Investigating of Some Agricultural and Quality Traits of Advanced Barley (*Hordeum vulgare* L.) Lines

İleri Kademe Arpa (*Hordeum vulgare* L.) Hatlarının Bazı Tarımsal ve Kalite Özelliklerinin Araştırılması

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Abstract

To meet the increasing raw material demand of the livestock and food sectors in our country is a need for new high-quality barley varieties that have a short vegetation period, resistance to lodging, homogeneous and plump grain, high grain and biomass yield, and compatible with the climate of the Central Anatolia Region. To meet this need, it was aimed to determine the appropriate lines by comparing 18 advanced barley lines belonging to the Transitional Zone Agricultural Research Institute with the standard varieties widely grown in the region. The trials were carried out in two locations, Eskişehir Center and Hamidiye fields of the Transitional Zone Agricultural Research Institute in the 2017-2018 crop year, in rainfed conditions. The trials were set up as a randomized complete block design with 4 replications in Eskişehir and 3 replications in Hamidiye. In the study, grain yield, days to heading, plant height, lodging score, thousand-grain weight, plump grain ratio, grain protein, and beta-glucan ratio properties of the breeding material were investigated. According to the results of the analysis of variance by combining the location averages, the differences between genotypes in all parameters except the beta-glucan ratio were found to be statistically significant. In the study were obtained that grain yield is between 4.56-6.67 t ha^{-1}; days to heading are between 115.4 - 124 days; plant height is between 81.6-101.4 cm; lodging score is between 0-100%; thousand-grain weight is between 35.7-47.4 g; the plump grain ratio is between 52.0-94.3%; grain protein content is between 10.05-12.75%; ß-glucan values are between 3.67-4.33% were obtained. Also, in the correlation analysis, a negative relationship was found significant between grain yield and days to heading, lodging score, and protein content characteristics, while a relationship was found significant to be positive with the plump grain ratio feature. When all the parameters are evaluated together, it is seen that lines 8, 11, 13, 14, 18, and 22 stand out as candidates for variety.

Keywords: Barley, Grain yield, Correlation, Quality, Selection

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Öz

Ülkemizdeki hayvancılık ve gıda sektörlerinin giderek artan hammadde talebini karşılamak için Orta Anadolu Bölgesi iklim koşullarına uyumlu vejetasyon süresi kısa, yatmaya dayanıklı, homojen ve dolgun taneli, yüksek tane ve biyomas verime sahip kaliteli yeni arpa çeşitlerine ihtiyaç vardır. Bu ihtiyacı gidermek amacıyla Geçit Kuşağı Tarımsal Araştırma Enstitüsü 'ne ait ileri kademe 18 adet arpa hattı bölgede yaygın olarak yetiştirilen standart çeşitlerle kıyaslanarak uygun hatların belirlenmesi hedeflenmiştir. Denemeler 2017-2018 ürün yılında yağışa bağımlı koşullarda Geçit Kuşağı Tarımsal Araştırma Enstitüsü 'nün Eskişehir Merkez ve Hamidiye deneme arazileri olmak üzere iki lokasyonda yürütülmüştür. Denemeler tesadüf blokları deneme deseninde Eskişehir de 4 tekerrürlü ve Hamidiye de ise 3 tekerrürlü olarak kurulmuştur. Araştırmada ıslah materyalinin tane verim, başaklanma süresi, bitki boyu, yatma değeri, bin tane ağırlığı, dolgun tane oranı tane protein ve beta-glukan oranı özellikleri incelenmiştir. Lokasyon ortalamaları birleştirilerek yapılan varyans analizi sonuçlarına göre beta-glukan oranı dışında tüm parametrelerde genotipler arasındaki farklılıklar istatistiksel olarak anlamlı bulunmuştur. Denemede ortalama olarak tane verim 4.56-6.67 t ha^{-1} arasında; başaklanma süresi 115.4-124 gün arasında; bitki boyu 81.6-101.4 cm arasında; yatma değeri % 0-100 arasında; bin tane ağırlığı 35.7-47.4 g arasında; dolgun tane oranı %52.0-94.3 arasında; tane protein içeriği % 10.05-12.75 arasında; ß-glukan oranı ise % 3.67-4.33 arasında elde edilmiştir. Ayrıca yapılan korelasyon analizinde tane verim ile başaklanma süresi, yatma değeri ve tane protein oranı özellikleri arasında olumsuz ilişki anlamlı görülürken, dolgun tane oranı özelliği ile olumlu ve önemli bulunmuştur. Tüm özellikler birlikte değerlendirildiğinde 8, 11, 13, 14, 18 ve 22 nolu hatların çeşit adayı olarak öne çıktıkları görülmüştür.

Anahtar Kelimeler: Arpa, Tane verim, Korelasyon, Kalite, Seleksiyon

1. Introduction

Barley (*Hordeum vulgare* L.) is one of the first plants to be domesticated by humanity (Smith and Nesbitt, 1995) and continues to play an essential role in modern agriculture today (Harwood, 2019). Although barley is mostly consumed as animal feed in our country, a little remaining of it is also used for malt production. Also, its use as a functional food is gradually increasing due to its content of dietary fibers, proteins, β-glucan, and arabinoxylan, which have a positive effect on human health (Baik and Ulrich, 2008; Köten et al., 2013).

The animal feed raw material production is inadequate in Turkey and was 3.9 billion USD paid for import in 2018 (Özkan, 2020). Increasing barley production will play an important role in meeting this need and reducing imports. Turkey is a significant barley producer with 8.3 million tons (Anonymous, 2021a) produced in 2020, 5.3% of the world production (Anonymous, 2021b), which was 156.4 million tons in total, was realized. Due to the development of animal husbandry and the fact that barley is earlier maturing than wheat, barley production is increasing as the first crop in areas where two crops can be grown per year (Öztürk et al., 2007). Lodging is one of the factors that cause crucial yield and quality loss in barley during the years when rainfall is high and these losses can be prevented by using durable cultivars (Sönmez and Yüksel, 2019). Plump grain size and homogeneity are some of the traits desired by the malt industry and are taken into account in determining the barley price (Sönmez et al., 2020).

The amount of precipitation falling in Central Anatolia regions and its distribution by months is quite variable. For this reason, there is a need for varieties that have a limited decrease in grain yield and quality in years when rainfall is low in the region, but that can increase yield and quality as much as possible when favorable conditions are seen. The breeding of new barley varieties that meet the livestock and malt industry's quality criteria with high yield potential will contribute to barley's enhancement production. Turkey 's first modern winter barley cultivar Güzak24 was registered by Emcet Yektay at Transitional Zone Agricultural Research Institute (TZARI) in 1937 (Sönmez et al., 2017). Since then, many barley cultivars were registered in the ongoing breeding studies here (Yüksel et al., 2011). In this study, it is aimed to determine the lines with short vegetation periods, resisted to lodging, plumped grain size, high grain yield, and quality by comparing the advanced barley lines of TZARI with the varieties commonly grown in the region under rainfed conditions.

2. Materials and Methods

2.1. Plant materials, experiment site, and trial management

As the material, advanced barley lines belonging to TZARI were used, and the pedigrees of the lines and the names of the standard varieties are given in *Table 1*.

Table 1. The pedigree of lines and the names of control varieties in the research

Genotype Number	Cultivar-Pedigree	Genotype Number	Cultivar-Pedigree
1	İnce-04	13	Cwb117-5-9-5/ST5819//Kalaycı
2	Ünver	14	Sonata/Cwb117-5-9-5//Cw117-77-9-7
3	Larende	15	Impact/Kalaycı
4	Burakbey	16	Aydanhanım/ST5822
5	Tarm-92	17	Impact/Kalaycı
6	Erginel-90	18	Cum//1246Lignee/78sakız/3/4654perga/4376Union//59TH/4/Özdemir-05
7	Narcis/Gk Omega	19	ZDM 1454/Zeynelağa
8	Clerine/Pompa	20	Gk Omega/Kalaycı97
9	11th/P15-B27281//ST4652/TOK/3/YEA389-3/YEA475-4	21	EFES-3/97-98DH4
10	3896 VTGX1- 15XCUM Somut//Zeynelağa	22	ST124/97-98DH4
11	Bolayır/Sonata	23	Ste/Antares//Viringa's/3/Angora/4/Sunrise/Cıho 15865 HO88ID SD Cıho 15865 Azure/5/Aydanhanım/6/Tarm-92
12	YEA389-3/YEA475-4//97-98DH8	24	ST5807/Zeynelağa

Field trials were established at TZARI Eskişehir Central campus (39° 46' 30" N, 30° 23' 44" E, Altitude 800 m) and Hamidiye Campus (39° 33' 24" N, 30° 54' 59" E, Altitude 900 m). The trials were carried out in rainfed conditions during the 2017-2018 crop growing season, and the precipitation and temperature values of the trial sites by months are given in *Table 2* (Anonymous, 2020). Eskişehir Central fields have a higher yield potential with a deep soil profile, clay soil structure, and a lower lime ratio. Hamidiye campus fields have low GY potential with shallow and clay-loam soil structure and high lime ratio. Field trials were established in a randomized complete block design with four replications in the Eskişehir campus and three replications in the Hamidiye. Plots were sowed in six rows sized 7.0 m × 1.2 m with a 20 cm distance between rows using a seeder. Seed sowing was carried on the second week of October at a sowing density of 500 seeds m^{-2}. Fertilization was made according to soil analysis results and before planting, 30 kg ha^{-1} N and 70 kg ha^{-1} P2O5; In the spring, 40 kg ha^{-1} N was applied at the stem elongation period. Herbicide with 2-4 D EHE + Florasulam effective ingredients was used to combat broadleaf weeds. The plots were harvested using a combined harvester as 5 m length on the first week of July.

Table 2. The means of long-term of some climatic data in Eskisehir District and monthly mean values for the trial years

| Months | Precipitation (mm) | | | | Temperature (°C) | |
| | Eskişehir | | Hamidiye | | Eskişehir | Hamidiye |
	2017-2018	MLY*	2017-2018	MLY	2017-2018	2017-2018
September	0.5	14.4	2.5	9.6	19.6	19.6
October	48.4	26.1	41.5	23.5	10.7	10.2
November	28.6	29.8	20.0	21.0	5.5	4.9
December	41.8	46.1	28.0	33.1	3.9	3.0
January	28.8	38.2	78.0	34.1	1.6	0.8
February	41.6	32.5	22.5	25.7	5.8	5.1
March	41.1	33.4	39.0	30.6	9.3	9.0
April	9.5	35.2	13.0	31.0	13.8	13.0
May	92.5	43.3	108.5	35.3	16.7	16.2
June	73.8	28.6	35.0	20.6	19.9	19.5
July	59.9	13.5	37.0	6.7	22.2	22.0
Total	466.5	341.1	425.0	271.2	129.9	123.3
Monthly Average	42.4	31.0	38.6	24.7	11.7	11.2

MLY: Means of many years

2.2. Data collection and analysis

Grain yield was calculated that obtained crop from the harvested parcels with the plot combine harvester was weighed in grams after cleaning and converted in ton ha-1. Days to heading were determined as the number of days from the beginning of the year following seed sowing until the date when more than half of the plants in the plot completely removed their spike from the flag leaf (Öztürk et al., 2016). Plant height was determined as cm by measuring the distance from the soil level of 10 plants from each plot to the tip of the uppermost spikelet excluding the awn. The lodging score was obtained by multiplying these two values by determining the percentage of plants showing lodging in the plots and the lodging angle (Pask et al., 2012). Thousand-grain weight was calculated by counting four hundred grains from the grains taken from the harvested product and weighing them in precision scales (Williams et al., 1988). Plump grain ratio was determined by using sieve analysis was made in the Sortimat device according to ICC standard 102/1 and 103/1 protocols (Pfeuffer GMB, Kitzingen, Germany). Samples (100 g) were shaken for 3 minutes in the sieve shaker, and the diameter sizes (large> 2.8 mm; medium = 2.8 - 2.5 mm; thin = 2.5 - 2.2 mm; 2.2 mm <under sieve) divided into four different sieve groups and the amount of those divided into groups was determined as a percentage (Özkaya and Özkaya, 2005). While the grains in the large and large-

medium groups were collected to form the plump grain ratio group, the weak and under-sieve grains were not considered. Grain protein content and beta-glucan ratio were determined by Near-Infrared Spectroscopy (NIR 6500, Foss, Hillerød, Denmark) device from whole grain flour. The device for grain protein content was calibrated according to American Association of Cereal Chemists International (AACCI) methods (46-19.01) and (32-23.01), respectively (Anonymous, 2010). Megazyme β-glucan analysis kits and absorbance values were measured at 510 nm in the spectrophotometer (McCleary and Codd, 1991). Statistical analysis was made using the JMP statistical program. Levene test was performed before the locations were analyzed together, and the equality of variances was checked. The significance of the differences between genotypes was determined by conducting the variance analysis "F" test. The least significant difference (LSD) test was used for the comparison of the means (Student, 1908). Correlation analysis was performed according to Pearson's (1920) method using corrected mean values. The mean squares and variance analysis table obtained from the parameters investigated are presented in *Table 3*. The average values of the genotypes were grouped at p <0.05 level according to the LSD test and compared and presented in *Table 4*.

3. Results and Discussion

3.1. Grain yield (GY)

When the results of the experiment were evaluated with analysis of variance, differences between genotypes and genotype x environment interaction were found to be significant at $p < 0.01$, while differences between environments were significant at $p < 0.05$ (*Table 3*). Average GY was 5.70 tons ha^{-1} in the experiment, while 5.90 t ha^{-1} from the lines; 5.11 t ha^{-1} average GY was obtained from control varieties (*Table 4*).

Table 3. Mean squares values of traits examined in the research and its significance status

Traits		Replications	Environment	Genotypes	Gen x Env.	Error	Total
Grain yield	DF	5	1	23	23	115	167
	MS	0.61	4.90*	1.87**	0.94**	0.46	0.78
Days to heading	DF	5	1	23	23	115	167
	MS	1.99	601.29**	57.04**	3.94**	4.38	10.86
Plant height	DF	5	1	23	23	115	167
	MS	121.46**	218.04	192.98**	37.48	30.31	57.21
Lodging score	DF	5	1	23	23	115	167
	MS	557.98	9800.61**	7592.58**	450.79	440.85	1533.39
Thousand grain weight	DF	3	1	23	23	69	119
	MS	49.11**	10.80	21.36**	4.52	4.70	11.29
Plump grain ratio	DF	3	1	23	23	69	119
	MS	172.44**	1104.01	248.83**	40.42**	15.22	97.84
Grain protein content	DF	3	1	23	23	69	119
	MS	3.55**	3.72	1.88**	0.92**	0.35	0.86
Grain ß-glucan ratio	DF	3	1	23	23	69	119
	MS	0.67**	3.65	0.07	0.11	0.08	0.13

**: Significant at the level $p < 0.01$; *: Significant at the level $p < 0.05$; DF: Degree of freedom; MS: Mean square

The highest GY of the lines was taken from line13 with 6.67 tons ha^{-1}, followed by line22 with 6.43 t ha^{-1} and line15 with 6.25 t ha^{-1} (*Table 4*). When the environments were examined, 5.88 t ha^{-1} from the Eskişehir location, and higher GY than Hamidiye was obtained (*Table 4*). In the 2017-2018 crop year, from seed sowing to the end of May, the end of the vegetation period, Eskişehir location received more than 11.3% high rainfall from many years, with 332.8 mm rainfall, while Hamidiye location was 353.0 mm and it received 44.7% higher precipitation than its many years (*Table 2*). Thus, an average GY of 5.88 t ha^{-1}, which can be considered high, was obtained for conditions based on rainfall in the Eskişehir. Although the soils are less fertile, much higher than expected GY was obtained from Hamidiye location due to the high rainfall. Similar to this study, Sönmez et al. (2017) reported that 4.90 t ha^{-1} was obtained from Eskişehir location and 4.07 t ha^{-1} was obtained from Hamidiye. In the study conducted by Aktaş (2017), it was declared that under rainfed conditions, the GY was lower than this study, with 3.36 t ha^{-1}. This situation is compatible with the opinion of Kalaycı et al. (1991) that the environmental factors that most affect the GY in barley are the precipitation during the growth period of the plant and the distribution of this precipitation during the year, temperature, and agricultural techniques. In this research, lines 8, 11, 12, 13, 14, 15,

18, and 22 prominent with GY values above 6 t ha. This situation is compatible with the research's aim to determine genotypes that can increase productivity under high yield conditions. One of the reasons why genotype x environment interaction was found significant in the study is that although the lines 7, 9 and 11 are among the genotypes with high yield in the Eskişehir environment, they are among the genotypes with low yield in Hamidiye.

Table 4. The mean values of genotypes and environments examined in the research and the comparison of the means, and the LSD and CV informations

Genotype No	GY (t ha⁻¹)		DTH (day)		PH (cm)		LS (%)		TGW (g)		PGR (%)		PC (%)		ßGL(%)
1	5.28	f-i	122.7	b	90.0	d-g	80.6	abc	40.93	fg	84.56	def	12.42	a-d	4.19
2	4.56	i	121.3	d-g	81.6	d-g	67.4	c-f	43.90	b-g	82.15	efg	12.26	a-f	4.09
3	5.52	d-g	122.5	bc	85.2	d-g	76.0	bcd	45.79	a-d	77.90	G	12.06	a-g	4.22
4	5.55	c-g	121.3	d-g	102.5	a	86.3	abc	44.29	a-f	91.47	Abc	11.42	f-i	4.05
5	4.63	hi	121.8	b-e	94.1	c-f	100.0	a	42.50	d-g	78.96	Fg	12.75	a	4.09
6	5.11	ghi	120.3	ghi	100.3	ab	70.6	b-e	35.66	h	52.01	H	11.50	d-h	4.02
7	5.80	b-g	118.8	jk	94.8	bcd	21.7	ij	46.80	ab	92.15	Ab	11.55	d-h	3.95
8	6.22	a-d	114.1	o	90.9	d-h	14.7	j	42.11	efg	94.30	A	10.56	ijk	3.98
9	5.54	c-g	113.2	o	99.2	abc	0.0	j	44.83	a-e	93.69	A	11.78	c-h	4.24
10	5.64	c-g	124.0	a	93.5	c-f	38.8	hi	42.24	efg	86.56	b-e	12.73	ab	3.98
11	6.04	a-e	118.1	kl	88.6	d-g	4.3	j	44.84	a-e	93.61	A	11.45	e-i	4.12
12	6.22	a-d	121.5	c-f	92.0	d-g	82.3	abc	46.59	ab	85.78	Cde	10.05	k	4.18
13	6.67	a	119.1	jk	83.1	d-g	1.9	j	41.61	efg	91.36	Abc	10.31	jk	3.86
14	6.05	a-e	120.7	fgh	91.4	d-g	9.0	j	44.98	a-e	85.35	Cde	10.97	h-k	3.67
15	6.25	abc	116.9	m	95.4	bcd	45.9	fgh	46.24	ab	92.23	Ab	12.18	a-f	4.07
16	5.35	e-h	119.6	ij	92.2	d-g	54.4	d-h	47.36	a	90.57	a-d	12.38	a-e	4.17
17	5.28	f-i	120.2	hi	94.4	cde	63.9	c-g	40.69	g	88.22	a-e	12.03	a-g	4.01
18	6.16	a-d	117.4	lm	101.4	a	1.5	j	46.13	abc	94.05	A	10.93	h-k	4.25
19	5.87	b-f	115.8	n	94.8	bcd	6.4	j	44.00	a-g	92.20	Ab	12.41	a-d	4.33
20	5.63	c-g	122.3	bcd	87.5	d-g	52.2	e-h	46.33	ab	86.77	b-e	12.16	a-g	4.16
21	5.93	b-f	121.8	b-e	92.1	d-g	43.5	ghi	43.69	b-g	84.78	Def	11.07	hij	3.89
22	6.43	ab	117.3	lm	88.3	d-g	3.8	j	42.74	c-g	92.19	Ab	11.81	b-h	4.08
23	5.41	efg	121.1	e-h	92.2	d-g	90.2	ab	44.68	a-e	89.89	a-d	12.68	abc	4.18
24	5.77	b-g	115.4	n	95.1	bcd	41.4	hi	44.81	a-e	91.16	abc	11.25	ghi	4.14
Means of Trial	5.70		119.5		92.5		44.0		43.90		87.16		11.70		4.08
Means of Lines	5.90		118.7		92.6		32.0		44.48		90.27		11.57		4.07
M. C. Varieties	5.11		121.7		92.3		80.2		42.18		77.84		12.07		4.11
LSD (0.05)	0.72		1.06		5.89		22.46		3.41		6.15		0.93		0.45
CV (%)	11.80		0.83		5.94		46.53		4.96		4.60		5.01		6.74
Means of Locations															
Eskisehir	5.88	A	117.6	B	93.7		51.7	A	43.53		83.4		11.92		4.30
Hamidiye	5.53	B	121.4	A	91.4		36.3	B	44.28		91.0		11.48		3.86

GY: Grain yield; DTH: Days to heading; PH: Plant height; LS: Lodging score; TGW: Thousand-grain weight; PGR: Plump grain ratio; PC: Protein content; ßGL: ß-glucan; M. C. Varieties: Means of control varieties; LSD: Least significant difference; CV: Coefficient of variation

3.2. Days to heading (DTH)

Days to heading is vital in terms of giving an idea about the maturation period of a variety. In the variance analysis performed by combining locations, differences between locations, genotypes, and genotype x environment interaction were significant at p<0.01 (*Table 3*). While the average of the experiments was 119.5 days, the mean of the lines was 118.7 days; the control varieties average was 121.7 days. While the trial average was 117.5 days in Eskişehir, this value was 121.4 days in Hamidiye. The shortest DTH was on line9 with 113.2

days, while the longest DTH was on line10 with 124.0 days (Table 4). Early maturing in barley is an essential feature in terms of drought and disease avoidance and post-harvest second crop forage production (Öztürk et al., 2014). According to Aydın and Katkat (1999), while resistance to drought increases with earliness, the yield potential of the variety also decreases. It is thought that the average of 119.5 days obtained in this study was due to the drought in April caused stress on the plant and shortened the DTH period (*Table 1*). In a study conducted by Sönmez and Yüksel (2019) in Eskişehir, the average DTH was 136.6 days, while Kara et al. (2019) was found 133.4 days in another study in Konya. The reason for the statistical difference about DTH between the related locations is that the Hamidiye site has an altitude higher than the Eskişehir site and the average temperature values are lower than the Eskişehir. A study was reported that the DTH is shortened under stress conditions (Al-Menai et al., 2013). Among the lines examined in this study, 8, 11, 13 15, 18, and 22 lines were found to stand out in terms of both high yield and earliness. This situation is compatible with the objectives of the study in terms of earliness.

3.3. Plant height (PH)

Taller plants have more storage assimilation potential than shorter plants and are drought tolerant. However, tallness enhances the risk of lodging and, therefore, affects flowering negatively and reduces the plant's photosynthetic capabilities (Gholipoor et al., 2013). In the analysis of variance, only the differences between genotypes were found statistically significant p <0.01 (*Table 3*). While the trial average for PH is 92.5 cm, the averages of lines, control varieties, and locations are also around this value (*Table 4*). When the lines were evaluated, the lowest PH was measured 83.1 cm on line13, while the highest PH was measured 101.4 cm in line18 (*Table 4*). Short cultivars have been improved by cereal breeders to reduce lodging and increase grain yield (Yu et al., 2010). However, as barley straw is a valuable product that generates additional income demanded by the livestock sector, PH should be considered in plant breeding. In this study, it is seen that line18 is the closest line to our breeding objectives with 101.4 cm PH. In another study conducted by Sönmez and Yüksel (2019) in Eskişehir, the average PH was found to be 84.2 cm in dry conditions as compatible with this research. Öztürk et al. (2016) reported that PH is a significant element in terms of resistance to the lodging of barley and that short or medium-height varieties with a PH of 85-95 cm are preferred. According to Kandemir (2004), it can be said that if PH is higher than 100 cm in barley, lodging is seen. Yüksel et al. (2017) also found between 92.5 cm and 129.5 cm PH in barley in their study in Eskişehir. Doğan et al. (2014) reported that, although the effect of inheritance is very high in PH, the environmental effect is also important.

3.4. Lodging score (LS)

Lodging in cereal is more common in barley plants than wheat and is one of the main factors causing yield losses in many countries (Cenci, 1984). In the variance analysis, the differences between genotypes and environments were found to be significant at the p<0.01 level (*Table 3*). While the means of experiments was 44.0%, the means of lines were 32.0%; the means of control varieties were 80.2% (*Table 4*). In the study, the lowest LS value was line9 with 0.0%, while the line that reached the highest value was line5 with 100% (Table 4). Although the plant height of the lines used in the trial was almost the same as the control varieties, LS values are lower than control varieties (*Table 4*). The results in this research indicate that LS value is taken into account at TZARI barley breeding program selection. Alkan and Kandemir (2015) reported that they found LS at a high rate of 68-90% and resistance to lodging is low for local barley varieties. In a study conducted by Saygılı et al. (2019), LS was ranged from 0.0-33.3% in the first year and between 55.0% and 77.7% in the second year. Especially the lines 8, 11, 13, 14, 18 and 22 stand out with low LS values together with high GY. The LS average of the Eskişehir location was 51.7%, and the LS average of 36.3% was higher than the Hamidiye location (*Table 4*). When the environments are evaluated, it is thought that higher LS observed in the Eskişehir environment, which has higher yield potential, compared to the Hamidiye environment, is compatible with the expectations (*Table 4*). It is known that many factors affect LS like wind, falling rain amount, soil characteristics, variety-based plant characteristics, sowing time, sowing frequency, fertilization, and plant growth regulator applications, etc. (Berry et al., 2002). LS is related to plant height, stem thickness and spike weight and generally occurs after heading. According to Akar et al. (1999), a significant yield loss is observed in barley plants due to lodging down in the years when the annual average amount of precipitation exceeds 400 mm in Central Anatolia and Transitional Zones. Lodging down not only reduces barley yield and grain quality but also indirectly reduces malt quality (Day and Dickson, 1958). PH is a vegetative feature that most affects the LS in barley (Anderson and Reinbergs, 1985).

3.5. Thousand-grain weight (TGW)

TGW is one of the important quality factors in terms of giving an idea about the size, plumpness, thinness of the grain as well as grain yield (Öztürk et al., 2007). In the analysis of both environments together, only the differences between genotypes were found to be statistically significant at the $p < 0.01$ level (*Table 3*). While the trial average was 43.90 g, the average of the lines was 44.48 g; the control varieties average was found to be 42.18 g (*Table 4*). When the lines were evaluated, the highest TGW was obtained from line16 with 47.36 g, while the lowest TGW was obtained from line17 with 40.69 g (*Table 4*). In this study, all genotypes except Erginel-90, which is a six-row control variety, were above the 40 g TGW limit, one of the malting quality criteria. The average TGW value found in this study was consistent with the values found by Sönmez and Yüksel (2019). The TGW results obtained in this study were found to be consistent with some studies (Sirat and Sezer, 2009; Aydoğan et al., 2011; İmamoğlu et al., 2016). Koca et al. (2015) was found higher TGW values than this study with 49.6 g. These results show that TGW of barley genotypes occurs under the influence of genotype and environment. TGW controlled by many genes is a feature that varies according to the variety and ecological conditions of the year. Atlı et al. (1989) stated that TGW should be higher than 40 g for malting barley.

3.6. Plump grain ratio (PGR)

It has been reported that sieve analyzes in barley provide information about the plumpness of the grain as well as the homogeneity of the grain (Kendal et al. 2010). In the combined variance analysis, differences between genotypes and genotype x environment interaction were significant at the $p < 0.01$ level (*Table 3*). Trial averages for PGR were obtained as 87.16%. The means of the lines were found to be higher than the means of control varieties (*Table 4*). When the lines were evaluated, the highest PGR was obtained from line8 with 94.30%, while the lowest PGR was obtained from line21 with 84.78% (*Table 4*). The lowest PGR value of the trials with, 52.01%, was obtained from Erginel-90, which is six-row control variety. If the sum of over two sieves (2.2 to 2.5 or 2.5 to 2.8) is more than 75%, this sample is considered to be homogeneous in terms of size (Elgün and Certel, 1987). The homogeneity of the grain is important in obtaining homogeneous color in the process of germination and roasting-drying simultaneously in malt production (Sirat, 2014). Except for genotype6, the PGR value of all the material is above 75% and sufficient for malting criteria. It was reported by Sönmez et al. (2020) that PGR in dry conditions in Eskişehir was lower (75.5%) than this study. In a study conducted in Konya in dry conditions, PGR was found to be lower (62.5%) than in this study (Aydoğan et al., 2017). In another study by Sirat and Sezer (2017), consistent with this study, they were found the PGR between 85.3% and 92.0%. According to Engin (1989), the correlation between grain size and malt extract ratio is positive and important.

3.7. Protein content (PC)

It is one of the essential quality criteria that determine the evaluation of the barley grain as malting. In the combined variance analysis, the differences between genotypes and genotype x environment interaction were significant at the $p < 0.01$ level (*Table 3*). The means of the trial was 11.70%. The means of the lines were lower than the means of the control varieties (*Table 4*). When the lines were evaluated, the highest PC was obtained from line10 with 12.73%, while the lowest PC was obtained from line12 with 10.05% (*Table 4*). In the experiment, the highest PC value of the experiment, with 12.75%, was obtained from Tarm-92, which is the genotype5 among the standards. It was reported that PC was found lower than this study with 10.9% by Öztürk et al. (2016). Aydoğan et al. (2011) reported that they found the average PC as 11.8% in the first year and 11.3% in the second year, compatible with this study. Again, in many studies conducted under rainfed conditions, it was reported that the average PC was determined higher than this study with 12.4% (Doğan et al., 2014; Aydoğan et al., 2016; Sönmez et al., 2020). Many researchers have reported that the amount of PC in the grain may vary according to genotype, environment, and agricultural applications (Fox, 2003; Doğan et al., 2014; Öztürk et al., 2016; Kızılgeçi et al., 2019). PC in malting barley is expected to be between 9 - 11.5% (Elgün and Certel, 1987). In this study, lines 8, 11, 12, 13, 14 and, 18 were found to be suitable for malting in terms of PC.

3.8. Beta-glucan (ßGL)

β-glucan is a high-molecular non-starch polysaccharide, and it is located in the sub-aleurone layer and cell walls of the endosperm in barley between 3-11% (Wood, 2007). The health benefits of barley ß-glucans include

reduction of blood cholesterol and glucose and decrease of weight by increased satiety, and hence, control of type-2 diabetes and heart diseases (Baik and Ulrich, 2008). According to the results of combined variance analysis, the differences between genotypes and environments and genotype x environment interaction are not significant (*Table 3*). While the means of the trial was 4.08%, the means of the lines and the control varieties were also found close to this value (*Table 4*). When the lines were evaluated, the values of ßGL between 3.67% and 4.33% were obtained (*Table 4*). In parallel with these results, the differences between genotypes for ßGL were found to be insignificant in the study conducted by Kon (2019), and the average ßGL was found to be 4.03% in the first year and 3.77 in the second year. It was reported that the ßGL is formed under the influence of genotype, mostly environmental conditions (Fox et al., 2003; Kon, 2019).

3.9. Correlations between traits (GY)

When the correlations between properties were examined, it was found that there was a negative relationship significant between GY and DTH, LS, and PC, while a positive relationship with PGR trait was found significant. As compatible with this study, some other studies were reported that the negative relationship between GY and DTH is meaningful (Öztürk et al., 2014; Öztürk et al., 2016). Again, it was reported by some researchers that there was a negative correlation between GY and PC, in compatible with this study (Kızılgeçi et al., 2016; Kızılgeçi et al., 2019). While the negative correlation of PGR with DTH and LS was found to be significant ($p < 0.05$), the relationship, with TGW was found to be positively significant ($p < 0.01$). Also, the relationship between DTH and LS was found to be positively significant ($p < 0.01$) (*Table 5*).

Table 5. Correlation coefficients and significance status of the traits which was examined in this research

	GY	DTH	PH	LS	TGW	PGR	PC	GßL
GY	1							
DTH	-0.405*	1						
PH	-0.046	-0.272	1					
LS	-0.667**	0.657**	0.022	1				
TGW	0.246	-0.111	-0.079	-0.137	1			
PGR	0.502*	-0.446*	-0.051	-0.482*	0.626**	1		
PC	-0.644**	0.282	-0.020	0.372	-0.032	-0.113	1	
GßL	-0.221	-0.204	0.151	0.177	0.251	0.118	0.369	1

GY: Grain yield; DTH: Days to heading; PH: Plant height; LS: Lodging score; TGW: Thousand grain weight;
PGR: Plump grain ratio; PC: Protein content; ßGL: ß-glucan

4. Conclusions

As a result of this research, the candidate lines were evaluated in terms of GY, DTH, PH, LS, TGW, PGR, PC, and ßGL parameters. All the parameters were considered together and it was determined that lines 8, 11, 13, 14, 18, and 22 had characteristics compatible with the breeding targets. It is suggested that some of these lines can be offered to the Directorate of Seed Registration and Certification Center as a variety candidate or can be used as a parent in the barley hybrid program.

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