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# PLASTICITY IN BEHAVIOR OF TURKISH MALTING BARLEY CULTIVARS UNDER SEMI-ARID AND CONTINENTAL CLIMATIC CONDITIONS

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## ABSTRACT

This study aimed to select stable cultivars in terms of desired agronomic or quality criteria from among 15 two rowed barley cultivars that may remain stable in varying year conditions during 2014-2015 and 2015-2016. Furthermore, relationships among these traits were investigated. Some agronomical and quality traits of barley were affected by years and cultivars. Yield, yield components and some quality parameters were affected by the cultivars. Also, days to ripening was affected by years, cultivars, and year × cultivar interaction. Crude protein content (CPC) was significantly positive correlated with ASH during both seasons. Starch ratio (SR) showed significantly negative correlations with ASH and CPC during both seasons. ADF and NDF had significant positive strong correlation with one another and ASH during both years while they showed significant negative correlations with SR. The results show that technological properties are not affected by the interaction of cultivar × year; therefore, these stable cultivars can be readily used in malt or feed technology if their technological features are considered. For example, cv. Ünver contained low ratios of ash, CPC, oil, soluble fiber and high SR in the malt industry; cv. Hasat which includes the opposite technological properties of cv. Ünver, was found be suitable for use in feed technology.

**KEYWORDS:**
Feed, malting barley, quality traits, yield, yield components

## INTRODUCTION

Barley is an old crop that has been cultivated from *H. vulgare ssp. spontaneum* in the Fertile Crescent of the Middle East for more than 10000 years ago [1]. The barley is generally used for malting and as animal feed. It has fourth place after corn (1.1 billion tons), wheat (749.5 million tons) and rice (741 million tons) with the production of 141.2 million tons in world trade. Barley is grown over an area of 46.9 million ha with grain yield of 3011 kg $ha^{-1}$ [2]. Barley is used as a food stuff in many parts of the World including the Middle East, North Africa, Northern and Eastern Europe, and Asia since long time ago. Now, two-thirds of the barley produced in the world is used in feed and one-third is used for brewing and malting; rest of the barley is used as human food [3]. Considering the health benefits of barley, its direct use in foods is comparatively low. It is helpful source of β-glucans for reduction of blood cholesterol [4]. It also has low glycemic index [5] with substantial amounts of antioxidant tocopherols and tocotrienols [6]. Technologic and nutritive performance of the β-glucans of barley increase further due to rheological characteristics of barley. Thus, they are consumed by mixing with other cereals to make bread, muffins, pasta, noodles, salad sauces, beverages, soups, reduced-fat dairy and meat products [7]. Apart from these, the protein contents are as higher as in animal meat. Bertholdsson [8] has reported that most of malting markets require near 11.5 percent of protein in barley grain. On the other hand, protein concentration of the barley grain may occasionally exceed these limit in malting barley due to the favorable nitrogen [9], drought [10], and high temperature together with water stress [11].

Yield and yield components are very important selection criteria in barley. Throughout the world, shrinkage of cultivation areas and rapid population growth have been the primary goal for improving grain yield of cereal crops including barley in breeding programs [12] for stable yield increases in barley [13]. Considerable evoloutions in various physiological characteristics were observed in terms of grain yield for genetic gain in the last century [14]. There is need to breed high-yielding cultivars for more grains per unit area [15]. It has been reported that the increase in the number of grain in the unit area is due to the rise of spike numbers per square meter and the grain numbers per spike and not due to clear improvement in the weight of one thousand barley grains [16]. Therefore there is need to gain more information about correlation between genetic gains in grain yield and agronomical traits like heading date, spike length, plant height, hectoliter weight, and thousand grain weight [17]. Baumer et al. [18] has pronounced the advantages of the semi-dwarf barley cultivars to obtain high yield and quality. Kleinknecht et al. [19] has reported effects of the influences of the genotypic and cultivar × environment interactions on variations in the agronomic traits of barley, and has emphasised the importance of optimization of field and laboratory assays. In a study, grain yield and other agronomical traits were significantly affected by cultivars, years, and cultivar × year interactions [17]. Again, Madic et al. [20] found cultivar × year interactions for plant height and grain yield and observed effects of year changes in years on the number of spikes per square meter and grain numbers per spike. These days greenhouse effects are source great variations on climate change is with adverse effects on cereals including barley grain yields [21]. Therefore, breeding of barley cultivars showing stable behaviour in face of greenhouse effects based adverse year conditions is desired.

The study aimed to quantify the behaviour of some agronomically important traits like grain yield and effective components on the grain yield of two-rowed winter barley cultivars under the semi-arid and continental climatic conditions of Gumushane Province of the Eastern Black Sea Region in Turkey.

## MATERIALS AND METHODS

**Characteristics of the Trial Soils.** Research was conducted at the farmers field of Siran county of the Gumushane province of Turkey, during 2014-2015 and 2015-2016 (at the Latitudes of 40° 11′ N, the Longitudes of 41° 85′ E, and the altitude of 1409 m asl). In the first season (2014-2015), soil was slightly alkaline (pH 7.77) and clay loamy. It was also medium lime (12.43 % $CaCO_3$), mild salty (0.18 %), poor for phosphorus (41.8 kg $P_2O_5$ $ha^{-1}$), rich for favorable potassium (1323 kg $K_2O$ $ha^{-1}$), and fine for organic matter (3.32 %). In the second season (2015-2016), soil was clayey, mild alkaline (pH 7.61), mild limy (3.33 % $CaCO_3$), medium salty (0.37 %), medium for phosphorus (80.8 kg $P_2O_5$ $ha^{-1}$), with sufficient amount of potassium (1266 kg $K_2O$ $ha^{-1}$), and poor organic matter (1.68 %) (Table 1).

**Climatic Conditions of the Trial Sites.** The climatic data of the trial sites were obtained from the Turkey General Directorate of Meteorology, Gümüşhane Meteorology Regional Directorate. The long term average (1950 to 2016) and 2014 to 2016 meteorological data or Siran county of Gümüşhane Province is given in Table 2. The table, showed that the annual total precipitation in the first year (2014-2015) and 2$^{nd}$ year (2015-2016) was 419.8 mm and 429.1 mm in the same order. The precipitation values of the second season between April and July, which corresponded to the period of stem elongation to grain filling, were higher compared to these values in the first year. Growth seasons' temperature means were close to each other, relative moisture values of the second season were lower than the first year values.

**Plant Materials.** Fifteen (15) two rowed Turkish barley cultivars were used as material in the research. The names, release years, and origins of these cultivars are given in the Table 3.

**TABLE 1**
**Physical and chemical properties of the trial soils.***

| Years | Saturation (%) | Total salt (%) | pH | $CaCO_3$ (%) | $P_2O_5$ (kg $ha^{-1}$) | $K_2O$ (kg $ha^{-1}$) | Organic matter (%) |
|---|---|---|---|---|---|---|---|
| **2014-2015** | 57.0 | 0.18 | 7.77 | 12.43 | 4.18 | 132.3 | 3.32 |
| **2015-2016** | 73.0 | 0.37 | 7.61 | 3.33 | 8.08 | 126.6 | 1.68 |

*Soil analysis was performed at the Laboratories of Soil Science Department, Kahramanmaras Sutcu Imam University Turkey.

**TABLE 2**
**The climate values for long term (1950 to 2016) average and 2014 to 2016 in Gumushane Province***

| Months | Average temperatures (°C) | | | Total precipitation (mm) | | | Relative humidity (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2014-2015 | 2015-2016 | Long term | 2014-2015 | 2015-2016 | Long term | 2014-2015 | 2015-2016 | Long term |
| October | 14.4 | 14.2 | 13.8 | 61.4 | 45.2 | 34.3 | 64.6 | 55.8 | 54.0 |
| November | 7.2 | 7.6 | 7.0 | 51.6 | 42.3 | 45.2 | 64.5 | 52.4 | 48.7 |
| December | 6.2 | -0.6 | -1.3 | 14.2 | 408 | 45.7 | 63.0 | 64.9 | 66.3 |
| January | 0.8 | -0.8 | 0.0 | 55.5 | 36.6 | 47.8 | 62.0 | 61.6 | 59.9 |
| February | 3.3 | 5.7 | 4.6 | 34.4 | 32.8 | 33.4 | 59.5 | 52.4 | 54.3 |
| March | 7.3 | 7.3 | 7.3 | 67.4 | 43.8 | 64.2 | 55.9 | 50.9 | 50.6 |
| April | 9.6 | 14.1 | 12.0 | 46.8 | 60.4 | 47.2 | 57.4 | 40.1 | 44.6 |
| May | 15.9 | 16.3 | 16.0 | 45.3 | 68.0 | 95.8 | 55.1 | 50.7 | 50.2 |
| June | 20.5 | 20.7 | 20.5 | 40.4 | 46.8 | 69.1 | 60.6 | 50.7 | 51.5 |
| July | 24.5 | 23.7 | 24.1 | 2.8 | 12.4 | 5.8 | 48.8 | 43.8 | 41.4 |
| Total/Mean | 10.97 | 10.82 | 10.40 | 419.8 | 429.1 | 488.5 | 59.14 | 52.33 | 52.15 |

*Meteorological data was obtained from the Regional Directorate of Meteorology at Gumushane, Turkey.

**TABLE 3**
**The names, release years, and origins of the cultivars in the research.**

| Cultivar | Release Year | Origin |
|---|---|---|
| Larende | 2006 | Bahri Dagdas International Agricultural Research Institute (Konya) |
| Beyşehir-98 | 1998 | Bahri Dagdas International Agricultural Research Institute (Konya) |
| Konevi-98 | 1998 | Bahri Dagdas International Agricultural Research Institute (Konya) |
| Karatay-94 | 1996 | Bahri Dagdas International Agricultural Research Institute (Konya) |
| Fahrettinbey | 2004 | Blacksea Agricultural Research Institute (Samsun) |
| Bolayır | 2007 | Trakya Agricultural Research Institute (Edirne) |
| Sladoran | 1998 | Trakya Agricultural Research Institute (Edirne) |
| Harman | 2011 | Trakya Agricultural Research Institute (Edirne) |
| Hasat | 2014 | Trakya Agricultural Research Institute (Edirne) |
| İnce-04 | 2004 | Transitional Zone Agricultural Research Institute (Eskişehir) |
| Çıldır-02 | 2002 | Transitional Zone Agricultural Research Institute (Eskişehir) |
| Kalaycı-97 | 1997 | Transitional Zone Agricultural Research Institute (Eskişehir) |
| Bilgi-91 | 1991 | Transitional Zone Agricultural Research Institute (Eskişehir) |
| Özdemir-2005 | 2005 | Transitional Zone Agricultural Research Institute (Eskişehir) |
| Ünver | 2013 | Transitional Zone Agricultural Research Institute (Eskişehir) |

**Field Experimental Setup and Studied Traits.** This research was conducted using randomized block design with three replications. The first sowing was carried out on 22.10.2014 and the second sowing was done on 04.11.2015 using seed sowing machine using 500 seeds $m^{-2}$, the plot dimensions consisted of 5 m × 1.2 m, and the space between plots was 35 cm. In the trials, nitrogen and phosphorus was applied at the rate of 100 and 60 kg/ha respectively; such that whole of the phosphorus and the half of the nitrogen were applied at the time of sowing. Rest of the nitrogen was applied at the sapling stage. The weeds were removed by hand or by hoeing without use of any herbicides. Each plot consisted of an area of $4m^2$ and an area 0.5 m was left before first and last rows in each plot. The harvesting was done with sickle on 13.07.2015 for the first year and on 16.07.2016 for the second year.

Measurement of agronomic parameters like days to heading (d), days to ripening (d), plant height (cm), spike number per $m^2$, spike length (cm), grains number per spike, spike yield (g), harvest index (%), grain yield (kg $ha^{-1}$), thousand grains weight (g), and test weight (kg $hl^{-1}$) were made following [22]. Other quality parameters like dry matter (%), ash content (%), crude protein content (%), starch ratio (%), ADF (acid detergent fiber, %), NDF (neutral detergent fiber, %), and FAT (oil content, %) were detected by NIT System Infratec 1241 Grain Analyzer (Foss, Hillerod, Denmark).

**Statistical Evaluations.** The variance analysis of the data obtained from the study was made using the statistical package program JMP 7.0.2 according to the randomized block design with the combined years. The significance level of differences in variation sources was examined by F test with this program. The statistical significance of the differences between the means was determined according to the LSD test. Correlations between the characters were also determined using the same statistical software.

## RESULTS AND DISCUSSION

Year combined variance analysis results and mean values for days to heading (DH), days to ripening (DR) and plant height (PH) are given in Table 4. The table, shows significant ($p$<0.01) differences among cultivars and differences ($p$<0.01) between years with no interaction between years and cultivars for days to heading. Days to heading remained 141.7 days during 2015-16 growth season that was 2.2 days longer than 2014-15 growth season with 139.5 days to heading. Whereas, the mean days to head for all cultivars remained 140.6 days. The days to heading for cultivars ranged 137.4 to 143 days. Cultivars Bolayır (137.4 days) and Hasat (137.7 days) showed the minimum DH values while Çıldır-02 showed a maximum value (143.0 days) for days to head. The results are in confirmation to the Rahal-Bouziane et al [23], who reported that DH showed significant variations for cultivars in their both years of growth and among cultivars. This study also confirms that each cultivar behaved variably irrespective of the effect of year and showed significant differences among them for DH. DH showed positive significant correlations at two growth seasons with DR, PH, GN (grain number per spike), SY (spike yield), and GY (grain yield), while it was significantly positive correlated with SL (spike length), TGW (thousand grain weight), and SR (starch ratio) during the first season only. This shows plasticity in behaviour of cultivars as affected by the climatic changes. DH was found to have negative significant correlation with ASH (ash content) during the first season (Table 10). Janfrozzadh and Fard [24] found similar correlations with DH that was positively significantly correlated with DR, GY, GN, and PH. Rahal-Bouziane et al. [23] showed that positive significant correlations of DH with PH, SL, TGW, and DR similarly to our study. On the other hand, they reported the negative significant correlation between DH and GN.

**TABLE 4**
**Effects of sowing years (2014-2015 and 2015-2016) on the days to heading, days to ripening and plant height of 15 Turkish barley cultivars cultivars.**

| Cultivars | Days to heading (days) | | | Days to ripening (days) | | | Plant height (cm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2014-2015 | 2015-2016 | Mean | 2014-2015 | 2015-2016 | Mean | 2014-2015 | 2015-2016 | Mean |
| Larende | 141.3 | 144.0 | 142.7 ab[§] | 186.0 g-k | 196.5 a | 191.3 a | 103.80 | 107.30 | 105.55 bcd |
| Beyşehir-98 | 140.7 | 144.3 | 142.5 ab | 185.7 g-k | 194.0 abc | 189.8 abc | 106.13 | 111.50 | 108.82 b |
| Konevi-98 | 140.0 | 145.0 | 142.5 ab | 185.0 i-l | 195.7 ab | 190.3 ab | 100.33 | 105.87 | 103.10 de |
| Karatay-94 | 140.7 | 142.0 | 141.3 abc | 185.7 g-k | 192.0 cde | 188.8 b-e | 111.53 | 114.97 | 113.25 a |
| Fahrettinbey | 140.7 | 140.3 | 140.5 cde | 185.7 g-k | 189.0 efg | 187.3 def | 99.73 | 107.23 | 103.48 cde |
| Bolayır | 136.3 | 138.5 | 137.4 f | 181.3 m | 185.3 h-k | 183.3 h | 90.00 | 96.00 | 93.00 g |
| Sladoran | 138.3 | 139.0 | 138.7 ef | 183.3 klm | 185.7 g-k | 184.5 gh | 93.00 | 92.07 | 92.54 g |
| Harman | 138.0 | 140.3 | 139.2 def | 183.0 klm | 189.7 def | 186.3 fg | 100.20 | 102.70 | 101.45 ef |
| Hasat | 136.7 | 138.7 | 137.7 f | 181.7 lm | 187.3 f-j | 184.5 gh | 96.93 | 100.53 | 98.73 f |
| İnce-04 | 140.0 | 141.7 | 140.8 bcd | 185.0 i-l | 190.0 def | 187.5 c-f | 103.33 | 104.33 | 103.83 cde |
| Çıldır-02 | 141.0 | 145.0 | 143.0 a | 186.0 g-k | 193.0 bcd | 189.5 a-d | 105.40 | 107.60 | 106.50 bc |
| Kalaycı-97 | 139.7 | 143.7 | 141.7 abc | 184.7 j-m | 190.3 def | 187.5 c-f | 106.00 | 106.27 | 106.14 bcd |
| Bilgi-91 | 138.0 | 140.3 | 139.2 def | 183.0 klm | 188.7 e-h | 185.8 fg | 100.93 | 102.60 | 101.77 ef |
| Özdemir-2005 | 140.7 | 142.7 | 141.7 abc | 185.7 g-k | 192.0 cde | 188.8 b-e | 103.13 | 104.10 | 103.62 cde |
| Ünver | 140.0 | 140.7 | 140.3 cde | 185.0 i-l | 188.3 f-i | 186.7 efg | 103.67 | 105.13 | 104.40 cde |
| Mean | 139.5 b | 141.7 a | 140.6 | 184.5 b | 190.5 a | 187.5 | 101.61 b | 104.55 a | 103.08 |
| CV (%) | | 1.15 | | | 1.09 | | | 2.84 | |

| | F value | $LSD_{0.05}$ | F value | $LSD_{0.05}$ | F value | $LSD_{0.05}$ |
|---|---|---|---|---|---|---|
| Year (Y) | 47.272** | 0.919 | 87.847** | 1.794 | 7.856* | 2.909 |
| Cultivar (C) | 7.764** | 1.859 | 7.672** | 2.372 | 20.095** | 3.387 |
| Y × C | 1.198 | NS | 2.091* | 3.355 | 0.975 | NS |

[§] The same letters in a single column are not statistically different using LSD test at 0.05 level of significance.
*, ** significant at probability levels of 0.05 and 0.01, respectively; CV, coefficient of variation; LSD, least significance difference; NS, non significant.

Days to ripening (DR) showed significant ($p<0.05$) interaction between years and cultivars. Days to ripening also showed significant differences among cultivars ($p<0.01$) and between years ($p<0.01$) in terms of days to ripening (Table 4). Accordingly, the second year (190.5 days) DR values were six days longer than the first year (184.5 days). The cultivars showed a range of 183.3 - 191.3 days in terms of DR. The minimum ripening periods was observed for cv. Bolayır (183.3 d), Sladoran (184.5 d), and Hasat (184.5 d). Whereas, the maximum DR were taken by the cv. Larende (191.3 d) and Konevi-98 (190.3 d). When the Y×G interactions were taken it was found that cv. Fahrettinbey, Sladoran and Ünver were in the same group during both growing years (2014-15 and 2015-16) and therefore these cultivars were not affected by year effects. Whereas, the other cultivarscultivars appeared in different groups during two years; so, these cultivars are differently affected by the year. DR was significantly positive correlated with PH, SY, and GY during two years, while it showed significant positive correlation with SL, GN, TGW and SR during the first year (Table 10). Janfrozzadh and Fard [24] observed positive correlations of DR with DH, GY, PH, and GN in agreement to this study. Contrarily, a significant negative correlation was noted between DR and ASH during the first year (Table 10). Rahal-Bouziane et al. [23] reported a positive significant correlation between DR and DH, PH, SL, TGW, and negative significant correlation with GN.

Years and cultivars showed no interaction in terms of plant height PH (Table 4). However, significant differences were noted among cultivars ($p<0.01$) and between years ($p<0.05$) in terms of plant height (Table 4). Thus, mean PH value in 2015-16 year (104.55 cm) was longer than 2014-15 year (101.61 cm). Cultivars showed changes between 92.54 cm (cv. Sladoran) - 113.25 cm (cv. Karatay-94) in plant height. Madic et al. [20] reported that plant height was affected by the year conditions (years) and the interaction of cultivar × year in contradiction to this study that shows a non significant interaction for this trait. Mirosavljevic et al. [25] stressed the effects of cultivars and years on the plant height that ranged 97.4 - 105.0 cm for 19 winter malting barley cultivars. PH was significantly positive correlated with SY and TGW during both growth years. It showed significant positive correlation with SR during the first year. PH was significantly positive correlated with SL and GN during the second year. There was a significant negative correlation between PH and ASH (Table 10). Rahal-Bouziane et al. [23] has reported a positive significant correlation of PH with DH, DR, TGW, and SL and negative significant correlation with GN. Similarly, Janfrozzadh and Fard [24] showed positive significant correlations between PH and GY, GN, DH, DR.

Significant differences ($p<0.01$) were noted among cultivars for induction of number of spikes per $m^2$ (SN) (Table 5). The minimum SN were noted in cv. Bolayır (367.5) eventhough the maximum SN were noted in cv. Larende (568.6). No significant differences were noted between years for SN with value of year (488.9 d and 481.4 d during the first and second years respectively. Madic et al. [20] reported that SN was affected by the years, but not affected by the cultivars and cultivar × year interaction. SN showed significant positive correlations with GN, SY, HI (harvest index), GY, and TGW during both growth years in our study (Table 10). Laidig et al. [26] found that SN was negatively significant correlated with GN, TW, and crude protein contents.

**TABLE 5**
**Effects of sowing years (2014-2015 and 2015-2016) on the spike number per m$^2$, spike length and grains number per spike of 15 Turkish barley cultivars.**

| Cultivars | Spike number per m$^2$ | | | Spike length (cm) | | | Grains number per spike | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2014-2015 | 2015-2016 | Mean | 2014-2015 | 2015-2016 | Mean | 2014-2015 | 2015-2016 | Mean |
| Larende | 572.0 | 565.1 | 568.6 a | 7.98 | 8.32 | 8.15 ab | 20.89 | 20.80 | 20.85 c-f |
| Beyşehir-98 | 487.6 | 493.7 | 490.7 ef | 7.40 | 7.04 | 7.22 def | 21.83 | 22.17 | 22.00 bc |
| Konevi-98 | 512.8 | 529.8 | 521.3 cd | 7.58 | 7.24 | 7.41 def | 22.06 | 22.39 | 22.23 b |
| Karatay-94 | 412.2 | 416.5 | 414.4 hi | 7.94 | 8.21 | 8.08 abc | 21.33 | 22.08 | 21.71 bcd |
| Fahrettinbey | 470.2 | 472.5 | 471.4 f | 7.68 | 8.52 | 8.10 abc | 20.19 | 20.12 | 20.16 f |
| Bolayır | 363.6 | 371.5 | 367.5 j | 6.18 | 6.82 | 6.50 gh | 17.83 | 18.06 | 17.95 g |
| Sladoran | 495.7 | 502.0 | 498.8 de | 5.90 | 6.15 | 6.03 h | 20.22 | 19.62 | 19.92 f |
| Harman | 425.0 | 449.5 | 437.2 gh | 5.71 | 6.28 | 6.00 h | 19.66 | 19.93 | 19.80 f |
| Hasat | 546.4 | 530.2 | 538.3 bc | 7.39 | 7.99 | 7.69 bcd | 20.17 | 20.52 | 20.35 f |
| İnce-04 | 490.7 | 502.8 | 496.8 e | 8.31 | 8.38 | 8.35 a | 21.83 | 21.47 | 21.65 b-e |
| Çıldır-02 | 499.7 | 514.4 | 507.0 de | 8.13 | 8.08 | 8.11 abc | 20.89 | 20.43 | 20.66 def |
| Kalaycı-97 | 560.4 | 549.9 | 555.2 ab | 5.94 | 5.80 | 5.87 h | 19.69 | 20.55 | 20.12 f |
| Bilgi-91 | 416.8 | 462.9 | 439.9 g | 6.67 | 7.23 | 6.95 efg | 18.45 | 18.34 | 18.40 g |
| Özdemir-2005 | 405.8 | 416.0 | 410.9 i | 6.64 | 6.92 | 6.78 fg | 20.11 | 20.81 | 20.46 ef |
| Ünver | 561.8 | 556.2 | 559.0 ab | 7.58 | 7.45 | 7.52 cde | 24.00 | 24.61 | 24.31 a |
| **Mean** | 481.4 | 488.9 | 485.1 | 7.14 b | 7.36 a | 7.25 | 20.61 | 20.79 | 20.70 |
| **CV (%)** | **4.37** | | | **7.59** | | | **4.98** | | |

| | F value | $LSD_{0.05}$ | F value | $LSD_{0.05}$ | F value | $LSD_{0.05}$ |
|---|---|---|---|---|---|---|
| **Year (Y)** | 1.744 | NS | 13.115* | 0.173 | 0.170 | NS |
| **Cultivar (C)** | 48.762** | 24.527 | 14.783** | 0.632 | 13.696** | 1.194 |
| **Y × C** | 0.774 | NS | 0.703 | NS | 0.287 | NS |

§ The same letters in a single column are not statistically different using LSD test at 0.05 level of significance.
*, ** significant at probability levels of 0.05 and 0.01, respectively; CV, coefficient of variation; LSD, least significance difference; NS, non significant.

**TABLE 6**
**Effects of sowing years (2014-2015 and 2015-2016) on spike yield, harvest index and grain yield of 15 Turkish barley cultivars.**

| Cultivars | Spike yield (g) | | | Harvest index (%) | | | Grain yield (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2014-2015 | 2015-2016 | Mean | 2014-2015 | 2015-2016 | Mean | 2014-2015 | 2015-2016 | Mean |
| Larende | 1.31 | 1.32 | 1.32 bcd | 36.67 | 38.17 | 37.42 ab | 6298 | 6447 | 6372 b |
| Beyşehir-98 | 1.38 | 1.42 | 1.40 ab | 34.67 | 35.17 | 34.92 de | 6046 | 6043 | 6044 cd |
| Konevi-98 | 1.21 | 1.24 | 1.23 cde | 35.00 | 35.17 | 35.09 cde | 5763 | 5895 | 5829 de |
| Karatay-94 | 1.33 | 1.36 | 1.35 bc | 33.67 | 34.83 | 34.25 de | 4845 | 4963 | 4904 gh |
| Fahrettinbey | 0.96 | 0.99 | 0.98 gh | 35.33 | 38.67 | 37.00 ab | 5051 | 5257 | 5154 g |
| Bolayır | 0.73 | 0.79 | 0.76 i | 30.00 | 33.67 | 31.84 f | 4194 | 4076 | 4135 i |
| Sladoran | 0.99 | 1.02 | 1.01 g | 36.00 | 38.67 | 37.34 ab | 5540 | 5556 | 5548 f |
| Harman | 1.03 | 0.95 | 0.99 g | 33.33 | 33.83 | 33.58 ef | 4989 | 5054 | 5022 g |
| Hasat | 0.96 | 0.98 | 0.97 gh | 36.67 | 37.17 | 36.92 abc | 6011 | 6000 | 6006 cd |
| İnce-04 | 1.26 | 1.16 | 1.21 de | 38.33 | 38.50 | 38.42 a | 5565 | 5520 | 5542 f |
| Çıldır-02 | 1.30 | 1.03 | 1.17 ef | 36.67 | 37.83 | 37.25 ab | 5736 | 5713 | 5725 ef |
| Kalaycı-97 | 1.20 | 1.17 | 1.19 ef | 37.00 | 38.50 | 37.75 ab | 6300 | 6106 | 6203 bc |
| Bilgi-91 | 0.83 | 0.87 | 0.85 hi | 34.33 | 35.00 | 34.67 de | 4820 | 4961 | 4890 gh |
| Özdemir-2005 | 1.10 | 1.03 | 1.07 fg | 36.67 | 37.67 | 37.17 ab | 4709 | 4711 | 4710 h |
| Ünver | 1.45 | 1.53 | 1.49 a | 34.67 | 37.33 | 36.00 bcd | 6761 | 6778 | 6769 a |
| **Mean** | 1.14 | 1.12 | 1.13 | 35.27 | 36.68 | 35.97 | 5509 | 5539 | 5524 |
| **CV (%)** | **9.74** | | | **4.56** | | | **4.23** | | |

| | F value | $LSD_{0.05}$ | F value | $LSD_{0.05}$ | F value | $LSD_{0.05}$ |
|---|---|---|---|---|---|---|
| **Year (Y)** | 0.096 | NS | 5.061 | NS | 0.212 | NS |
| **Cultivar (C)** | 21.334** | 0.128 | 7.553** | 1.899 | 55.997** | 270.28 |
| **Y × C** | 0.972 | NS | 0.731 | NS | 0.317 | NS |

§ The same letters in a single column are not statistically different using LSD test at 0.05 level of significance.
*, ** significant at probability levels of 0.05 and 0.01, respectively; CV, coefficient of variation; LSD, least significance difference; NS, non significant.

Statistically significant ($p$<0.05) differences were noted among cultivars for spike length. Significant differences were also noted between years in terms of spike length. No interaction was noted between cultivars and years for this trait (Table 5). SL value of the second year (7.36 cm) was longer compared to the first year's value (7.14 cm). SL values ranged 5.87 to 8.35 cm among the cultivars used in the study. So, the minimum values were noted for the cv. Kalaycı-97 (5.87 cm), Harman (6.00 cm), and Sladoran (6.03 cm) and the the longest SL values were noted for the cultivars İnce (8.35 cm) and Larende (8.15 cm). During the first year, SL was significantly positive correlated with GN and SY while it was significantly negative correlated with CPC (crude protein content) (Table 10). Contrarily, Rahal-Bouziane et al. [23] noted a negative significant correlation between SL and GN. They also observed positive significant relationships of SL with PH, TGW, DH, and DR.

Grain number per spike (GN) showed significant variations among cultivars ($p$<0.01) (Table 5). The highest GN value was noted for cv. Unver (25.32) and the lowest GN values were noted for cv. Bolayır (17.95) and Bilgi-91 (18.40). Contrarily, Madic et al. [20] noted significant effect of the interaction of cultivar × years. At both growth years, GN showed significant positive associations with SY, GY, and TGW (Table 10). Janfrozzadh and Fard [24] found positive correlation between GN and GY and noted negative correlation between GN and TGW. At the first year, GN was significantly positive correlated with HI and SR. It was significantly negative correlated with ASH and CPC (Table 10). The findings in this study showed partial differencess with Laidig et al. [26] who reported that numbers of kernels per spike showed negative significant correlations with TGW. They also emphasized the GN's non-significant relations by test weight (TW), crude protein content (CPC) of kernel, and kernel extract ratio that is an indicator of the starch ratio (SR).

Spike yield (SY), which expresses grains weight per spike, showed statistically differences ($p$<0.01) among the cultivars. No statistical difference was noted between years and no significant interaction was noted between years and cultivars (Table 6). The cv. Ünver (1.49 g) and cv. Beyşehir-98 (1.40 g) had the highest SY; and cv. Bolayır (0.76 g) and cv. Bilgi-91 (0.85 g) had the lowest SY values. SY was significantly positively correlated with GY and TGW during two growth years. It showed significantly positive correlation with HI and SR during the first year. SY showed significantly negative correlations with ASH and CPC (Table 10).

Statistically significant differences ($p$<0.01) were noted among cultivars for Harvest index (HI) and these values ranged 31.84% in cv. Bolayır to 38.42% in cv. İnce-04 (Table 6). HI showed significantly positive correlation with GY during the growth years. It was significantly negative correlated with CPC during first year. It was significantly positively correlated with DM durinthe second year (Table 10).

Statistically significant ($p$<0.05) differences were found among cultivars for grain yield (GY) values (Table 6). Contrarily, Petkovski et al. [27] noted significant interaction between years and year × cultivars. The highest GY was noted from cv. Ünver (6769 kg $ha^{-1}$). The lowest GY was noted from cv. Bolayır (4135 kg $ha^{-1}$) in this study. In the study of Ben Naceur et al. [28], a high variation was observed among barley genotypes with similar precipitation regime, but they obtained lower yield values ranging from 1943 to 4805 kg $ha^{-1}$. In contradiction, Laidig et al. [26] reported low variation for cultivars and cultivar × year. However, they emphasised that all variation sources (cultivars, years, and their interaction) were statistically significant for grain yield. Mirosavljevic et al. [25] also showed strong effects of these variation sources on the grain yield. GY showed significantly positive correlations with DH, DR, SN, GN, SY, TGW, and HI during growth years while it was significantly negative associated with FAT during the second year (Table 10). Janfrozzadh and Fard [24] found positive significant correlations between GY and DH, DR, GN, PH. Also, Laidig et al. [26] found positive significant phenotypic correlations between GY and SN and TGW while GY was significantly and negatively correlated with TW and CPC (crude protein content).

Statistically significant differences were noted among cultivars ($p$<0.01) and between years (p<0.05) for thousand grain weight (TGW). No interaction was noted for the years × cultivars interaction (Table 7). In this way, TGW of the second growth year (2015-16) with 43.80 g was greater than the first year (2014-15) with value of 43.00 g. However, strong Y×G interaction on the TGW has been noted by other researchers [25,29]. The TGW values of the cultivars for mean years ranged 39.77 g - 48.61 g. The highest TGW values were noted from the cv. Ünver (48.61 g) and cv. Larende (47.74 g) while the lowest values were noted from the cv. Harman (39.77 g), İnce-04 (40.78 g), Hasat (40.85 g), and Bolayır (41.02 g). Mirosavljevic et al. [25] noted lower values of 35.8 to 43.5 g. Similar results were noted by [30,29,26]. TGW was significantly positively correlated with PH, SN, GN, SY, and GY during both years while it showed significantly positive correlations with DH and DR during the first year (Table 10). Similar findings related to correlations were noted between TGW and DR, DH, PH, and SL by [23]. Laidig et al. [26] also found positive significant correlation of TGW with GY and SN in similarly to these findings. However, they noted negative significant correlation of TGW with GN, TW and CPC. Some researchers also found negative significant correlations between TGW and GN [24, 26].

**TABLE 7**
**Effects of sowing years (2014-2015 and 2015-2016) on thousand grains weight, test weight and dry matter of 15 Turkish barley cultivars.**

| Cultivars | Thousand grains weight (g) | | | Test weight (kg hl$^{-1}$) | | | Dry matter (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2014-2015 | 2015-2016 | Mean | 2014-2015 | 2015-2016 | Mean | 2014-2015 | 2015-2016 | Mean |
| Larende | 46.93 | 48.55 | 47.74 a | 71.30 | 69.66 | 70.48 abc | 90.03 | 90.14 | 90.09 ab |
| Beyşehir-98 | 44.50 | 45.22 | 44.86 bc | 69.98 | 69.69 | 69.84 cd | 90.00 | 89.89 | 89.95 abc |
| Konevi-98 | 42.83 | 43.86 | 43.35 cd | 70.20 | 70.82 | 70.51 abc | 90.09 | 89.99 | 90.04 ab |
| Karatay-94 | 45.57 | 45.44 | 45.51 b | 70.47 | 70.77 | 70.62 abc | 89.91 | 89.97 | 89.94 abc |
| Fahrettinbey | 41.93 | 43.93 | 42.93 d | 70.56 | 71.33 | 70.95 b | 89.92 | 89.96 | 89.94 abc |
| Bolayır | 40.40 | 41.63 | 41.02 ef | 69.82 | 70.36 | 70.09 a-d | 89.87 | 89.72 | 89.80 c |
| Sladoran | 41.47 | 42.65 | 42.06 de | 69.80 | 70.10 | 69.95 bcd | 89.96 | 89.82 | 89.89 bc |
| Harman | 39.53 | 40.00 | 39.77 f | 70.82 | 71.21 | 71.02 a | 90.03 | 89.73 | 89.88 bc |
| Hasat | 40.67 | 41.02 | 40.85 ef | 69.53 | 70.28 | 69.91 cd | 90.29 | 89.96 | 90.13 a |
| İnce-04 | 41.17 | 40.38 | 40.78 ef | 70.42 | 69.84 | 70.13 a-d | 89.89 | 89.62 | 89.76 c |
| Çıldır-02 | 42.13 | 43.82 | 42.98 d | 69.96 | 70.35 | 70.16 a-d | 89.86 | 90.03 | 89.95 abc |
| Kalaycı-97 | 45.30 | 44.37 | 44.84 bc | 70.54 | 71.28 | 70.91 ab | 90.21 | 89.93 | 90.07 ab |
| Bilgi-91 | 43.10 | 43.48 | 43.29 cd | 69.40 | 69.09 | 69.25 d | 89.98 | 89.80 | 89.89 bc |
| Özdemir-2005 | 42.03 | 42.90 | 42.47 de | 70.15 | 70.53 | 70.34 abc | 89.91 | 90.00 | 89.96 abc |
| Ünver | 47.47 | 49.74 | 48.61 a | 70.85 | 70.94 | 70.90 ab | 89.74 | 89.91 | 89.83 c |
| Mean | 43.00 b | 43.80 a | 43.40 | 70.25 | 70.42 | 70.34 | 89.98 | 89.90 | 89.94 |
| CV (%) | | 3.71 | | | 1.12 | | | 0.21 | |
| | F value | | $LSD_{0.05}$ | F value | | $LSD_{0.05}$ | F value | | $LSD_{0.05}$ |
| Year (Y) | 9.589* | | 0.512 | 0.550 | | NS | 3.329 | | NS |
| Cultivar (C) | 14.961** | | 0.713 | 2.110* | | 0.979 | 2.030* | | 0.212 |
| Y × C | 0.512 | | NS | 0.866 | | NS | 1.340 | | NS |

§ The same letters in a single column are not statistically different using LSD test at 0.05 level of significance.
*, ** significant at probability levels of 0.05 and 0.01, respectively; CV, coefficient of variation; LSD, least significance difference; NS, non significant.

Significantly differences ($p<0.05$) were noted among cultivars for test weight (TW); TW ranged 69.25 to 71.02 kg hl$^{-1}$ among cultivars with cultivars Bilgi-91 and Harman respectively (Table 7). These ranges of cultivars for TW were 68.4 to 72.2 kg hl$^{-1}$ in the study of [31]. Mirosavljevic et al. [25] observed the effects of cultivars, years, and their interaction on the test weight which changed from 73.4 to 76.6 kg hl$^{-1}$ for the barley cultivars. TW showed significantly negative correlation with NDF during second year (Table 10). Campbell et al. [32] presented negative strong correlations of TW with ADF and NDF. They also revealed the positive significant correlation between TW and starch ratio (SR). Laidig et al. [26] found weak negative correlation between TW and GY while they reported the weak negative correlations of TW with SN and TGW. Also, they noted moderate positive correlation between TW and CPC.

Statistically significant differences ($p<0.05$) were noted among cultivars for dry matter (DM). They ranged 89.76% with cv. İnce-04 to 90.13% with cv. Hasat (Table 7). Our data were the range of Campbell et al. [32] who noted a range of 89.31 to 93.97% DM. During both years, DM was significantly positive correlated with ASH and CPC while it was significantly negatively correlated with SR. It showed significantly positive correlation with NDF during the first year (Table 10).

Statistically significant differences ($p<0.01$) were noted among cultivars for ash content (ASH) (Table 8). The lowest ASH value was noted from cv. Ünver (1.825%) and the highest value was noted from the cv. Hasat (2.237%). During both years, ASH was significantly positive correlated with CPC, ADF, and NDF while it was significantly negatively correlated with SR (Table 10).

As seen in the Table 8, all variation sources (years, cultivars, and Y×G interaction) did not show statistically significant differences for crude protein content (CPC). Nonetheless, the CPC values among cultivars ranged 11.76% to 13.44%. Similar results were found by Przulj et al. [30]. Contrarily, Bertholdsson [8], See et al. [33] and Mirosavljevic et al. [25] recommended < 11.5% protein ratio if the cultivars are meant for malting. The findings in this study showed all cultivars had values above the threshold level. Therefore, these cultivars seem suitable for use as forage in terms of protein. Thus, Mirosavljevic et al. [25] found average grain protein content values of 11.3%. Also, the grain ptotein contents (11.9% as average of malting cultivars) of Fox et al. [31] were similar to these researchers who showed lower CPC values. Significantly negative correlation between CPC and SR was found at both years in our study (Table 10). Laidig et al. [26] evaluated the extract content (EC) instead of SR, and so they found negative moderate significant relation between CPC and EC. They also found very strong correlations between CPC and grain yield. Although the CPC did not have a correlations with grain yield in our study, it showed negative significant correlations with some yield components such as spike length, grain numbers per spike, spike yield, and harvest index.

**TABLE 8**
**Effects of sowing years (2014-2015 and 2015-2016) on ash content, crude protein content and starch ratio of 15 Turkish barley cultivars.**

| Cultivars | Ash content (%) | | | Crude protein content (%) | | | Starch ratio (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2014-2015 | 2015-2016 | Mean | 2014-2015 | 2015-2016 | Mean | 2014-2015 | 2015-2016 | Mean |
| Larende | 2.066 | 2.190 | 2.128 ab | 12.54 | 13.24 | 12.89 | 57.93 | 55.45 | 56.69 de |
| Beyşehir-98 | 2.076 | 2.060 | 2.068 bc | 12.36 | 11.99 | 12.18 | 57.38 | 57.62 | 57.50 de |
| Konevi-98 | 1.980 | 2.056 | 2.018 b-e | 11.64 | 12.69 | 12.17 | 57.55 | 58.00 | 57.78 cde |
| Karatay-94 | 2.010 | 2.106 | 2.058 bcd | 12.10 | 12.28 | 12.19 | 58.84 | 57.04 | 57.94 b-e |
| Fahrettinbey | 2.053 | 2.040 | 2.047 b-e | 12.79 | 12.85 | 12.82 | 57.55 | 57.71 | 57.63 cde |
| Bolayır | 2.233 | 2.073 | 2.153 ab | 13.92 | 12.72 | 13.32 | 55.06 | 57.97 | 56.52 e |
| Sladoran | 2.170 | 2.086 | 2.128 ab | 12.81 | 11.60 | 12.21 | 56.35 | 58.47 | 57.41 de |
| Harman | 2.026 | 1.943 | 1.985 cde | 13.12 | 12.62 | 12.87 | 57.80 | 59.61 | 58.71 a-d |
| Hasat | 2.273 | 2.200 | 2.237 a | 13.03 | 12.58 | 12.81 | 53.03 | 54.47 | 53.75 f |
| İnce-04 | 1.900 | 1.940 | 1.920 def | 11.87 | 12.33 | 12.10 | 59.82 | 60.26 | 60.04 ab |
| Çıldır-02 | 1.883 | 1.943 | 1.913 ef | 12.56 | 11.79 | 12.17 | 59.70 | 59.54 | 59.62 abc |
| Kalaycı-97 | 1.983 | 2.056 | 2.020 b-e | 13.54 | 13.33 | 13.44 | 57.60 | 58.09 | 57.85 cde |
| Bilgi-91 | 1.830 | 2.070 | 1.950 c-f | 12.47 | 13.09 | 12.78 | 60.13 | 56.47 | 58.30 b-e |
| Özdemir-2005 | 1.930 | 2.156 | 2.043 b-e | 12.15 | 11.36 | 11.76 | 58.99 | 57.66 | 58.33 b-e |
| Ünver | 1.810 | 1.840 | 1.825 f | 11.74 | 12.15 | 11.95 | 60.73 | 60.64 | 60.69 a |
| Mean | 2.015 | 2.051 | 2.033 | 12.58 | 12.44 | 12.51 | 57.90 | 57.93 | 57.92 |
| CV (%) | 6.05 | | | 7.56 | | | 3.15 | | |
| | F value | | $LSD_{0.05}$ | F value | $LSD_{0.05}$ | | F value | | $LSD_{0.05}$ |
| Year (Y) | 0.029 | | NS | 0.157 | NS | | 0.001 | | NS |
| Cultivar (C) | 5.105** | | 0.138 | 1.736 | NS | | 4.819** | | 2.109 |
| Y × C | 1.223 | | NS | 0.823 | NS | | 1.408 | | NS |

§ The same letters in a single column are not statistically different using LSD test at 0.05 level of significance.
*, ** significant at probability levels of 0.05 and 0.01, respectively; CV, coefficient of variation; LSD, least significance difference; NS, non significant.

**TABLE 9**
**Effects of sowing years (2014-2015 and 2015-2016) on ADF, NDF and FAT of 15 Turkish barley cultivars.**

| Cultivars | ADF (%) | | | NDF (%) | | | FAT (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2014-2015 | 2015-2016 | Mean | 2014-2015 | 2015-2016 | Mean | 2014-2015 | 2015-2016 | Mean |
| Larende | 7.52 | 8.36 | 7.94 ab | 22.50 | 24.53 | 23.52 a | 1.86 | 1.62 | 1.74 ef |
| Beyşehir-98 | 7.63 | 7.94 | 7.79 abc | 22.68 | 23.29 | 22.99 abc | 1.88 | 1.79 | 1.84 cde |
| Konevi-98 | 7.03 | 7.82 | 7.43 b-f | 21.58 | 22.62 | 22.10 c-f | 1.97 | 2.06 | 2.02 a |
| Karatay-94 | 7.12 | 6.80 | 6.96 d-h | 22.11 | 22.58 | 22.35 b-e | 1.77 | 1.87 | 1.82 cde |
| Fahrettinbey | 6.59 | 6.42 | 6.51 gh | 21.03 | 20.63 | 20.83 h | 1.84 | 1.96 | 1.90 abc |
| Bolayır | 6.98 | 7.08 | 7.03 c-g | 22.08 | 21.74 | 21.91 d-g | 1.99 | 2.00 | 2.00 ab |
| Sladoran | 7.05 | 7.91 | 7.48 a-e | 22.01 | 22.61 | 22.31 b-e | 1.62 | 1.73 | 1.67 fg |
| Harman | 6.08 | 6.38 | 6.23 h | 20.86 | 21.33 | 21.10 fgh | 1.61 | 1.57 | 1.59 g |
| Hasat | 8.02 | 8.52 | 8.27 a | 23.00 | 23.56 | 23.28 ab | 1.88 | 1.87 | 1.88 bcd |
| İnce-04 | 7.02 | 6.29 | 6.66 fgh | 21.70 | 20.99 | 21.35 e-h | 1.85 | 1.75 | 1.80 c-f |
| Çıldır-02 | 6.85 | 7.58 | 7.22 b-g | 21.75 | 22.69 | 22.22 cde | 1.76 | 1.76 | 1.76 def |
| Kalaycı-97 | 6.54 | 6.89 | 6.71 e-h | 22.00 | 22.47 | 22.24 cde | 1.84 | 1.80 | 1.82 cde |
| Bilgi-91 | 5.98 | 7.33 | 6.66 f-h | 20.87 | 22.81 | 21.84 d-h | 1.88 | 1.85 | 1.87 b-e |
| Özdemir-2005 | 7.10 | 8.14 | 7.62 a-d | 21.90 | 23.47 | 22.69 a-d | 1.78 | 1.96 | 1.87 b-e |
| Ünver | 6.36 | 6.94 | 6.65 fgh | 20.53 | 21.28 | 20.91 gh | 1.78 | 1.81 | 1.79 c-f |
| Mean | 6.92 b | 7.36 a | 7.14 | 21.77 b | 22.44 a | 22.11 | 1.82 | 1.83 | 1.82 |
| CV (%) | 9.65 | | | 3.99 | | | 6.55 | | |
| | F value | $LSD_{0.05}$ | | F value | | $LSD_{0.05}$ | F value | | $LSD_{0.05}$ |
| Year (Y) | 13.811* | 0.325 | | 20.006* | | 0.414 | 0.029 | | NS |
| Cultivar (C) | 4.451** | 0.797 | | 5.188** | | 1.019 | 5.105** | | 0.138 |
| Y × C | 0.960 | NS | | 1.205 | | NS | 1.223 | | NS |

§ The same letters in a single column are not statistically different using LSD test at 0.05 level of significance.
*, ** significant at probability levels of 0.05 and 0.01, respectively; CV, coefficient of variation; LSD, least significance difference; NS, non significant.

Statistically significant differences (*p*<0.01) were noted among cultivars for starch ratio (SR) and SR values changed from 53.75% in cv. Hasat to 60.69% in cv. Ünver (Table 8). Campbell et al. [32] presented lower data that ranged 48.11 to 64.84%, but the mean values among six cultivars used in their study was 58.17%. [31] presented the average SR values (56.9 to 58.8%) for malting barleys. For SR, of both years and the Y×G interaction were not statistically different. This situation has showed that SR was not effected by year in other word years or growth year (Table 8). Campbell et al. [32] presented the medium variance (30.2%) of cultivar × year for starch ratio of barley. SR showed significantly negative correlation with NDF during both years, while it was significantly negative correlated with ADF during the first year (Table 10). Campbell et al. [32] found medium strong negative correlations SR versus ADF plus NDF. But these correlations were very strong in our study, especially for the first year.

Statistically significant differences were noted among cultivars (p<0.01) and between years (p<0.05) for ADF (Table 9). ADF value was the highest (7.36%) during 2015-16 and the lowest (6.92%) in 2014-2015 growth year. When the cultivars was evaluated to find differences among cultivars, it was observed that ADF values ranged 6.23% for cv. Harman to 8.27% for cv. Hasat. These findings were higher than the results of some researchers [32, 34, 31]. During both growth years, there were significantly positive correlations between ADF and NDF (Table 10). Similarly, Campbell et al. [32] also emphasise high correlation between ADF and NDF.

Statistically significant differences (*p*<0.01) were noted among cultivars for NDF values. Statistically different (p<0.05) NDF values were also noted between years (Table 9). Campbell et al. [32] noted interaction of cultivar × year for ADF and NDF which these traits were similar to each other for the variance of interaction. NDF values was higher in the second growth year (22.44%) than the first year (21.77%). The mean NDF values of the cultivars ranged 20.83% in cv. Fahrettinbey to 23.52% in cv. Larende. However, Campbell et al. [32] noted lower range (13.50% to 16.40%) for NDF among barley cultivars.

Statistically significant differences (*p*<0.01) were noted among cultivars for FAT (Table 9). Campbell et al. [32] emphasized high interaction of cultivar × year with 75.9% variance. FAT content ranged 1.59% (cv. Harman) to 2.02% (cv. Konevi-98) in the study (Table 9). Some researchers have presented close results for this trait [32,35]. Bravi et al. [35] has also stressed the importance of low lipid content of barley grains because of their high capability to malting and friability.

**TABLE 10**
**Correlations among the traits of 15 cultivars of two rowed barley.**

| Traits | DR | PH | SN | SL | GN | SY | HI | GY | TGW | TW | DM | ASH | CPC | SR | ADF | NDF | FAT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DH§ | .99$^{**}$ | .64$^{**}$ | .34 | .41$^{**}$ | .39$^{**}$ | .58$^{**}$ | .26 | .38$^{*}$ | .41$^{**}$ | .27 | -.15 | -.46$^{**}$ | -.14 | .49$^{**}$ | -.17 | -.12 | -.05 |
| | .83$^{**}$ | .51$^{**}$ | .29 | .06 | .32$^{**}$ | .40$^{**}$ | .03 | .32$^{*}$ | .26 | -.02 | .29 | -.04 | .00 | .00 | .06 | .16 | .10 |
| DR | | .64$^{**}$ | .32 | .39$^{**}$ | .38$^{**}$ | .56$^{**}$ | .27 | .36$^{*}$ | .40$^{**}$ | .25 | -.15 | -.46$^{**}$ | -.13 | .49$^{**}$ | -.18 | -.13 | -.06 |
| | | .55$^{**}$ | .23 | .21 | .28 | .41$^{**}$ | .02 | .31$^{*}$ | .29 | .03 | .49$^{**}$ | .20 | .17 | -.22 | .12 | .30$^{*}$ | -.04 |
| PH | | | .20 | .34 | .24 | .57$^{**}$ | .20 | .27 | .48$^{**}$ | .20 | -.01 | -.30$^{*}$ | -.19 | .31$^{*}$ | -.06 | -.00 | .00 |
| | | | .13 | .40$^{**}$ | .43$^{**}$ | .54$^{**}$ | -.09 | .25 | .36$^{*}$ | .09 | .21 | -.09 | .06 | .01 | -.12 | .08 | -.08 |
| SN | | | | .23 | .39$^{**}$ | .42$^{**}$ | .48$^{**}$ | .93$^{**}$ | .44$^{**}$ | .13 | .23 | -.11 | -.12 | .04 | .10 | .03 | .04 |
| | | | | .11 | .43$^{**}$ | .46$^{**}$ | .41$^{**}$ | .92$^{**}$ | .39$^{**}$ | -.05 | .14 | -.18 | .05 | .08 | .25 | .20 | -.28 |
| SL | | | | | .52$^{**}$ | .58$^{**}$ | .23 | .29 | .20 | .08 | -.22 | -.18 | -.35$^{*}$ | .18 | .18 | .08 | .19 |
| | | | | | .19 | .20 | .16 | .15 | .21 | -.15 | .19 | .06 | .06 | -.18 | -.01 | .03 | .01 |
| GN | | | | | | .80$^{**}$ | .30$^{*}$ | .54$^{**}$ | .35$^{*}$ | .16 | -.24 | -.31$^{*}$ | -.38$^{*}$ | .35$^{*}$ | .09 | -.06 | -.02 |
| | | | | | | .79$^{**}$ | .06 | .60$^{**}$ | .45$^{**}$ | .07 | .17 | -.22 | -.12 | .21 | -.02 | -.03 | .02 |
| SY | | | | | | | .32$^{*}$ | .60$^{*}$ | .52$^{**}$ | .23 | -.11 | -.36$^{*}$ | -.32$^{*}$ | .37$^{*}$ | .11 | .08 | -.13 |
| | | | | | | | .12 | .65$^{**}$ | .60$^{**}$ | .03 | .29 | -.10 | -.04 | .12 | .04 | .04 | -.04 |
| HI | | | | | | | | .41$^{**}$ | .20 | -.03 | .11 | -.16 | -.31$^{*}$ | .16 | .22 | .16 | -.11 |
| | | | | | | | | .37$^{*}$ | .09 | .13 | .31$^{*}$ | .23 | .13 | -.18 | .08 | .02 | -.03 |
| GY | | | | | | | | | .50$^{**}$ | .17 | .15 | -.16 | -.13 | .11 | .06 | .02 | .03 |
| | | | | | | | | | .57$^{**}$ | -.02 | .28 | -.12 | .06 | .01 | .21 | .20 | -.31$^{*}$ |
| TGW | | | | | | | | | | .10 | -.09 | -.18 | -.28 | .25 | .10 | .06 | .15 |
| | | | | | | | | | | -.04 | .27 | -.04 | -.07 | -.06 | .17 | .24 | -.13 |
| TW | | | | | | | | | | | .16 | -.06 | .04 | .04 | -.07 | -.12 | -.20 |
| | | | | | | | | | | | .07 | -.16 | .01 | .17 | -.19 | -.30$^{*}$ | .09 |
| DM | | | | | | | | | | | | .35$^{*}$ | .41$^{**}$ | -.51$^{**}$ | .23 | .44$^{**}$ | .02 |
| | | | | | | | | | | | | .40$^{**}$ | .33$^{*}$ | -.38$^{*}$ | .08 | .16 | .08 |
| ASH | | | | | | | | | | | | | .36$^{*}$ | -.91$^{**}$ | .58$^{**}$ | .61$^{**}$ | .27 |
| | | | | | | | | | | | | | .44$^{**}$ | -.88$^{**}$ | .30$^{*}$ | .50$^{**}$ | .19 |
| CPC | | | | | | | | | | | | | | -.39$^{**}$ | -.27 | .12 | .05 |
| | | | | | | | | | | | | | | -.58$^{**}$ | -.26 | .04 | -.07 |
| SR | | | | | | | | | | | | | | | -.55$^{**}$ | -.61$^{**}$ | -.19 |
| | | | | | | | | | | | | | | | -.26 | -.54$^{**}$ | -.03 |
| ADF | | | | | | | | | | | | | | | | .84$^{**}$ | .16 |
| | | | | | | | | | | | | | | | | .81$^{**}$ | .02 |
| NDF | | | | | | | | | | | | | | | | | .11 |
| | | | | | | | | | | | | | | | | | -.24 |

§: In the same line, upper values show the first year (2014-2015) while the below values refer to the second year (2015-2016). $^{*}$, $^{**}$ indicate significance at the 0.05 and 0.01 probability levels, respectively. DH: days to heading, DR: days to ripening, PH: plant height, SN: spike number per square meter, SL: spike length, GN: grain number per spike, SY: spike yield, HI: harvest index, GY: grain yield, TGW: thousand grain weight, TW: test weight, DM: dry matter, ASH: ash content, CPC: crude protein content, SR: starch ratio, ADF: acid detergent fiber, NDF: neutral detergent fiber, FAT: oil content.

## CONCLUSION

Statistically significant differences were observed among the cultivars for all evaluated traits except CPC. This evidence will play an important role in the proper use of the cultivars in barley malting or feed technology. What is more gratifying is that characteristics excluding DR are unaffected by cultivar × year interaction. This means that cultivars will remain stable in the face of changing year conditions. This is an important technological feature, as these features must not be affected by the year too much. The correlation between technological characteristics and yield components, for example, the significant positive relationships of SR with GN and SY are important in terms of grain yield and malt technology. In the study, SR had strong negative correlation with CPC. It was reconfirmed that low protein high starch-containing cultivars are more important in the malt industry.

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