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Variations in spike traits among pure lines selected from a barley landrace

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ABSTRACT

Landraces account for a large part of the variation in gene banks. The use of a landrace in breeding programs necessitate the characterization of pure lines selected from the landrace. The aim of the present study was to determine the variations for spike characters in a barley landrace originating from Turkey. Twenty-five pure lines selected Turkish barley landrace Tokak (PI 470281) were evaluated in three field trials along with cv. Tokak 157/37. Spike traits such as heading time, number of grains per spike, spike length and spikes per square meter were determined. As the average of trials, the spikes per square meter of lines ranged from 223.4 (Line 217) to 291.3 (Line 59) and heading time from 72.5 day (Line 62) to 79.8 day (Line 217). As an average of locations, the number of grains per spike varied in a narrow range of 20.0 (Line 212) - 22.8 (Line 210) and spike lengths from 6.67 cm (Line 59) to 8.49 cm (Line 208). There were no considerable differences among the lines in terms of the spike length and the number of grains per spike. The lines evaluated had earlier heading than the Tokak variety, except for Line 217. Majority of lines produced more spikes per unit area than cv Tokak 157/37 in all locations. Therefore, the lines studies could be used as a gene source to increase grain yield under limited yield conditions. Further, evaluation of these lines in other characteristics related to drought tolerance may enable the identification of new variations for drought tolerance.

1. Introduction

Landraces contain valuable variations for plant breeding. The preference for elite genotypes with superior characteristics in plant breeding has led to the intensive use of some germplasm resources (von Korff et al., 2008). Genetic variations within landraces account for a large part of the variation in gene banks (Jaradat et al., 2004). Therefore, the use of landraces with valuable genetic variations for plant breeding necessitates their comprehensive evaluations.

Spike characteristics are important traits that could facilitate high grain yields, which is the most important breeding objective of barley. Time to heading is significantly associated with the adaptability. Early heading is an escape mechanism from the terminal drought that occurs after the flowering (Yue et al., 2006). Late heading could increase yield potential by supporting vegetative growth in areas with high rainfall or irrigation. Except for thousand-seed weight, grain yield components are the spike traits such as the number of grains per spike and spikes per square meter (Gambín and Borrás, 2010). Targeted changes in spike characteristics may support adaptability or yield potential. These are highly environment-dependent traits. Therefore, accurate determination of the genetic variation in these traits require repeated plots and multi-location field trials. In order to measure these characters efficiently, a systematic reduction of line numbers can be achieved through determining and eliminating the identical ones from the population (Saygili et al., 2021a). In this way, it could be possible to combine the power of DNA markers and repetitive field trials.

Landraces can carry considerable variations in some plant characteristics. Alemayehu and Parlevliet (1997) showed that

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variations within landraces vary, and one landrace might have a high level of variation for one trait and another landrace might have high variation for another trait. Akinci and Yildirim (2009), who examined a total of 800 accessions belonging to 29 Turkish barley landraces, reported wide variations for time to heading. Jaradat et al. (2004) identified large variations in an Oman barley landrace in terms of spike traits such as spike density, spikelet number, spike weight, and number of grains per spike. However, due to the conscious selection of farmers who used the landraces, the variation in morphological traits may be less than that in biochemical or molecular traits that are not visible to farmers and cannot be subjected to selection (Koebner et al., 2003).

The use of landraces as genetic sources has some advantages. The most important of these is that landraces are genetically and agronomically more similar to cultivated varieties than wild relatives while containing more variation than the cultivated varieties. Some parts of fertile crescent, the important gene center of barley, are part of Turkey (Kilian et al., 2006). Therefore, the populations from this region may contain significant novel variations. The aim of the present study was to determine the variations in a barley landrace originating from Turkey for spike characters, and to obtain useful information by identifying new genetic materials for plant breeding purposes.

2. Materials and methods

2.1. Plant material

In the study, 25 genetically different lines selected among 46 plants in Turkish barley landrace Tokak (PI 470281) based on genetic diversity level using SSR markers (Kandemir et al., 2010) were evaluated. These lines were grown in multi-location field trials along with Tokak 157/37, a commercial barley variety with some cultivation in Turkey.

2.2. Field trials

Three field trials were conducted: Tokat in 2009 and 2010 and Artova in 2010. In 2009, the trial in Tokat was carried out at the Central Black Sea Transition Zone Agricultural Research Institute, in 2010 in a farmer's field near the same Institute, and the 2010 Artova trial was carried out in a farmer's field in the Artova district. The soil characteristics of experimental lands are given in Table 1.

Table 1. Some soil properties of experimental lands and planting dates

Trial	Altitude	Latitude	Longitude	Planting date	Soil structure	Total salt %	pH	Lime %	P_2O_5 kg/ha	K_2O kg/ha	Organic matter %
Tokat 2009	574	40.32652	36.44748	March 6	Clayed loam	0.023	7.88	13.6	75.6	146	1.82
Tokat 2010	592	40.33253	36.46857	February 21	Clay	0.013	8.25	3.9	73.4	299	1.19
Artova 2010	1106	40.05423	36.29539	March 12	Clay	0.013	8.33	3.5	69.1	769	0.65

The long term (35 years) average temperature was 14.1 ºC in Tokat and 8.1 ºC in Artova. The average temperature of the experimental years in Tokat was 13.0 ºC in 2009 and 14.9 ºC in 2010 while in Artova it was 11.9 ºC in 2010. The long-term total rainfall was 557.7 mm in Tokat, and 464.1 mm in Artova. The total rainfall in Tokat was 582.6 mm in 2009 and 518.2 mm in 2010 whereas the total rainfall of Artova in 2010 was 665.0 mm. The monthly distributions of precipitation and temperatures are given in Figure 1.

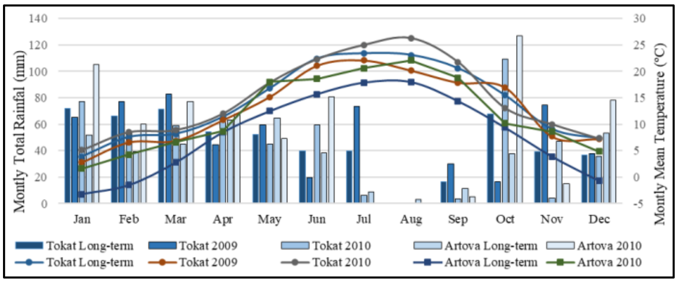

Figure 1. Climatic data for long term and experimental years

The experimental design was Randomized Complete Blocks with three replications in Tokat 2009 trial and four in Tokat 2010 and Artova 2010 trials. Each plot consisted of a total of five rows of 3 m long. The row spacing was 30 cm. Accordingly, the area of each plot was 4.5 square meter. A short stature wheat variety was planted between the barley plots and at the ends of the blocks to prevent the lodging of one plot from affecting that of other. Planting was carried out manually. The seeding rate was 200 kg/ha. Plots were fertilized with 75 kg/ha P_2O_5 and 100 kg/ha N. All of the phosphorus fertilizer and half of the nitrogen fertilizer were given during planting while the remaining half of the nitrogen was given before the stem elongation period.

2.3. Investigated traits

Data were collected in three trials for heading time (day), number of grains per spike, spike length (cm) and spikes per square meter. Heading time (day) was the time elapsed from the planting to the date when 50% of the plants in the plot showed awn. Spike length (cm) was the average length of the spikes from 40 random plants excluding awns. Number of grains per spike was the average number of grains of 40 random plants. The spikes per square meter was calculated from the grain yield, average number of grains per spike and average weight of one grain (thousand grain weight/1000) (Aisawi et al., 2015).

2.4. Statistical analyses

The data obtained from the trials were subjected to analysis of variance. First, all variables were analyzed as three separate trials and then variance homogeneity test (Bartlett's test) was applied. Since the characters examined did not have homogeneous variances, the results are presented separately, not as combination of all trials. Lines were grouped using Duncan's multiple range test. MSTAT-C statistical analysis software was used in all statistical analyses (Freed et al., 1988).

3. Results

Turkish barley landrace Tokak (PI 470281) was examined in previous studies for DNA markers and morphological characters (Kandemir et al., 2010), and malt quality, yield and associated characteristics (Saygili et al., 2021b). Significant variations were found based on DNA markers, malt quality and yield. In the present study, variations in terms of spike characteristics were examined.

Heading time of 26 genotypes showed significant differences in all locations ($p<0.01$). Heading time of the lines differed by about 7 days in Tokat 2009, 6 days in Tokat 2010 and 9 days in Artova 2010 trial (Table 2). Lines 51, 56, 59 and 62 reached heading earliest in all trials while cv. Tokak 157/37 and Line 217 later than other genotypes in all locations.

The spike lengths of the lines showed significant differences in all locations ($p<0.05$). In all trials, the Lines 50, 51, 53, 59, 62, 64, 201, 206, 215 and 228 had relatively shorter spikes while the Lines 44, 56, 207, 208 and 213 had longer spikes (Table 2). As the average of the three locations, spike lengths ranged from 6.67 cm (Line 59) to 8.49 cm (Line 208). Cv. Tokak 157/37 had a moderate spike length of 7.74 cm.

Significant differences were determined among the lines for the number of grains per spike in two of the three locations ($p<0.01$). As an average of locations, the number of grains per spike varied in a narrow range of 20.0 (Line 212) - 22.8 (Line 210) (Table 3). In Tokat 2009 and Tokat 2010 trials, the lowest. number of grains per spike was observed in Line 212, while in Artova 2010 trial, Line 59 had the least number of grains per spike.

Significant differences were found among the lines in terms of the spikes per square meter. As the average of trials, the spikes per square meter of lines ranged from 223.4 (Line 217) to 291.3 (Line 59) (Table 3). The highest number of spikes was obtained from Lines 46, 53, 67 and 207 in Tokat 2009 trial, from Lines 50, 51, 59 and 201 in Tokat 2010 trial and from Lines 50, 53 and 59 in Artova 2010 trial. Line 217 produced consistently less spikes per unit area in all trials. Lines 46 and 53 produced greater number of spikes in Tokat 2009 trial, where rainfall was lower during the vegetation period, while they produced consistently high spikes in other trials.

Table 2. Heading time and spike length of barley lines

Genotypes	Heading time (days)				Spike length (cm)			
	Tokat 2009**	Tokat 2010**	Artova 2010**	Means	Tokat 2009*	Tokat 2010*	Artova 2010**	Means
40	71.7 ef	76.3 bcd	74.3 b-e	74.1	8.40 ab	6.99 a-d	7.68 d-g	7.69
44	73.3 b-e	76.3 bcd	74.5 b-e	74.7	8.41 ab	7.60 ab	8.65 a-e	8.22
46	74.3 bc	76.5 bc	75.8 bc	75.5	6.32 e	6.96 a-d	7.96 c-f	7.07
50	72.7 de	76.0 bcd	74.8 bcd	74.5	7.61 a-e	7.06 a-d	7.84 d-g	7.50
51	70.7 f	75.5 b-e	73.8 cde	73.3	7.12 a-e	6.60 bcd	7.59 efg	7.10
53	74.7 b	75.5 b-e	75.5 bc	75.2	6.90 b-e	6.84 a-d	7.65 d-g	7.13
56	72.0 ef	74.8 de	73.8 cde	73.5	7.90 a-e	7.18 a-d	8.69 a-d	7.92
59	71.7 ef	75.8 b-e	73.8 cde	73.8	7.0 b-e	6.14 d	6.88 g	6.67
61	72.3 e	76.5 bc	74.3 b-e	74.4	6.41 de	7.16 a-d	8.41 a-f	7.32
62	70.7 f	74.3 e	72.5 e	72.5	6.60 cde	6.22 d	7.52 fg	6.78
64	74.0 bcd	76.3 bcd	75.5 bc	75.3	7.20 a-e	6.53 bcd	7.61 efg	7.11
67	72.7 de	76.5 bc	73.3 de	74.2	7.80 a-e	7.34 abc	8.13 b-f	7.76
201	71.7 ef	76.5 bcd	76.3 b	74.8	7.00 b-e	6.78 a-d	7.82 d-g	7.20
206	72.7 de	76.0 bcd	74.3 b-e	74.3	7.30 a-e	6.96 a-d	8.21 b-f	7.49
207	74.0 bcd	77.0 b	75.0 bcd	75.3	8.00 a-d	7.72 a	9.10 ab	8.27
208	73.3 b-e	76.8 bc	75.0 bcd	75.0	8.05 ab	7.56 ab	9.31 a	8.46
210	72.0 ef	75.5 b-e	75.3 bcd	74.3	7.40 a-e	6.77 a-d	8.21 b-f	7.46
212	72.0 ef	75.8 b-e	75.8 bc	74.5	6.70 cde	6.52 bcd	8.40 a-f	7.21
213	73.0 cde	76.0 bcd	75.3 bcd	74.8	8.21 abc	7.09 a-d	8.61 a-e	7.97
215	71.7 ef	76.0 bcd	74.0 cde	73.9	6.63 cde	6.26 cd	7.49 fg	6.78
217	78.0 a	80.5 a	81.0 a	79.8	8.21 a-d	7.55 ab	8.00 c-f	7.88
221	71.7 ef	75.3 cde	75.0 bcd	74.0	7.63 a-e	6.89 a-d	7.94 c-f	7.48
224	73.0 cde	76.8 bc	75.3 bcd	75.0	6.92 b-e	7.06 a-d	8.99 abc	7.65
227	72.3 e	76.0 bcd	73.3 de	73.9	6.82 b-e	7.18 a-d	8.16 b-f	7.38
228	73.0 cde	75.8 b-e	73.8 cde	74.2	7.92 a-e	6.97 a-d	7.78 d-g	7.55
Tokak 157/37	77.3 a	80.0 a	79.8 a	79.0	8.71 a	7.02 a-d	8.05 c-f	7.93

*,** indicates significance levels at $p<0.05$ and $p<0.01$ respectively. The differences between the means denoted by the same letters are not significant at $p<0.05$

Significant differences were found among the lines in terms of the spikes per square meter. As the average of trials, the spikes per square meter of lines ranged from 223.4 (Line 217) to 291.3 (Line 59) (Table 3). The highest number of spikes was obtained from Lines 46, 53, 67 and 207 in Tokat 2009 trial, from Lines 50, 51, 59 and 201 in Tokat 2010 trial and from Lines 50, 53 and 59 in Artova 2010 trial. Line 217 produced consistently less spikes per unit area in all trials. Lines 46 and 53 produced greater number of spikes in Tokat 2009 trial, where rainfall was lower during the vegetation period, while they produced consistently high spikes in other trials.

Table 3. Number of grains per spike and spikes per square meter

Genotype	Number of grains per spike				Spikes per square meter			
	Tokat 2009[NS]	Tokat 2010**	Artova 2010**	Means	Tokat 2009*	Tokat 2010**	Artova 2010**	Means
40	22.4	20.3 a-d	21.8 cde	21.5	154.7 f	275.9 ef	312.6 b-e	247.7
44	22.4	22.0 abc	24.3 abc	22.9	203.9 a-e	306.5 b-e	305.4 b-e	271.9
46	18.6	21.7 abc	23.5 a-e	21.3	230.8 ab	311.9 bcd	330.6 bc	291.1
50	21.4	21.5 abc	22.4 b-e	21.8	198.4 b-f	321.1 abc	338.9 ab	286.1
51	19.9	19.6 bcd	21.0 de	20.2	177.0 c-f	346.9 a	329.8 bc	284.6
53	19.9	22.3 ab	23.2 a-e	21.8	204.0 a-e	309.4 b-e	338.2 ab	283.9
56	20.6	21.1 abc	23.1 a-e	21.6	163.5 c-f	262.3 fg	315.3 bcd	247.0
59	20.6	19.4 cd	20.6 e	20.2	178.5 c-f	327.1 ab	368.3 a	291.3
61	19.5	20.6 abc	23.2 a-e	21.1	156.8 ef	295.5 b-f	306.0 b-e	252.8
62	20.2	20.7 abc	23.3 a-e	21.4	189.0 b-f	283.1 def	283.1 d-g	251.7
64	20.9	20.2 a-d	22.6 a-e	21.2	173.4 c-f	279.5 def	307.4 b-e	253.4
67	20.1	20.9 abc	23.1 a-e	21.4	210.4 abc	305.3 b-e	284.7 d-g	266.8
201	20.3	20.8 abc	22.9 a-f	21.3	193.9 b-f	326.9 ab	293.7 def	271.5
206	20.0	21.1 abc	23.0 a-e	21.4	190.2 b-f	281.6 def	294.1 def	255.3
207	20.3	20.5 abc	23.6 a-d	21.5	245.3 a	293.8 b-f	298.8 cde	279.3
208	21.1	21.6 abc	24.2 abc	22.3	153.2 f	295.2 b-f	288.9 def	245.8
210	22.1	22.0 abc	24.8 ab	23.0	199.1 b-f	291.8 c-f	291.9 def	260.9
212	18.4	18.0 d	23.7 a-d	20.0	198.1 b-f	281.3 def	330.5 bc	270.0
213	22.5	21.2 abc	24.3 abc	22.7	176.7 c-f	245.0 gh	297.9 cde	239.9
215	19.5	19.9 a-d	22.8 a-e	20.7	163.8 c-f	292.4 c-f	261.6 fg	239.3
217	20.2	21.3 abc	21.4 cde	21.0	169.2 c-f	215.3 h	285.6 d-g	223.4
221	22.8	21.3 abc	23.9 a-d	22.7	205.3 a-d	279.4 def	290.9 def	258.5
224	19.1	20.8 abc	25.4 a	21.8	180.3 c-f	309.1 b-e	280.7 d-g	256.7
227	19.1	21.0 abc	23.0 a-e	21.0	176.9 c-f	294.9 b-f	309.6 b-e	260.5
228	20.4	20.6 abc	21.7 cde	20.9	159.5 def	306.9 b-e	276.5 efg	247.6
Tokak 157/37	22.7	22.4 a	21.8 cde	22.3	160.1 def	242.6 gh	253.0 g	218.6

[NS]. Not-significant. *,** indicates significance levels at p<0.05 and p<0.01 respectively. The differences between the means denoted by the same letters are not significant at p<0.05.

Significant differences were found among the lines in terms of the spikes per square meter. As the average of trials, the spikes per square meter of lines ranged from 223.4 (Line 217) to 291.3 (Line 59) (Table 3). The highest number of spikes was obtained from Lines 46, 53, 67 and 207 in Tokat 2009 trial, from Lines 50, 51, 59 and 201 in Tokat 2010 trial and from Lines 50, 53 and 59 in Artova 2010 trial. Line 217 produced consistently less spikes per unit area in all trials. Lines 46 and 53 produced greater number of spikes in Tokat 2009 trial, where rainfall was lower during the vegetation period, while they produced consistently high spikes in other trials.

4. Discussion

The spikes per square meter is a major yield determinant. Rainfall was lower in the first year. Therefore, the spikes per square meter was also lower overall. Having more spikes in drought conditions is an indicator of tolerance to drought (Al-Ajlouni et al., 2016). It could be concluded that the lines that can produce more spikes per square meter in the first year (Lines 46, 53, 67 and 207) had better drought tolerance. Considering that some lines had variable spikes per square meter (Line 67) while some lines had consistently low (Line 217) and some consistently high (Line 217) across the trials, it could be stated that there was a considerable variability in terms of the spikes per square meter. On the other hand, majority of lines produced more spikes per unit area than the control variety Tokak 157/37 in all locations. Variations in landraces may be shaped by altitude and ecological factors. Abebe et al. (2010), who studied Ethiopian landraces, stated that the important characters that result in variation are the altitude and ecological factors. The spike number variations observed among our lines may also have been shaped by environmental factors. In addition, the reactions of the lines with the spikes per square meter under low yield conditions showed that they could have superior adaptation capabilities.

Heading time is an important trait for adaptability. The variation in heading time was not high among the lines. Based on the average of locations, except for Line 217, the difference between the earliest heading lines (72.5 days) and the latest (75.5 days) was only three days. A major part of the variation in heading time was due to Line 217. However, the majority of the lines had earlier heading than cv. Tokak 157/37, which is known for its adaptability (Yuksel and Akcura, 2012). Early heading is considered to be an important drought tolerance mechanism through escaping from the effects of terminal drought (Debaeke and Aboudrare, 2004). Tokak 157/37 is an early heading cultivar (Kaydan and Yagmur, 2007). Therefore, lines heading earlier than Tokak 157/37 could have beneficial alleles for early flowering, which could be advantageous for drought tolerance.

The variations among the lines for spike length and number of grains per spike were not high. In terms of overall average, the differences among the lines with the lowest and the highest values (1.82 cm for spike length and 2.8 grains for number of grains per spike) were quite low. In fact, this is something expected for landraces. The number of grains per spike and the length of the spike are traits that can be observed visually. In the past, the preferences of farmers using landraces may have led to the low variation in these characters. Similar inferences were made by other researchers such as Amezrou et al. (2018) and Hagenblad et al. (2019) who studied other visually identified characters in landraces. However, albeit low, there were some variations for the spike length and the number of grains per spike. Since the farmers cultivating landraces have produced their seeds from bulked plants rather than single seeds or spikes (Demissie and Bjornstad, 1996; Yadav et al., 2018), most of the variations in landraces have been transferred from the past to the present.

5. Conclusions

New alleles are needed in breeding programs increasingly being carried out with limited gene pools. In this study, the variations among pure lines isolated from a barley landrace in terms of time to heading and spikes per square meter showed that the landraces are of great importance in terms of adaptability. The majority of the lines examined had earlier heading than the control variety Tokak 157/37 and produced more spikes per square meter. Therefore, the lines studied could be used as a genetic source to increase grain yield under limited yield conditions. The use of pure lines selected from a landrace in breeding programs necessitate the characterization of the landrace. Therefore, evaluation of these lines in terms of variations in traits related to drought tolerance may enable the identification of new alleles.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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