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Original article

Yield and Yield Components in Barley Genotypes (*Hordeum vulgare* L.) Genotypes under Rainfed Conditions

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Abstract

Grain yield and yield components in barley are complexes depending on the environmental effects and agronomical practices under rainfed environment conditions. This research was carried out in the Trakia region in Edirne (Turkey) location during the 2017-2018 cycles. The experiment was set up with 25 genotypes in a randomized complete block design (RCBD) with four replications. Grain yields (GY), plant height (PH), peduncle length (PL), spike length (SL), number of kernel per spike (KNS), spike weight (SW), spike number per square meter (SNM) and flag leaf area (FLA) were investigated. The combined analysis of variance (ANOVA) revealed significant differences among genotypes for all parameters (P<0.01) except spike length and spike number per square meter. Averaged the overall mean grain yield, genotypes G4 (8432 kg ha^{-1}), and G21 (8119 kg ha^{-1}) had the highest grain yield. Kernel number per spike varied from the lowest to 20.8 (G11) and the highest to 49.2 (G22) in genotypes. The longest peduncle (30.7 cm) was measured in G13. Genotypes G7 (8.46 cm) and G14 (8.23 cm) had the longest spike length. In the research significant (p<0.01) difference was observed in the flag leaf area in barley genotypes. Genotype G23 had the largest flag leaf area (12.67 cm^2) and followed by G11 (12.10 cm^2). Grain yield was positively correlated with peduncle length (r=0.554**) and spike number per square meter (r=0.442*). Spike weight and kernel number per spike were positively and significantly correlated (r=0.666**). Flag leaf area positively affected and increased spike weight (r=0.572**) and kernel number per spike. These results showed that peduncle length had a positive effect on grain yield. Flag leaf area had a significant positive effect on the spike weight of the genotypes. Low precipitation and high temperatures from shooting up to heading stages negatively affected grain yield and yield components.

Keywords: Barley, Yield, Physiological traits, Agronomic characters.

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INTRODUCTION

Barley (*Hordeum vulgare* L.) is a widely cultivated cereal crop in many rainfed areas in the Mediterranean region where drought is considered the main yield-limiting factor (Tambussi et al., 2005). Barely is one of the five important crops that are commonly used as human and animal food and also in malt production (Anonymous, 2010). Barley is often subjected to extreme drought stress that significantly affects production (Ceccarelli et al., 2007). Depending on the stress conditions (timing and intensity) of the target environments, some adaptive traits can be considered for yield improvement under drought if they enable plants to cope with a stress event that tends to occur every year at the same growth stage. For instance, a good level of earliness is an effective breeding strategy for enhancing yield stability in Mediterranean environments where wheat and barley are exposed to terminal drought stress nearly every year. In this condition shortening crop duration, a typical escape strategy can be useful in synchronizing the crop cycle with the most favorable environmental conditions (Blum, 1988). Drought is among the main abiotic stress that affects crop growth and productivity, leading to lower income for farmers. Climate change is expected to increase the global frequency and severity of drought events, causing high temperatures and scarce rainfall, which will dramatically increase and prolong drought (Rahim et al., 2021). Drought conditions at early growth stages are known to reduce seed germination percentage and rate and it can affect negatively seedling establishment. The developing plants will have poor tillering capacity leading to fewer plants and tillers per unit area and thus lower yield potential (Dodig et al., 2014). Additionally, drought at the period of stem elongation causes reduction in number of grains per unit area due to it is negative effect on floret formation and fertility (Fisher and Turner, 1978).

Improving crop yields is essential to meet the increasing pressure of global food demands. The loss of high-quality land, the slowing in annual yield increases of major cereals, increasing fertilizer use, and the effect of this on the environment all indicate that we need to develop new strategies to increase grain yields with less impact on the environment. One strategy that could help address this concern is by narrowing the yield gaps of major crops using improved genetics and management (Chapagain and Good, 2015). A number of physiological studies have identified some traits for which presence/expression is associated with plant adaptability to drought-prone environments. Among them, traits such as small plant size, reduced leaf area, and early maturity lead to a reduced total seasonal evapotranspiration, and to a reduced yield potential (Karamanos and Papatheohari, 1999). Earliness is a favourable character in barley due to early maturating cultivars less affected by diseases and other environmental factors, followed after harvesting farmers produce second crops in the same growing season. The amount of rainfall during the growing season is enough but the distribution of this rainfall is not regular and variation in weather conditions in the regions causes some biotic and abiotic stress factors (Öztürk et al., 2014). Stem length is one of the most important initial selection criteria in barley breeding works, being a direct component of lodging resistance and an indirect component of both yield and quality (Madic et al., 2012). Reducing plant height has played an important role in improving crop yields. The success of a breeding program relies on the source of dwarfing genes. For a dwarfing or semi-dwarfing gene to be successfully used in a breeding program, the gene should have minimal negative effects on yield and perform consistently in different environments (Wang et al., 2014). The environmental impact in barley is important for yield and quality parameters. Some plant organs such as leaf area affect yield and quality. In this experiment, grain yield, yield components, flag leaf and correlation among these traits were investigated over two various growing cycles.

MATERIALS and METHODS

Plant Materias and Examined Traits

This research was carried out in Trakya region, Edirne (41° 38′ 59′′ N and 26° 35′ 49′′ E, altitude 41 m), (Turkey) region during the 2017-2018 growing cycles. The experiment was set up with 25 genotypes (Table 1) in a randomized complete blocks design (RCBD) with four replications. Each plot had 6 meters long, in 6 rows, spaced 0.17 meters apart. Sowings were performed by using a plot drill and a seed rate of 500 seeds m^2 and fertilizer 160 kg ha^{-1} N and 40 kg ha^{-1} P_2O_5 was used. Grain yields (GY), plant height (PH), peduncle length (PL), spike length (SL), number of kernel per spike (KNS), spike weight (SW), spike number per square meter (SNM) and flag leaf area (FLA) relationship among these characters were investigated.

Flag leaf area (cm^2): In the study, 10 flag leaves were randomly selected in each sub-subplot and their length (FLL) and width (FLW) were measured by a ruler. Flag leaf area (FLA) was then calculated using the following formula (Fowler and Rasmussen, 1969).

FLA (cm^2) = (length x width) × 0.68 (Fowler and Rasmussen, 1969)

Plant height (cm): The height of ten randomly taken plants was measured at harvest maturity from the ground level to the tip of the tallest spike in centimetres and averaged.

Peduncle length (cm): The length of ten randomly taken plants was measured at harvest maturity in centimetres and averaged.

Spike length (cm): The length often randomly taken plants was measured at harvest maturity in centimetres and averaged.

Spike number per square meter: The spike number per square meter (SNM) was determined by counting the spike per 1 square meter in each plot.

The number of kernels per spike: Ten heads were randomly selected before harvest and then it was determined by averaging the total number of the kernel.

Spike weight (g): In the experiment, 10 heads were randomly selected in each subplot and their weight was measured and averaged.

Table 1. Pedigree and spike types of the barley genotypes investigated in the study

Genotype	Pedigree	Spike type
G1	Sladoran (LC)	2
G2	Osk4.39/2.84//Obz/Rod	2
G3	Sllo/Robust//Quına/3/Chıa.73T/4/Cby/5/NS529	2
G4	Slad//HB 854/Ast/3/Osk 4.39/2-84/4/Obz/Rod/5/Bar	2
G5	Bolayır (LC)	2
G6	Slad/3/Vict//Yrm/Lhfm/4/Zlatko	2
G7	Slad//HB 854/Ast/3/Osk4.39/2-84/4/Obz/Rod/5/Bar	2
G8	Sllo/Robust//Quına/3/Chıa.73T/4/Cby/5/NS 529	2
G9	Rod/Ope//Bar	2
G10	Martı (LC)	6
G11	Slad/5/Espl/3/Rhodes/CI14100//Lignee527/4/Petunia1	2
G12	Rod/Ope//Bar	2
G13	Osk 4.39/2-84/8/Flam/Nov//Hb854/Ast/7/Botond/6/YEA395-15/4/Yky387 /3/Api/Cm67//Manch/5/Rm1508//Suit/Nac	2
G14	Osk 4.39/2-84/8/Flam/Nov//Hb854/Ast/7/Botond/6/YEA395-15/4/Yky387 /3/Api/Cm67//Manch/5/Rm1508//Suit/Nac	2
G15	Harman (LC)	2
G16	Rod/Scala//Princ	2
G17	Zlat//Rod/Scala	2
G18	Olton/4/Domina/Rhode"S"//Igri/3/Chy50//Trial/Hudson/5/M320/6/NS 519	2
G19	Yky387/3/Api/cm67//Manch/4/RPE73-21/Pye"S"/5/Metro/6/Barun	2
G20	Hasat (LC)	2
G21	Slad/5/Espl/3/Rhodes/CI14100//Lignee527/4/Petunia1	2
G22	Sllo/Robust//Quina/3/Chia.73T/4/Cabuya/5/Tocte/Petunia1//Boldo/Mja	6
G23	Tocte/3/Gal/PI6384//Esc.II.72.607.1E.4E.5E/4/Boldo/Mja/5/Slad	6
G24	Tocte/3/Gal/PI6384//Esc.II.72.607.1E.4E.5E/4/Boldo/Mja/5/Slad	6
G25	Tocte/3/Gal/PI6384//Esc.II.72.607.1E.4E.5E/4/Boldo/Mja/5/Slad	6

Statistical Analysis

In the research, to evaluate significant differences between genotypes, the analysis of variance (ANOVA) was performed. The means of the genotypes were compared using the least significant differences (LSD) at a probability level of p = 0.05. Letter groupings were generated by using a 5% level of significance. Data were analyzed statistically for analysis of variance the method described by Gomez and Gomez (1984). The regression equations were calculated according to Finlay and Wilkinson (1963), and Eberhart and Russell (1969). Regression graphs were used to predict the adaptability of genotypes and the correlations between the quality parameters were determined by Pearson's correlation analysis.

Meteorological Conditions

Summarized meteorological data for the crop cycles from October to June is provided in Table 2. Monthly precipitations, relative air humidity, maximum, minimum and mean temperature were recorded from the weather station of the Institute experimental site. Average daily mean temperatures during plant growth stages from September to June were 12.1 °C, the mean maximum temperature was 25.0°C, and the mean minimum temperature was -0.1°C. Total rainfall was 799.6 mm and mean humidity was 77.3%. Low precipitation and high temperatures in April and May negatively affected yield and yield components (Table 2).

Table 2. Meteorological conditions in experimental field in 2017-2018 growing cycles

Months	**Rainfall (Long year)**	**Rainfall (mm)**	**Mean Humidity (%)**	**Temperature ºC**		
				Min.	**Max.**	**Mean**
October 2017	52.9	135.2	77.1	3.8	27.8	13.6
November 2017	72.4	71.6	75.7	-2.1	27.4	9.5
December 2017	61.7	119.6	85.1	-4.2	20.8	7.4
January 2018	48.1	55.6	88.1	-5.2	15.1	4.3
February 2018	46.9	101.8	89.5	-5.4	16.1	5.7
March 2018	52.2	145.6	88.8	-11.0	20.2	8.9
April 2018	51.0	3.0	61.3	2.6	31.7	16.6
May 2018	56.0	18.8	64.0	9.2	31.1	20.3
June 2018	41.5	148.4	66.4	11.7	34.8	22.6
Total/Mean	482.7	799.6	77.3	-0.1	25.0	12.1

RESULTS and DISCUSSION

The results of the variance analysis (ANOVA) of the research are presented in Table 3. The combined ANOVA revealed significant differences among genotypes for all parameters (P<0.01) except spike length and spike number per square meter.

Table 3. Result of the variance analysis for parameters investigated in genotypes

Parameters	**SS**	**MS**	**F Ratio**
Grain yield (GY)	210391.430	8766.309	2.587**
Plant height (PH)	2565.000	106.875	4.667**
Peduncle length (PL)	414.329	17.264	6.162**
Spike length (SL)	19.337	0.806	1.154ns
Kernel number per spike (KNS)	5637.494	234.896	14.071**
Spike weight (SW)	1.496	0.062	2.309**
Spike number per square meter (SNM)	28470.660	1186.278	1.503ns
Flag leaf area (FLA)	650.678	27.112	10.159**

*, ** Significant at p<0.05 and p<0.01 respectively. ns: non-significant. SS: Sum of square, MS: mean of square

Crop yield in barley is a complex character depending upon a large number of environmental, morphological and physiological characteristics. In the present study, yield and yield components were significantly affected by the genotypic difference. According to the results, there were highly significant differences in yield among genotypes due to yield components and genotypic differences. Averaged the overall mean grain yield was 7382 kg ha^{-1}. Genotypes G4 (8432 kg ha^{-1}), G21 (8119 kg ha^{-1}), and G13 (8107 kg ha^{-1}) had the highest grain yield. The yield difference in genotypes was caused by environmental factors such as soil structure, precipitation and temperature (Table 4).

Table 4. The mean yield and investigated parameters in barley genotypes

Genotype	GY	PL	SL	KNS	SW	PH	SNM	FLA
G1	6706h	22.3h	6.78c	27.9cde	1.07d-g	92.3e-h	192a-d	7.34c-g
G2	7455b-h	25.6c-f	7.60abc	22.5ef	1.11d-g	101.3abc	216ab	7.55c-f
G3	7506b-h	26.8cd	7.51abc	28.6cd	1.21a-e	98.5a-e	223a	8.43bc
G4	8432a	25.7c-f	6.78c	21.5f	0.93g	100.8a-d	224a	3.76j
G5	7187d-h	23.5fgh	7.66abc	32.3c	1.07d-g	95.3c-g	208ab	5.63e-j
G6	7275d-h	25.3c-f	7.38abc	21.9f	0.97fg	88.0h	214ab	4.54ıj
G7	6784gh	22.9gh	8.46a	25.4def	1.12d-g	91.3fgh	205abc	5.13g-j
G8	7576b-g	25.9cde	7.66abc	23.3def	0.95fg	89.0gh	208ab	4.77hıj
G9	7268d-h	22.5h	7.46abc	21.8f	1.22a-e	89.5gh	207ab	4.05j
G10	7290c-h	25.9cde	7.43abc	21.8f	1.16b-g	95.3c-g	221ab	5.75d-j
G11	6916fgh	25.7c-f	7.11bc	20.8f	1.09d-g	102.8ab	204abc	12.10a
G12	7743a-e	29.7ab	7.58abc	22.5ef	1.12c-g	103.3a	225a	5.33f-j
G13	8107abc	30.7a	7.37abc	21.3f	1.07d-g	96.5b-f	222ab	4.95hıj
G14	7189d-h	27.3bc	8.23ab	24.8def	1.16b-g	100.5a-d	188a-d	6.78c-ı
G15	6940e-h	26.4cd	6.53c	32.3c	1.36ab	102.3ab	166cd	11.05a
G16	7498b-h	26.7cd	6.60c	21.4f	1.02efg	102.3ab	159d	7.74cde
G17	7134e-h	25.6c-f	7.15bc	22.7ef	1.06d-g	102.8ab	200abc	7.29c-g
G18	7564b-g	29.7ab	7.35abc	24.5def	1.26a-d	102.8ab	196a-d	5.61e-j
G19	6761gh	23.6e-h	6.82c	40.3b	1.20a-e	93.8e-h	204abc	5.38f-j
G20	6778gh	24.6d-h	7.64abc	24.8def	1.21a-e	90.8fgh	183bcd	11.75a
G21	8119ab	26.8cd	7.32abc	24.5def	1.25a-e	101.0a-d	193a-d	10.43ab
G22	7631a-f	25.2c-g	7.48abc	49.2a	1.35abc	91.8fgh	202abc	8.00cd
G23	6975e-h	25.6c-f	7.36abc	45.8ab	1.43a	94.5d-h	196a-d	12.67a
G24	7758a-e	25.6c-f	7.46abc	25.5def	1.17b-f	92.0e-h	211ab	6.86c-h
G25	7964a-d	25.7c-f	7.66abc	23.3def	1.11d-g	92.3e-h	225a	5.75d-j
Mean	7382	25.8	7.37	26.8	1.15	96.4	203.5	7.14
LSD $_{(0.05)}$	81.9	2.35	1.17	5.75	0.23	6.72	39.5	2.29

**: *P*<0.01, *: *P*<0.05, GY: Yield (kg ha^{-1}), PL: Peduncle length (cm), SL: Spike length (cm), KNS: Number of kernel per spike, SW: Spike weight (g), PH: Plant height (cm), SNM: Spike number per square meter, FLA: Flag leaf area (cm^2)

The number of grains and the weight of the spike is an important yield component that positively affects the yield. Some climatic factors such as low and high temperatures and precipitation may also affect the number of grains in the spike during the development period of the spike draft. Kernel number in spike varied in 2-rowed genotypes from the lowest 20.8 (G11) and the highest to 32.3 (G5). The kernel number of spikes varied between 32.3 and 49.2 in genotypes with 6 rows. In the study spike weight was significantly ($P<0.01$) affected by genotypes and agronomic practices. Maximum spike weight (1.43 g) was recorded in G23 followed by G15 (1.36 g) and G22 (1.35 g). Due to the lowest kernel number in two-rowed genotypes, the lowest spike weight was recorded in two-rowed genotypes (Table 4).

The lowest spike weight was in G4 (0.93 g), G8 (0.95 g) and G6 (0.97 g). Stem length is one of the most important initial selection criteria in barley breeding works, being a direct component of lodging resistance and an indirect component of both yield and quality (Madic et al., 2012). Our results indicated that taller plants (103.3 cm) were produced by G12 and followed by G11, G15, and G16. The mean plant height was 96.4 cm. The short plant was measured in genotype G6 (88.0 cm). Significant ($P<0.01$) differences were observed in peduncle length and spike length in barley genotypes. The longest peduncle (30.7 cm) was measured in G13 followed by G12 and G18, while the short peduncle was measured in G1, G9 and G7. It is a preferred feature in breeding studies for fertile regions because it has more grains and therefore high yields in long-headed genotypes. Genotypes G7 (8.46 cm) and G14 (8.23 cm) had the longest and G15 (6.53 cm) and G16 (6.60 cm) shortest spike lengths.

Depending on the stress conditions of the target environments, some adaptive traits can be considered for yield improvement under drought if they enable plants to cope with a stress event that tends to occur every year at the same growth stage (Blum 1988). The tillering capacity of plants can vary according to many factors such as genotypic features, soil structure, planting depth and date, and planting density. Related barley (*Hordeum vulgare* L.) lines, with small and large leaf areas, were developed and used to study the effect of leaf area on photosynthesis, light penetration, and grain yield. In yield trials, large leaf lines exceeded small leaf lines in the flag leaf area by 70% and in LAI by 25%. Lines with small leaves produced more heads and higher grain yields than lines with large leaves when plants did not lodge. Where lodging occurred, however, large leaf lines had higher kernel weights and were higher yielding (Berdahl et al. 1971). In the research significant ($P<0.01$) differences were observed in the flag leaf area in barley genotypes. Genotype G23 had the largest flag leaf area (12.67 cm^2) and followed by G11 (12.10 cm^2). In barley, the flag leaf contributes less to yield than the second and third leaves due to the less photosynthetic area. However, it benefits from light more than other leaves. In this respect, the position of the leaf is also important.

The regression coefficients and relationships among the characters examined in the study are given in Figure 1. Flag leaf area in genotypes had a positive effect on spike weight (R^2=0.327). Flag leaf area is also negatively related to spike number per square meter in genotypes. Peduncle length and spike number per square meter had a positive effect on grain yield. There was a positive relation between spike weight and kernel number per spike (R^2=0.443) and also plant height and peduncle length. These results showed that the flag leaf area of the genotypes had a significant positive effect on spike weight. Spike weight also positively correlated with kernel number per spike (Figure 1).

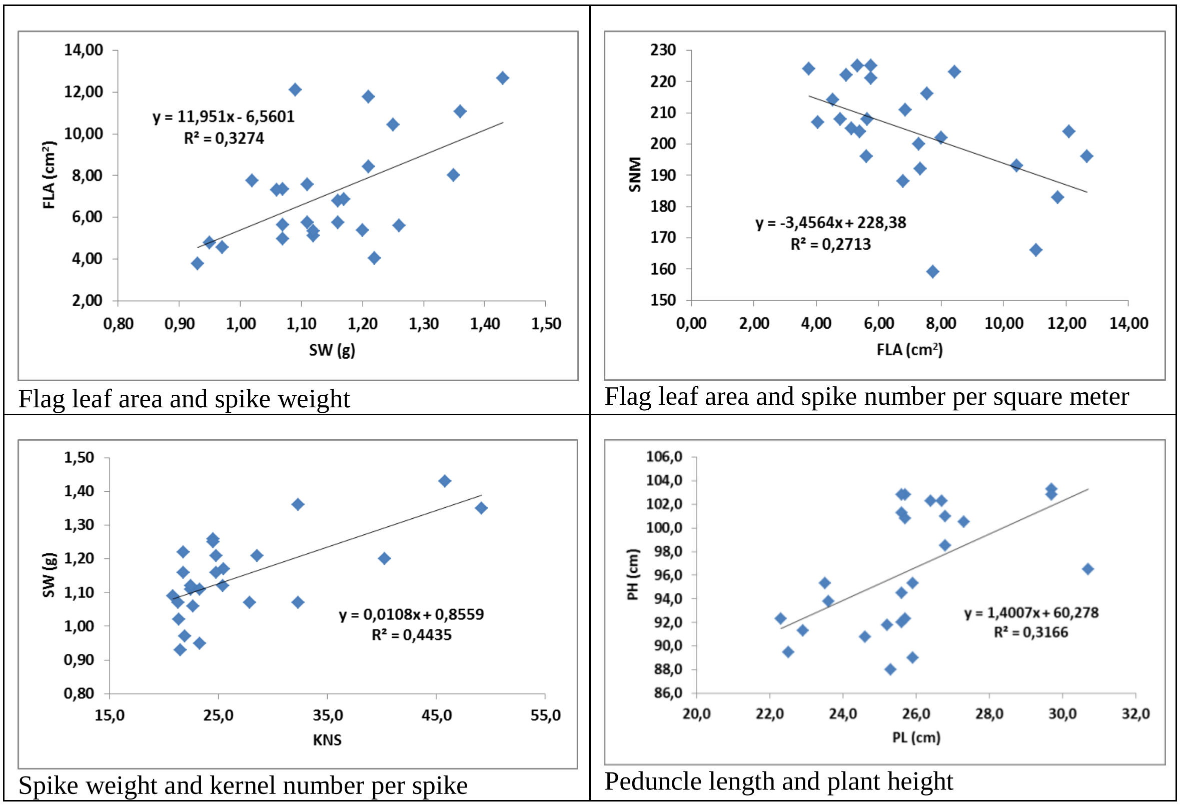

Figure 1. Relation between yield and yield component in barley genotypes

Correlation coefficients among investigated parameters were determined by Pearson's correlation analysis (Table 5). Different correlation coefficients were determined between the parameters examined in the study. Grain yield was positively correlated with peduncle length (r=0.554**) and spike number per square meter. Plant height was positively correlated with peduncle length (r=0.563**). Spike weight and kernel number per spike were positively and significantly correlated (r=0.666**). Flag leaf area positively affected and increased spike weight (r=0.572**) and kernel number per spike.

Table 5. Correlation coefficient among parameters investigated in barley genotypes

Traits	GY	PH	PL	SL	KNS	SW	FLA
PH	0.207						
PL	0.554**	0.563**					
SL	-0.023	-0.317	-0.011				
KNS	-0.280	-0.218	-0.244	-0.089			
SW	-0.249	0.045	0.031	0.015	0.666**		

Traits	GY	PH	PL	SL	KNS	SW	FLA
FLA	-0.355	0.262	-0.004	-0.201	0.329	0.572**	
SNM	0.442*	-0.204	0.113	0.351	-0.182	-0.309	-0.521**

**: P<0.01, *: P<0.05, GY: Yield (kg da^{-1}), PH: Plant height (cm), PL: Peduncle length (cm), SL: Spike length (cm), KNS: Number of kernel per spike, SW: Spike weight (g), FLA: Flag leaf area (cm^2), SNM: Spike number per square meter.

The increase in plant density decreased the leaf area and caused a negative relationship between the flag leaf area and the number of spikes per square meter. (r=-0.521**). Different factors such as genetic structure, precipitation and temperature were effective in obtaining different correlation coefficients between parameters in genotypes.

Conclusion

Averaged the overall mean grain yield genotypes G4, G21, and G13 had the highest grain yield. Spike weight is directly related to yield .In the study, maximum spike weight was recorded in G23 followed by G15 and G22. Significant differences were observed in peduncle length and spike length in barley genotypes. The longest peduncle was measured in G13 followed by G12 and G18. Genotypes G7 and G14 had the longest and G15 and G16 shortest spike length. In the research, significant differences were observed in flag leaf area in barley genotypes. Genotype G23 had the largest flag leaf area and followed by G11. Genotype G23 had also the highest spike weight and followed by G15. Grain yield was positively correlated with peduncle length and spike number per square meter. Plant height was positively correlated with peduncle length. Spike weight and kernel number per spike were positively and significantly correlated. Flag leaf area positively affected and increased spike weight and kernel number per spike. The increased flag leaf area promoted higher photosynthesis rates and enhanced spike weight. The high number of plants per square meter reduced the leaf area of the flag. Peduncle length had a positive effect on grain yield. In the study, lower precipitation and high temperatures from shooting and heading negatively affected yield and yield components. It is important to carry out studies in different environmental conditions since many factors such as genetic factors, soil structure, precipitation and temperature affect plant development. Spikes, stems and leaves in barley are organs that contribute significantly to yield and yield elements with photosynthetic activity. Although the first leaf contributes less to yield than the other leaves, this contribution may increase in large-leaved genotypes due to the benefit of more light. Yield components in barley can contribute to yield at different rates according to genotype and environmental conditions.

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