EVALUATION OF MACROELEMENT CONTENTS IN HAY AND STRAW FROM CEREAL SPECIES AND VARIETIES

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Abstract. For cost-effective animal production, feed must be of high quality and low cost. This study analyzed the nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) contents of hay and straw from various cereal species and varieties, comparing these properties across them. One of the factors affecting feed quality is the amount of nutrients in the feed. Therefore this study was conducted to examine the nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) contents of hay and straw of cereal species and varieties and to compare these properties between cereal species and varieties. The study included three bread wheat, three durum wheat, three triticale, and four barley varieties, representing four cereal species and 13 varieties. The dry grasses of these species and varieties were collected at the spike stage, and the straws were collected when the seeds reached physical maturity. Near-infrared spectroscopy (NIRS) was used to determine the N, P, K, Ca, and Mg contents in the hay and straw. It was observed that these properties showed statistically significant differences at species and variety levels and between years. The results showed that first-year varieties had higher N, P, and K contents but lower Ca and Mg contents in both hay and straw. Regarding N content, both hay (except barley) and straw were deficient, whereas P content was sufficient in both. Regarding K content, cereal dry grasses were found to be adequate, whereas straws were found to be deficient (except barley). In terms of Ca content, the dry grasses of the cereals were at an adequate level and the straws were deficient only for triticale. In terms of Mg content, the dry grasses were at an adequate level and the straws were deficient.
Keywords: *nitrogen, phosphorus, potassium, calcium, magnesium, hay, straw*

Introduction

In Turkey, livestock forage is sourced primarily from three main categories: meadow and pasturelands, forage crops cultivated in arable fields, and plant production residues (Avcioğlu et al., 2009; Sayar et al., 2010; Cacan and Yuksel, 2016). Among these, forages from meadow pastures and forage crops are classified as quality roughage, while cereal straws form the majority of crop production residues.

In Turkey, the quality of roughage required to support livestock productivity often falls short of demand. Shortages in quality roughage from meadow pastures and forage crops are often supplemented with cereal straw (Yavuz et al., 2020). Cacan and Yuksel (2016) reported that Turkey's roughage needs 70 million tons and 29.2 million tons of this amount is met from crop production residues, mostly cereal straws. Yavuz et al. (2020) reported that Turkey's roughage needs 78.6 million tons and 49 million tons of this amount is met from cereal straws. In other years, the share of cereal straw in roughage resources exceeded 60% (Okuyucu and Okuyucu, 2006). Due to the inadequacy of quality forage production in Turkey, low-quality cereal by-products such as straw and hay are mostly used to meet the forage needs of farm animals.

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For economic animal production, animal performance should be high, and the feed consumed by the animal should be of high quality and low cost. One of the factors affecting feed quality is the amount of nutrients in the feed (Yucel et al., 2014; Ozyazici and Acikbas, 2019). Plants require nutrients at different rates to sustain their life. According to their amounts in plants, nutrients are divided into two categories: macro and micronutrients. The main macronutrients are defined as carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. Among these macronutrients, carbon is supplied by carbon dioxide in the air and oxygen by water (Orak et al., 2004; Bolat and Kara, 2017).

Knowledge of the nutrient content of roughages used in the feeding of ruminants provides healthy and balanced feeding. The use of roughages whose nutrient content is determined in animal feeding can only determine how much the roughages meet the animal’s requirements. Therefore, by knowing the contribution of roughage to the ration, it is understood whether animal production is economically conducted (Zahal and Kaya, 2020). For animals to be fed in a balanced and rational manner, feed should contain 1.5% N, 0.21% P, 0.65% K, 0.31% Ca, and 0.10% Mg (Kidambi et al., 1989; Bolat and Kara, 2017).

Nitrogen, one of the macronutrients, is the most deficient nutrient element in water. It is also an element that controls plant growth. Nitrogen in nature mainly originates from the atmosphere. Plants can benefit from nitrogen produced as a result of the breakdown of organic matter in the soil. Nitrogen plays a major role in protein and chlorophyll synthesis. In nitrogen deficiency, vegetative development is negatively affected (Bolat and Kara, 2017). Phosphorus facilitates the transfer and storage of energy during photosynthesis and other metabolic processes in plants, as well as generative development, dry matter formation, and storage (Lambers et al., 2003; Gecer and Yılmaz, 2011). Potassium has vital metabolic, physiological, and biochemical functions in plants. These functions increase the yield and quality of plant products. Potassium promotes root development, prevents lodging, increases nitrogen efficiency, and increases resistance to diseases and pests. Potassium increases the nutritional value of food and fodder crops, if it increases the protein content and helps improve the quality of fodder crops grown in pasture (Kacar, 2005).

Calcium is effective in the uptake of plant nutrients, root secretion, and protection of plant tissues against freeze-thaw stress. In the presence of sufficient calcium, plants are more resistant to diseases. Calcium also plays a role in protein formation and carbohydrate transport in plants (Plaster, 1991; Cepel, 1996; Kacar and Katkat, 2010). Magnesium is involved in chlorophyll structure in plants. Therefore, in magnesium deficiency, chlorophyll levels decrease, and photosynthesis slows down. As a natural consequence of this, growth retardation and a decrease in the amount of products occur in plants. In magnesium deficiency, protein synthesis also decreases in plants (Aktas and Ates, 1998; Ozbek et al., 2001; Kacar and Katkat, 2010).

Macronutrients are nutrients that are necessary for plant development and when consumed by animals to obtain the expected life share and productivity. It has been observed that scientific studies on the macronutrient content of cereal grass and straw are insufficient. Therefore, this study was carried out to determine the macronutrient contents (nitrogen, phosphorus, potassium, calcium, and magnesium) of cereal hay and straw, which are intensively used in animal feeding in Turkey to meet the roughage needs of animals.

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Materials and methods

Vegetal material

This two-year study was carried out at Agricultural Application and Research Center of Bingol University during the 2015-2016 and 2016-2017 growing seasons. The types and varieties of plant materials used in this study and the institutions (GAP International Agricultural Research and Training Center- GAPUTAEM and Eskişehir Transitional Zone Agricultural Research Institute- Eskişehir GKTAEM) where they were obtained can be seen in *Table 1*.

Table 1. *Types and varieties of grains used in the study and institutions from which they were supplied*

	Species	Varieties	Location
1	Bread wheat	Pehlivan	GAPUTAEM
2	Bread wheat	Syrena odes'ka	GAPUTAEM
3	Bread wheat	Krasunia odes'ka	GAPUTAEM
4	Durum wheat	Yelken-2000	Eskişehir GKTAEM
5	Durum wheat	Kunduru-1149	Eskişehir GKTAEM
6	Durum wheat	Dumlupınar	Eskişehir GKTAEM
7	Triticale	Karma	GAPUTAEM
8	Triticale	Tacettinbey	GAPUTAEM
9	Triticale	Ayşehanım	GAPUTAEM
10	Six-row barley	Erginel-90	GAPUTAEM
11	Six-row barley	Kıral-97	GAPUTAEM
12	Two-row barley	Sur-93	GAPUTAEM
13	Two-row barley	Şahin-91	GAPUTAEM

Meteorological data in the experimental area presented in *Table 2*. As seen in *Table 2*, in general, the growing seasons of 2015-16 and 2016-17 were less rainy and had lower relative humidity values than the long-term average. In terms of temperature, the 2015-16 growing season was higher than the long-term average and the 2016-17 growing season was lower than the long-term average.

Table 2. *Monthly rainfall, average temperature, relative humidity during experimental years (2015-2016, 2016-2017) and long-term average (2000-2015) for Bingöl province*

Months	Average temperature (°C)			Total precipitation (mm)			Relative humidity (%)		
	2015-16	2016-17	Long years	2015-16	2016-17	Long years	2015-16	2016-17	Long years
October	14.3	15.2	14.2	220.9	4.4	70.3	68.3	43.0	58.9
November	14.4	6.4	6.5	18.9	53.7	91.8	56.4	47.9	64.7
December	1.3	-2.2	0.2	46.2	152.6	121.8	58.6	73.4	70.7
January	-2.8	-3.7	-2.5	235.1	63.9	154.0	75.3	71.1	73.3
February	2.4	-2.3	-0.9	86.3	32.9	137.7	73.7	61.6	72.2
March	7.0	5.9	4.9	125.5	114.5	124.1	60.4	64.7	64.2
April	13.9	10.8	10.9	45.5	166.4	103.8	48.4	58.8	61.2
May	16.3	16.4	16.2	62.2	92.4	66.8	57.4	56.2	55.8
June	22.2	22.6	22.6	34.6	9.6	18.4	43.6	39.0	42.5
July	27.0	28.0	27.0	3.5	0	7.3	33.4	28.1	36.7
Total/Avg.	**11.6**	**9.7**	**9.91**	**878.7**	**690.4**	**896.0**	**57.6**	**54.4**	**60.0**

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According to the soil analyses, the soil texture in the experimental area was sandy, clayey, and loamy. According to the limit values reported by Sezen (1995) and Karaman (2012); it was determined that the pH value was slightly alkaline (7.54), lightly salted (180.9 µS/cm), organic matter content was low (1.68%), potassium content was high (75.88 kg da^{-1}) and phosphorus content was low (3.59 kg da^{-1}).

Experimental design

The experiment was laid out on October 13, 2015 in the first year and on October 17, 2016 in the second year. The experiment was carried out with three repetitions according to the randomized block trial design. 500 seeds per square meter were sown in 6 rows in each parcel, with the parcel length being 5 m and the distance between rows being 20 cm. After planting, 4 kg N and 8 kg P fertilizer per decare was applied to the trial area using pure material. Fertilization was made by adding 4 kg of nitrogen over pure matter during the stalk emergence period of the plants, and the total nitrogen amount was completed to 8 kg da^{-1} (Cacan et al., 2017; Karabulut and Cacan, 2018). The experiments were conducted under dry conditions.

In the study, harvesting for hay was carried out between 01 and 15 May in both years, paying attention to the spike stage of the cereals, and harvesting for straw was carried out between 06 and 11 July in both years, paying attention to the full maturity stage of the cereals. For hay and straw, 500 g samples were collected from each plot and dried in an oven at 700°C for 48 h (Anonymous, 2016). Crude protein, phosphorus, potassium, calcium, and magnesium analyses of the dried and milled samples were carried out by NIRS (Near Infrared Spectroscopy - Foss Model 6500) at the Dicle University Science and Technology Center Research and Application Laboratory. The nitrogen content of the samples was calculated using the measured crude protein values (Cacan et al., 2017; Basbag et al., 2018).

Statistical analysis

The research was conducted and completed according to the randomized blocks experimental design. Varieties were considered as the first factor and year as the second factor and analysis of variance was performed according to the two-factor factorial experimental design in randomized blocks. Therefore, the results of variance analysis as variety, year and variety x year interaction were shown and interpreted in the tables. In addition, a second analysis of variance was applied to compare the species within each other and the results were supported with graphs. The results of both analysis of variance were compared with Tukey test (Kalayci, 2005).

Results and discussion

Nitrogen

The two-year N contents of hay and straw from cereal species and varieties are presented in *Table 3*. It can be seen that the differences in the N content of hay of cereal varieties between varieties and years are statistically significant, whereas the year x variety interaction is insignificant. The lowest N content was obtained from Sur-93 variety, while Pehlivan, Dumlupınar, Karma, Tacettinbey and Ayşehanım varieties were in the same group with the lowest values. The highest N rate was obtained from Şahin-91 and Syrean odes’ka, Krasunia odes’ka, Yelken-2000 and Kunduru-1149 varieties in

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the same group. Cereal varieties had higher average N contents in 2016 than in 2017. As the average over the two years, an average of 1.86% N content was obtained from hay of cereal varieties (*Table 3*).

It was observed that the differences in the N content of straws of cereal varieties between varieties and years were statistically significant, whereas the year x variety interaction was insignificant. The lowest N content was obtained from the Ayşehanım, Karma and Dumlupınar varieties, whereas the highest N content was obtained from the Erginel-90, Kral-97 and Sur-93 varieties. The straws of cereal varieties contained higher average N content in 2016 than in 2017. As the average over the two years, an average of 0.74% N content was obtained from straw from cereal varieties (*Table 3*).

Table 3. *N (%) content of hay and straw of cereal species and varieties*

Species	Varieties	Hay			Straw		
		2016	**2017**	**Average**	**2016**	**2017**	**Average**
Bread wheat	Pehlivan	1.77	1.64	1.70 bc	0.79	0.81	0.80 abc
	Syrena odes'ka	1.93	1.95	1.94 ab	1.00	0.64	0.82 abc
	Krasunia odes'ka	1.93	2.00	1.97 ab	0.83	0.87	0.85 abc
Durum wheat	Yelken-2000	2.03	1.89	1.96 ab	0.79	0.71	0.75 bc
	Kunduru-1149	2.05	1.82	1.93 ab	0.73	0.71	0.72 c
	Dumlupınar	1.90	1.63	1.77 bc	0.63	0.53	0.58 cde
Triticale	Karma	1.82	1.59	1.70 bc	0.47	0.33	0.40 de
	Tacettinbey	2.06	1.58	1.82 bc	0.72	0.52	0.62 cd
	Ayşehanım	2.02	1.61	1.81 bc	0.42	0.26	0.34 e
Barley	Erginel-90	2.01	1.80	1.91 abc	1.08	0.98	1.03 a
	Kıral-97	2.03	1.83	1.93 abc	1.19	0.95	1.07 a
	Sur-93	1.73	1.58	1.66 c	1.23	0.79	1.01 ab
	Şahin-91	2.20	2.09	2.14 a	0.70	0.59	0.65 cd
Average		1.96 A	1.77 B	1.86	0.81 A	0.67 B	0.74
		CV (%): 7.38, P(variety): 0.0001, P(Year): 0.0001, P(variety x year): 0.0895, P(Species):0.2096			CV (%): 18.28, P(variety): 0.0001, P(Year): 0.0001, P(variety x year): 0.1276, P(Species):0.0001		

It was observed that the average N content determined in the straw of cereal varieties was numerically lower than the N content determined in the hay of cereal varieties. Since the interactions were insignificant, it is not possible to compare the varieties within the year with the within other year varieties. However, looking at the general averages, it is seen that while higher N content was obtained from hay and straw in 2016, lower N content was obtained in 2017. It is necessary to obtain a higher N content from the grass harvested and dried while it is green and still in the spike stage. The nitrogen content and, accordingly, the protein content decreases as the ripening period or drying period of the plants is prolonged. Therefore, cereal straws are expected to have lower N content. However, it is possible to explain the higher N content obtained in 2016 as follows. In 2016, it is predicted that the cereal varieties made better use of the amount of N in the soil and therefore had a higher N content, although fertilization was made, it is predicted that the cereal varieties received a lower amount of N from the soil in the second year due to the decrease in the N reserve in the soil in the second year and therefore had a lower N content in the 2nd year.

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As a result of the species-based evaluation, the N contents of the hay and straw of cereals are presented in *Figure 1*. It is seen that the N content of the varieties given in *Table 3*, which are classified as species, is 1.91% from barley, 1.87% from bread wheat, 1.89% from durum wheat and 1.78% from triticale. There were no statistically significant differences between these ratios for hay between cereal species. In terms of straw, 0.94% N was obtained from barley, 0.82% from bread wheat, 0.68% from durum wheat, and 0.45% from triticale. The differences between these ratios among cereal species in terms of straw content were statistically significant. The highest N content was observed in barley and bread wheat, whereas the lowest values were observed in durum wheat and triticale (*Table 3*; *Fig. 1*).

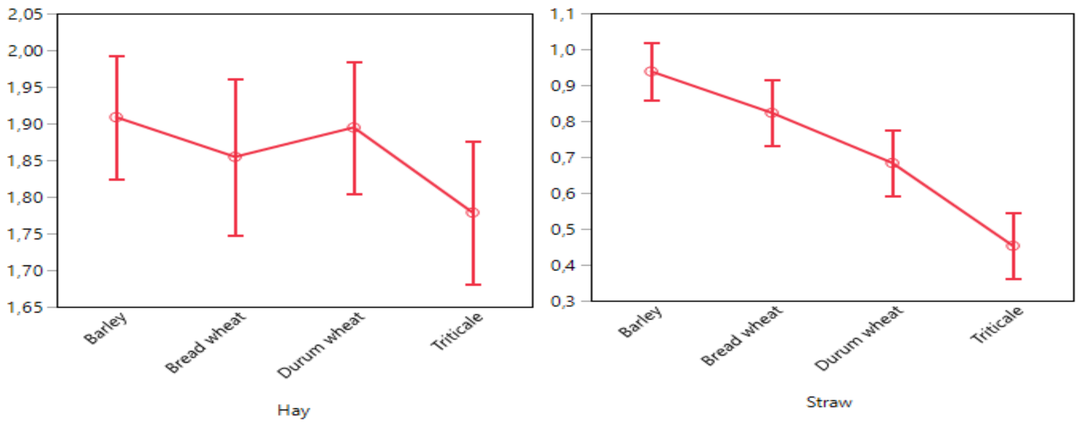

***Figure 1.** N ratios (%) detected in hay and straw of cereal species*

Jones et al. (1991) reported that N content between 2.00-3.00% in wheat and 1.75-3.00% in barley during the spike period was sufficient. Regarding these limit values, it is understood that the N content of the hay of cereals was deficient for bread, durum wheat, and triticale but sufficient for barley. The N content of straws from cereal varieties was inadequate for all varieties.

Yolcu (2008) reported that cereals have an important role in animal nutrition in terms of mineral content. Yolcu (2008) reported that the N content of barley and wheat was 2.19% and 1.83%, respectively, Kızılgoz and Sakin (2009) reported that the N content of wheat stems and leaves was 2.63-3.96%, Uslu et al. (2021) reported that the average N content of triticale varieties was 0.96-2.20%, and Solmaz et al. (2022) reported that the N content of wheat was 2.24-2.42%. In this study, it was observed that the average N content of 1.66% and 2.14% obtained from the hay of cereal varieties is similar to that of previous studies, whereas the N content of 0.72-1.07% obtained from straw is lower than that of the other studies.

Phosphorus

The two-year P contents of hay and straw from cereal species and varieties are presented in *Table 4*. It is determined that the differences in the P content of hay of cereal varieties between varieties and years and year x variety interactions are statistically significant. While the lowest P level was obtained only from the Pehlivan variety, the highest P content was obtained from all other varieties examined. Cereal varieties had higher average P content in 2016 than in 2017. In terms of year x variety

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interaction, the highest P ratio was obtained from Yelken-2000, Dumlupınar, Karma, Tacettinbey, and Ayşehanım varieties in 2016 and the lowest P ratio was obtained for the Pehlivan variety in 2017. As the average over the two years, an average P rate of 0.37% was obtained from hay from cereal varieties (*Table 4*).

It was found that the differences in the P content of straws of cereal varieties between varieties and years were statistically significant, whereas the year x variety interaction was insignificant. While the lowest P level was obtained only from the Pehlivan variety, the highest P content was obtained from all other varieties examined. The straws of cereal varieties contained higher average P content in 2016 than in 2017. As the average over the two years, an average of 0.23% P content was obtained from straw from cereal varieties (*Table 4*).

Table 4. *P (%) content of hay and straw of cereal species and varieties*

Species	**Varieties**	**Hay**			**Straw**		
		2016	**2017**	**Average**	**2016**	**2017**	**Average**
Bread wheat	Pehlivan	0.36 abc	0.33 c	0.34 b	0.25	0.18	0.21 b
	Syrena odes'ka	0.37 abc	0.37 abc	0.37 ab	0.29	0.15	0.22 ab
	Krasunia odes'ka	0.38 abc	0.38 abc	0.38 ab	0.29	0.19	0.24 ab
Durum wheat	Yelken-2000	0.40 a	0.36 abc	0.38 a	0.28	0.18	0.23 ab
	Kunduru-1149	0.38 abc	0.37 abc	0.38 ab	0.28	0.18	0.23 ab
	Dumlupınar	0.40 a	0.37 abc	0.39 a	0.28	0.18	0.23 ab
Triticale	Karma	0.41 a	0.34 bc	0.37 ab	0.27	0.17	0.22 ab
	Tacettinbey	0.41 a	0.34 bc	0.38 ab	0.27	0.18	0.22 ab
	Ayşehanım	0.41 a	0.34 bc	0.37 ab	0.26	0.18	0.22 ab
Barley	Erginel-90	0.39 abc	0.36 abc	0.37 ab	0.30	0.22	0.26 a
	Kıral-97	0.39 abc	0.38 abc	0.38 ab	0.29	0.19	0.24 ab
	Sur-93	0.36 abc	0.35 abc	0.36 ab	0.30	0.21	0.26 ab
	Şahin-91	0.40 ab	0.38 abc	0.39 a	0.33	0.18	0.25 ab
Average		0.39 A	0.36 B	0.37	0.28 A	0.18 B	0.23
		CV (%): 5.26, P(variety): 0.0205, P(Yearl): 0.0001, P(variety t x year): 0.0046, P(Species):0.3712			CV (%): 9.20, P(variety): 0.0036, P(Year): 0.0001, P(variety x year): 0.0725, P(Species):0.2636		

It was observed that the average P content in the straw of cereal varieties was numerically lower than that in the hay of the cereal varieties. In addition, whereas higher P content was obtained from hay and straw in 2016, lower P content was obtained in 2017. It is expected and necessary to obtain higher P content from grass harvested at the spike stage. However, it is possible to explain the higher P content obtained in 2016 as follows. In 2016, it is predicted that the cereal varieties made better use of the amount of P in the soil and therefore had a higher P content, although fertilization was made; however, due to the decrease in the Preserve in the soil in the second year, the cereal varieties received a lower amount of P from the soil in the second year and therefore had a lower P content in the 2nd year.

As a result of the species-based evaluation, the P contents of the hay and straw of cereals are presented in *Figure 2*. When the cereals are evaluated based on species, i.e., when the cereal varieties given in *Table 4* are averaged as species, 0.37% P content is

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obtained from barley, 0.36% from bread wheat, 0.38% from durum wheat, and 0.37% from triticale. There were no statistically significant differences between these ratios among cereal species in terms of hay. In terms of straw, 0.25% P content was obtained from barley, 0.22% from bread wheat, 0.23% from durum wheat, and 0.22% from triticale. The differences between these ratios among cereal species in terms of straw content were not statistically significant (*Table 4*; *Fig. 2*).

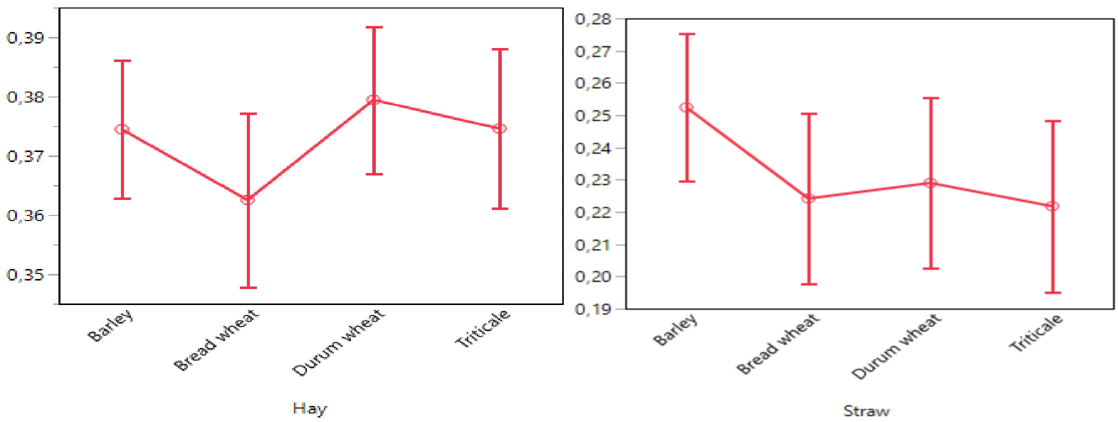

Figure 2. *P ratios (%) detected in hay and straw of cereal species*

Jones et al. (1991) reported that a P content between 0.20-0.50 per cent in wheat and barley during the spike period was sufficient. In terms of these limit values, although straw contents were close to the lower limit values, the P contents of both hay and straw for all cereal varieties were sufficient.

Cacan and Yılmaz (2015) reported that P, K, Ca, and Mg are important parameters determining the quality of grass produced in animal feeding. Yolcu (2008) reported a P content of 0.34% in barley and wheat, Cacan and Yılmaz (2015) reported a P content of 0.31% in wheat, Egrıtas and Onal Asci (2015) reported a P content of 0.29% in triticale, Cacan et al. (2017) reported P content of 0.36% in eight different wheat varieties, Uslu et al. (2021) 36%. Uslu et al. (2021) reported that the average P content in triticale varieties was 0.18-0.28%, Basbag et al. (2018) reported that P content in bread and durum wheat was 0.45%, and Solmaz et al. (2022) reported that P content in wheat was 0.19-0.26%. In this study, the average P content of 0.34-0.39% obtained from the hay of cereal varieties and the average P content of 0.21-0.26% obtained from cereal straws are similar to the findings of the researchers.

Potassium

The two-year K contents of hay and straw from cereal species and varieties are presented in *Table 5*. It is observed that the differences in the K content of hay among cereal varieties and years and year x variety interactions are statistically significant. The lowest K content was observed in bread wheat varieties Pehlivan, Syrena odes’ka, and Krasunia odes’ka, while the highest K content was observed in all other varieties. Cereal varieties had higher average K content in 2016 than in 2017. In terms of year x variety interaction, the highest K content was obtained from triticale varieties Karma, Tacettinbey and Ayşehanım in 2016, whereas the lowest K content was obtained from bread wheat varieties in 2016 and 2017. As the average

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over the two years, an average 1.99% K ratio was obtained from the dry grass of the cereal varieties (*Table 5*).

It was observed that differences in the K content of straws of cereal varieties between varieties and year and year x variety interactions were found to be statistically significant. The lowest K content was observed in Kunduru-1149 varieties, whereas the highest K content was observed in barley varieties. In terms of year x variety interactions, the highest and lowest K rates were obtained from barley varieties in 2016 and bread and durum wheat varieties in 2016 and 2017. It was observed that cereal straws contained higher average K content in 2016 than in 2017. As the average over the two years, an average K content of 1.37% was obtained from straw cereal varieties (*Table 5*).

It was observed that the average K content in the straw of cereal varieties was numerically lower than that in the hay of the cereal varieties. In addition, higher K content was obtained from hay and straw in 2016 than in 2017. This situation is predicted to be realized as in the case of the N and P ratios. In other words, it is expected that a higher K content will be obtained from the grass harvested and dried during the spike stage, and the higher K content obtained in 2016 is related to the higher utilization of the varieties from the amount of K in the soil in the 1nd year and the lower K content in the 2nd year due to the decrease in the K reserve in the soil in the 2nd year.

Table 5. *K (%) contents of hay and straw of grain species and varieties*

Species	Varieties	Hay			Straw		
		2016	2017	Average	2016	2017	Average
Bread wheat	Pehlivan	1.60 d-g	1.35 fg	1.48 d	1.37 d-g	1.10 g-j	1.23 cde
	Syrena odes’ka	1.30 g	1.87 c-g	1.58 cd	1.14 f-j	0.76 hij	0.95 ef
	Krasunia odes’ka	1.77 c-g	1.68 c-g	1.72 bcd	1.47 c-g	0.64 j	1.06 def
Durum wheat	Yelken-2000	2.11 a-f	2.06 a-g	2.09 ab	1.06 g-j	1.39 d-g	1.22 cde
	Kunduru-1149	2.00 b-g	2.06 a-g	2.03 abc	0.81 hij	0.80 hij	0.81 f
	Dumlupınar	2.14 a-e	2.04 b-g	2.09 ab	1.19 e-i	1.22 e-h	1.20 cde
Triticale	Karma	2.82 a	1.54 efg	2.18 ab	1.69 a-e	0.68 ij	1.19 cde
	Tacettinbey	2.76 ab	1.60 d-g	2.18 ab	1.49 b-g	1.09 g-j	1.29 cd
	Ayşehanım	2.77 ab	1.48 efg	2.13 ab	1.80 a-d	1.02 g-j	1.41 bc
Barley	Erginel-90	1.90 c-g	1.65 c-g	1.78 a-d	2.05 a	1.64 a-f	1.84 a
	Kıral-97	2.17 a-e	2.22 a-e	2.19 ab	2.08 a	1.97 abc	2.02 a
	Sur-93	2.37 a-d	2.02 b-g	2.19 ab	2.00 ab	1.81 a-d	1.90 a
	Şahin-91	2.39 abc	2.05 a-g	2.22 a	2.07 a	1.35 d-g	1.71 ab
Average		2.16 A	1.82 B	1.99	1.56 A	1.19 B	1.37
		CV (%): 12.3, P(Variety): 0.0001, P(Year): 0.0001, P(Variety x Year): 0.0001, P(Species):0.0001			CV (%): 11.8, P(Variety): 0.0001, P(Year): 0.0001, P(Variety x Year): 0.0001, P(Species):0.0001		

As a result of the species-based evaluation, the K content of the hay and straw from cereals is presented in *Figure 3*. When the cereals were evaluated based on species, i.e., when the cereal varieties given in *Table 5* were averaged as species, we found that 2.10% K content was obtained from barley, 1.59% from bread wheat, 2.07% from durum wheat, and 2.16% from triticale. A statistically significant difference was found

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between these ratios for cereal species in terms of hay. The lowest K ratios were obtained from bread wheat, barley, durum wheat, and triticale, and they constituted the group with the highest statistical values. In terms of straw, 1.87%, 1.08%, 1.08%, 1.08%, and 1.30% K content was obtained from barley, bread wheat, durum wheat, and triticale, respectively. The differences between these ratios among cereal types in terms of straw content were statistically significant. The highest K rate was obtained from barley, whereas the lowest K rate was obtained from bread wheat, durum wheat, and triticale (*Table 5*; *Fig. 3*).

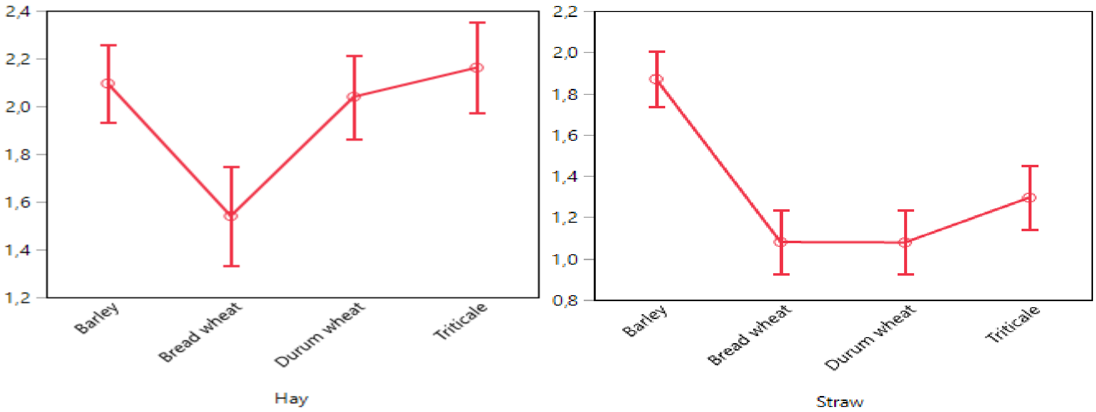

Figure 3. *K ratios (%) detected in hay and straw of cereal species*

Jones et al. (1991) reported that a K content between 1.50-3.00% was sufficient for wheat and barley during the spike period. In terms of these limit values, it is understood that the K content of the dry grasses of the cereals was adequate, while the K content of the straws was adequate for barley varieties but inadequate for bread, durum wheat, and triticale.

Cacan et al. (2017) reported that the use of cereals as a source of roughage in Anatolia, where cereal agriculture has been practiced throughout history, will contribute to closing the roughage gap. Yolcu (2008) reported a K content of 1.55% in barley and 1.47% in wheat, Cacan and Yılmaz (2015) reported K content of 0.93% in wheat, Egrıtas and Onal Asci (2015) reported K content of 0.48-0.52% in triticale, Cacan et al. (2017) reported K content in eight different wheat varieties to be 1.92%, Basbag et al. (2018) reported K content of bread wheat as 2.72%, durum wheat as 2.90%, Uslu et al. (2021) reported average K content of triticale varieties as 0.86-1.61% and Solmaz et al. (2022) reported K content of wheat as 1.77-2.65%. In this study, the average K content of 1.48-2.22% obtained from the hay of cereal varieties and the average K content of 0.81-2.02% obtained from cereal straws are higher than the results obtained by Cacan and Yılmaz (2015) and Egrıtas and Onal Asci (2015) and are similar to the findings of other researchers.

Calcium

The two-year Ca contents of hay and straw from cereal species and varieties are presented in *Table 6*. It is observed that the differences in Ca content of hay among cereal varieties and years are statistically significant, whereas the year x variety interaction is statistically insignificant. The lowest Ca content was obtained from barley

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varieties, especially Sur-93, whereas the highest Ca content was obtained from all other varieties except the Dumlupınar variety. It was observed that cereal varieties contained lower average Ca contents in 2016 than in 2017. For the two years, an average of 0.44% Ca content was obtained from the dry grass of the cereal varieties (*Table 6*).

It was observed that differences in the Ca content of straws of cereal varieties among varieties and years and year x variety interactions were found to be statistically significant. The lowest Ca content was obtained from the Dumlupınar variety of durum wheat and Erginel-90 barley and triticale varieties, while the highest Ca content was obtained from the remaining varieties. In terms of year x variety interaction, the lowest Ca content was obtained from the Ayşehanım variety in 2016 and the highest Ca content was obtained from the Şahin-91 variety in 2017. It was observed that the straws of cereal varieties contained lower average Ca contents in 2016 than in 2017. As the average of 2 years, an average Ca content of 0.33% was obtained from the straw of cereal varieties (*Table 6*).

Table 6. *Ca (%) content of hay and straw of different grain species and varieties*

Species	Varieties	Hay			Straw		
		2016	2017	Average	2016	2017	Average
Bread wheat	Pehlivan	0.42	0.47	0.45 a-e	0.31 e-j	0.46 abc	0.39 ab
	Syrena odes'ka	0.53	0.55	0.54 a	0.37 b-f	0.47 ab	0.42 a
	Krasunia odes'ka	0.44	0.53	0.49 abc	0.34 b-f	0.42 a-e	0.38 ab
Durum wheat	Yelken-2000	0.47	0.54	0.51 ab	0.32 e-i	0.38 b-f	0.35 abc
	Kunduru-1149	0.46	0.51	0.49 abc	0.27 f-k	0.48 ab	0.38 ab
	Dumlupınar	0.43	0.43	0.43 b-f	0.19 jkl	0.34 d-h	0.27 de
Triticale	Karma	0.45	0.49	0.47 a-d	0.22 h-l	0.33 d-h	0.28 cde
	Tacettinbey	0.46	0.48	0.47 a-d	0.17 kl	0.33 d-h	0.25 de
	Ayşehanım	0.43	0.44	0.44 a-e	0.13 l	0.31 e-j	0.22 e
Barley	Erginel-90	0.35	0.39	0.37 def	0.27 f-k	0.32 e-i	0.30 cde
	Kıral-97	0.33	0.46	0.39 c-f	0.25 g-l	0.45 a-d	0.35 abc
	Sur-93	0.35	0.30	0.33 f	0.21 i-l	0.43 a-e	0.32 bcd
	Şahin-91	0.39	0.32	0.36 ef	0.23 g-l	0.53 a	0.38 ab
Average		0.43 B	0.45A	0.44	0.25 B	0.40 A	0.33
		CV (%): 11.9, P(variety): 0.0001, P(Year): 0.0202, P(variety x year): 0.1408, P(Species):0.0001			CV (%): 11.6, P(variety): 0.0001, P(Year): 0.0001, P(variety x year): 0.0001, P(Species):0.0003		

It was observed that the average Ca content in the straw of cereal varieties was numerically lower than that in the hay of the cereal varieties. In addition, lower Ca contents were obtained from hay and straw in 2016 than in 2017. It is necessary to obtain a higher Ca content in cereal hay than in straw. The lower Ca content in the hay and straw of cereals in 2016 is also predicted to be due to the interaction and balance between macroelements. Previous studies have also shown that when P and K ratios are high, generally lower Ca and Mg ratios are obtained (Basbag et al., 2023; Cacan and Kokten, 2024).

As a result of an evaluation made based on species, Ca contents obtained from hay and straw from cereals are presented in *Figure 4*. When cereals were evaluated based on

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species, that is when the cereal varieties listed in *Table 6* were averaged as species, 0.36% Ca content was obtained from barley, 0.49% from bread wheat, 0.47% from durum wheat, and 0.46% from triticale. A statistically significant difference was found between these ratios among cereal species in terms of hay. The lowest Ca ratios were obtained from barley, bread wheat, durum wheat, and triticale, which constituted the group with the highest value statistically. In terms of straw, 0.34% Ca was obtained from barley, 0.40% from bread wheat, 0.33% from durum wheat, and 0.25% from triticale. There were statistically significant differences between these ratios for cereal types looking at the content of straw. The lowest Ca content was obtained from triticale, whereas the highest values were found from barley, bread wheat, and durum wheat (*Table 6*; *Fig. 4*).

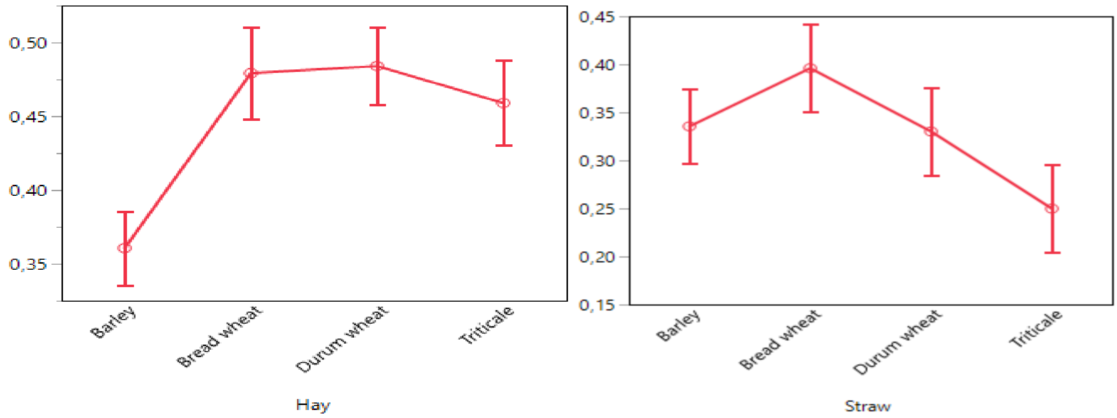

Figure 4. *Ca content (%) in hay and straw from cereal*

Jones et al. (1991) reported that it is sufficient to have Ca content between 0.20-0.50% in wheat and 0.30-1.20% in barley during the spike period. In terms of these limit values, the Ca contents of the hay and straw used in cereals are adequate.

Basbag et al. (2018) reported that cereal can be used in animal feeding. Yolcu (2008) reported Ca content of 0.68% in barley and 0.24% in wheat, Cacan and Yılmaz (2015) reported Ca content of 0.49% in wheat, Egrıtas and Onal Asci (2015) reported Ca content of 0.37-0.39% in triticale, Cacan et al. (2017) reported Ca content of 0.41% in eight different wheat varieties, Basbag et al. (2018) 41%, Basbag et al. (2018) reported Ca content in bread wheat as 0.39%, in durum wheat as 0.45%, Uslu et al. (2021) reported average Ca content in triticale varieties as 0.07-0.15% and Solmaz et al. (2022) reported Ca content in wheat as 0.58-0.68%. In this study, the average Ca content of 0.33-0.54% obtained from the dry grass of cereal varieties and the average Ca content of 0.22-0.42% obtained from cereal straws were similar to the findings of the researchers.

Magnesium

The two-year Mg content of hay and straw from cereal species and varieties is presented in *Table 7*. It can be seen that the differences in the Mg content of hay of cereal varieties in terms of variety, year, and year x variety interactions are statistically significant. The lowest Mg content was observed in durum wheat varieties, especially the Dumlupınar variety, while the highest Mg content was observed in all other

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varieties. In terms of year x variety interaction, the lowest Mg rate was obtained from the Dumlupınar variety in 2016, whereas the highest Mg rate was found from Erginel-90 variety in 2017. Cereal varieties contained lower average Mg content in 2016 than in 2017. As the average over the two years, an average of 0.16% Mg content was obtained from the dry grass of the cereal varieties (*Table 7*).

It was observed that differences in the Mg content of straws of cereal varieties between varieties and years and year x variety interactions were found to be statistically significant. The lowest Mg content was obtained from the Ayşehanım variety, whereas the highest Mg content was obtained from the Yelken 2000 variety. In terms of year x variety interaction, the lowest Mg ratio was obtained from the Karma, Tacettinbey and Şahin-91 varieties in 2016 and the highest Mg ratio was obtained from the Yelken-2000 variety in 2017. The straws of cereal varieties contained lower average Mg content in 2016 than in 2017. As the average over the two years, an average of 0.08% Mg content was obtained from the straw of the cereal varieties (*Table 7*).

Table 7. *Mg (%) content of hay and straw from grain species and varieties*

Species	Varieties	Hay			Straw		
		2016	**2017**	**Average**	**2016**	**2017**	**Average**
Bread wheat	Pehlivan	0.12 de	0.19 ab	0.15 abc	0.05 f-i	0.09 c-f	0.07 def
	Syrena odes'ka	0.16 a-d	0.19 ab	0.18 a	0.07 efg	0.15 ab	0.11 ab
	Krasunia odes'ka	0.13 b-e	0.18 abc	0.16 ab	0.08 d-g	0.13 abc	0.10 abc
Durum wheat	Yelken-2000	0.12 de	0.18 abc	0.15 abc	0.07 fg	0.16 a	0.12 a
	Kunduru-1149	0.12 cde	0.14 b-e	0.13 bc	0.02 hij	0.14 ab	0.08 c-f
	Dumlupınar	0.10 f	0.14 b-e	0.12 c	0.01 ij	0.12 abc	0.07 ef
Triticale	Karma	0.13 b-e	0.19 ab	0.16 ab	0.01 j	0.04 g-j	0.03 g
	Tacettinbey	0.16 a-e	0.19 ab	0.17 a	0.01 j	0.12 bcd	0.06 ef
	Ayşehanım	0.16 a-e	0.15 a-e	0.16 abc	0.08 d-g	0.04 g-j	0.06 f
Barley	Erginel-90	0.16 a-d	0.20 a	0.18 a	0.06 fgh	0.14 ab	0.10 a-d
	Kıral-97	0.16 a-d	0.16 a-d	0.16 ab	0.06 fg	0.16 ab	0.11 ab
	Sur-93	0.17 a-d	0.16 a-d	0.16 ab	0.06 fg	0.11 b-e	0.09 b-e
	Şahin-91	0.16 a-d	0.16 a-d	0.16 ab	0.01 j	0.14 ab	0.08 c-f
Average		0.14 B	0.17 A	0.16	0.05 B	0.12 A	0.08
		CV (%): 11.7, P(variety): 0.0001, P(Year): 0.0001, P(variety x year): 0.0034, P(Species):0.0208			CV (%): 16.3, P(variety): 0.0001, P(Year): 0.0001, P(variety x year): 0.0001, P(Species):0.0159		

It was observed that the average Mg content in the straw of cereal varieties was numerically lower than that in the hay of the cereal varieties. In addition, hay and straw had lower Mg content in 2016 than in 2017. It is necessary to obtain higher Mg content in cereal hay than in straw. The lower Mg content in the hay and straw of cereals in 2016 is predicted to be due to the interaction and balance between macroelements. It has also been revealed by previous studies that in the years when P and K ratios were high, lower Ca and Mg ratios were generally obtained (Basbag et al., 2023; Cacan and Kokten, 2024).

As a result of the species-based evaluation, the Mg contents obtained from the hay and straw of cereals are presented in *Figure 5*. When the cereals were evaluated based

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on species, that is, when the cereal varieties given in *Table 7* were averaged as species, 0.17% Mg was obtained from barley, 0.16% from bread wheat, 0.13% from durum wheat, and 0.16% from triticale. It was determined that there was a statistically significant difference between these ratios for cereal types in terms of hay. The lowest K ratios were obtained from durum wheat, barley, bread wheat, and triticale, constituting the group with the highest statistical value. In terms of straw, the average Mg content of barley, bread wheat, durum wheat, and triticale were 0.09%, 0.09%, 0.09%, and 0.05%, respectively. A statistically significant difference was found between these ratios for cereal types in terms of straw. While the lowest Mg content was found in triticale, the highest values were found in barley, bread wheat and durum wheat (*Table 7*; *Fig. 5*).

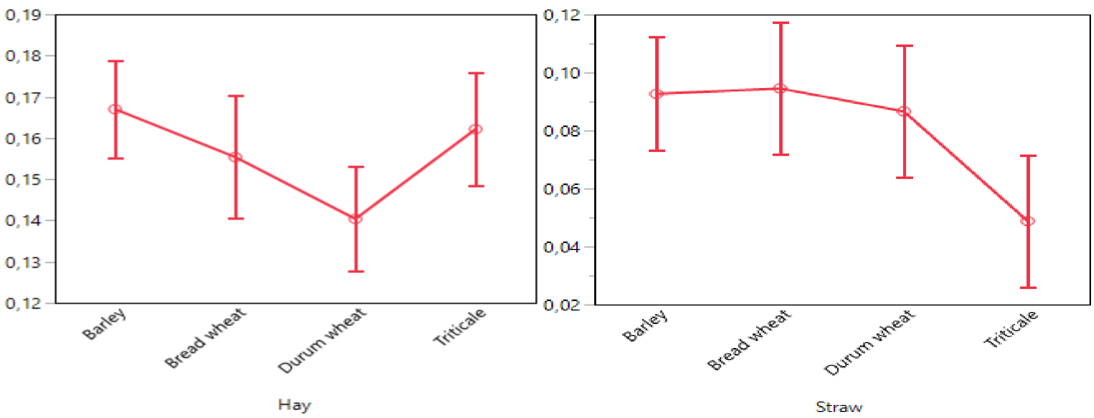

Figure 5. *Mg ratios (%) detected in hay and straw from cereal*

Jones et al. (1991) reported that the Mg content of wheat and barley was between 0.15% and 0.50% during the spike period. Regarding these limit values, it is understood that the Mg content of the dry grasses of cereals was adequate for all varieties except Kunduru-1149 and Dumlupınar varieties of durum wheat, while the Mg content of straw was inadequate for all varieties.

Cacan and Kokten (2019) reported that cereal grains have an important role in animal nutrition. Yolcu (2008) reported Mg content of 0.28% in barley and 0.24% in wheat, Cacan and Yılmaz (2015) reported Mg content of 0.14% in wheat, Egrıtas and Onal Asci (2015) reported Mg content of 0.14-016% in triticale, Cacan et al. (2017) reported Mg content of 0.14% in eight different wheat varieties, Basbag et al. (2018) 0.13%, Basbag et al. (2018) reported Mg content in bread wheat of 0.14% and 0.16% in durum wheat, Uslu et al. (2021) reported average Mg content in triticale varieties was 0.09-0.18% and Solmaz et al. (2022) reported Mg content in wheat was 0.12-0.15%. In this study, the average Mg content of 0.12-0.18% obtained from the hay of cereals and the average Mg content of 0.06-0.12% obtained from the straw of cereals were similar to the findings of the researchers.

Conclusion

In this study, in which the N, P, K, Ca, and Mg contents of both dry grasses and straws of some cereal species and varieties were analyzed, it was concluded that both

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dry grasses (except barley varieties) and straws of cereals were deficient in N content, while both dry grasses and straws of cereals were deficient in P content. In terms of K content, it was concluded that cereal dry grasses were sufficient and straws were deficient (except barley varieties); in terms of Ca content, dry grasses and straws of cereals were sufficient; and in terms of Mg content, dry grasses were sufficient and straws were deficient.

Author contributions. Both authors contributed to the writing of the manuscript and literature search.

Conflict of interests. The authors declare that they have no conflict of interests.

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