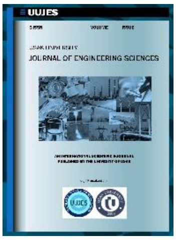

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Research article

INVESTIGATION OF YIELD, PHYSICAL QUALITY AND PHYSIOLOGICAL CHARACTERISTICS OF SOME TWO-LINE AND SIX-LINE BARLEY GENOTYPES IN ESKISEHIR CONDITIONS

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Abstract

In this study carried out in Eskişehir dry farming conditions, advanced two-row and six-row barley genotypes and their parents and physiological characteristics, physical quality elements, and yields of some varieties adapted to the region were investigated. The study was carried out in Eskişehir Osmangazi University, Faculty of Agriculture, Field Crops Department, in the research and application field, for two years in 2012-2013 and 2013-2014 production seasons. In the study, heading time, flowering time, flag leaf area, SPAD value, canopy temperature, test weight, thousand-grain weight, grain largeness ratio, and yield parameters were investigated. According to the findings obtained; Significant differences were determined between cultivars, hybrids, and parents in terms of yield, quality, and physiological characteristics. While the CLR x PLS 6-row hybrid stands out in terms of quality and physiological characteristics, the 2-row cultivar candidate of the same hybrid stood out in terms of yield and it was predicted that these hybrids could be evaluated as cultivar candidates with desired characteristics.

Keywords: *Two-row barley; six-row barley; yield; physical quality characteristics, physiological characteristics; hybrid.*

1. Introduction

Barley is one of the first cultivated plants in the world. Barley residues from Mesopotamia and Egypt are much more abundant than wheat residues, and these findings show that barley was more prominent for human consumption than wheat in history [1]. Barley, which was used as human food in the past, has started to be used more as animal feed, with wheat and rice coming to the fore in time [2]. However, in recent years, the amount of dietary fibers, protein, β-glucan, cellulose, arabinoxylan, and rich starch in barley has

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attracted the attention of food manufacturers [3]. In addition, being early and less affected by drought, being tolerant to salinity, and using its straw in animal feeding are other factors that make barley stand out [4].
139.589.000 tons of barley is produced in an area of 48.249.000 hectares in the world. The world average yield is calculated as 289 kg/da. In the first place in barley production in America with 41%, followed by Russia with 12%, Australia with 6%, Canada with 6%, and Ukraine with 5.4%. In Turkey, this rate has been determined as 5%. In our country, 7 million tons of barley is produced on an area of approximately 2.612.000 hectares each year [5]. 6.5 million tons of barley produced in our country is used as feed, 231 thousand tons for beer, and 67 thousand tons as human food. Barley is grown in every region of Turkey, mostly in Central and Southeastern Anatolia. Eskişehir, on the other hand, meets 3.7% of barley production in Turkey, that is, approximately 256 thousand tons. Eskişehir barley yield average is around 293 kg/da [6-7-8].
The most important purpose of breeding and variety development studies is to increase the amount and quality of the product to be obtained from the unit area. In the selection studies carried out in terms of yield, comparison can be made according to the direct yields of the genotypes, and indirect selection can be made by examining the factors that affect the yield [9]. In addition to the agronomic features that affect the yield, it is important to focus on the physiological features. For this reason, breeding programs have been put into use by plant breeders, aiming to develop new barley genotypes that are compatible with different regions and will provide high yield and quality even in marginal conditions, and that include physiological selection tools. Physiological characteristics have an important effect on increasing genetic improvement in terms of yield and are being investigated as a complementary element in barley breeding [10]. As in all grains, the performance of varieties in different environments varies in barley. In the Eskişehir region, there is a large environmental difference even between short distances, and varieties that can maintain the same performance in changing environments are desired.
In this study carried out in Eskişehir conditions, the physiological characteristics, physical quality elements and yields of advanced two-row and six-row barley genotypes and their parents and some varieties adapted to the region were investigated.

2. Materials and Method

The study was carried out in Eskişehir Osmangazi University, Faculty of Agriculture, Department of Agronomy, in the research and application field, for two years in 2012-2013 and 2013-2014 production seasons. Five barley crosses, 2 parents and 3 locally adapted barley cultivars were used in the study. The genotype, parent and cultivar characteristics are given in Table-1.

Table 1 Characteristics of hybrids, parents and cultivars used in the study

Genotype	Spike structure	Genotype	Spike structure
PLS x CLR	6 rows	Kalaycı 97	2 rows
PLS x CLR	2 rows	Plasant	6 rows
PLS x KLC	6 rows	Cumhuriyet 50	2 rows
CLR x PLS	2 rows	İnce-04	2 rows
CLR x PLS	6 rows	Özdemir-05	2 rows

Sowing was carried out according to the randomized blocks experimental design with 3 replications, 500 seeds per square meter, 1.2 meters x 4 meters (4.8 m^2), 20 cm row spacing, 6 rows of trial drills were made on the plots. In the experiment carried out in arid conditions, fertilization was made with pure 6 kg/da P_2O_5 and 6 kg/da N (divided) calculation. Weed control was achieved with chemical pesticides. Sowing was done on 15.10.2012 and 25.10.2013.

The soil structure of the experimental land is clay loam. Lime content is medium (4.43-4.91%), pH value is between 7,5-8,3%, slightly alkaline (basic) and poor in organic matter (1.3-1.5%).
The climate data of the years (2012-2013 and 2013-2014) and long years (1975-2014) of the research are given in Table 1.

Table 2 Meteorological data for many years (1975-2014) and 2012-2013 and 2013-2014 years in the vegetation period in Eskişehir province

	2012-2013		2013-2014		Long-Term (1975-2014)	
	Total Precipitation (mm)	Average Temperature (°C)	Total Precipitation (mm)	Average Temperature (°C)	Total Precipitation (mm)	Average Temperature (°C)
October	16.1	14.2	65.0	9.8	26.1	12.4
November	14.5	7.3	15.0	6.7	29.8	6.5
December	73.2	2.2	1.5	1.7	46.1	3.2
January	18.5	1.7	21.0	3.6	38.2	0.5
February	36.5	4.3	7.0	6.0	32.5	2.9
March	33.2	7.1	27.1	6.2	33.4	6.0
April	37.8	10.8	23.2	11.3	35.2	10.6
May	9.5	17.7	53.8	16.4	43.3	15.4
June	14.0	20.0	70.5	19.9	28.6	19.8
July	0.8	21.6	20.4	23.7	13.5	22.7
Total	**254.1**		**304.5**		**326.7**	
Average		**10.7**		**10.5**		**10**

In the study, heading time and flowering time were calculated as the number of days from the planting date to the date when more than half of the plants in the plot were spiked and bloomed [11]. The flag leaf area was measured after the flowering period, by measuring the width and length of the flag leaf, and Kalaycı et al. (1998) [12]., it was calculated according to the formula YA = YB x YE x 0.75. SPAD value (chlorophyll content of flag leaf) was measured during the head period with a Minolta instrument that measures chlorophyll proportionally in the SPAD unit in the flag leaf [13]. Canopy temperature, Jackson et al. [14] it was measured in degrees Celsius (°C) with a portable infrared thermometer, according to the method proposed by (1981). While reading between 12:00 and 14:00 at noon after the spike period, the device was held at an angle of 30° from the ground (the most suitable angle with a view to the leaves), and two measurements were made for each plot, from the North and the South, and the average was taken. Test weight was determined in kilograms with a liter test weight measuring instrument [15]. Thousand-grain weight was weighed by counting 100 grains 4 times and was calculated by proportioning to 1000 grains [15]. Grain largeness ratio was determined in 100 g sample using an oval-hole sieve with a hole length of 2.5 mm, and the amount remaining on the sieve was determined as % [16]. The yield was obtained by converting the grain yields obtained from the plot to the yield per decare [17].
Evaluations of these elements were analyzed in SAS and MINITAB package programs according to the experimental design of divided plots divided into random blocks. To see the effective differences, the 'F' test was used and the coefficients of variation were calculated. Comparisons between mean values are given using the 'LSD' test [18-19].

3. Results and discussion

In the study, heading time, flowering time, flag leaf area, SPAD value, canopy temperature, test weight, thousand-grain weight, grain largeness ratio and yield parameters were examined. average values are given in table 4 and two-year average values are given in table 5.

3.1 Heading Time

When the variance analysis table is examined in terms of the time to head in our study (Table 3), it is seen that the years are insignificant, and the interaction between genotypes and genotype x years is important. Kaydan and Yağmur (2007) [20] stated that there may be significant differences between varieties in their study. Looking at Table 5., the earliest genotype was Kalaycı 97 with 190.33 days, while the latest genotype was Cumhuriyet 50 with 208 days. Ülker et al. (1999) [21], in their study, reported that the heading time was between 205 days and 213 days. Earliness in barley is an important feature in terms of drought avoidance and second crop production [22]. However, some researchers argue that the drought resistance of early cultivars has increased, but the yield potential has decreased, and low temperatures that may be encountered on these dates may stress the plant [23].

Table 3 Variance Analysis Results of the Parameters Evaluated in the Experiment

	D.F.	Heading Time	Flowering Time	Flag Leaf Area
Replication	2	189.050öd	0.117öd	0.079öd
Year	1	16.017öd	114.817**	26.083*
Error-1	2	142.917	0.217	0.453
Genotype	9	151.372*	57.046**	11.385**
Year x Genotype	9	162.869*	2.335**	0.444**
Error	36	163.631	0.463	0.105
General	59	159.303	11.298	2.328
	CV (%)	6.20	1.61	16.42
	D.F.	**SPAD Value**	**Canopy Temperature**	**Test Weight**
Replication	2	1.962öd	1.307öd	0.329öd
Year	1	88.817**	35.236*	0.267öd
Error-1	2	0.057	0.641	0.054
Genotype	9	52.144**	1.848**	26.167**
Year x Genotype	9	1.460öd	0.630*	10.248**
Error	36	1.618	0.267	1.002
General	59	10.738	1.204	6.184
	CV (%)	5.88	3.59	3.85
	D.F.	**Thousand Grain Weight**	**Grain Largeness Ratio**	**Yield**
Replication	2	1.378öd	0.908öd	60.773öd
Year	1	84.135**	1960.479**	13201.667**
Error-1	2	0.236	9.126	22.517
Genotype	9	76.653**	989.422**	10499.501**
Year x Genotype	9	0.562	30.223**	481.556**
Error	36	0.681	2.653	94.708
General	59	13.675	190.726	1959.445
	CV (%)	9.47	23.07	10.88

**: p<0.05, **: p<0.01, ns: Not significant.*

3.2 Flowering Time

When the variance analysis table of the flowering time was examined in our study (Table 3), it was determined that the years, genotypes and their interaction, genotype x years, are very important. Various researchers have similarly reported that varieties, years and genotype x environment interaction are very important and differences may occur in flowering time [24-25]. When the average table of the two years is examined, the earliest flowering days were obtained from the PLS x CLR genotype with 204.67 days, while the latest flowering day was obtained from the Cumhuriyet 50 and İnce-04 varieties with 213.17. When evaluated in general, the time between the earliest flowering and the latest flowering genotypes was approximately 1 week. Similarly, Akıncı and Yıldırım (2009) [24] examined local varieties and observed that there were differences in the flowering time of up to 15 days within the genotypes. Early harvest is a desired feature in cereals, and high temperatures, drought and dry winds occurring during the earing and flowering period cause serious reductions in yield [26].

3.3 Flag Leaf area

In our study, when the variance analysis table of the flag leaf area was examined (Table 3), it was determined that years were important, and genotypes and their interaction, genotype x years, were very important. Similarly, in some studies, it was determined that the difference between genotypes in terms of flag leaf area was important and changed according to years [27-28-29-30]. When the average table of the two years is examined, the highest flag leaf area with 10.89 cm2 was obtained from the CLR x PLS hybrid, while the lowest flag leaf area was obtained from the thin-04 variety with 7.25 cm2. When we look at the comparison of the two years, it is seen that the flag leaf area values obtained in the second year are higher than the first year. Although the flag leaf area varies according to the species and variety, it also differs according to the developmental periods of the plant and the years [31-32]. Müjdeci et al. (2005) [32] stated that grain yield is closely related to flag leaf area. However, in areas where conditions limit plant growth, a large leaf area can have a negative effect as there is a large evaporation surface [33].

3.4 SPAD Value

When the analysis of the variance table (Table 3) is examined, it is seen that the age and genotypes make a very important difference in terms of SPAD value, and the year x genotype interaction is insignificant. Similarly, it has been observed that while genotype, environment and years are important, their interactions are insignificant [29-31-34]. According to the mean table, the highest SPAD value was obtained from the Ince-04 (59.57) variety, while the lowest SPAD value was obtained from the PLS x KLC hybrid. When the two years are compared, it is seen that the SPAD values obtained in the second year are higher than in the first year. The flag leaf chlorophyll content should be high, and it has been reported that genotypes with high SPAD value with high precipitation show more photosynthesis capacity and give higher grain yield [35].

Table 4 Average values of parameters examined in barley cultivars and cultivar candidates by years

Years	Heading Time (day)	Flowering Time (day)	Flag Leaf Area (cm^2)	SPAD Value	Canopy Temperature (°C)	Test Weight (kg)	Thousand Grain Weight (g)	Grain Largeness Ratio (%)	Yield (kg/da)
2013	203.97A	207.70B	8.62B	54.55B	31.37A	64.60A	37.87B	65.58A	391.96B
2014	202.93A	210.47A	9.94A	56.98A	29.84B	64.73A	40.24A	54.15B	421.63A
Average	203.45	209.08	9.28	55.77	30.60	64.67	39.06	59.87	406.80

3.5 Canopy Temperature

In our study, when the variance analysis table of canopy temperature was examined (Table 3), it was determined that years and year x genotype interaction were important ($p<0.05$), and genotypes were very important ($p<0.01$). Canopy temperature varies from variety to variety. Even in the same varieties planted in different places and years, significant differences occur due to regional and climatic differences [36-37]. According to the average table (Table 5), the highest canopy temperature was obtained from the PLS x KLC hybrid with 31.67 °C, while the lowest vegetation (canopy) temperature was obtained from the Ince-04 variety with 29.59 °C. Studies show that the canopy temperature is inversely proportional to the SPAD value [38]. In our study, this inverse ratio was revealed (Table 5). A low canopy temperature is desirable. The less the plant gets warm compared to the ambient temperature, the better its resistance to heat and drought [39-40]. It was determined that the canopy temperature in the 2014 production season was higher than in the 2013 production season (Table 5). It has been stated that physiological characteristics based on canopy temperature will play an important role as selection criteria and it is possible to develop cultivars that can use soil moisture more effectively by selecting genotypes with low leaf temperature [41-42].

3.6 Test Weight

According to the variance analysis table of the test weight, while the years were insignificant in our study, the interaction of genotypes and genotype x years was very important (Table 5). Studies have also shown that genotype and genotype x environment interaction is significant at the 1% level [43-44-45]. In addition, it was stated that the different test weights obtained from the genotypes resulted from the grain characteristics of the genotypes (uniformity in the grain, husk ratio, endosperm structure). According to the average table, the highest test weight was obtained from the CLR x PLS hybrid with 67.67 kg/hl, while the lowest test weight was obtained from the Plasant variety with 59.75 kg/hl. Aydogan et al. (2021) [45] reported that the test weight was between 58.42-66.71 kg/hl in Eskişehir conditions, and the trial average was 64.30 kg/hl. Our study is in harmony with these data. Test weight of barley is an important quality criterion, and it is the desired element to be high, especially in barley used in the beer and malt industry [46].

Table 5 Two-year average values of the parameters examined in barley cultivars and cultivar candidates

Genotypes	Heading Time (day)	Flowering Time (day)	Flag Leaf Area (cm²)
PLS x CLR	202.17**AB**	204.67**E**	9.82**B**
PLS x CLR	203.33**AB**	206.00**D**	9.92**B**
PLS x KLC	203.17**A**	206.67**D**	10.80**A**
CLR x PLS	205.33**A**	208.17**C**	10.89**A**
CLR x PLS	202.67**AB**	207.00**D**	9.27**D**
Kalaycı 97	190.33**B**	211.00**B**	6.61**F**
Plesant	206.00**A**	209.00**C**	9.79**BC**
Cumhuriyet 50	208.00**A**	213.17**A**	9.30**CD**
İnce-04	207.00**A**	213.17**A**	7.25**E**
Özdemir-05	206.50**A**	212.00**B**	9.18**D**
Average	**203.45**	**209.08**	**9.28**
LSD Year	13.28	1.19	0.75
LSD Genotype	14.99	1.07	0.51
LSD YearxGenotype	21.20	1.51	0.72
Genotypes	**SPAD Value**	**Canopy Temperature (°C)**	**Test Weight (kg)**
PLS x CLR	57.13**BC**	30.74**BC**	63.42**D**
PLS x CLR	53.02**D**	30.73**BC**	65.33**BC**
PLS x KLC	50.52**E**	31.67**A**	65.42**B**
CLR x PLS	56.45**BC**	30.13**CD**	63.83**CD**
CLR x PLS	58.15**AB**	30.45**BC**	67.67**A**
Kalaycı 97	55.50**C**	30.89**ABC**	65.17**BC**
Plesant	58.17**AB**	31.01**AB**	59.75**E**
Cumhuriyet 50	57.03**BC**	30.39**BCD**	65.75**B**
İnce-04	59.57**A**	29.59**D**	64.50**BCD**
Özdemir-05	52.13**DE**	30.43**BC**	65.83**B**
Average	**55.77**	**30.60**	**64.67**
LSD Year	0.61	0.89	0.26
LSD Genotype	2.00	0.81	1.57
LSD YearxGenotype	2.11	0.86	2.22
Genotypes	**Thousand Grain Weight (g)**	**Grain Largeness Ratio (%)**	**Yield (kg/da)**
PLS x CLR	35.64**DE**	48.83**D**	409.33**C**
PLS x CLR	39.08**C**	65.17**C**	398.62**CD**
PLS x KLC	34.85**E**	46.26**E**	444.50**B**
CLR x PLS	44.85**A**	74.26**A**	405.50**C**
CLR x PLS	34.55**E**	37.53**F**	503.00**A**
Kalaycı 97	40.12**C**	66.85**C**	389.17**DE**
Plesant	42.30**B**	50.92**D**	378.67**EF**
Cumhuriyet 50	42.90**B**	72.89**AB**	355.83**G**
İnce-04	39.48**C**	70.51**B**	371.17**F**
Özdemir-05	36.78**D**	65.47**C**	412.17**C**
Average	**39.06**	**59.87**	**406.80**
LSD Year	1.24	7.74	12.16
LSD Genotype	1.30	2.56	15.28
LSD YearxGenotype	1.37	2.62	21.61

3.7 Thousand Grain Weight

According to the variance analysis table of thousand-grain weight, which is evaluated as both yield and quality criteria, years and genotypes were found to be very important, while their interaction, year x genotype, was determined to be insignificant. Studies have also emphasized that there are significant differences between years and genotypes [47-48-49]. When the average table is examined, the highest thousand-grain weight was obtained from the two-row CLR x PLS hybrid with 44.85 g, followed by Cumhuriyet 50 and Plasant varieties, which are also two-row. Ergun et al. (2017) [49] stated that the thousand-grain weight of two-row barley was higher than that of six-row barley, in general, in Central Anatolian dry conditions. The lowest thousand-grain weight value was obtained from the 6-row PLS x KLC hybrid. In the average table comparing the two years, it is seen that the thousand-grain weight values obtained in the second year are higher than the first year (Table 4). Thousand-grain weight is an important feature among yield and quality criteria, and it varies according to the variety and ecological conditions of the year [50-51].

3.8 Grain Largeness Ratio

When the variance analysis table of the grain largeness ratio analysis, which gives information about the fullness and homogeneity of the grain in barley, is examined, it is seen that the interaction of years, genotypes and year x genotype is very important ($p<0.01$). It has been determined by many researchers that genotypes and years have significant differences in terms of grain largeness ratio in studies with barley [52-53-44]. When the average table is examined, the highest grain largeness ratio of 74.26% was obtained from the 2-row CLR x PLS hybrid, while the lowest grain largeness ratio value of 37.53% was obtained from the 6-row CLR x PLS hybrid. As with the thousand-grain weight, the size of the 2-row barley was higher than the 2-row barley. According to the average table in which the years are evaluated, it is seen that the grain largeness ratio values obtained in the first year (65.58%) are quite high compared to the second year (54.15%). This is an indication that the grain largeness ratio is highly affected by climatic factors. Grain largeness ratşo plays an important role in increasing the yield and in the emergence of varieties with high nutritional value. These high-yielding varieties obtained are primarily preferred in both the livestock and malt industries. Researchers state that the proportion of 1st quality malt grain remaining on 2.5 mm and 2.8 mm sieves should be more than 80-85% [54-55].

3.9 Yield

Years of yield, genotypes and their interaction, year x genotype interaction, were found to be significant at the level of 0.01. Many researchers have stated that there are significant differences between these characteristics in yield [37-44-47-56]. The lowest value obtained between 255.83 kg/da and 503.00 kg/da yield was obtained from Cumhuriyet 50 variety and the highest value was obtained from CLR x PLS 6 row barley cross. In previous studies with barley; It is seen that the yield varies between 321-576 kg/da [57], 244-594 kg/da [58], 424.9-498.2 kg/da [59]. According to the two-year average table, it is seen that the yield obtained in the second year is higher than the first year (Table 4). It can be said that this difference between years is due to climatic conditions, especially precipitation. By causing the yield to be high in the second year; It can be said that the amount of precipitation in this growing season is due to the more regular distribution of barley, especially in April, May and June, which is the development period of barley, compared to the first year. It has been reported that the yield is the result of the interaction of the genetic potential of the plant, environmental factors and cultivation techniques [60]. In addition, [44] Sirat and Sezer (2017) stated that yield changed according to years.

4. Conclusion

According to the findings obtained from the study carried out in Eskişehir ecological conditions for 2 years; Significant differences were determined between cultivars, hybrids and parents in terms of yield, quality and physiological characteristics. Barley maintains its importance as a strategic product in the world and Turkey, and this importance will increasingly continue in the future. In addition to increasing barley production in our country, it is of great importance to increase its physiological properties. While the CLR x PLS 6-row hybrid stands out in terms of quality and physiological characteristics, the 2-row cultivar candidate of the same hybrid stands out in terms of yield. Both hybrids show early characteristics as desired in terms of head and flowering time. For this reason, it is predicted that CLR x PLC (2-row) and CLR x PLC (6-row) hybrids can be evaluated as cultivar candidates with desired characteristics.

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