NARDI FUNDULEA, ROMANIA ROMANIAN AGRICULTURAL RESEARCH, NO. 43, 2026
www.incda-fundulea.ro; doi.org/10.59665/rar4340 First Online: March, 2026. DII 2067-5720 RAR 2026-94

Determining Grain Quality (Physical and Chemical) Properties and Nutritional Values in Some Two-Rowed Barley (*Hordeum vulgare conv. distichon*) Cultivars Grown in Terrestrial Climate Conditions

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ABSTRACT

Barley grain is rich in nutritional value and mineral elements. It is an important cereal crop used human food, malt and feed for animals. This study was conducted to determine some physical and chemical quality characteristics, like thousand-grain and hectoliter weight, protein, moisture, ash, starch, oil, ADF (acid detergent fiber), NDF (neutral detergent fiber) percent, potassium (K), magnesium (Mg), and phosphorus (P) contents of 14 two-rowed barley cultivars (Akar, Burakbey, Tarm-92, Aydanhanım, Zeynelağa, Keser, Balkan-96, Hilal, Sur 93, Şahin 91, Çumra-2001, Erciyes, Efes-98, Anadolu 98) with a randomized complete block design and three replications for two years during the 2016-2018 growing seasons (wintery) in the terrestrial climate conditions of Şiran-Gümüşhane (Türkiye) located in the Eastern Black Sea Region. According to the two-year mean results, the thousand-grain weight of the cultivars ranged between 35.74-46.27 g, hectoliter weight 62.03-68.18 kg hl^{-1}, protein percent 10.20-14.08%, moisture percent 09.32-09.75%, ash percent 1.99-2.21%, starch percent 57.22-61.77%, oil percent 1.52-2.02%, ADF percent 5.72-7.82%, NDF percent 21.19-23.20%, K content 0.657-0.742%, Mg content 0.156-0.191% and P content 0.401-0.430%. A positive and significant correlation was determined between thousand-grain weight and hectoliter weight, starch, oil, ADF, NDF, K, Mg, and P percent. Aydanhanım, Çumra-2001, Akar, Efes-98 and Balkan-96 cultivars were the prominent cultivars in terms of Physical and chemical quality characteristics and mineral substance values were evaluated in the study. Therefore, it is seen that these cultivars can be recommended to farmers who grow forage barley in the region.

Keywords: barley and cultivars, quality, crude protein percent, ADF, NDF, mineral substance.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the first cultivated plants (Sönmez et al., 2020). Owing to its high protein contents, digestible fiber and β-glucan levels, barley is mostly used in animal feeds and in malt production (Erbaş Köse and Mut, 2019a). In some countries, barley flour is used as an additive to wheat flour (Sipahi et al., 2010; Alkan and Kandemir, 2015). Barley is very rich in mineral substances and has a vital importance in human and animal nutrition (Sönmez and Yılmaz, 2000; Erbaş Köse and Mut, 2019b). Mineral substances participate in the structure of tissues and organs, regulating the acid-base balance and osmotic balance in the body (Kutlu, 2008). In addition, by participating in the structure of some vitamins, hormones, and enzymes, they take part in the performance of metabolic activities and the stimulation of muscles and nerves. However, since it cannot be synthesized from the bodies of animals like organic compounds, the need for mineral substances is supplied by external feeds (Kutlu, 2008; Alkan and Kandemir, 2015; Erbaş Köse and Mut, 2019b).

Barley is also considered the highest source of calories and protein in human and especially animal nutrition (Erbaş Köse and Mut, 2019a). Since the protein percent of barley is important for nutrition, it is desirable to be high in “barley forage” and less than 12% in malt barley to avoid color turbidity, the bitterness of flavor, and the shortening of storage time (Sirat, 2014). The protein ratio is affected by the cultivation techniques, as well as being early or temporary, wintery or summery, and dry or humid in the yellowness period (Sirat, 2014; Erbaş Köse and Mut, 2019a).

Received 20 January 2026; accepted 30 March 2026.

The physical properties and chemical content of barley vary according to the genetic characteristics of the cultivars, the ecological and climatic conditions, and the preferred cultivation processes (Gou et al., 2003; Erbaş Köse and Mut, 2019b). It has a very high tolerance for saline soils, which is a big problem from an agricultural point of view. Barley is an important cultivated plant that is used for soil reclamation in regions where barrenness is seen due to its salinity resistance, and it forms good compliance with industrial plants and legumes in irrigated areas (Topal, 1993; Erbaş Köse and Mut, 2019a).

In addition to physical properties such as thousand-grain weight, hectoliter weight, and grain uniformity in barley, chemical properties such as protein percent, oil, starch, and ash contents and digestibility are also important features for quality.

Although our region (Gümüşhane-Türkiye) has a very important animal potential, the yield capacities of meadow-pasture areas, is very low. In this case, increasing the potential of barley to become a concentrate feed is even more important. In particular, there is a need for carrying out breeding studies to test the performance of early harvested and high-yielding cultivars with resistance to drought, heat, disease, and pests (Kendal et al., 2011; Oral et al., 2017).

The barley cultivation area in the world is 44.045.907 hectares, production is 141.996.861 tons, and yield per hectare is 3223.8 kg (FAO, 2024). In Turkey, with a cultivation area of 3.254.867 hectares and a production of 8.100.000 tons, it ranks second in terms of cultivation and production among cereals (TUIK, 2024). In Gümüşhane, the barley cultivation area is 86.433 decares, its production is 29.748 tons and its yield is around 2905.0 kg ha^{-1} (TUIK, 2024).

This study was carried out with aim to determine some physical, chemical, and mineral element values in the barley grain in the two-rowed barley cultivars grown under the terrestrial climatic conditions of Şiran-Gümüşhane in the Eastern Black Sea Region and to determine the cultivars with superior properties. Based on the results, high-performing varieties are recommended for producers cultivating barley as forage in the region.

MATERIAL AND METHODS

This study was carried out for two years on a farmer's field in the Şiran district of Gümüşhane province (Türkiye) with winter cultivars between 2016-2018. A total of 14 two-rowed barley cultivars developed by different institutions were used as materials in the study. Some basic information about these cultivars is given in Table 1.

Table 1. Two-rowed barley cultivars used in the research, the year in which they were registered, and their institutions

No	Cultivars	Release year	Origin
1	Akar	2012	Field Crops Central Research Institute-Ankara/Türkiye
2	Burakbey	2013	Field Crops Central Research Institute-Ankara/Türkiye
3	Tarm-92	1992	Field Crops Central Research Institute-Ankara/Türkiye
4	Aydanhanım	2002	Field Crops Central Research Institute-Ankara/Türkiye
5	Zeynelağa	2003	Field Crops Central Research Institute-Ankara/Türkiye
6	Keser	2007	Transitional Zone Agricultural Research Institute-Eskişehir/Türkiye
7	Balkan-96	1996	Trakya Agricultural Research Institute-Edirne/Türkiye
8	Hilal	2010	Ege Agricultural Research Institute-İzmir/Türkiye
9	Sur 93	1993	GAP International Agricultural Research and Education Center-Diyarbakır
10	Şahin 91	1991	GAP International Agricultural Research and Education Center-Diyarbakır
11	Çumra-2001	2001	Anadolu Efes Brewing and Malt San.A.Ş.-Konya/Türkiye
12	Erciyes	2006	Anadolu Efes Brewing and Malt San.A.Ş.-Konya/Türkiye
13	Efes-98	1998	Anadolu Efes Brewing and Malt San.A.Ş.-Konya/Türkiye
14	Anadolu 98	1998	Anadolu Efes Brewing and Malt San.A.Ş.-Konya/Türkiye

According to the results of the analysis of soil samples taken from the research areas, both years were similar and the soil of the first year was clay loam (66.0%), moderately

chalky (13.56%), salt-free (0.14%), good in organic matter (3.48%) and slightly alkaline (7.67). In addition, in terms of nutritional elements, the phosphorus content was moderate (6.33 kg da^{-1}) and the potassium content (133.7 kg da^{-1}) was sufficient. In the second year, the texture class of the soils was clay loam (54.0%), unsalted (0.06%), good in organic matter (3.62%), slightly alkaline (8.01), moderate in phosphorus (7.48 kg da^{-1}), and sufficient in potassium (122.4 kg da^{-1}) (Özyazıcı et al., 2016).

Some climate values of the years in which the research was conducted are given in Table 2. The amount of precipitation affecting grain yield was significantly higher in the second year of the study compared to the average of the first year. In the first and second years of the study, the total amount of precipitation was 267.5 and 422.2 mm, respectively, while the total long-years rainfall was 487.8 mm. The average temperature in the first year, second year, and the long-term period during the vegetation period was 7.72, 10.22, and 9.08ºC, respectively. The average relative humidity was 55.69% and 57.91% in the first and second years, respectively, while the long-term rainfall average was 58.09%.

Table 2. Climatic data for trial years* and long years**

Months	October	November	December	January	February	March	April	May	June	July	**Mean/ Total**
Total precipitation (mm)											
2016-2017	16.5	8.1	52.4	7.8	3.1	20.1	52.5	74.7	32.3	0.0	**267.5**
2017-2018	39.0	19.8	54.2	17.5	7.3	58.4	6.4	117.4	86.4	15.8	**422.2**
Long years	37.3	23.2	74.0	37.7	14.3	54.8	37.0	118.4	78.4	12.7	**487.8**
Average temperature (°C)											
2016-2017	11.3	4.5	-3.3	-1.9	-1.1	5.6	9.1	13.4	17.8	21.8	**7.72**
2017-2018	11.0	5.6	2.8	1.7	5.0	8.7	11.7	15.2	18.7	21.8	**10.22**
Long years	12.0	5.4	0.6	-0.6	2.5	6.6	10.7	14.0	18.2	21.4	**9.08**
Relative humidity (%)											
2016-2017	59.3	51.0	67.2	56.9	56.6	53.5	51.4	57.7	55.4	47.9	**55.69**
2017-2018	56.5	59.1	65.9	65.1	55.8	55.0	41.8	63.6	61.7	54.6	**57.91**
Long years	57.7	58.7	67.9	62.7	58.1	55.4	47.5	61.7	58.7	52.5	**58.09**

* Climate data was obtained from Gümüşhane Provincial Directorate of Meteorology.
** Long-term period: Average values obtained in 1995-2016.

In the research, the sowing density was arranged to be 500 seeds per m^2, and sowing was done in 8 rows with 20 cm row spacing on 6 m long parcels with a grain drill. Sowing was carried out on October 11, 2016 in the first year and October 17, 2017 in the second year. The research was established in 3 replications according to the randomized complete block design, and 10 kg of pure nitrogen (N) and 6 kg of phosphorus (P_2O_5) fertilizer per decare were applied according to the results of the soil analysis. All of the phosphorus was applied as a Diammonium Phosphate (DAP) fertilizer with sowing, so half of the nitrogen was applied before sowing and the other half before the bolting period. No irrigation was done in the study. Cultural (with hand hoe) struggle with weeds took place in two stages (after the emergence of plants and during the tillering period). Harvesting was carried out by hand (sickle) on 07.07.2017 in the first year and 13.07.2018 in the second year.

In the study, thousand-grain weight, hectoliter weight, grain crude protein percent, moisture, ash, starch, oil, ADF (insoluble fiber in acid detergent) and NDF (insoluble fiber in neutral detergent) percent, potassium (K), magnesium (Mg) and phosphorus (P) contents were examined. Thousand-grain weight, hectoliter weight, crude ash percent, grain crude protein percent, and oil percent measurements and analyzes were made according to Elgün et al. (2001). The ADF and NDF values were determined according to Van Soest et al. (1991), the starch content

was determined according to the Ewers Polarimetric method (AACC, 2005), and the phosphorus (P) percent was determined according to the "Olsen" method. Potassium (K) and Magnesium (Mg) percent were determined by Atomic Absorption Spectroscopy (Kacar, 1994; Erbaş Köse and Mut, 2019a).

The data obtained in the study were analyzed using the JMP 7.0.2 statistical package software according to the randomized complete block research desigs (JMP, 2007). P-probability values were determined by using F-test to see effective differences between genotypes; comparisons between average values were evaluated according to the LSD test and then grouped. Correlations between the studied parameters were determined using the same package software.

RESULTS AND DISCUSSION

Thousand grain weight (g)

For thousand-grain weight, statistically, significant differences were found between years, cultivars ($p<0.01$ level), and years × cultivar interaction ($p<0.05$ level). According to the two-year averages, the highest thousand-grain weight was noted for Aydanhanım cultivar (46.27 g), followed by Çumra-2001 (44.93 g) and Akar (44.04 g) cultivars. The lowest thousand-grain weight was determined in the Burakbey (35.74 g) cultivar (Table 3). The highest thousand-grain weight of 41.39 g was obtained in the second year of the study, while this value was 39.21 g in the first year (Table 3). The difference in thousand-grain weight between years is due to the total rainfall in the cultivation period and the performance of the genotypes. The fact that barley cultivars differed according to the years in terms of thousand-grain weight has led cultivar × year interaction to be significant. Although thousand-grain weight is a feature that differs according to the cultivar, it is highly affected by environmental conditions (Erbaş Köse and Mut, 2019a). In the second year of the study, better climatic conditions extended the grain-filling period and increased the thousand-grain weight. It has been determined that cultivars that are more tolerant to drought, especially in rainfall-based conditions, have fewer losses in the thousand-grain weight (Aktaş, 2017; Erbaş Köse and Mut, 2019a). In previous studies, the differences between genotypes in terms of thousand-grain weight were related to environmental factors (Sirat and Sezer, 2017; Aydoğan et al., 2021) and the genotypic structure of the cultivars (Yüksel and İkincikarakaya, 2022).

Thousand-grain weight is an important yield and quality parameter within agronomic characteristics. In malt barley, the thousand-grain weight should be above 40 g (Alkan and Kandemir, 2015; Sirat and Sezer, 2017).

Hectoliter weight (kg hl^{-1})

For hectoliter weight, the differences between years and cultivars were statistically significant at the level of 1% (Table 3). According to the two-year averages, the highest hectoliter weight was obtained from Aydanhanım cultivar with 68.18 kg hl^{-1}, followed by Çumra-2001 (67.48 kg hl^{-1}) and Akar (67.04 kg hl^{-1}) cultivars, respectively. The lowest hectoliter weight was determined in the Keser cultivar with 62.03 kg hl^{-1} (Table 3). Hectoliter weight has been indicated by some researchers to vary depending on characteristics of the cultivar, environmental factors, and grain characteristics (uniformity in grain, glume percent, endosperm structure) (Sirat and Sezer 2017; Erbaş Köse and Mut 2019a). Kızılgeçi et al. (2016) and Aydoğan et al. (2021) reported that hectoliter weight differed according to the cultivars. The researchers reported that the hectoliter weight ranged between 61.57-73.44 kg hl^{-1} (Kızılgeçi et al., 2016), 65.1-73.5 kg hl^{-1} (Oral et al., 2017), 65.77-70.76 kg hl^{-1} (Sirat and Sezer, 2017), 56.17-67.41 kg hl^{-1} (Erbaş Köse and Mut, 2019a), 57.34-64.31 kg hl^{-1} (Aydoğan et al., 2021), and 64.3-74.1 kg hl^{-1} (Yüksel et al., 2021).

Seed protein contents (%)

According to the results of the combined variance analysis, the differences between the cultivars in terms of grain seed protein

content were found to be statistically significant ($p<0.01$) (Table 3). In the barley cultivars, the grain seed protein content varied between 10.20-14.08%. While the lowest value of grain seed protein content was found in Aydanhanım cultivar with 10.20%, the highest grain seed protein content was determined in Efes-98 (14.08%), Anadolu 98 (13.53%) and Sur 93 (13.30%) cultivars respectively (Table 3). In other studies, grain seed protein content was reported between 14.00-17.20% (Oral et al., 2017), 11.70-14.24% (Kızılgeçi et al., 2019), 09.72-11.83% (Muruz and Çelik, 2020), 12.73-15.65% (Sirat and Bahar, 2020), 12.42-13.63% (Sönmez et al., 2020), 09.4-13.9% (Yüksel et al., 2021). Although the results obtained from our research were in agreement with some of the work done by these researchers, they were also low or high compared to some of them.

We estimate that the difference in terms of grain seed protein content between the cultivars used in our research is closely related to the genetic characteristics of the cultivars. In addition, we think that the difference between the data and values of grain seed protein content obtained from our study and the results of other researchers may have been due to the differences in the climate and soil structure of the locations where the studies were conducted, differences in cultivation techniques, cultivars and the sowing and harvest dates.

Table 3. Average values of the characters of the barley cultivars used in the research

Cultivars	Thousand grain weight (g)			Hectoliter weight (kg hl^{-1})			Seed protein contents (%)		
	2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
Akar	42.62 b-e	45.46 ab	44.04 abc	66.06	68.02	67.04 ab	10.31	10.52	10.42 ef
Burakbey	30.89 j	40.59 d-h	35.74 e	61.71	64.81	63.26 ef	11.16	11.92	11.54 cde
Tarm-92	41.26 c-f	43.87 a-d	42.57 bc	63.80	66.93	65.36 bcd	10.85	11.21	11.03 ef
Aydanhanım	45.99 ab	46.55 a*	46.27 a**	66.96	69.40	68.18 a**	10.10	10.30	10.20 f
Zeynelağa	40.90 d-g	43.54 a-e	42.22 c	63.37	65.52	64.45 cde	11.21	10.91	11.06 ef
Keser	36.38 ı	38.20 f-ı	37.29 de	59.55	64.52	62.03 f	12.19	12.49	12.34 bcd
Balkan-96	40.08 e-h	43.22 a-e	41.65 c	64.73	66.61	65.67 bc	11.15	11.68	11.42 def
Hilal	38.92 f-ı	36.43 ı	37.68 de	61.97	64.13	63.05 ef	12.23	13.40	12.82 b
Sur 93	38.83 f-ı	38.74 f-ı	38.79 d	59.88	66.78	63.33 ef	13.06	13.54	13.30 ab
Şahin 91	37.04 hı	38.68 f-ı	37.86 de	61.75	64.36	63.06 ef	13.08	12.30	12.69 bc
Çumra-2001	44.64 abc	45.22 ab	44.93 ab	66.46	68.50	67.48 a	10.54	10.12	10.33 ef
Erciyes	37.60 ghı	40.18 e-h	38.89 d	63.93	64.91	64.42 cde	12.69	12.69	12.69 bc
Efes-98	38.10 f-ı	38.67 f-ı	38.38 d	61.50	65.05	63.27 ef	13.93	14.22	14.08 a**
Anadolu 98	35.63 ı	40.17 e-h	37.90 de	63.15	64.63	63.89 de	13.82	13.25	13.53 ab
Mean	39.21 b	41.39 a**	40.30	63.20 b	66.01a**	64.61	11.88	12.04	11.96
LSD	Cultivar: 2.55, Year: 0.64, C×Y: 3.61			Cultivar: 1.77, Year: 1.61			Cultivar: 1.22		
MS	63.7563			21.1838			9.68813		
CV (%)	5.46			2.37			8.87		

There is no difference between the averages indicated by the same letter with a probability of $*p<0.05$, $**p<0.01$.
MS: Mean of squares, CV: Coefficient of variation.

Moisture content (%) in seed

For moisture content, the effect of year, cultivar, and year × cultivar interaction of the barley cultivars was found to be statistically significant ($p<0.01$) (Table 4). As an average of years, the moisture percent in the 2016-2017 and 2017-2018 growing seasons was 9.39% and 9.59%, respectively. The two years average of the values of the cultivars in the research ranged between 9.32-9.75%. The highest moisture percent was obtained from the Çumra-2001 cultivar with 9.75%, followed by Keser (9.63%), Hilal (9.61%), and Şahin 91 (9.60%). The lowest moisture percent was found in Erciyes (9.32%) and Anadolu 98 (9.331%) cultivars (Table 4). The moisture percent is a very important factor in terms of grain trading and storage. The amount of moisture in barley grain varies depending on the climatic conditions where it grows, the shortness of rainfall or maturity

period during the harvest season, the storage method, the rise in the relative humidity and temperature of the storage place (Zia-Ur, 2006; Hong et al., 2007; Bulut, 2012; Sirat et al., 2022). Moisture is a key factor affecting the survival of the grain and the storage quality of the grain mass (Dizlek, 2012). In previous studies, researchers reported that the moisture percent ranged from 8.0% to 8.4% (Oral et al., 2017), 7.9% to 8.4% (Kendal, 2020), 9.21% to 9.88% (Sirat and Bahar, 2020), 9.96% to 10.02 (Akkoyun et al., 2021), and 9.44% to 9.72 (Sirat et al., 2022).

Ash content (%) in seed

Regarding seed ash content, the average of the cultivars in both years showed significant differences at the level of $p \leq 0.01$. As shown in Table 4, the ash percent was 2.04% and 2.16% in the first and second years, respectively. Due to climatic effects, changes were observed in the ash percent of the cultivars in different years. It has been reported that the amount of ash in the grains increased due to temperature increase and water stress (Öztürk and Aydın, 2004; Egesel et al., 2009; Mut et al., 2017). According to the average of the years, the ash percent of the cultivars ranged between 1.99-2.21% (Table 4). The amount of ash varied depending on the cultivar of barley, the climate in which it is grown, and the soil characteristics (Mut et al., 2017). Different researchers have reported that the ash percent differs according to cultivars (Ereifej et al., 2007; Egesel et al., 2009; Anjum et al., 2014; Mahla et al., 2015). In the studies, ash content was reported between 2.04% and 2.56% by Alkan and Kandemir (2015), 2.54% and 2.72% by Koca et al. (2015), 1.62% and 1.82% by Mut et al. (2017), 1.771% and 2.097% by Erbaş Köse and Mut (2019a), 2.00% and 2.31% by Sirat and Bahar (2020), 1.87% and 2.13% by Akkoyun et al. (2021), and 1.25% and 1.60% by Sirat et al. (2022).

Starch content (%)

The biggest component of barley grain is starch, which is found in the form of granules in the endosperm and represents an average of 60-64% of the grain weight (Kızılgeçi et al., 2018). Starch accumulation in the grain takes place during the grain-filling process and is widely affected by the environment (Sönmez et al., 2020). Starch percent differences between the cultivars were found to be statistically significant ($p<0.01$). According to the two-year averages, the highest starch percent was determined in the Aydanhanım cultivar with 61.77%, followed by Çumra-2001 (61.70%) and Akar (60.41%) cultivars. The lowest starch percent was determined in Burakbey (57.22%), Erciyes (57.39%), and Sur 93 (57.64%), respectively (Table 4).

In the 2016-2017 and 2017-2018 cultivation seasons, the starch percent was 58.05% and 60.13%, respectively. In parallel with the amount of precipitation in the second year with the highest rainfall, the starch percent also had the highest value. In the first year, it was determined that the thousand-grain weight decreased, the grains remained small and the starch percent decreased due to adverse climatic conditions and low rainfall (Table 2). In the studies, starch percent in barley ranged between 68.6-70.5% (Oral et al., 2017), 57.15-62.40% (Erbaş Köse and Mut, 2019a), 59.8-61.2% (Kızılgeçi et al., 2019), 66.4-70.9% (Kendal, 2020), 52.61-58.60% (Sirat and Bahar, 2020), 55.27-53.67% (Sönmez et al., 2020), 61.82-64.09% (Akkoyun et al., 2021), 56.36-62.74 (Erbaş Köse et al., 2021), and 60.9-64.9% (Yüksel et al., 2021). Kendal (2013) reported that the amount of starch may vary depending on environmental conditions. Different researchers have reported that the starch content differs according to cultivars and growing conditions (Mahla et al., 2015; Sirat and Bahar, 2020).

Table 4. Average values of the characters of the barley cultivars used in the research

Cultivars	Moisture content (%)			Ash conten (%)			Starch conten (%)		
	2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
Akar	9.25 gh	9.54 def	9.40 de	2.04	2.11	2.08	59.67	61.15	60.41 ab
Burakbey	9.51 def	9.53 def	9.52 bcd	2.04	2.21	2.13	56.73	57.70	57.22 c
Tarm-92	9.20 gh	9.68 bcd	9.43 de	1.97	2.04	2.01	57.28	60.62	58.95 bc
Aydanhanım	9.26 gh	9.68 bcd	9.47 b-e	1.98	2.10	2.04	60.09	63.45	61.77 a**
Zeynelağa	9.22 gh	9.53 def	9.38 de	2.05	2.13	2.09	57.00	60.74	58.87 bc
Keser	9.55 def	9.71 a-d	9.63 ab	2.13	2.28	2.21	58.34	59.67	59.01 bc
Balkan-96	9.51 def	9.38 efg	9.44 cde	2.08	2.12	2.10	58.56	59.62	59.09 bc
Hilal	9.83 ab	9.39 efg	9.61 ab	2.01	2.24	2.13	56.24	60.19	58.22 bc
Sur 93	9.66 bcd	9.16 gh	9.40 de	2.20	2.15	2.18	58.82	56.45	57.64 c
Şahin 91	9.60 b-e	9.61 b-e	9.60 abc	1.94	2.20	2.07	56.47	61.39	58.93 bc
Çumra-2001	9.57 c-f	9.93 a**	9.75 a**	1.92	2.05	1.99	61.94	61.46	61.70 a
Erciyes	9.07 hı	9.58 cde	9.32 e	2.03	2.26	2.15	55.57	59.21	57.39 c
Efes-98	9.34 fg	9.74 a-d	9.54 bcd	2.07	2.23	2.15	57.82	60.32	59.07 bc
Anadolu 98	8.87 ı	9.78 abc	9.33 e	2.03	2.17	2.10	58.13	59.83	58.98 bc
Mean	9.39 b	9.59 a**	9.49	2.04 b	2.16 a**	2.10	58.05	60.13	59.09
LSD	Cultivar: 0.167, Year: 0.062, C×Y: 0.235			Year: 0.050			Cultivar: 2.450		
MS	0.09579			0.02312			11.5799		
CV (%)	1.51			5.29			3.57		

There is no difference between the averages indicated by the same letter with a probability of $*p<0.05$, $**p<0.01$.
MS: Mean of squares, CV: Coefficient of variation.

Oil content (%) in seeds

As a result of the evaluation made in the research, the difference in cultivars and cultivar × year interaction were statistically significant at the level of $p<0.01$ in the combined years for oil content (Table 5). According to the average of two years, the highest oil percent was obtained from Aydanhanım (2.02%), Çumra-2001 (1.96%), and Akar (1.95%) cultivars. The lowest oil percent was determined in Hilal (1.52%) and Şahin 91 (1.58%) cultivars. It was determined that the average oil percent of years and cultivars was 1.80% (Table 5). Researchers have reported that the oil percent differs depending on the cultivar, climatic conditions, and cultivation technique (Grausgruber et al., 2000; Ereifej et al., 2007; Barteczko et al., 2009; Mut et al., 2017; Sirat et al., 2022). According to the studies, the oil percent varies between 2.34-2.61% (Karaşahin, 2017), 1.581-2.085% (Erbaş Köse and Mut, 2019a), 1.36-2.01% (Sirat and Bahar, 2020), 1.66-1.96% (Akkoyun et al., 2021), 1.94-2.81% (Erbaş Köse et al., 2021).

ADF content (%)

According to the combined variance analysis results, the cultivar and year × cultivar interaction was statistically significant for the differences in the acid detergent-insoluble fiber (ADF) values of the genotypes at the level of $p<0.01$ (Table 5). In the study, the averages of the years showed a variation between 5.72-7.82% for ADF values. While the highest ADF value was obtained from the Aydanhanım cultivar with 7.82%, the lowest ADF value was determined in the Erciyes cultivar with 5.72%, followed by Sur 93 (5.81%), Efes-98 (5.87%) and Şahin 91 (5.92%) cultivars (Table 5). Cultivar × year interaction was also found to be statistically significant for cultivars responding differently to changing climatic conditions. In the previous studies, the ADF values of barley grains were 3.6% to 4.1 (Brand et al., 2003), 7.52% to 7.91% (Han et al., 2003), 2.5% to 3.1% (Rakha et al., 2013), 6.53% to 9.07% (Alkan and Kandemir, 2015), 6.31% to 6.86% (Alijosius et al., 2016), 5.898% to 7.523% (Erbaş Köse and Mut, 2019a), 3.65% to 6.49% (Güney, 2019), 5.38% to 8.52% (Muruz and Çelik, 2020), 5.52% to 8.65 (Sirat and Bahar, 2020) and 6.24% to 6.74 (Aydoğan et al., 2021). The most important reason for the difference between ADF- and NDF-related results in

this research are thought to be related to the amount of glume in the cultivars. Kowieska et al. (2011) reported that the ADF and NDF contents of barley cultivars grown in summer and winter under Poland conditions ranged between 10.4-10.7% and 25.3-26.9%, respectively. Researchers have reported that ADF values differ according to cultivars and years (Brand et al., 2003; Barteczko et al., 2009; Can and Ayan, 2017; Mut et al., 2017). Tekce and Gül (2014) stated that NDF and ADF promote salivary secretion in ruminants, ensure that rumen pH remains within normal limits and that NDF and ADF contents are important for the prevention of many metabolic diseases.

NDF content (%)

The neutral detergent fiber (NDF) average values and the significance of differences between the barley cultivars are given in Table 5. For NDF, the years had significant differences at the level of $p<0.01$. NDF values were 21.88% and 22.62% in 2016-2017 and 2017-2018, respectively. Considering the average of the cultivars, the NDF percent was obtained lowest from the Erciyes cultivar (21.19%) and highest from the Çumra-2001 cultivar (23.20%) (Table 5). In the previous studies, the NDF values of barley grains ranged between 15.00-30.00% (Fox et al., 2003), 19.9-24.5% (Fife et al., 2008), 19.77-26.61% (Alkan and Kandemir, 2015), 18.76-20.87% (Alijosius et al., 2016), 22.00-24.87% (Erbaş Köse and Mut, 2019a), 19.86-23.37% (Muruz and Çelik, 2020), 20.42-25.03 (Sirat and Bahar, 2020), and 19.59-25.36% (Aydoğan et al., 2021). The neutral detergent fiber value directly affects the nutrition of the animals, and as the NDF value in the feed decreases, the amount of feed consumed by animals increases (Alkan and Kandemir, 2015; Mut et al., 2017; Sirat and Bahar, 2020; Sirat et al., 2022).

Table 5. Average values of the characters of the barley cultivars used in the research

Cultivars	Oil conten (%)			ADF conten (%)			NDF conten (%)		
	2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
Akar	1.98 ab	1.93 a-d	1.95 a	6.90 cde	7.36 bc	7.13 bc	22.37	23.21	22.79
Burakbey	1.75 f-j	1.79 d-ı	1.77 bc	6.89 cde	5.82 hı	6.35 ef	21.44	22.05	21.75
Tarm-92	1.76 f-j	1.93 a-d	1.85 b	6.93 cde	7.82 b	7.37 b	21.70	23.03	22.37
Aydanhanım	2.07 a**	1.97 ab	2.02 a**	7.18 cd	8.46 a**	7.82 a**	22.15	23.95	23.05
Zeynelağa	1.80 c-h	1.84 b-g	1.82 b	6.71 def	6.40 efg	6.55 de	20.69	22.31	21.50
Keser	1.72 g-j	1.80 c-h	1.76 bc	6.67 def	6.93 cde	6.80 cd	22.63	22.27	22.45
Balkan-96	1.90 b-f	1.74 g-j	1.82 b	6.91 cde	6.98 cd	6.94 cd	21.99	22.50	22.25
Hilal	1.41 k	1.63 j	1.52 d	5.93 ghı	6.73 def	6.33 ef	22.30	22.59	22.44
Sur 93	1.65 ıj	1.77 e-j	1.71 c	5.79 hı	5.82 hı	5.81 g	22.39	22.55	22.47
Şahin 91	1.38 k	1.78 e-j	1.58 d	6.27 fgh	5.58 ı	5.92 g	22.12	22.39	22.26
Çumra-2001	1.95 abc	1.98 ab	1.96 a	7.08 cd	7.08 cd	7.08 bc	22.99	23.40	23.20
Erciyes	1.68 hıj	1.73 g-j	1.70 c	5.94 ghı	5.51 ı	5.72 g	20.17	22.21	21.19
Efes-98	1.81 c-h	1.82 c-h	1.81 b	5.91 ghı	5.82 hı	5.87 g	21.21	21.90	21.56
Anadolu 98	1.92 b-e	1.77 e-j	1.84 b	5.96 ghı	6.28 fgh	6.12 fg	22.20	22.36	22.28
Mean	1.77	1.82	1.80	6.50	6.61	6.56	21.88 b	22.62 a**	22.25
LSD	Cultivar: 0.100, C × Y: 0.150			Cultivar: 0.400, C × Y: 0.570			Year: 0.210		
MS	0.11541			2.532			2.03005		
CV (%)	5.04			5.26			6.01		

There is no difference between the averages indicated by the same letter with a probability of $*p<0.05$, $**p<0.01$.
MS: Mean of squares, CV: Coefficient of variation.

Potassium content (%)

The potassium (K) content of the barley seeds was found to significantly differ in the year ($p<0.01$), cultivar, and year × cultivar interaction ($p<0.05$) (Table 6). According to two-year potassium averages, the potassium value ranged between 0.657-0.742%. The highest potassium values were obtained from Balkan-96 (0.742%), Akar (0.739%), Aydanhanım (0.728%), Keser (0.714%) and Hilal (0.710%) cultivars, respectively. The lowest potassium value (0.657%) was

determined in Burakbey cultivar. When the potassium values were examined for the years, the potassium value obtained in the second year of the study was 0.715%, while the potassium value (0.690%) was lower in the first year (Table 6). Genetic differences and environmental factors are the two main factors affecting the mineral substance content of barley (Gou et al., 2003; Erbaş Köse and Mut, 2019b). Researchers reported that the difference in potassium percent may be due to the parameters such as cultivar, presence of nutrients in the soil, temperature, moisture percent, light intensity and position, and growing period (Dung et al., 2010; Fazaeli et al., 2012; Karaşahin, 2017). In previous studies, researchers reported that potassium was the highest in the grain and that potassium elements constituted about 45% of the total amount of microelements in the grain (Stewart et al., 1988; Alkan and Kandemir, 2015). Mineral substances are vital for the development and growth of animals, their reproduction, and healthy and ideal body functions. The amount of mineral substances in the feed, excess or deficiency adversely affects the quality of the feed and causes diseases such as rickets, milk fever, abortus, weakness, loss of appetite, and tetany (Kumar and Soni, 2014; Karaşahin, 2017).

Magnesium content (%)

The differences in magnesium (Mg) content of the barley cultivars for years ($p<0.05$) and cultivars ($p<0.01$) were found to be statistically significant (Table 6). According to the two-year magnesium averages, the Mg content ranged between 0.156-0.191%. The highest magnesium values were obtained from Çumra-2001 (0.191%) and Aydanhanım (0.180%) cultivars, and the lowest magnesium value was obtained from Sur 93 cultivars with 0.156% content. When the magnesium content was examined for the years, it was determined as 0.163% and 0.176% in the first year and the second year of the study, respectively (Table 6). In the previous studies, magnesium value was reported to vary between 1161.5-1439.1 mg kg^{-1} (Alkan and Kandemir, 2015), 0.129-0.150% (Mut and Erbaş Köse, 2018), 0.153-0.175% (Erbaş Köse and Mut, 2019a), 0.175-0.199% (Sirat and Bahar, 2020) and 0.113-0.135% (Sirat et al., 2022). In studies conducted in previous years, it was found by many researchers that Mg values differed according to cultivars (Myer and Lozano, 2004; Poutanen, 2012; Jakobsone et al., 2015; Mut and Erbaş Köse, 2018).

Phosphorus content (%)

According to the combined variance analysis, the difference between the cultivars for phosphorus (P) value of the genotypes was found to be statistically significant ($p<0.01$) (Table 6). When the two-year phosphorus averages were examined, the phosphorus content of the cultivars was determined to range between 0.401-0.430%. The highest phosphorus content was obtained from the Çumra-2001 cultivar with 0.430%, followed by Akar and Aydanhanım (0.426%) cultivars. The lowest phosphorus content was determined in the Efes-98 cultivar with 0.401%. In the studies, it was reported that the phosphorus value ranged from 2690.8 to 3898.6 mg kg^{-1} (Alkan and Kandemir, 2015), 2395.9 to 4494.2 mg kg^{-1} (Erbaş Köse and Mut, 2019b), 0.363% to 0.408% (Mut and Erbaş Köse, 2018), 0.399% to 0.425% (Erbaş Köse and Mut, 2019a), 0.425% to 0.450% (Sirat and Bahar, 2020) and 0.360% to 0.387% (Sirat et al., 2022). It has been reported by many researchers that phosphorus values differ according to cultivars (Poutanen, 2012; Jakobsone et al., 2015; Mut and Erbaş Köse, 2018).

Table 6. Average values of the characters of the barley cultivars used in the research

Cultivars	Potassium content (%)			Magnesium content (%)			Phosphorus content (%)		
	2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
Akar	0.718 b-e	0.760 ab	0.739 ab	0.166	0.176	0.171 bcd	0.415	0.437	0.426 ab
Burakbey	0.682 c-g	0.631 g	0.657 d	0.156	0.167	0.162 cd	0.396	0.426	0.411 c-f
Tarm-92	0.678 efg	0.726 a-e	0.702 a-d	0.162	0.188	0.175 bc	0.408	0.428	0.418 bc
Aydanhanım	0.665 efg	0.792 a*	0.728 abc	0.170	0.189	0.180 ab	0.411	0.441	0.426 ab
Zeynelağa	0.684 c-g	0.713 b-e	0.698 a-d	0.164	0.182	0.173 bc	0.406	0.433	0.419 bc
Keser	0.722 a-e	0.707 b-f	0.714abc	0.154	0.174	0.164 cd	0.398	0.426	0.412 cde
Balkan-96	0.732 a-e	0.751 abc	0.742 a*	0.164	0.181	0.173 bc	0.407	0.432	0.420 bc
Hilal	0.726 a-e	0.695 b-g	0.710 abc	0.164	0.163	0.163 cd	0.402	0.430	0.416 bcd
Sur 93	0.686 c-g	0.711 b-e	0.698 a-d	0.154	0.159	0.156 d	0.389	0.421	0.405 of
Şahin 91	0.667 efg	0.715 b-e	0.691 bcd	0.161	0.173	0.167 bcd	0.398	0.432	0.415 cde
Çumra-2001	0.639 fg	0.750 a-d	0.694 a-d	0.183	0.199	0.191 a**	0.417	0.443	0.430 a**
Erciyes	0.690 b-g	0.683 c-g	0.687 cd	0.168	0.165	0.166 bcd	0.392	0.424	0.408 def
Efes-98	0.684 c-g	0.699 b-g	0.691 bcd	0.161	0.167	0.164 cd	0.381	0.421	0.401 f
Anadolu 98	0.681 c-g	0.679 d-g	0.680 cd	0.161	0.176	0.169 bcd	0.383	0.428	0.406 ef
Mean	0.690 b	0.715 a**	0.702	0.163 b	0.176 a*	0.170	0.400	0.430	0.415
LSD	Cultivar: 0.050, Year: 0.013, C×Y: 0.071			Cultivar: 0.015, Year: 0.009			Cultivar:0.010		
MS	0.00321			0.00045			0.00046		
CV (%)	6.14			7.74			2.11		

There is no difference between the averages indicated by the same letter with a probability of $*p<0.05$, $**p<0.01$.
MS: Mean of squares, CV: Coefficient of variation.

Correlations between the evaluated traits

The correlation coefficients calculated from the two-year results of the features tested in the study are given in Table 7. As seen in the table, there was a positive and significant relationship between thousand grain weight and hectoliter weight (r=0.606**), starch percent (r=0.335**), oil percent (r=0.495**), ADF (r=0.446**), NDF (r=0.291**), potassium (r=0.286**), magnesium (r=0.479**) and phosphorus (r=0.368**) percent, and a negative significant relationship between thousand-grain weight and crude protein percent (r=-0.511**). In the previous studies, a positive and significant correlation between thousandm grain weight and oil percent, starch percent, ADF value, and hectoliter weight, and a negative and significant correlation between thousand-grain weight and crude protein percent (Mut et al., 2017; Sirat and Bahar, 2020) were determined. Likewise, a positive and significant correlation was found between hectoliter weight and oil percent (r=0.448**), ADF (r=0.466**), potassium (r=0.309**), magnesium (r=0490**), phosphorus (r=0537**), starch (r=0.251*) and NDF (r=0.262*) and negative significant correlation was found between hectoliter weight and crude protein percent (r=-0.357**). The research of Sönmez et al. (2020), as well as Yüksel and Ünver İkincikarakaya (2022), support our findings. A positive correlation was found between crude protein percent and crude ash percent (r=0.240*) and a negative correlation was determined between crude protein percent and oil percent (r=-0.451**), ADF (r=-0.512**), magnesium (r=-0349**), NDF (r=-0.233*) and phosphorus (r=-0.279*) percent. In parallel with this study, there was a positive correlation between hectoliter weight and grain starch percent in another study (Kızılgeçi et al., 2019), while they also reported a positive correlation between hectoliter weight and grain crude protein percent, which is different from our study. We found that there was a significant positive correlation between starch percent and NDF (r=0.297**), magnesium (r=0.419**), oil (r=0.257*), ADF (r=0.259*) and potassium (r=0.252*) percent. In addition, a significant positive relationship was determined between the ADF percent and potassium (r=0.356**), magnesium (r=0.355**), phosphorus (r=0.283**) and NDF (r=0.241*) percent (Table 7). Similar results were obtained in studies on this subject (Erbaş Köse and Mut, 2019a; Kızılgeçi et al., 2019; Sirat and Bahar, 2020; Sönmez et al., 2020; Aydoğan et al., 2021).

Table 7. Correlation coefficients and significance levels between the traits analyzed in barley cultivars

Traits	TGW	HW	SPC	MC	ASH	SC	OC	ADF	NDF	PC	MC
TGW	1.000	-	-	-	-	-	-	-	-	-	-
HW	0.606**	1.000	-	-	-	-	-	-	-	-	-
SPC	-0.511**	-0.357**	1.000	-	-	-	-	-	-	-	-
MC	0.117	0.060	-0.045	1.000	-	-	-	-	-	-	-
ASH	-0.152	-0.060	0.240*	0.227*	1.000	-	-	-	-	-	-
SC	0.335**	0.251*	-0.181	0.172	0.152	1.000	-	-	-	-	-
OC	0.495**	0.448**	-0.451**	-0.111	0.021	0.257*	1.000	-	-	-	-
ADF	0.446**	0.466**	-0.512**	0.103	-0.278*	0.259*	0.405**	1.000	-	-	-
NDF	0.291**	0.262*	-0.233*	0.267*	0.051	0.297**	0.158	0.241*	1.000	-	-
PC	0.286**	0.309**	-0.168	0.192	0.082	0.252*	0.119	0.356**	0.266*	1.000	-
MC	0.479**	0.490**	-0.349**	0.286**	-0.100	0.419**	0.317**	0.355**	0.376**	0.274*	1.000
PC	0.368**	0.537**	-0.279*	0.338**	0.115	-0.086	0.231*	0.283**	0.281**	0.213	0.358**

Significance level: * $p< 0.05$ and ** $p< 0.01$.
TGW: thousand grain weight, *HW*: hectoliter weight, *SPC*: seed protein contents, *MC*: moisture contents, *ASH*: ash contents, *SC*: starch contents, *OC*: oil contents, *ADF*: acid detergent fiber, *NDF*: neutral detergent fiber, *PC*: potassium contents, *MC*: magnesium contents, *PC*: phosphorus contents.

CONCLUSIONS

Protein, oil, starch, and mineral content in barley are very important in terms of animal nutrition, and, as they directly influence quality, digestibility, and energy value. For this purpose, the research was carried out for two years in the 2016-2018 growing period (winter) with 14 two-rowed barley cultivars in the terrestrial climate conditions of Şiran-Gümüşhane (Türkiye) in the Eastern Black Sea Region, and some physical and chemical quality characteristics, as well as mineral substance values in the grain of barley cultivars, were determined. According to the results of the research, cultivars with superior quality for animal feed are Aydanhanım, Çumra-2001, and Akar in terms of thousand-grain weight and hectoliter weight; Efes-98, Anadolu 98 and Sur 93 in crude protein content; Aydanhanım, Çumra-2001, and Akar in terms of starch, oil, ADF and NDF content; and Aydanhanım, Akar, Çumra-2001 and Balkan-96 in terms of mineral substance (K, Mg, P) values. Therefore, although these cultivars have sufficient qualities to be recommended to farmers producing forage barley in the region, it should be remembered that our findings undoubtedly depend on the cultivars we used in our study, as well as both ecology and time, and their interaction with each other, so the obtained results should not be generalized.

ACKNOWLEDGEMENTS

We would like to thank Prof. Dr. Khalid Mahmood Khawar (Yozgat Bozok University), Assoc. Prof. Dr. Yusuf Savsatlı and Dr. Onder Albayrak (Recep Tayyip Erdogan University), Cengiz Erdem and Arslan Uzun (Blacksea Agricultural Research Institute) for their contributions.

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