COMPARISON OF AGRO-PHYSIOLOGICAL COMPONENT OF BARLEY (*Hordeum vulgare* L) GENOTYPES UNDER RAINFED CONDITION

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Abstract

This research was carried out to assess yield and agronomic and physiological parameters of barley genotypes under rainfed conditions. The experiments were set up with 25 barley genotypes in a completely randomized blocks design with four replications during the 2017-2018 growing cycle at two locations in Edirne and Tekirdağ in the Trakia region, Turkey. Grain yield, plant height, days of heading, peduncle length, spike length, spike number per square meter, kernel number per spike, spike weight, flag leaf area, NDVI, canopy temperature, chlorophyll content, 1000-kernel weight, test weight, protein ratio, grain uniformity were investigated. The results of the study showed that there were significant differences among genotypes based on investigated characters. The highest grain yield (8509 kg ha^{-1}) was computed for the G22 line. Grain yield was positively slightly correlated with spike weight, kernel number per spike, NDVI (Z55), 1000-kernel weight, test weight, and grain uniformity but no correlated with flag leaf area. There was a significant positive relation with spike weight and flag leaf area, spike length and kernel number per spike. Flag leaf area positively significantly correlated with kernel number per spike, and slightly positively correlated with spike length. Biomass (NDVI) at Z55 growth stage had a positive direct effect on grain yield, spike weight, peduncle length, spike number per square meter, 1000-kernel weight, test weight, protein ratio and grain uniformity. A negative correlation was observed between canopy temperature with grain yield, spike number per square meter, plant height, biomass (at Z55), 1000-kernel weight, test weight, protein ratio and grain uniformity. Therefore, biomass and canopy temperature would be important selection criteria for improved grain yield and yield components in the breeding material studied.

Key words: *Barley, genotypes, yield component, physiological parameters, environment effect*

1. INTRODUCTION

Barley (*Hordeum vulgare* L.) is a major cereal crop. It is well adapted to various abiotic stresses in the dry areas of West Asia and North Africa (Grando et al., 2005, Baum et al., 2007). Barley is cultivated on more than 40 million hectares in developing countries. In most developing countries, where it is subjected to extreme water deficits during dry seasons, it is often the only rain-fed crop that farmers can grow (Ceccarelli, 1994). Barley grain is used primarily as an energy and protein source for animal feed. The high protein content is desirable for feed production. Variation in weather conditions in the regions, year effect, soil fertility and pest management can affect barley grain quality significantly. Protein quantity in grain varies depending on weather conditions and amount of the nitrogen fertilizer in the region (Öztürk et al., 2017). Besides barley yield, grain size is an important indicator that correlates with grain weight and protein content. Many authors, however, point out that the relationship between these characteristics is complex (Eagles et al., 1995; De Ruiter, 1999; Paynter et al., 2013). Barley grain has lower protein and energy levels than wheat, but it is the only cereal and the only staple food resource in arid and semi-arid regions of some developing countries. Climate change will be a significant challenge for delivering grain with consistent yield and quality in the future due to the complex effects of atmospheric CO_2 and changing temperature and rainfall patterns on barley development (Nuttall et al., 2017).

Knowledge of the physiological traits that limit yield under inimical conditions provides new opportunities for future breeding and growing strategies (Tambussi et al., 2005; Gonzalez et al., 2010). Many morphological and physiological characteristics are affected by drought stress (Rollins et al., 2013). Selection efficiency could be improved if a particular physiological and/or morphological trait

related to improved seed yield under drought is identified and used in the selection process (Ludlow and Muchow, 1990). Drought stress during the grain-filling period reduced morpho-physiological traits and grain yield. Chlorophyll content affected the grain yield and was associated positively with yield increases under three water treatments (Istanbuli et al., 2020). The correlation of CTD with yield was not affected by the irrigation status of the crop under well-watered conditions. The possible use of these traits in selection for yield under hot conditions is discussed (Reynolds et al., 1994). The normalized difference vegetation index (NDVI) is widely used at ground level and from low, high and satellite altitudes to measure vegetative greenness and canopy photosynthetic size. The field-portable NDVI sensor provides rapid ground level measurement of crops at a resolution to characterize the canopy for leaf area index (LAI) and green area index (GAI), biomass and nutrient content. Data can be used to estimate yield prediction, biomass accumulation and growth rate, ground cover and early vigor, senescence pattern estimations, and biotic and abiotic stress detection (Pask 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).

Grain yield in barley is a complex character depending on a large number of environmental, agronomical and physiological characters. Grain yields also depend upon other yield components (Alam et al., 2007; Öztürk et al., 2018). In the study, grain yield, yield components, agronomic and physiological parameters were assessed of barley genotypes under rainfed conditions.

2. MATERIALS AND METHODS

The experiments were set up with 25 barley genotypes in a Randomized Complete Blocks Design (RCBD) with four replications during the 2017-2018 growing cycle at two locations in Edirne and Tekirdağ in the Trakia region, Turkey. Agronomic characters such as; grain yield (kg ha^{-1}), plant height (cm), peduncle length (cm), spike length (cm), days of heading, number of spike per square meter, number of kernel per spike, grain uniformity (%), and spike weight (g) parameters were investigated. The parameter days to heading (DH) was estimated from 1st January to the moment when 50% of main stems in a plot had at least half of emerged ears. In the experiments, 1000-kernel weights and test weight was determined. Test weight (TW) was measured with a 1L container. Thousand kernel weight (TKW) was measured with an electronic seed counter using seed samples, from which all broken kernels were manually removed. All tests for wheat physical properties were conducted at least in duplicate. Also, protein ratio (Köksel et al., 2000; Anonymous, 2002; Anonymous, 1990) were investigated.

Data physiological parameters were recorded for chlorophyll content and canopy temperature (Fisher, 2001; Reynolds et al., 2001; Babar et al., 2006) at the heading stage (Z55). A handheld portable SPAD-502 chlorophyll meter (Minolta) provides a convenient means of assessing relative leaf chlorophyll content. Ten flag leaves were used to take chlorophyll meter readings from each plot at the heading stage (Adamsen et al., 1999; Babar et al., 2006; Pask et al., 2012). A handheld infrared thermometer was used to measure canopy temperature CT (°C). The data were taken from the same side of each plot at a 1m distance from the edge and approximately 50cm above the canopy at an angle of 30° to the horizontal. Readings were made between 13.00 and 15.00h on sunny days (Jackson et al., 1981; Babar et al., 2006; Reynolds et al., 2012; Pask et al., 2012). Normalized difference vegetative index (NDVI) was taken at the GS55 growth stage and it was determined with in-field measurements using a hand-held Ntech ‘Greenseeker’ NDVI meter (Pask et al., 2012). Yield component such as peduncle length, spike length, spike number per square meter, kernel number per spike, spike weight and flag leaf area was investigated in the Edirne location (E1). Physiological parameters such as normalized difference vegetative index, canopy temperature and chlorophyll content were investigated in Edirne (E1) location at heading stages (Z55).

To evaluate significant differences between genotypes, the analysis of variance (ANOVA) was performed. The differences between genotype means of parameters were tested by the L.S.D test

(0.05) (Kalaycı, 2005). Letter groupings were generated by using a 5% level of significance. Data were analyzed statistically for analysis of variance in 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.

3. RESULTS AND DISCUSSION

The results of the variance analysis of the research are presented in Table 1. The combined ANOVA revealed significant differences (P<0.01 and P<0.05) among genotypes for all traits except NDVI and protein ratio (Table 1).

Table 1. Mean square and F ratio for yield, morphological and quality parameters measured in 25 barley genotypes.

Parameters	**Genotypes (G)**	
	Mean square (MS)	**F Ratio**
Grain yield (GY)	31823.20	11.894**
1000-kernel weight (TKW)	21.513	5.297**
Test weight (TW)	7.203	2.037*
Protein ratio (PRT)	0.431	0.308ns
Grain uniformity (GU)	562.561	5.390**
Plant height (PH)	124.88	8.838**
Days of heading (DH)	53.23	12.308**
Spike number per square meter (SNM)	27288.9	2.847**
Number of kernel per spike (KNS)	376.946	49.287**
Chlorophyll content (SPAD)	11.58	2.984**
Normalized differences vegetative index (NDVI)	0.004	1.661ns
Canopy temperature (CT)	1.688	2.107**
Spike weight (SW)	0.184	9.097**
Flag leaf area (FLA)	9.031	5.853**
Peduncle length (PL)	74.97	4.245**
Spike length (SL)	2.841	10.363**

*, ** Significant at p<0.05 and p<0.01 respectively. ns: non-significant

Table 2. Mean grain yield, quality and morphological parameters of the genotypes across two locations in the 2017-2018 cycles

No	Genotype	GY	TKW	TW	PRT	GU	DH	PH
1	Sladoran	6766^{c-f}	36.3^{bcd}	69.6^{a-g}	9.9^{a}	67.5^{a-d}	101.5^{abc}	93.5^{def}
2	G2	5975^{hı}	34.9^{b-e}	68.5^{c-g}	9.3^{a}	62.4^{a-f}	102.3^{ab}	90.5^{fg}
3	G3	7096^{bcd}	38.1^{abc}	69.2^{a-g}	10.0^{a}	82.8^{a}	99.3^{cde}	92.0^{efg}
4	G4	6880^{b-e}	36.5^{bcd}	67.6^{d-g}	9.5^{a}	50.5^{c-g}	99.5^{b-e}	90.8^{fg}

5	Bolayır	6499^{efg}	35.7^{bcd}	72.9^{a}	10.0^{a}	53.9^{c-f}	96.8^{efg}	101.8^{ab}
6	G6	7229^{bcd}	36.0^{bcd}	71.2^{a-d}	9.8^{a}	49.9^{d-g}	96.0^{fg}	98.0^{bcd}
7	G7	7133^{bcd}	36.0^{bcd}	67.7^{d-g}	9.0^{a}	48.7^{d-h}	99.5^{b-e}	95.3^{c-f}
8	G8	7264^{bc}	36.7^{bcd}	70.7^{a-f}	9.3^{a}	60.2^{b-f}	100.8^{a-d}	91.3^{fg}
9	G9	7173^{bcd}	37.5^{abc}	68.2^{d-g}	9.4^{a}	61.2^{b-f}	100.8^{a-d}	94.8^{def}
10	Martı	6415^{e-h}	33.2^{def}	68.4^{c-g}	9.5^{a}	55.1^{c-f}	96.3^{fg}	101.3^{ab}
11	G11	5916^{hij}	29.9^{f}	66.8^{fg}	9.1^{a}	11.4^{ı}	95.3^{g}	97.3^{b-e}
12	G12	7315^{b}	36.4^{bcd}	69.3^{a-g}	9.0^{a}	49.8^{d-g}	102.3^{ab}	92.5^{efg}
13	G13	5444^{j}	30.1^{f}	66.3^{g}	9.3^{a}	19.8^{ı}	100.8^{a-d}	93.0^{d-g}
14	G14	6719^{def}	34.4^{cde}	70.7^{a-e}	10.4^{a}	31.1^{ghı}	98.3^{def}	97.0^{b-e}
15	Harman	6847^{b-e}	38.7^{ab}	70.9^{a-e}	9.8^{a}	64.4^{a-e}	97.0^{efg}	101.0^{ab}
16	G16	6544^{efg}	40.9^{a}	71.5^{a-d}	9.6^{a}	77.2^{ab}	100.5^{a-d}	104.3^{a}
17	G17	6802^{cde}	36.2^{bcd}	72.8^{a}	9.5^{a}	61.7^{b-f}	98.1^{d-g}	101.0^{abc}
18	G18	6760^{c-f}	37.8^{abc}	70.8^{a-e}	9.7^{a}	60.8^{b-f}	98.3^{def}	95.0^{def}
19	G19	6796^{cde}	37.5^{abc}	70.8^{a-e}	9.7^{a}	59.4^{b-f}	101.0^{a-d}	104.8^{a}
20	Hasat	6847^{b-e}	38.7^{ab}	72.5^{ab}	10.2^{a}	71.4^{abc}	101.3^{abc}	104.3^{a}
21	G21	6283$^{f-ı}$	34.9^{b-e}	72.1^{abc}	9.5^{a}	28.0^{hı}	97.5^{efg}	98.3^{bcd}
22	G22	8509^{a}	31.0^{ef}	70.1^{a-g}	9.1^{a}	41.7^{fgh}	102.5^{a}	91.0^{fg}
23	G23	6169^{ghı}	29.6^{f}	69.2^{a-g}	10.4^{a}	48.6^{d-h}	88.8^{h}	88.0^{gh}
24	G24	5946^{hij}	29.7^{f}	68.7^{b-g}	10.5^{a}	45.2^{e-h}	91.0^{h}	87.8^{gh}
25	G25	5839^{ıj}	29.8^{f}	67.2^{efg}	10.5^{a}	47.3^{d-h}	91.3^{h}	84.0^{h}
Mean		7685	35.1	69.7	9.6	52.4	98.2	95.5
LSD (0.05)		69.4	4.1	3.8	2.4	21.0	2.9	5.3

Significance at *: P<0.05; **: P<0.01; GY: Grain yield (kg ha^{-1}), TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%), GU: Grain uniformity (%), DH: days of heading, PH: Plant height (cm),

Due to various environmental conditions, grain yield is a complex character depending on a large number of environmental, agronomical and physiological characters (Öztürk et al., 2018). Grain yields are also depending upon other yield components such as spike per square meter and kernel number per spike. Because of various environmental effects, there were significant differences among genotypes based on grain yield. The mean yield of the experiment was 7685 kg ha^{-1}. The highest grain yield was determined with 8509 kg ha in genotype G22 and followed by the G12, G8, and G6 (Table 2).

The number of grain in a spike in barley has predominant importance for yield potential and kernel weight is one of the major yield components. There was a very highly significant variation in thousand grains weight of barley genotypes based on their spike types and other genotypic traits. There were significant differences among genotypes based on TKW ($p<0.01$) and TW ($p<0.05$). 1000-kernel weight ranged from 29.6 g (G23) to 40.9 g (G16) among genotypes and the mean value was 35.1 g across two locations. Genotypes Harman, Hasat and G3 had the other highest 1000-kernel weight (Table 2). Mean test weight of twenty-five genotypes indicated that the highest TW in genotypes Bolayır (72.9 kg), G17 (72.8 kg) and Hasat (72.5 kg), whereas, the lowest test weight was observed in G13 (66.3 kg). There was no significant difference among genotypes for protein ratio. The maximum

and lowest protein ratio varied from 9.1% to 10.5%. The grain uniformity in barley is another important parameter of malting barley production. The uniformity of grain depends to a large extent on the structure of the genotype of the spikes. Most cases of mechanical damage occur during harvest, cleaning or transportation. Consequently, commercial quality declines. There was a highly significant difference among genotypes for grain uniformity and the minimum was 11.4% and a maximum of 82.8%. Genotype G3, G16 and Hasat was the highest grain uniformity (Table 2).

Earliness is a favourable character in barley in the region, due to rainfall fluctuation. Another reason, followed after early maturating crops farmers are produced second crops, especially for animal feed silage. There was a significant difference among genotypes for days of heading and the early heading genotype was G23 and the late heading was G22. Plant height is an important morphological character directly linked with the productive potential of plants in terms of grain yield (Alam et al., 2007). Stem length and solidness are the most important selection criteria in barley breeding works, being a direct component of lodging resistance. The shortest plant height was 84.0 cm (G25) and the tallest 104.8 cm (G19).

Table 3. Yield component and physiological parameters of the genotypes in Edirne location in 2017-2018 cycles

No	Genotype	SW	FLA	PL	SL	KNS	SNM	NDVI	SPAD	CT
1	Sladoran	1.11^{d-g}	7.16^{c-g}	27.05^{a-d}	6.47$^{f-ı}$	24.03$^{f-ı}$	738^{b-f}	0.73^{a-f}	52.5^{abc}	24.25^{ab}
2	G2	1.08^{efg}	7.99^{cd}	24.12$^{e-ı}$	7.32^{def}	25.93^{efg}	662^{c-h}	0.72^{a-f}	49.3^{efg}	23.65^{a-d}
3	G3	1.13^{c-f}	5.31^{gh}	27.66^{a}	6.31^{hı}	23.93$^{f-ı}$	746^{b-e}	0.74^{a-f}	49.3^{efg}	23.25^{b-e}
4	G4	1.08^{efg}	6.51^{d-h}	24.81^{b-h}	6.41^{ghı}	22.37^{g-j}	912^{a}	0.76^{a-d}	49.3^{efg}	22.93^{cde}
5	Bolayır	1.07^{efg}	10.13^{b}	26.85^{a-e}	7.24^{d-g}	24.33$^{f-ı}$	714^{b-f}	0.77^{ab}	47.9^{fg}	22.63^{de}
6	G6	1.07^{efg}	5.91^{e-h}	26.19^{a-g}	7.64^{cde}	23.47^{f-j}	777^{a-d}	0.73^{a-f}	50.9^{a-e}	23.35^{a-e}
7	G7	1.08^{efg}	6.61^{d-h}	24.00$^{f-ı}$	6.20^{hı}	20.90^{hıj}	840^{ab}	0.78^{a}	47.5^{fg}	22.98^{cde}
8	G8	0.99^{fg}	5.86^{e-h}	24.26$^{d-ı}$	5.84^{ıj}	21.30^{hıj}	641^{d-h}	0.72^{a-f}	51.0^{a-e}	23.35^{a-e}
9	G9	1.16^{c-f}	4.65^{h}	24.74^{c-h}	6.24^{hı}	21.93^{g-j}	766^{bcd}	0.75^{a-e}	49.5^{d-g}	22.50^{de}
10	Martı	1.24^{b-e}	8.51^{bcd}	27.58^{ab}	5.17^{ıj}	35.87^{d}	604^{fgh}	0.71^{b-f}	47.4^{fg}	24.33^{ab}
11	G11	1.03^{efg}	5.76^{fgh}	24.50^{d-h}	8.38^{bc}	26.30^{efg}	751^{bcd}	0.69^{ef}	52.5^{abc}	24.58^{a}
12	G12	0.98^{fg}	7.14^{c-g}	22.60^{hı}	6.52$^{f-ı}$	20.53^{ıj}	708^{b-g}	0.73^{a-f}	48.9^{efg}	23.08^{b-e}
13	G13	1.14^{c-f}	7.51^{c-f}	22.28^{hı}	8.07^{bcd}	25.20^{e-h}	738^{b-f}	0.68^{f}	50.0^{c-f}	23.13^{b-e}
14	G14	0.89^{g}	7.09^{d-g}	23.97^{ghı}	7.43^{de}	20.53^{ıj}	713^{b-f}	0.70^{c-f}	48.7^{efg}	23.23^{b-e}
15	Harman	1.26^{b-e}	9.16^{bc}	27.74^{a}	6.28^{hı}	25.33^{e-h}	762^{bcd}	0.76^{abc}	52.2^{a-d}	23.38^{a-e}
16	G16	1.06^{efg}	4.89^{h}	26.79^{a-f}	6.05^{hı}	19.17^{j}	669^{c-h}	0.76^{a-d}	49.8^{c-g}	22.18^{e}
17	G17	1.09^{efg}	6.97^{d-g}	26.23^{a-g}	7.40^{de}	23.30^{f-j}	775^{a-d}	0.78^{a}	51.0^{a-e}	22.13^{e}
18	G18	1.10^{efg}	5.92^{e-h}	28.60^{a}	6.86^{e-h}	22.89^{g-j}	734^{b-f}	0.78^{a}	49.0^{efg}	23.55^{a-d}
19	G19	1.48^{b}	7.46^{c-f}	28.08^{a}	7.19^{efg}	27.68^{ef}	746^{b-e}	0.77^{abc}	47.2^{g}	22.43^{de}
20	Hasat	1.15^{c-f}	5.73^{fgh}	27.45^{abc}	7.25^{d-g}	22.73^{g-j}	781^{abc}	0.78^{a}	50.1^{b-f}	22.45^{de}
21	G21	1.36^{bc}	7.48^{c-f}	28.70^{a}	8.72^{ab}	29.70^{e}	729^{b-f}	0.72^{a-f}	53.0^{a}	22.88^{cde}
22	G22	2.19^{a}	12.71^{a}	24.38^{d-h}	9.39^{a}	71.22^{a}	610^{e-h}	0.76^{a-d}	49.1^{efg}	24.08^{abc}
23	G23	1.34^{bcd}	7.10^{d-g}	24.40^{d-h}	6.46^{ghı}	44.12^{b}	573^{gh}	0.71^{b-f}	52.8^{ab}	23.25^{b-e}

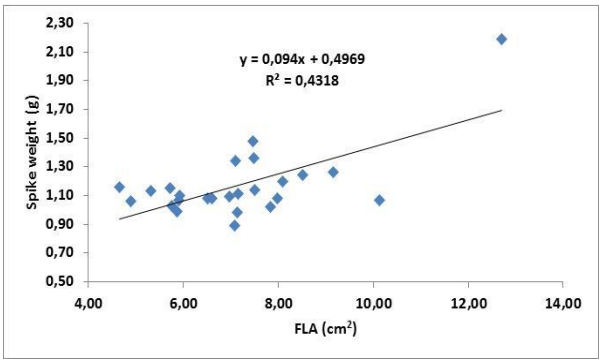
24	G24	1.20^{c-f}	8.09^{cd}	24.29$^{d-ı}$	6.28^{hı}	42.03^{bc}	605^{fgh}	0.72^{a-f}	49.8^{c-g}	23.90^{abc}
25	G25	1.02^{efg}	7.83^{cde}	21.50^{ı}	6.26^{hı}	38.43^{cd}	564^{h}	0.69^{def}	50.9^{a-e}	23.58^{a-d}
Mean		1.17	7.17	25.5	6.93	28.1	712.9	0.74	50.0	23.3
LSD (0.05)		0.23	2.04	2.81	0.86	4.52	137.7	0.067	2.8	1.25

Significance at *: P<0.05; **: P<0.01; SW: Spike weight (g), FLA: Flag leaf area (cm^2), PL: Peduncle length (cm), SL: Spike length (cm), KNS: Kernel number per spike, SNM: Spike number per square meter, NDVI: Normalized difference vegetative index, SPAD: Chlorophyll content, CT: Canopy temperature (^oC).

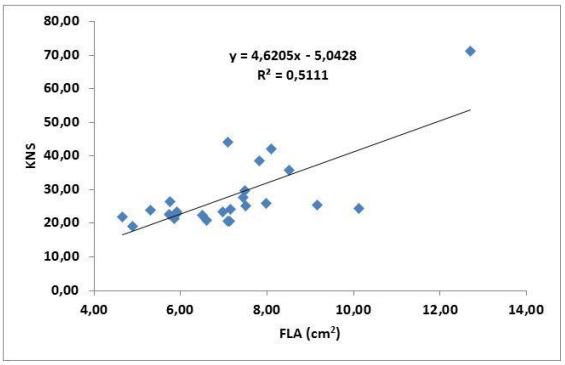
In the research spike was randomly selected from each plot before harvesting and then weighted. Spike weight in genotypes varied from 0.89 g to 2.19 g (Table 3). The lowest spike weight was determined in G14, while the highest was determined in G22 and G19. Flag leaf significantly affects and contributes to grain yield and yield components. There was a significant difference among genotypes and the mean was 7.17 cm2. In the present study flag leaf positively affected spike weight, spike length and kernel number per spike. The lowest flag leaf area was measured in G9 (4.65 cm^2) and G16 (4.89 cm^2). G22 (12.71 cm^2) and Bolayır (10.13 cm^2) had higher flag leaf area (Table 3). There was a significant difference (p<0.01) among genotypes for peduncle length. With regard to genotypic effects, G25 (21.50 cm) exhibited the lowest peduncle. On the other hand, genotype G21, which was showed the highest peduncle length of 28.70 cm, and followed by G18 and G19 (Table 3). Spike length varies depends on genotype effect, environment factors and also agronomic applications. In the present study, G22 had a higher spike length (9.39 cm) and followed by G21, G11 and G13. Genotypes Martı and G8 had a short spike length (Table 3). Grain yield is a complex character depending upon a large number of, environmental, morphological and physiological characters. Grain yields also depending upon yield components such as kernel number per spike and spike number per square meter. The number of tillers per plant is an important character, which ensures a higher yield. The number of grains in spike ranged from 19.17 to 71.22 among genotypes and G22 had the highest grain in spike. The number of spikes per square meter is related to the higher tillering capacity and is an important factor of yield. Based on the mean value of the spike number per square meter ranged from 564 to 912 among genotypes and G4 and G7 had the higher tillering capacity (Table 3).

There was no difference among genotypes for normalized difference vegetation index (NDVI). The highest NDVI was determined in genotypes G7, G17, G18 and Hasat while lowest in G13, G11 and G25. There was a significant difference among genotypes for chlorophyll content. Chlorophyll content of the genotypes minimum was 47.2 (G19) and the highest 53.0 (G21). G21, G23, and Sladoran had the highest chlorophyll content. Canopy temperature (CT) and normalized difference vegetation index (NDVI) was measured at the heading (Z55) stage of the genotypes. To avoid the effect of soil temperature on the CT, the data were taken when the infrared thermometer viewed no soil because of high leaf coverage areas. With regard to canopy temperature, G11 had the highest CT of 24.58^{o}C. On the other hand, genotype G17 (22.13^{o}C) and G16 (22.18^{o}C) had the lowest canopy temperature under rainfed conditions (Table 3).

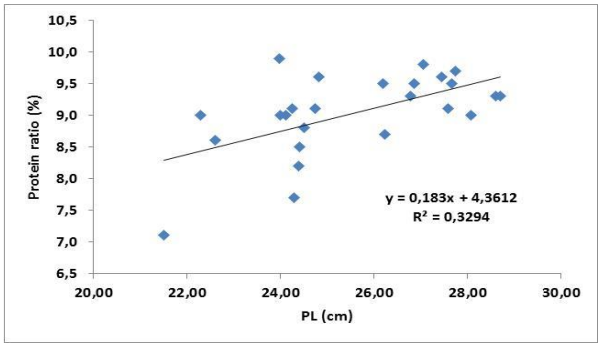
Linear regression was used to determining the association of grain yield, quality and physiological parameters. Flag leaf had a positive effect on spike weight (R^2=0.431) and kernel number per spike (R^2=0.511). Increasing in peduncle length of barley genotypes positively affected protein ratio (R^2=0.329) and 1000-kernel weight (R^2=0.305). Normalized difference vegetative index (NDVI) had a positive effect on grain yield (R^2=0.357) and test weight (R^2=0.465). The higher canopy temperature especially under drought stress conditions negatively affected yield and yield components. In the present study canopy temperature negatively affected and reduced 1000-kernel weight (R^2=0.352) and test weight (R^2=0.402) in genotypes (Figure 1).



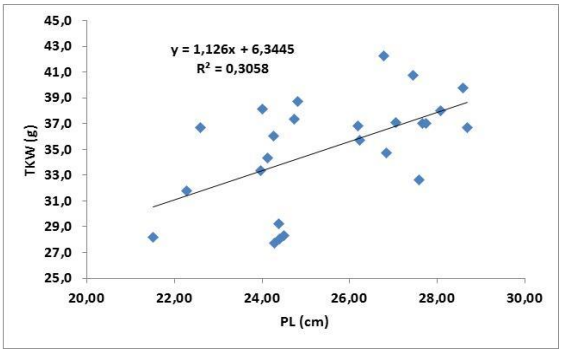
1a. Flag leaf area and spike weight



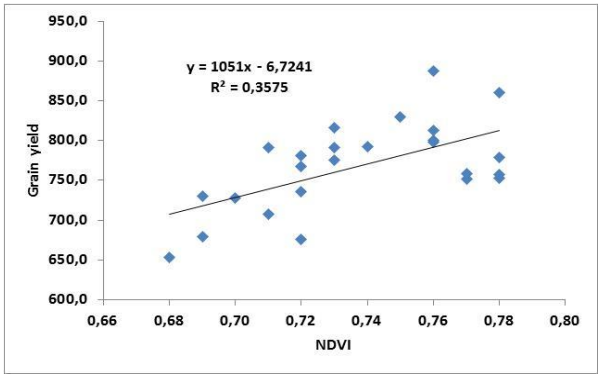
1b. Flag leaf area and kernel number per spike



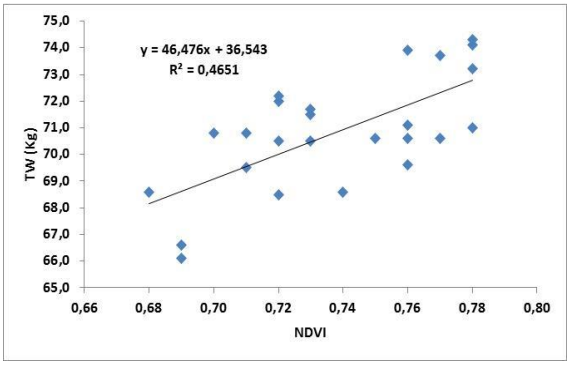
1c. Peduncle length and protein ratio



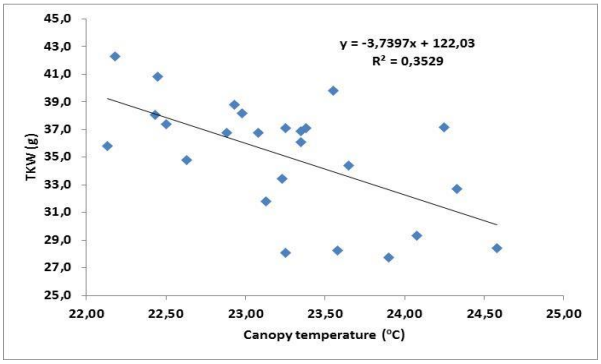
1d. Peduncle length and TKW



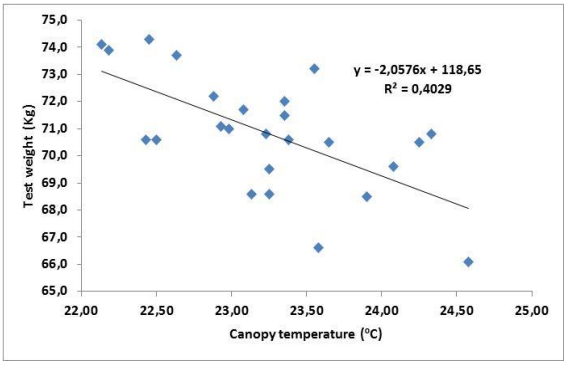
1e. NDVI and grain yield



1f. NDVI and TW



1g. Canopy temperature and TKW



1h. Canopy temperature and test weight

Figure 1. The comparison of some characters investigated in this research

Correlation among different traits is generally due to the presence of the linkage effect of different genes. Environment plays an important role in the development of phenotypic correlation (Ali et al., 2009). Correlation coefficients based on the investigated parameters were determined by Pearson's correlation analysis (Table 4 and 5). Grain yield was positively slightly correlated with spike weight, kernel number per spike, biomass (Z55), 1000-kernel weight, test weight, and grain uniformity but no correlated with flag leaf area. There was a significant positive relation with spike weight and flag leaf area (r=0.657**), spike length (r=0.473*) and kernel number per spike (r=0.834**). Flag leaf area positively significantly correlated with kernel number per spike (r=0.715**), and slightly positively correlated with spike length. It was found significant positive correlation between peduncle length with plant height (r=0.672**), NDVI (at Z55) (r=0.529**), 1000-kernel weight (r=0.553**), test weight(r=0.510**), protein ratio (r=0.574**), and grain uniformity (r=0.430*). It was found a highly significant negative correlation between kernel number per spike with the number of spike per square meter spike (r=-0.606**), 1000-kernel weight (r=-0.666**), and protein ratio (r=-0.598**).

Table 4. Correlation coefficients among yield component and agronomic characters

Parameter	GY	SW	FLA	PL	SL	KNS	SNM
SW	0.395						
FLA	0.063	0.657**					
PL	0.101	0.158	-0.087				
SL	-0.130	0.473*	0.368	-0.020			
KNS	0.234	0.834**	0.715**	-0.182	0.345		
SNM	0.183	-0.262	-0.376	0.257	0.100	-0.606**	
DH	0.140	0.107	-0.051	0.124	0.177	-0.289	0.426*
PH	-0.066	-0.018	-0.107	0.672**	0.082	-0.386	0.373
SPAD	-0.125	-0.045	-0.150	0.015	0.212	0.052	-0.098
NDVI	0.598	0.208	0.005	0.529**	-0.067	-0.143	0.477*
CT	-0.187	0.162	0.320	-0.177	0.057	0.438*	-0.385
TKW	0.296	-0.252	-0.472*	0.553**	-0.232	-0.666**	0.628**
TW	0.229	-0.116	-0.126	0.510**	-0.081	-0.391	0.300
PRT	0.027	-0.248	-0.286	0.574**	-0.019	-0.598**	0.618**
GU	0.357	-0.155	-0.361	0.430*	-0.473*	-0.390	0.272

Significance at *: P<0.05; **: P<0.01; GY: Grain yield (kg ha^{-1}), SW: Spike weight (g), FLA: Flag leaf area (cm^2), PL: Peduncle length (cm), SL: Spike length (cm), KNS: Kernel number per spike, SNM: Spike number per square meter,

The correlation coefficient among quality parameters showed that there was a positive and significant relationship with 1000-kernel weight and test weight (r=0.737**), protein ratio (r=0.682**) and grain uniformity (r=0.784**). Test weight was significantly positively correlated with grain uniformity (r=0.577**), and protein ratio (r=0.506*) (Table 5).

Table 5. Correlation coefficients among physiological parameters and quality characters

Parameters	DH	PH	SPAD	NDVI	CT	TKW	TW	PRT
PH	0.307							
SPAD	-0.350	-0.198						
NDVI	0.373	0.482*	-0.351					
CT	-0.245	-0.447*	0.197	-0.538**				
TKW	0.612**	0.567**	-0.219	0.668**	-0.594**			
TW	0.394	0.606**	-0.201	0.682**	-0.635**	0.737**		
PRT	0.470*	0.575**	-0.041	0.302	-0.228	0.682**	0.506*	
GU	0.469*	0.215	-0.249	0.628**	-0.400*	0.784**	0.577**	0.385

Significance at *: P<0.05; **: P<0.01; DH: days of heading, PH: Plant height (cm), SPAD: Chlorophyll content, NDVI: Normalized difference vegetative index, CT: Canopy temperature (^{o}C), TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%)

Biomass (NDVI) at the Z55 growth stage had a positive direct effect on grain yield, spike weight, peduncle length, spike number per square meter, 1000-kernel weight, test weight, protein ratio and grain uniformity. A negative correlation was observed between canopy temperature with grain yield, spike number per square meter, plant height, NDVI at Z55, 1000-kernel weight, test weight, protein ratio and grain uniformity. Therefore, NDVI and canopy temperature would be important selection criteria for improved grain yield and yield components in the breeding material studied. The results revealed that spike number per square meter was positively and significantly correlated with 1000-kernel weight, protein ratio, days of heading, and NDVI at the Z55 growth stage. Plant height had a positive correlation with 1000-kernel weight, test weight and protein ratio.

4. CONCLUSION

The results of variance analysis revealed significant differences among genotypes for all traits except NDVI and protein ratio. Because of various environmental effects, there were significant differences among genotypes based on grain yield. There was a very highly significant variation in thousand grains weight of barley genotypes based on their spike types and other genotypic traits. Yield components such as spike weight, kernel number per spike had a positive effect on grain yield so grain yield was positively slightly correlated with spike weight, kernel number per spike, NDVI, 1000-kernel weight, test weight, and grain uniformity but no correlated with flag leaf area. There was a significant positive relation with spike weight and flag leaf area, spike length and kernel number per spike. Flag leaf area had a positive effect on spike weight, spike length and kernel number per spike. Normalized differences vegetation index had a positive direct effect on grain yield, spike weight, peduncle length, spike number per square meter, 1000-kernel weight, test weight, protein ratio and grain uniformity. A negative correlation was observed between canopy temperature with grain yield, spike number per square meter, plant height, NDVI, 1000-kernel weight, test weight, protein ratio and grain uniformity. Therefore, physiological parameters such as chlorophyll content, canopy temperature and normalized differences vegetation index (NDVI) could be used in selection in barley breeding program for yield potential under rainfed conditions.

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