 1998). For selected traits, various statistical methods were applied to interpret the genotype-by-environment interactions in diverse environments (Pour-Aboughadareh et al., 2022). The linear regression models are commonly used to calculate yield stability parameters (Sabaghnia et al., 2013).

In this study, eighteen advanced winter barley lines developed as part of the barley breeding studies of the Central Research Institute of Field Crops were observed in multi-location trials and compared with six check cultivars widely cultivated in the region. The yield performance of the candidate genotypes was analyzed based on the linear regression model across nine different locations. The study aimed to identify candidate lines with high and stable grain yield across Central Anatolia and the transitional regions.

Materials and Methods

Using six check cultivars, seven malting and eleven feed barley regional yield trial lines (MBRYT and FBRYT; hereafter referred to as G) developed by the Central Research Institute for Field Crops were tested as plant material in the study. All genotypes used in the study are given in Table 1.

The yield trials were conducted at nine locations (L) across Central Anatolia and the transition regions in the 2019-2020 growing season. Monthly precipitation amounts for the locations where the trials were carried out in the 2019-2020 growing season are given in Table 2. During the 2019-2020 growing season, the average precipitation varied from 208.8 to 413.0 mm throughout the locations of Ikizce (L1), Altınova (L2), Gözlü (L3), Malya (L4), Ulaş (L5), Sarkışla (L6), Konya (L7), Karapınar (L8) and Afyonkarahisar (L9). The total precipitation values in majority of the locations were lower than the long-term average (Table 2). The soil conditions at all locations were slightly alkaline and poor in organic matter while the levels of P_2O_5, K_2O, and $CaCO_3$ were relatively reasonable.

In all locations, field trials were arranged according to a randomized complete block design (RCBD) with four replicates. The experiments were conducted with a plot seeder during 15-30 October 2019. Genotypes were sown in plots (5 m long and 1.08 m wide) with a seed density of 500 seeds per m^2. As for fertilizer application, all the phosphorus (70 kg P_2O_5/ha) and half of the nitrogen (35 kg N/ha) were applied as di ammonium phosphate (DAP 18-46%) along with sowing. The remaining nitrogen (Ammonium nitrate, 35 kg N/ha) was applied following the tillering stage in spring 2019-20. Genotypes were harvested with a plot harvester when the grain moisture content was approximately 12%, and the grain yield values were converted to kg/ha.

Significance levels of differences between grain yields of genotypes and locations were determined using combined analysis of variance (ANOVA), and then genotypes were ranked using Student's t multiple comparison tests (LSD) (Montgomery 2013). Regression coefficient (b), coefficient of determination (R^2), deviation from regression (S^2d_i), and coefficient of variance (CV) were used as stability parameters. The stability parameters used here are a function of the deviations and slope from the regression of genotype yield on the environmental index introduced by Finlay and Wilkinson (1963), Eberhart and Russell (1966), Pinthus (1973) and the environmental coefficient of variance Francis and Kannenberg (1978). In addition, a Bi-Plot graph was created via Principal Component Analysis (PCA) to show the similarity of locations to each other and the specific adaptations of genotypes to environments (Yan and Tinker 2006). Combined analysis of variance and principal component analysis (PCA) were performed in the JMP 11 statistical package. Stability analysis was performed using the *avcıistatistik*® Excel add-in (Avcı, 2023) and the STABILITYSOFT, an online stability analysis platform (Pour-Aboughadareh et al., 2019).

Results and Discussion

During the 2019-2020 growing season, the combined analysis of variance results for grain yield indicates that the main effects of genotypes (G), locations (L), and the G by L interactions, were statistically significant at the $p<0.01$ level across nine locations (Table 3).

As the interactions between locations and genotypes were found to be statistically significant, the analyses of the variance of the genotypes were performed separately according to the locations in which the experiments were carried out. As a result of the variance analyses, the differences between the yield means of the genotypes in all locations were found to be statistically significant at the $p<0.01$ level. The grain yield values of the genotypes in nine locations and their overall mean yields are shown in Table 4. The grand mean yield of all locations was 3545 kg/da. Previous studies also reported similar yield results in this region (Akgun et al. 2012; Yüksel and Akcura 2012; Ergün et al. 2023). Among the locations, the highest yield was obtained from Konya (L7) with 5406 kg/ha, and the lowest yield was obtained from Afyonkarahisar (L9) with 2114 kg/ha. Konya was followed by Sarkısla with 4627 kg/ha and Ikizce with 4346 kg/ha (Table 4).

When the genotypes with the highest grain yield in the locations where the experiments were conducted, in Ikizce (L1), Gozlu (L3), Konya (L7), and Karapınar (L8), were considered one by one, cv. Sayım 40 came first with yields of 5594, 5788, 6295 and 3269 kg/ha respectively. In Altınova (L2) and Malya (L4), cv. Larende was the first-ranked cultivar in these locations with yields of 3283 and 3534 kg/ha, respectively. In Ulaş (L5), cv. Asil (5241 kg/ha) and at Sarkısla (L6), numbered line G13 (5509 kg/ha) were the barley genotypes with the highest yields in these locations. In Afyonkarahisar (L9), which has the lowest average grain yield, cv. Tarm-92 was found as the highest-yielding genotype in this location with a grain yield of 2928 kg/ha. The cv. Sayım 40 ranked first among all genotypes with a grain yield of 4392 kg/ha, followed by cv. Larende with a grain yield level of 4076 kg/ha when considering the general mean data of the genotypes. Among the candidate lines, G23 was found to be the highest-yielding line (3959 kg/ha) in the same statistical group as these two registered cultivars. Cv. Burakbey was the fourth highest-yielding cultivar with a yield level of 3913 kg/ha after these genotypes (Table 4).

The data from the stability analyses carried out to evaluate the responses of the barley genotypes to different locations and to determine the most suitable areas are given in Table 5. When examining the (a) value, which is one of the determinants of the adaptability of genotypes for favorable or unfavorable locations. It was observed that the cv. Tarm 92 (1437.25) and the line G9 (1419.05) had the highest values. This result shows that these genotypes can adapt well to low-yielding locational conditions. On the other hand, G16, G4, G6, and G8 were the genotypes with negative and the lowest (a) values (-1466.29, -1197.10, -987.22 and -558.27 respectively). This indicates that these genotypes may be more suitable for favorable locations. The regression coefficient (b) is one of the most widely utilized indicators of yield stability (Akçura et al. 2005). If the b value of a genotype is closer to 1, this genotype is considered to have wide adaptability and good stability. Genotypes with a b-value less than 1 are well adapted to unfavorable locational conditions, while genotypes with a b-value greater than 1 are better adapted to high-yielding locational conditions (Finlay and Wilkinson 1963). Genotypes with yields close to the mean, b values around 1 and deviations from regression (S^2d_i) as close to zero as possible can be characterized as stable (Eberhart and Russel 1966). Among the genotypes in the study, the genotypes with b values closest to 1 were G11 and G17 with b values of 0.99 (Table 5 and Figure 1). In addition, G16, G14, cv. Asil, G2, G19 and cv. Tosunpaşa are the genotypes that can be classified as the most stable when their b values are considered. However, when genotypes above the average yield (3545 kg/ha) are considered, cv. Asil, cv. Tosunpaşa, G14, G19 and G11 are the genotypes with both stable and sufficiently high yields (Table 5 and Figure 1). According to the Bi-Plot stability graph generated according to regression coefficient (b) and average grain yields (kg/ha) of the genotypes (Figure 1), lines G23 and G6 increase their yield potential as locational conditions become more favorable. In addition, cv. Sayım 40, cv. Burakbey and the line G13 also showed acceptable levels of stability and it can be said that the yield potential of these genotypes is higher in favorable locations (Figure 1). On the other hand, Figure 1 reveals that the cultivars Tarm 92 and Larende have moderate stability when considering the b value and these genotypes can be classified as good adapted to unfavorable locational conditions.

The coefficient of determination (R^2) is another important parameter relating to stability and its higher value indicates that the genotype is more stable (Teich 1983). Among the genotypes in the study, the highest R^2 values were observed in lines G19 and G22 with 0.98, followed by G2 with 0.97 and G12 with 0.96. The lowest values were observed in lines G9 (0.45) and G18 (0.60). The R^2 values of lines G11 and G17, which had the closest b values to 1, were as high as 0.93 (Table 5). Another common method of assessing yield stability is to examine the deviation from regression. A deviation from regression (S^2d_i) is a measure of how much the yield of a particular genotype deviates from the yield predicted by the regression model under specific environmental conditions. The lower value of this parameter is interpreted as an indication that the yield of the genotype is close to the expected and more stable (Eberhart and Russell 1966; Teich 1983). Among the lines and cultivars in the study, the lowest S^2d_i values were found in lines G19, G22, G12, and G2. While cv. Tosunpaşa had the lowest S^2d_i value among the cultivars, the other cultivars generally had high values for this parameter. This value is relatively low in G11 and G17, which have the b value closest to 1 among the lines. The genotypes with the greatest deviation from the regression are the lines G18 and G9, which also have the lowest b values (Table 5). Francis and Kannenberg (1978) determined the stability of genotypes by evaluating the coefficient of variation (CV) and yield values together. In this concept, genotypes were divided into four groups according to low or high CV and yield values and it was suggested that genotypes with low CV and high yield could be defined as the most desirable group. Among the genotypes with the lowest CV values and yields above the overall mean were the cultivars Tarm 92, Larende, Sayım 40 and Asil and the lines G11 and G13 (Table 5).

Bi-Plot analysis has become a useful statistical technique in plant breeding and agricultural studies (Yan and Tinker 2006). In the Bi-Plot generated from principal component analysis (PCA), the first two principal components (PC1 54.4% and PC2 24.6%) explained 79% of the total variation (Figure 2) in the yield of the genotypes across locations. PC1 shows a close relationship with the average yield values of the genotypes, while PC2 gives information about the stability (b value) of the genotypes. More stable genotypes are closer to the center of the PC2 axis. Ikizce (L1) and Konya (L7) were the most representative locations in PC1, while Sarkısla (L6) and Malya (L4) were the most representative locations in PC2. The distance between two locations is a function of their differences in genotype discrimination (Yan and Tinker 2006). According to the Bi-Plot graph, the experimental locations are divided into two main groups. While L3, L6 and L7 formed one group among themselves, L1, L2, L4, L5, L8 and L9 formed another main group and were the locations with the most similar results in the 2019-2020 growing season. Cv. Sayım 40 generally ranked the first in all locations. G23 seems to be a genotype better adapted to L7, L3 and L6 locations. On the other hand, G6 appears to be a genotype better adapted to higher-yielding locations (L3, L6 and L7). The cultivars Tarm 92, Asil, and Larende stood out, particularly in the L4, L5 and L9 locations. This shows that these varieties can perform well in unfavorable locations (Figure 2).

Conclusions

The differences among the grain yields of the barley genotypes used in this study and the locations as well as their interactions were statistically significant. Among all the genotypes, cv. Sayım 40 was the highest-yielding genotype, ranking first in four out of the nine locations across the Central Anatolia and Transitional Regions. It was followed by cv. Larende, line G23 and cv. Burakbey regarding high grain yield potential over the region. When the genotypes were considered in terms of grain yield and multiple stability parameters, the most stable and above-average yielding genotypes were identified as cv. Asil and cv. Tosunpaşa varieties and lines G23, G19, G13 and G11. Cv. Tarm 92 maintained its high performance in less favorable conditions. Overall, these results indicate that, cv. Sayım 40 highest yielding cultivar for Central Anatolia and Transitional Regions, while line G23 was the most promising barley line. The findings of this study suggest that line G23 can be evaluated for variety registration.

Conflict of interests

The authors declare that they have no conflict interests.

Acknowledgments

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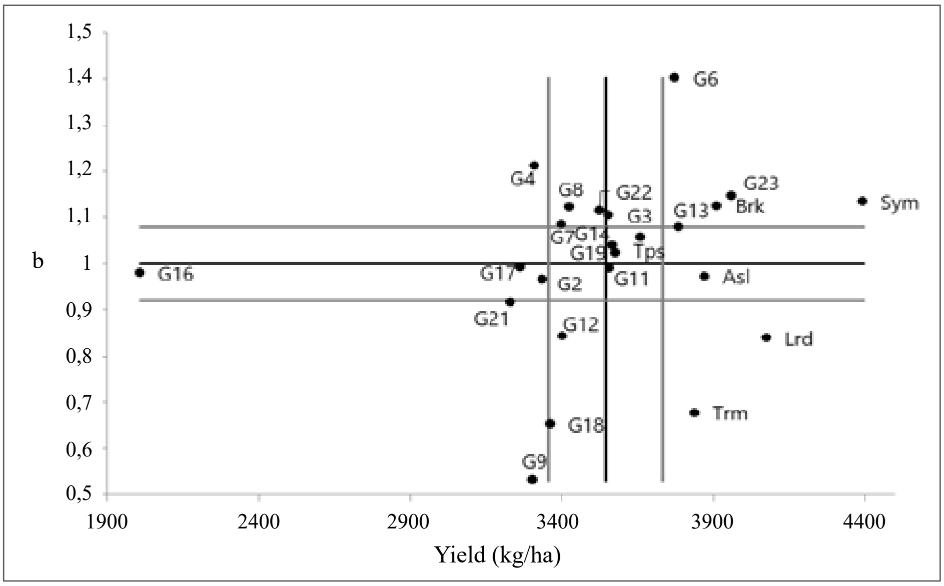

Figure 1. Two-way stability graph showing b value and yield averages of genotypes.

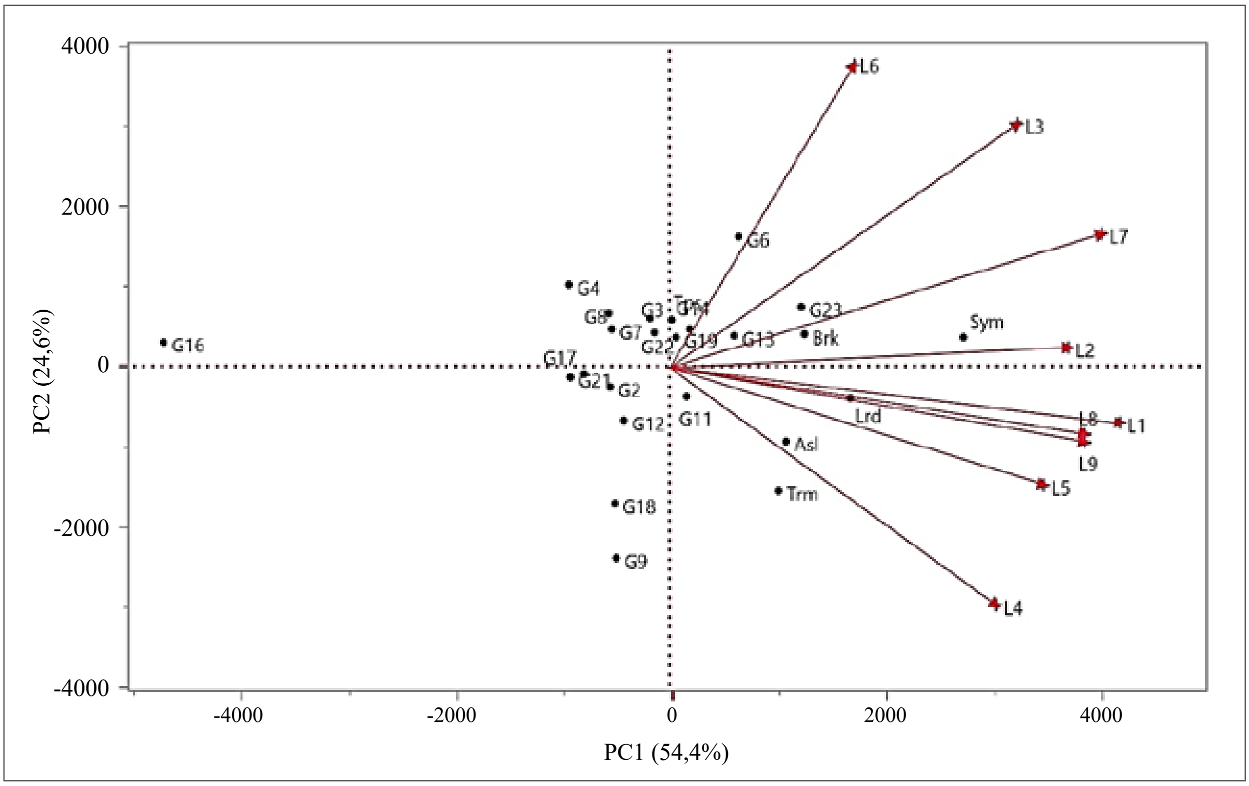

Figure 2. Bi-Plot displaying the result of Principal Component Analysis (PCA).

Table 1. Barley genotypes in the multi-location yield trials.

Number	Identifier	Lines/Cultivars Name	Number	Identifier	Lines/Cultivars Name
1	Trm	Tarm 92 (Check)	13	G13	FBRYT -1-110
2	G2	MBRYT -1	14	G14	FBRYT -1-111
3	G3	MBRYT -4	15	Tps	Tosunpaşa (Check)
4	G4	MBRYT -5	16	G16	FBRYT -1-117
5	Brk	Burakbey (Check)	17	G17	FBRYT -1-122
6	G6	MBRYT -9	18	G18	FBRYT -2-201
7	G7	MBRYT -11	19	G19	FBRYT -2-202
8	G8	MBRYT -13	20	Asl	Asil (Check)
9	G9	MBRYT -23	21	G21	FBRYT -2-208
10	Sym	Sayım 40 (Check)	22	G22	FBRYT -2-221
11	G11	FBRYT -1-103	23	G23	FBRYT -2-222
12	G12	FBRYT -1-104	24	Lrd	Larende (Check)

MBRYT: Malting barley regional yield trial, FBRYT: Feed barley regional yield trial, G: Genotype

Table 2. Monthly and annual total precipitation (mm) data for the experimental locations.

Locations	Years	October	November	December	January	February	March	April	May	June	Total
Ikizce (L1)	19-20	23.4	31.8	50.8	28.6	38.7	13.8	28.6	47.8	27.0	290.5
	LT	22.7	29.1	37.7	36.3	34.0	35.7	40.2	46.9	35.7	318.3
Altınova (L2)	19-20	5.0	16.0	34.0	35.0	52.0	30.0	23.8	48.2	45.0	289.0
	LT	25.0	22.7	34.5	36.7	25.5	36.0	22.0	38.5	31.6	272.5
Gozlu (L3)	19-20	3.2	7.0	29.2	22.4	43.6	17.6	29.6	30.0	26.2	208.8
	LT	27.6	25.3	40.8	36.7	22.2	27.7	18.4	35.5	38.0	272.2
Malya (L4)	19-20	0.0	14.0	54.0	24.0	46.0	22.0	21.0	31.0	5.0	217.0
	LT	23.0	25.7	31.0	45.0	30.5	31.9	28.4	37.9	28.9	282.3
Ulas (L5)	19-20	23.0	13.0	16.3	42.3	57.0	60.3	14.7	32.1	38.9	297.6
	LT	37.9	36.1	23.8	34.8	29.0	38.2	37.7	54.7	47.1	339.3
Sarkısla (L6)	19-20	7.8	16.5	19.3	24.2	48.2	51.5	22.3	45.4	102.6	337.8
	LT	24.0	30.0	48.0	44.0	34.0	41.0	58.0	47.0	35.0	361.0
Konya (L7)	19-20	13.0	45.8	112.4	36.0	29.0	6.4	3.4	23.4	35.8	305.2
	LT	32.7	34.1	42.4	36.6	24.7	27.1	35.4	41.7	26.6	301.3
Karapınar (L8)	19-20	13.8	31.0	142.6	71.2	27.6	48.2	8.8	18.4	7.2	368.8
	LT	29.0	38.8	37.7	28.8	26.5	23.0	25.1	23.4	14.2	246.5
A.karahisar (L9)	19-20	11.1	11.7	64.2	63.3	57.8	42.2	18.2	83.5	60.6	412.6
	LT	35.3	33.2	46.7	44.9	39.7	45.0	45.1	54.5	42.0	386.4

19-20 : 2019-2020 growing period; LT : Long-term average (20 years)

Table 3. Result of combined analysis of variance.

Source	DF	Mean Square	F Ratio
Genotypes	23	69095	22.63*
Replications (Location)	27	31187	10.21*
Locations	8	1251293	409.78*
Genotype by Locations	184	8357	2.74*
Error	621	3053	-

*Statistically significant at p<0.01 level; DF: Degrees of Freedom

Table 4. Grain yield data of barley genotypes in nine locations (kg/ha).

Genotype	L1	L2	L3	L4	L5	L6	L7	L8	L9	Mean
Tarm-92	4776 ad*	2877 a	3524 ık	3472 ab	4495 ad	4054 bc	5433 ad	2980 ac	2928 a	3837 bf
G2	4302 bf	2670 a	3766 fj	1782 df	3894 be	4116 bc	5004 ad	2235 fg	2268 bg	3337 gı
G3	3714 df	3087 a	4278 dh	1846 df	4325 ae	5126 ab	5258 ad	2526 af	1835 gk	3555 eı
G4	3541 ef	2908 a	3973 fj	1163 fg	3711 ce	5140 ab	5358 ad	2286 eg	1695 ık	3308 hı
Burakbey	5383 ab	3162 a	4950 bd	2035 df	4079 be	4557 ab	5733 ac	2826 ae	2488 ad	3913 bd
G6	4652 ae	3202 a	5116 ac	1416 eg	3689 ce	5332 ab	6153 ab	2519 af	1878 fk	3773 bf
G7	3758 df	3013 a	4168 eı	1857 df	3667 ce	4647 ab	5359 ad	2709 af	1415 k	3399 gı
G8	3498 f	2957 a	4153 eı	1903 df	3959 be	5137 ab	5279 ad	2365 df	1578 jk	3425 gı
G9	4538 af	3025 a	2663 l	3080 ac	4048 be	2876 c	4639 ce	2900 ad	1955 ej	3303 hı
Sayım 40	5594 a	3044 a	5788 a	3078 ac	4820 ab	4914 ab	6295 a	3269 a	2730 ab	4392 a
G11	4638 af	2850 a	3781 fj	2137 cf	3884 be	4091 bc	5667 ad	2720 af	2255 cg	3558 eı
G12	4208 cf	2859 a	3506 ık	2536 bd	3880 be	4373 ab	4802 bd	2469 cf	1998 ej	3403 gı
G13	4730 ae	3033 a	4074 eı	2227 ce	4108 be	5509 a	5365 ad	2424 df	2603 ac	3786 bf
G14	4777 ad	2786 a	4282 dh	1902 df	3348 e	5331 ab	4809 bd	2439 cf	2518 ac	3577 dh
Tosunpaşa	3831 df	3092 a	4476 cf	2156 cf	4327 ae	4997 ab	5394 ad	2735 af	1935 ej	3660 cg
G16	2130 g	1368 b	2908 kl	600 g	2159 f	3963 bc	3298 e	933 h	705 l	2007 j
G17	4325 bf	3193 a	3716 gj	1772 df	3401 e	4112 bc	5016 ad	1810 g	2025 dj	3263 hı
G18	3850 df	2806 a	3316 jl	3490 ab	4614 ac	3973 bc	4279 de	2205 fg	1733 hk	3363 gı
G19	4513 af	2843 a	4391 cg	1970 df	3744 be	4803 ab	5103 ad	2541 af	2198 ch	3567 eh
Asil	5124 ad	2850 a	3621 hk	2621 bd	5241 a	4452 ab	5515 ad	3033 ab	2390 be	3872 be
G21	4381 bf	2584 a	3554 hk	1360 eg	3478 de	4206 ab	4642 ce	2543 af	2325 bf	3230 ı
G22	4288 bf	2831 a	4020 fj	1686 df	4062 be	4948 ab	5299 ad	2464 cf	2138 cı	3526 fı
G23	4596 af	3036 a	5231 ab	2686 bd	4161 ae	5312 ab	5768 ac	2588 af	2255 cg	3959 bc
Larende	5150 ac	3283 a	4783 be	3934 a	3744 be	5074 ab	5477 ad	2351 eg	2885 a	4076 ab
Mean	4346	2890	4085	2196	3951	4627	5406	2494	2114	3545
CV (%)	13.8	16.2	13.0	24.7	14.7	15.9	14.4	11.6	11.8	15.5
F Ratio	5.9*	2.4*	7.6 *	8.5*	4.1*	2.9*	2.7*	9.8*	15.8*	22.6*
LSD	1126	876	998	1019	1089	1377	1406	542	468	3365

* Means with the same letter are statistically in the same group, LSD: Least significant differences (0.01)

Table 5. Stability parameters related to grain yield of barley genotypes.

Genotypes	Yield (kg/ha)	Rank	a	b	R^2	S^2d_i	CV
Trm	3837	6	1437.25	0.68	0.72	263489.64	23.71
G2	3337	19	-84.74	0.97	0.97	45356.09	33.55
G3	3555	13	-359.53	1.10	0.93	136287.86	36.77
G4	3308	20	-987.22	1.21	0.92	188294.07	43.57
Brk	3913	4	-76.37	1.13	0.92	156804.49	34.16
G6	3773	8	-1197.10	1.40	0.94	176146.70	43.67
G7	3399	17	-447.43	1.08	0.93	121939.64	37.69
G8	3425	15	-558.27	1.12	0.92	156308.19	38.97
G9	3303	21	1419.05	0.53	0.45	517384.75	27.42
Sym	4392	1	370.33	1.13	0.89	231094.87	31.21
G11	3558	12	47.93	0.99	0.93	107896.40	32.92
G12	3403	16	415.61	0.84	0.96	39578.52	28.79
G13	3786	7	-38.92	1.08	0.95	93821.38	33.40
G14	3577	10	-55.04	1.02	0.88	213071.95	34.85
Tps	3660	9	-85.08	1.06	0.94	101640.65	33.94
G16	2007	24	-1466.29	0.98	0.86	224602.96	59.94
G17	3263	22	-251.05	0.99	0.93	110247.76	35.96
G18	3363	18	1051.23	0.65	0.60	415525.98	28.48
G19	3567	11	-114.64	1.04	0.98	35621.92	33.60
Asl	3872	5	424.56	0.97	0.82	313015.75	31.70
G21	3230	23	-20.00	0.92	0.91	125194.24	33.99
G22	3526	14	-424.01	1.11	0.98	36817.00	36.43
G23	3959	3	-103.49	1.15	0.95	104718.52	33.91
Lrd	4076	2	1103.23	0.84	0.75	348306.45	27.11

References

Akçura M, Kaya Y and Taner S, (2005). Genotype-environment interaction and phenotypic stability analysis for grain yield of durum wheat in the Central Anatolian Region. Turkish Journal of Agriculture and Forestry 29(5):369-375.

Akgun N, Topal A and Akcura M, (2012). Evaluation of Central Anatolian barley landraces for crop improvement. Romanian Agricultural Research 29:87-93.

Avcı M, (2023). Araştırma sonuçlarının excel addin makrosu ile istatistiksel analizi, https://yeniavciistatistik.blogspot.com

Becker HC and Léon J, (1988). Stability analysis in plant breeding. Plant Breeding 101:1-23. https://doi.org/10.1111/j.1439-0523.1988.tb00261.x

Eberhart SA and Russell WA, (1966). Stability parameters for comparing varieties. Crop Science 6:36-40.

Ergün N, Aydoğan S, Sayim İ, Bilir M, Çetin ÖG and Karahan E, (2023). Grain yield and stability of feed barley (*Hordeum vulgare* L.) genotypes under dry conditions of Central Anatolia. In Çolak AM, Seydoşoğlu S. and Mertoğlu K. (Eds) 13th International Conference on Agriculture, Animal Science and Rural Development Proceeding Book. Uşak. p.23 https://doi.org/10.5281/zenodo.10406033

FAOSTAT (2023). Crops and livestock products. https://www.fao.org/faostat/en/#data/QCL. Accessed 06.12.2023

Finlay KW and Wilkinson GN, (1963). The analysis of adaptation in a plant-breeding programme. Crop and Pasture Science 14:742-754.

Francis TR and Kannenberg LW, (1978). Yield stability studies in short-season maize. I. A descriptive method for grouping genotypes. Canadian Journal of Plant Science 58(4): 1029-1034. https://doi.org/10.4141/cjps78-157

Lee SY, Lee HS, Lee CM, Ha SK, Park HM, Lee SM, Kwon Y, Jeung JU and Mo Y, (2023). Multi-environment trials and stability analysis for yield-related traits of commercial rice cultivars. Agriculture 13(2):256. https://doi.org/10.3390/agriculture13020256

Montgomery DC, (2013) Design and analysis of experiments (Eighth edition). John Wiley & Sons, Newyork

Newton AC, Flavell AJ, George TS, Leat P, Mullholland B, Ramsay L and Bingham IJ, (2011). Crops that feed the world 4. Barley a resilient crop? Strengths and weaknesses in the context of food security. Food Security 3: 141-178. https://doi.org/10.1007/s12571-011-0126-3

Pinthus MJ, (1973) Estimate of genotypic value: A proposed method. Euphytica 22: 121–123. https://doi.org/10.1007/BF00021563

Pour-Aboughadareh A, Yousefian M, Moradkhani H, Poczai P and Siddique KHM, (2019). STABILITYSOFT: A new online program to calculate parametric and non-parametric stability statistics for crop traits. Applications in Plant Sciences 7(1): e1211. https://doi.org/10.1002/aps3.1211

Pour-Aboughadareh A, Barati A, Koohkan SA, Jabari M, Marzoghian A, Gholipoor A and Kheirgo M, (2022). Dissection of genotype-by-environment interaction and yield stability analysis in barley using AMMI model and stability statistics. Bulletin of the National Research Centre 46(1):19. https://doi.org/10.1186/s42269-022-00703-5

Sabaghnia N, Mohammadi M and Karimizadeh R, (2013). Yield stability of performance in multi-environment trials of barley (*Hordeum vulgare* L.) genotypes. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis 61(3):787-793. https://doi.org/10.11118/actaun201361030787

Saisho D and Purugganan MD, (2007). Molecular phylogeography of domesticated barley traces expansion of agriculture in the Old World. Genetics 177(3):1765–1776. https://doi.org/10.1534/genetics.107.079491

Teich AH, (1983). Yield stability of cultivars and lines of winter wheat. Cereal Research Communications 197-202. http://www.jstor.org/stable/23781406

Tokgöz M, (1997). The effect of rainfall to barley yield in Turkey. Journal of Agricultural Sciences 03(02):97-102. https://doi.org/10.1501/Tarimbil_0000000319

TSI, (2023). Database of Turkish Statistical Institute. https://data.tuik.gov.tr/Kategori/GetKategori?p=Tarim-111. Accessed 06.12.2023

Yan W and Tinker NA, (2006). Biplot analysis of multi-environment trial data: Principles and applications. Canadian journal of plant science 86(3): 623-645. https://doi.org/10.4141/P05-169

Yüksel S and Akçura M, (2012). Pattern analysis of multi-environment yield trials in barley (*Hordeum vulgare* L.). Turkish Journal of Agriculture and Forestry 36(3): 285-295. https://doi.org/10.3906/tar-1103-41