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Stability Analysis of Lines Selected from a Barley Landrace under Rainfed Conditions

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ABSTRACT

The evaluation of stability and genotype-environment interaction are some of the most important ways to evaluate the performance of lines within a population across environments. The aim of the present study was to evaluate some purelines selected from a barley landrace along with cv. Tokak 157/37 under different environments. Seven field trials with different rainfall characteristics were conducted to investigate the grain yield stability levels of the lines. Correlation coefficients were calculated between the grain yields and the amount of precipitation at planting-harvesting period, and stability analyzes were performed. Average grain yields of the lines selected from Tokak landrace varied between 3.30 (Lines 56 and 228) and 3.95 t/ha (Line 207). All genotypes had significant correlations of r = 0.714-0.942 between seasonal precipitation and grain yields. Lines 64 and 228 had clearly higher correlation coefficients than others, but they had quite low average yields across the environments and do not offer any specific advantage for low or high yielding environments. On the other hand, Line 50 did not have the highest average grain yield but its relatively high correlation coefficient between precipitation and grain yield makes this line a promising one for the environments with higher yield potential. The most stable lines with above the average grain yields were Lines 207 and 50. Lines 207 and 50 had higher yields and higher stability in the studied environments compared to others. Line 207 had a relatively higher level of correlation coefficient between grain yield and seasonal precipitation, and its overall yield average was higher than that of Line 50, indicating promising yield potential for the conditions that can produce higher grain yields than the ones evaluated in the present study. Thus, the findings showed the potential of landraces to harbor beneficial gene alleles for variable growing conditions including the environmental stress environments.

1. Introduction

Cool season cereals such as barley are mostly grown under rainfed conditions. High yielding modern cultivars developed for high yielding intensive farming environments may incur substantial yield losses in less favorable conditions. On the other hand, landraces were developed by ancient farmers during the times when intensive farming was not practiced. They are more resilient plant populations that could have yield stability across variable production conditions.

Grain yields of cereals grown under rainfed conditions are influenced by the amount of precipitation. Water use efficiency (WUE) and drought tolerance are synonymously used terms (Tardieu, 2022). However, under water deficit conditions, efficient use of water (EUW), not WUE, has been proposed to be considered in plant breeding programs since selection for higher WUE under these conditions tend to favor plant traits associated with less water use such as early flowering and smaller leaf area (Blum, 2009).

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Due to heavy focus on grain yields under optimum conditions for which modern cultivars are mostly developed, cultivated varieties may lack tolerance to environmental stresses such as water scarcity (Jones and Qualset, 1984).

Landrace varieties are plant populations developed by ancient farmers. Even in self-pollinated crops such as barley, they are made of plants that look phenotypically similar but in fact are mixtures of genotypes (Saygili et al., 2021). The genetic diversity they harbor are very useful for plant breeding considering the fact that they are easy to pollinate with modern cultivars and have genes less deleterious for crop yields and quality traits. They may also have genes that allow them to perform better under limited water conditions (Reynolds et al., 2007). Under water stress conditions, barley landraces were found to have a 60% yield advantage over the modern cultivars (Grando et al. 2001). Similarly, Tokak (PI 470281), a landrace of Turkey used in Anatolian plateau where arid conditions prevail, could have genes for effective water use in rainfed conditions.

DNA markers are important tools to identify different genotypes and genes of interests. They are useful in determining the genetic diversity levels of landrace varieties as well as to isolate specific purelines from them to further characterize in large scale field tests. Simple sequence repeats markers (SSRs) constitute a specific subclass of DNA markers with a very high polymorphism rate and ease of use (Varshney et al., 2008). They have been used in many crops so far including barley. Using 30 SSR markers, barley landrace Tokak were characterized and found to have very high genetic diversity level (Kandemir et al., 2010). Purelines were selected from this landrace to further evaluate in field tests.

The evaluation of stability and environment-genotype interaction are some of the most important ways to evaluate the performance of a population with genotypic differences across the environment. The aim of the present study was to evaluate 10 purelines selected from PI 470281 barley landrace along with cultivated variety Tokak 157/37 under seven field trials with varying rainfall characteristics and to investigate their grain yield stability levels.

2. Material and Method

In the study, 10 lines selected from the Tokak Turkish barley landrace (PI 470281) (Kandemir et al., 2010) using SSR markers and Tokak 157/37 variety were used. Field trials were conducted in a total of seven environments (five trials in Tokat Kazova in 2008-2012, and two in Tokat Artova in 2010 and 2011). Tokat Kazova (hereafter Tokat) trials were carried out at the Central Black Sea Transition Zone Agricultural Research Institute in 2008, 2009, 2012, in a producer's field near the same Institute in 2010, and at experimental lands of Tokat Gaziosmanpaşa University Agricultural Application and Research Center in 2011. Tokat Artova (hereafter Artova) trials were carried out at a producer's field near the village of Kunduz in Artova district in 2010, and at a producer's field near the village of Artova-Taşpınar in 2011. Some information about the experimental lands is given in Table 1.

The average long term temperature (35 years) is 14.1 ºC in Kazova and 8.1 ºC in Artova regions. The long term total precipitation is 557.7 mm in Kazova and 464.1 mm in Artova. The monthly precipitation and temperature values in the environments where the trials were carried out are given in Figure 1 and Figure 2. From planting to the date the plants started to turn yellow, precipitation was 183 mm in 2008 Tokat, 207 mm in 2009 Tokat, 228 mm in 2010 Tokat, 239 mm in 2010 Artova, 299 mm in 2011 Tokat, 267 mm in 2011 Artova and 256 mm in 2012 Tokat trial.

Trials were set up in a randomized complete blocks design with three replications. Each plot consisted of a total of five rows of 3 m long. The row spacing was 30 cm. Thus, each plot area was 4.5 square-meter. A wheat variety with a short plant height was planted as two rows between the plots and on the sides of the blocks so that the lodging of one plot should not affect that of the adjacent one. Sowing was done by hand with a sowing rate of 200 kg/ha. The plots were fertilized with 75 kg/ha of P205 and 100 kg/ha N. All of the phosphorus fertilizer was given at planting while half of the nitrogen fertilizer were given at planting and the other half before the stem elongation period.

Table 1. Characteristics of experimental areas

Environment	Elevat.	Latit.	Longit.	Planting date	Soil texture	Total salt %	pH	$CaCO_3$ %	P_2O_5 kg/ha	K_2O kg/ha	Organic matter %
2008 Tokat	570	40.327	36.452	10 March	Clayed-loam	0.038	7.71	10.1	111	1108	1.45
2009 Tokat	574	40.326	36.447	6 March	Clayed-loam	0.023	7.88	13.6	76	146	1.82
2010 Tokat	592	40.332	36.468	21 February	Clayed	0.014	8.25	3.9	73	299	1.19
2010 Artova	1106	40.054	36.295	12 March	Clayed	0.012	8.33	3.5	69	770	0.65
2011 Tokat	589	40.333	36.477	19 February	Clayed	0.013	8.17	4.5	124	441	1.38
2011 Artova	1189	40.133	36.332	17 March	Sandy-loam	0.024	8.17	4.3	86	321	2.48
2012 Tokat	576	40.328	36.452	14 March	Clayed-loam	0.043	7.75	9.2	113	1142	1.78

The plants were harvested with large scissors, dried in loose bundles and threshed. Yields per hectare were calculated from the grain obtained from the plots according to the 12% constant humidity (Kandemir et al., 2022). Pearson correlation coefficient was calculated between the yields of the lines and the amount of precipitation at planting-harvesting period Microsoft Excel software. Stability analyzes were performed using GEA-R software (Pacheco et al., 2015). In the mean vs. stability view, scaled by standard deviation (SD), centered by tester – centered G+GE and SVP HJ – (Dual Metric Preserving) model was used.

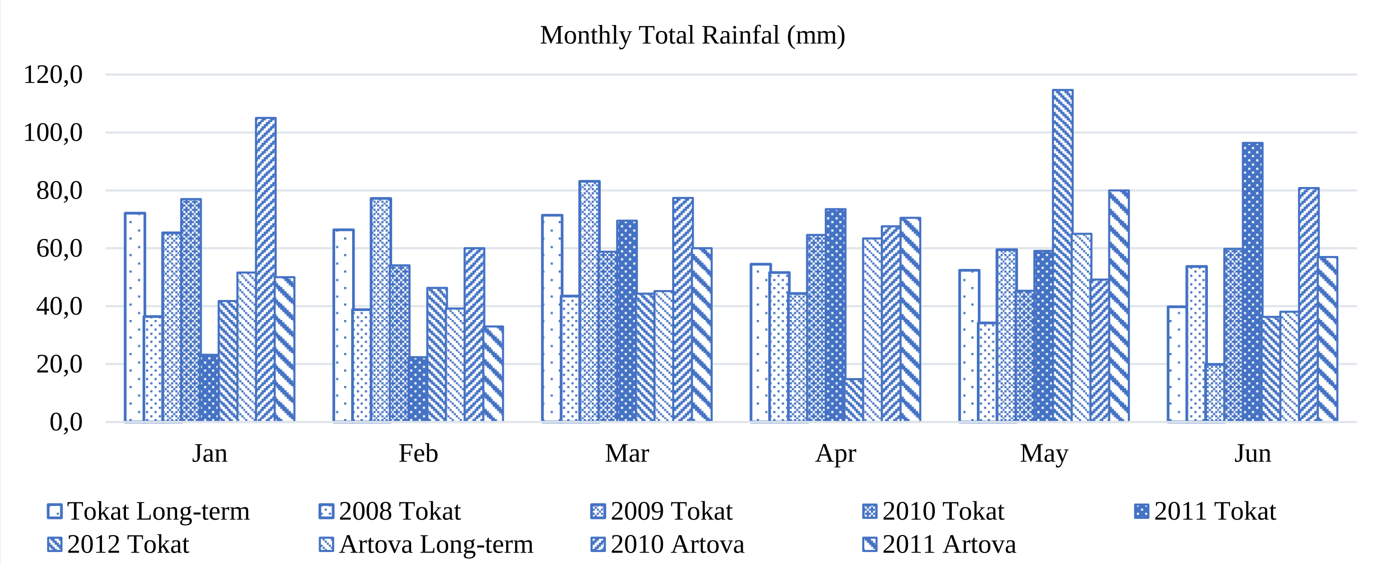

Figure 1. Monthly precipitation values in the environments

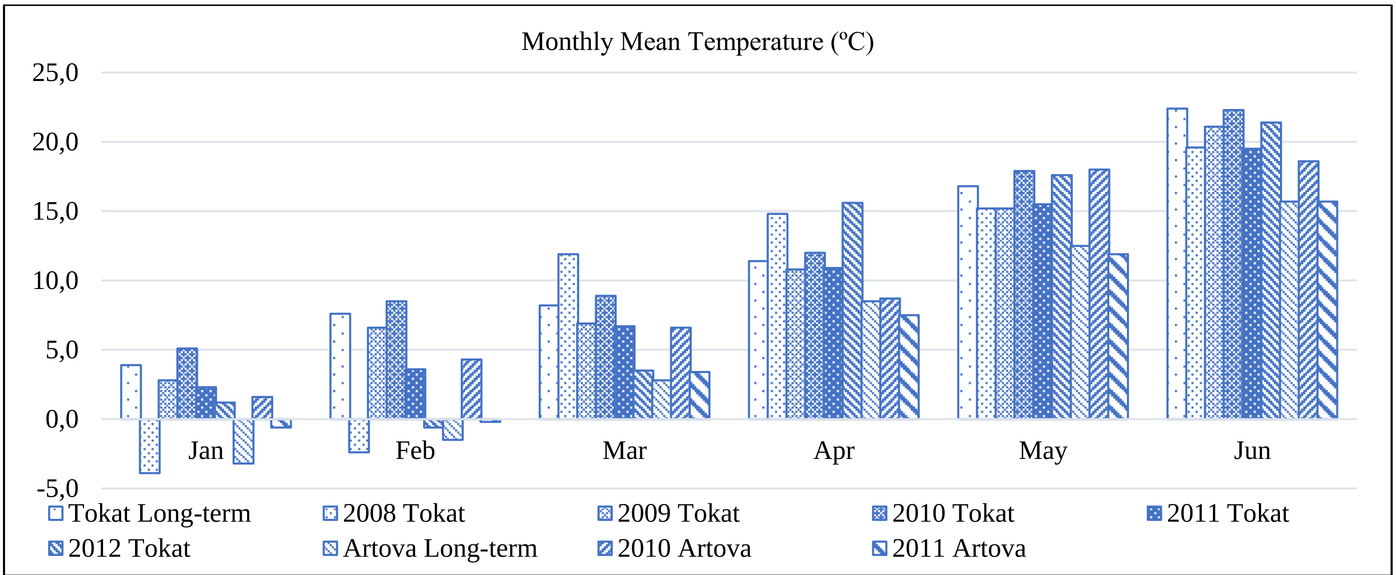

Figure 2. Monthly mean temperature values in the environments

3. Results and Discussion

Barley grain yields across seven environments varied from 1.84 to 5.57 t/ha (Figure 3). Average grain yields of the lines selected from Tokak landrace PI 470281 varied from 3.30 (Lines 56 and 228) to 3.95 t/ha (Line 207). Most lines had similar or higher grain yields compared to control variety Tokak 157/37 (Table 2). Tokak 157/37 is known with a good adaptation ability (Diab et al., 2004). It is a selection from a landrace. In other words, it was not subjected to much genetic manipulation. This variety had a large seed size (Kandemir, 2004), and had considerable acreage in Turkey as both feed and malt until recent years. Thus, the lines selected from PI 470281 had fairly good yield potential comparable to that of the commercial variety of Tokak 157/37.

Seven environments had total precipitation values of 183.0-299.0 mm during the period from planting to the harvest. Correlation coefficients between seasonal precipitation and grain yields were calculated for each genotype as an indication of the effective use of water from the precipitation Table 2. All genotypes had significant correlations between seasonal precipitation and grain yields (range: 0.714-0.942). Similar significant correlations of r = 0.70 and 0.784, respectively, were observed in spring barley (Yau and Ryan, 2013) and winter wheat (Jolánkai et al., 2018). Some lines such as Lines 64, 228 and 50 (r = 0.942, 0.930 and 0.904, respectively) had clearly higher correlation coefficients than others. The first two of them had quite low average yields across the environments including the low yielding ones such as 2008 Tokat and 2009 Tokat and do not offer any specific advantage for low or high yielding environments. On the other hand, although the Line 50 did not have the highest average grain yield, its relatively high correlation coefficient between precipitation and grain yield makes this line a promising one for the environments with higher yield potential than the ones evaluated in the present study.

Table 2. Grain yields (t/ha) of lines at environments and their correlations with total precipitation during the planting-harvest period

Genotype	2008 Tokat	2009 Tokat	2010 Tokat	2010 Artova	2011 Tokat	2011 Artova	2012 Tokat	Mean	Correlation coefficient
40	3.41	1.76	2.66	3.08	5.34	4.07	4.42	3.53	0.770*
50	2.87	2.00	3.12	3.31	6.35	4.32	4.50	3.78	0.904**
53	2.42	1.90	2.96	3.38	5.78	3.70	5.04	3.60	0.888**
56	2.42	1.58	2.63	3.19	5.37	3.66	4.28	3.30	0.898**
64	2.17	1.62	2.58	3.06	5.44	4.25	4.24	3.34	0.942**
207	3.97	2.38	3.03	3.42	6.64	3.81	4.37	3.95	0.714*
210	2.61	1.83	2.78	3.12	5.49	3.74	4.38	3.42	0.892**
212	2.08	1.64	2.40	3.47	6.23	3.50	5.40	3.53	0.871**
217	3.30	1.74	2.43	2.97	4.90	4.03	4.47	3.41	0.746*
228	2.07	1.67	3.11	2.94	5.38	3.66	4.29	3.30	0.930**
Tokak 157/37	2.86	2.13	2.82	3.16	4.30	3.70	4.37	3.33	0.817**
Mean	2.74	1.84	2.77	3.19	5.57	3.86	4.52	3.50	0.880
Precipitation$^{\beta}$	183	206.9	228	238.5	299	267	256	240	

$^{\beta}$ Precipitation is the amount of rainfall during the vegetation period.
* and **: significant at 5% and 1% level of probability, respectively.

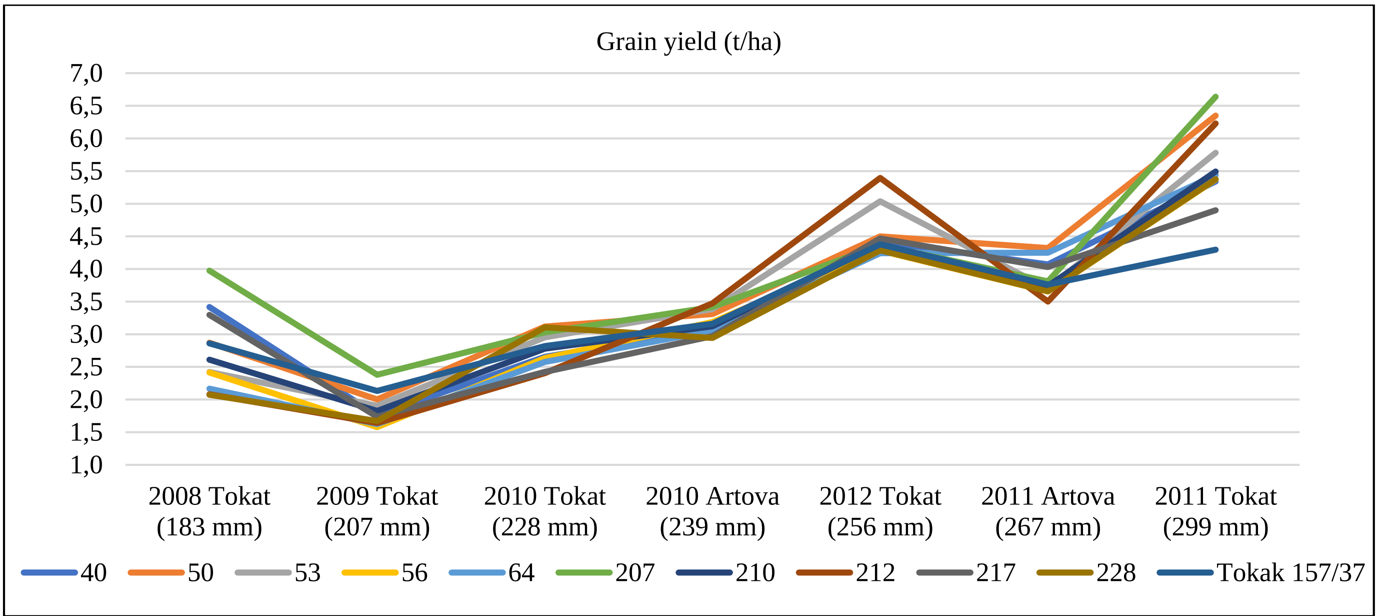

Figure 3. Grain yields of lines across trials. Values in parentheses are the amount of rainfall during the vegetation period. The trials were ordered according to amount of precipitation.

In Figure 4 comparing the stability and average yields, the line denoted by a circled arrow shows the average grain yield line of environments. The arrow indicates the direction of increasing grain yield (Frutos et al., 2014). The lines with the highest yield averages were 207, 50, 53, 212 and 40. The distances of the lines to the yield line indicates their instability, i.e., the lines closest to the average yield line are the most stable ones. The most stable lines with above the average grain yields were the 207 and 50. On the other hand, line 212 was unstable. Based on these findings, Lines 207 and 50 had higher yields and higher stability in the studied environments compared to other lines. Although Line 207 had lower grain yields than the environment averages in 2011 Artova and 2012 Tokat, its overall yield average was higher than that of Line 50, and more prominent in the chart compared to the Line 50.

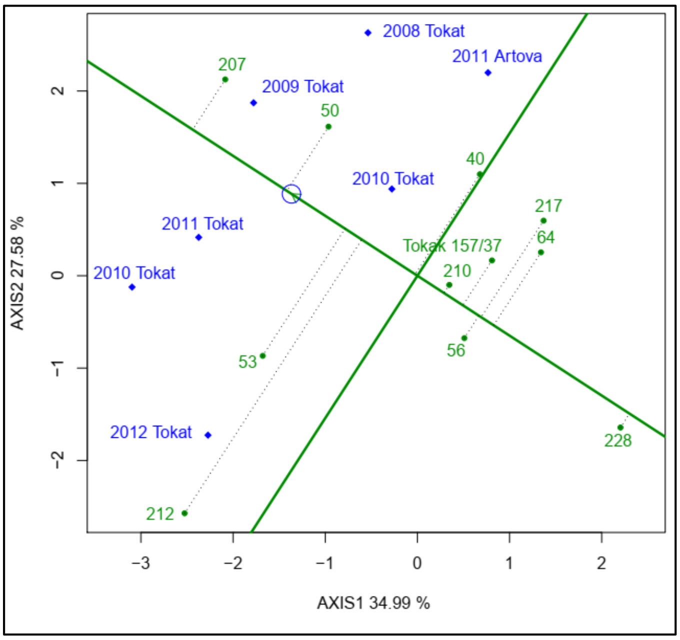

Figure 4. The mean vs. stability of the genotype and genotype environment interaction (GGE) biplot based on grain yield. The small blue rectangular indicate the seven environments where the field trials were conducted. The small green circles show the 11 genotypes.

Although the idea of stable genotypes that can maintain yield levels across environments seem to be appealing, it could also mean that the genotype cannot benefit better from the high yielding environments such as those with more precipitation. While there is a tradeoff between grain yield levels and yield stability especially in semiarid conditions (Du et al., 2020), in wetter conditions, the genotypes that have higher than the average yield and can perform better are preferable. Therefore, lines having a high level of correlation between amount of precipitation and grain yield and having higher than average grain yields would be more desirable. Of the all lines evaluated in the present study, Line 210 was the most stable and had the highest level of correlation between precipitation and grain yield, but its average yield was lower than the others. On the other hand, Line 212 which had a high level of correlation between precipitation and grain yield and higher than the average grain yields was also unstable. Similar to Line 207, Line 50 was stable and had high grain yields but it had a high level of correlation between precipitation and grain yield. It was found that the Line 207 had the lowest level of correlation coefficient between precipitation and grain yield (Table 2). Moreover, in both the lowest (2008 and 2009 Tokat) and the highest rainfall environments (2011 Tokat), the highest grain yield was obtained from the Line 207. This finding revealed that Line 207 performed better with less dependence on varying precipitation conditions compared to other lines.

4. Conclusion

Ten lines selected from Tokak landrace PI 470281 were evaluated under seven rainfed conditions compared with Tokak 157/37 commercial barley variety known for its good adaptation and stress tolerance characteristics. Most lines had comparable or higher grain yields than Tokak 157/37 under these conditions. Tokak 157/37 had yield stability across the environments but low grain yield averages. Two lines had both high grain yields and fairly good yield stability. One of them also had a relatively higher level of correlation coefficient between grain yield and seasonal precipitation, indicating promising yield potential for the conditions that can produce higher grain yields than the ones evaluated in the present study. Thus, our findings revealed the potential of landraces to offer useful gene alleles for different growing conditions especially the ones under the environmental stresses.

Declaration of Competing Interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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