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Research article

Comparison of foreign-origin alfalfa cultivars in terms of quality and macro-micro element contents under semi-arid climatic conditions of Turkey

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Abstract

This study was carried out to determine the quality and nutrient contents of some alfalfa cultivars of foreign origin under semi-arid climatic conditions of Turkey and to compare them in terms of these characteristics. A total of 13 cultivars were used in the study, 12 of which were of foreign origin and 1 of which was a standard cultivar. The study was established and conducted according to a randomized complete block design. There was no statistical difference among alfalfa cultivars in terms of CP, ADF, NDF, RFV, Ca, Mg and P contents. The highest K values were obtained from all cultivars except La Torre. The highest Fe content was obtained from Iside; the highest Cu content from Iside, Bilensoy and Riviera vicentina; the highest Mn content from Iside and Sabrina; and the highest Zn content from Iside. Higher values were obtained in the first year for ADF, NDF, Mg, Fe, Cu and Mn, and in the second year for RFV, P, K and Zn. As a result, although there were some differences among the cultivars in terms of microelements, it was determined that there were no statistically significant differences among the cultivars in terms of macro elements (except K) and CP, ADF, NDF and RFV parameters, which are of great importance in animal nutrition. Therefore, it was concluded that all alfalfa cultivars of foreign-origin produced high-quality forage comparable to standard cultivars and can be used as an alternative to standard cultivars in semi-arid climatic conditions of Turkey.

Keywords: Forage quality, Lucerne, *Medicago sativa*, Nutrients.

Introduction

Forage crops are plants that contain nutrients that livestock must take into their bodies in order to survive and produce the products expected from them; in addition, they do not adversely affect animal health or animal products when fed within certain limits, which are cultivated or grow spontaneously in nature (Hatipoğlu *et al*., 2009). The main purpose of forage crop production is to provide fodder with the quality roughage required by livestock. The potential of forage crop agriculture is undoubtedly one of the most important factors affecting a country's production of animal products (Ekiz *et al*., 2011). Forage crops have great importance in animal nutrition in terms of being a cheap source, containing essential nutrients for the rumen flora of animals, being rich in vitamins and minerals, increasing the reproductive power of animals and provide high quality animal products (Serin and Tan, 2001).In animal nutrition, it is very important to provide cheap and quality feed to farm animals. Forage crops also have benefits such as bringing organic matter to the soil and preventing erosion (Ekiz *et al*., 2011). In addition, one of the most important benefits of mixed or pure cultivation of forage crops is to reduce the grazing pressure on pastures, which are our natural forage resources (Sayar *et al*., 2015).

Natural grassland and pastures are the most important forage resources for our animals. However, these areas have been subjected to heavy and excessive grazing for years due to some reasons (legal issues, unconsciousness, etc.) and now they are far from supplying the forage needs of livestock (Yildiz and Cacan, 2023). One of the most effective methods in reducing these pressures on pastures is promoting the cultivation of forage crops and in addition to this, it is necessary to provide quality forage. Alfalfa, which is defined as the queen of forage crops, has high adaptability, a long lifespan, can be harvested many times in a vegetation period, high productivity, high nutritional value and some cultivars are grazeable; due to these reasons, it differs from other forage crops. This valuable forage crop is found naturally in almost every region of Turkey and its cultivation has been increasingly widespread in recent years (Kır and Soya, 2008).

Alfalfa (*Medicago sativa* L.) is a forage plant with high value and gives plenty of forage. Turkey is the gene center of alfalfa and the oldest recorded information states that alfalfa was used as a forage crop in Turkey 3300 years ago (Hansen, 1988; Soya *et al*., 2004). Alfalfa is rich in protein, as well as vitamins such as carotene (Provitamin A) and tocopherol (vitamin E). With the help of its deep root system, alfalfa easily benefits from water and plant nutrients found in deep areas that other plants could not use. Alfalfa leaves a nitrogen-rich soil for the next plant in its root nodosities (Soya *et al*., 1997). Alfalfa is naturally found in almost every region of Turkey. Cultivation of alfalfa has become increasingly common in recent years. This situation makes it necessary to research and adapt new cultivars for our country, in addition to existing alfalfa cultivars. Because of the mentioned reasons, it has become compulsory to develop new cultivars of forage crops and especially alfalfa. Introducing new alfalfa cultivars to a region and initiating breeding and evaluating efforts is of great importance (Iqbal *et al*., 2017). Many studies have been conducted both in Turkey and in different countries of the world regarding the quality and mineral substance content of alfalfa cultivars in various climatic conditions (Sharma, 2013; Donmez and Hatipoglu, 2023; Popa *et al*., 2024; Ünal, 2024; Varol *et al*., 2024; Begna *et al*., 2025; Lee *et al*., 2025). This study was carried out to determine the quality traits and macro and microelement contents of some foreign-origin alfalfa (*Medicago sativa* L.) cultivars and to compare the cultivars in terms of these traits under semi-arid ecological conditions of Turkey.

Materials and Methods

Plant materials and study site: A total of 13 alfalfa cultivars were used in the study, 12 of which were of foreign origin (Iside, Osjecka 99, Ezzelina, Diane, Prosementi, Queen, Emiliana, Riviera vicentina, Banat vs, La Torre, Sabrina and Escorial) and the remaining one was used as a standard cultivar (Bilensoy 80). The alfalfa cultivars used in the study were obtained from different institutions and organizations. According to the Registration Reports of the Ministry of Agriculture and Forestry, the average dormancy values of cultivars used in the study varied between 4 and 7. This research was conducted in Bingöl University Genç Vocational School Application and Research Area under irrigated conditions between 2019 and 2021. The average altitude of the research area was 1125 m (Fig 1).

Soil and climatic characteristics: The climate data of the Bingöl province for 2020, 2021 and long years were recorded (Table 1). According to the data obtained, the monthly average temperature value was 13.8 ˚C, total precipitation was 839.2 mm and relative humidity was 51.9% for 2020 and the monthly average temperature value was 14.2°C, total precipitation was 668 mm and relative humidity was 48.5% for 2021. It was observed that the average temperature values for the years 2020 and 2021were above the long-term average, while the precipitation amounts and relative humidity values were below the long-term averages.

Analysis of soil samples taken from 10 different points and 0 to 30 cm depth of the research location was carried out in Bingöl University, Faculty of Agriculture, Soil Science and Nutrition Department Laboratory. The soil structure of the research location was found to be sandy-loam (clay rate 19.11%, loamy rate 16.71% and sand rate 64.18%), pH level neutral, salt-free, less limy, organic matter and available phosphorus ratios low, and potassium content sufficient.

Experimental design and laboratory analysis: The trial was conducted on 21 June 2019, following the soil preparation made in May. The research was set up with three replications according to the randomized complete block design. In the experiment, parcel lengths were 5 m, the distance between rows was 20 cm and 6 rows were

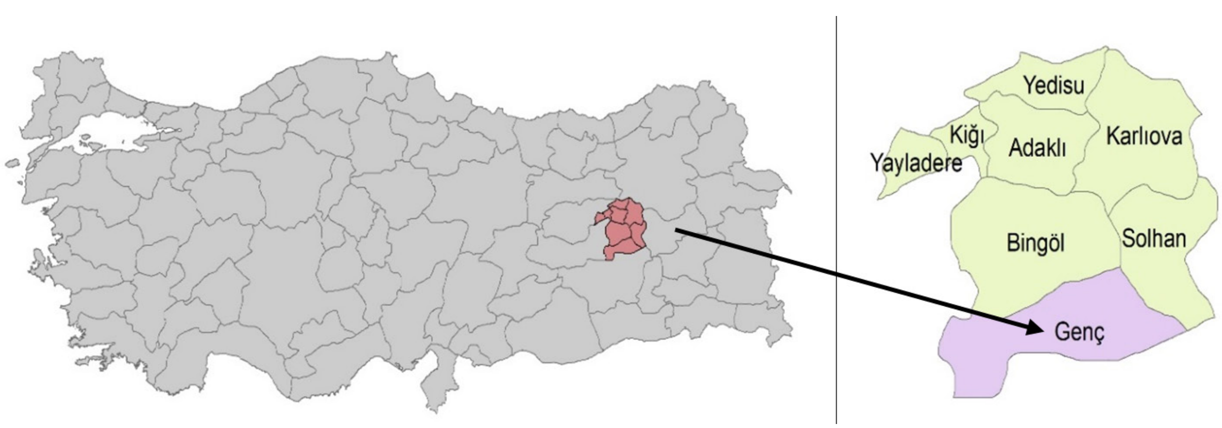

Fig 1: Location of research area

Table 1. Climate data of Bingöl province

Month	Average temperature (^{0}C)			Total precipitation (mm)			Relative humidity (%)		
	2020	2021	LY	2020	2021	LY	2020	2021	LY
January	0.4	-1.1	-2.2	81.4	185.0	136.5	65.2	69.3	72.8
February	0.8	4.0	-0.9	102.5	56.2	131.0	67.0	60.2	71.0
March	7.5	6.1	4.7	265.8	133.9	131.3	69.1	62.4	65.2
April	11.4	14.3	10.9	134.0	22.5	110.1	60.5	50.2	61.1
May	16.9	20.4	16.2	138.8	3.3	80.6	55.6	33.3	56.9
June	22.4	24.4	22.2	10.0	1.8	21.1	40.6	30.2	44.3
July	27.0	28.4	26.7	5.7	0.2	6.9	35.3	28.6	37.2
August	26.5	27.3	26.7	0.6	3.9	4.9	29.9	31.0	36.0
September	24.0	21.3	21.3	1.2	12.7	14.8	32.3	36.1	41.3
October	17.1	14.8	14.5	0.0	72.6	69.0	36.3	41.8	56.4
November	8.5	9.4	6.8	56.2	67.2	94.7	59.7	66.5	65.2
December	3.1	1.4	0.7	43.0	109.1	131.1	72.0	72.5	73.1
Average/Total	13.8	14.2	12.3	839.2	668	932	51.9	48.5	56.7

LY: Long years

planted in each parcel. 30 kg of seed were used per hectare in planting. Before sowing, 4 kg nitrogen (N) and 10 kg phosphorus (P_2O_5) were applied to experimental plots (Çaçan *et al.*, 2018; Çaçan *et al.*, 2020).

The experiment was irrigated by sprinkler irrigation. Depending on the climate, the irrigation interval varied between 7 and 12 days. When any weeds, diseases and pests were detected in the parcels, they were managed. After 2019, the year of establishment of alfalfa cultivars, four cuttings were made each year in 2020 and 2021. In both years, analyses were performed on samples belonging to the second cutting.

Crude protein, acid detergent fiber (ADF), neutral detergent fiber (NDF), calcium (Ca), magnesium (Mg), phosphorus (P) and potassium (K) analyses were performed at Ondokuz Mayıs University of Agriculture Faculty Laboratory with the help of a NIRS (Near Infrared Spectroscopy) device. Digestible dry matter (DDM=88.9-(0.779xADF%)), dry matter intake (DMI=120/NDF%) and relative feed values (RFV=(DDM x DMI)/1.29) were calculated using ADF and NDF values (Morrison, 2003). Fe (iron), Cu (copper), Mn (manganese) and Zn (zinc) contents of alfalfa cultivars were determined at Bingöl University Central Laboratory Application and Research Center with the help of an ICP-MS device.

Statistical analysis: The data were subjected to analysis of variance (ANOVA) with the help of the JMP statistical software (a software belonging to the SAS program), and the differences among the groups were compared with the Tukey test. In addition, Dunnett's test was used to compare the cultivars of foreign origin with the standard cultivar (JMP, 2018).

Results and Discussion

CP, ADF, NDF contents and RFV: Crude protein (CP), ADF, NDF and relative feed value (RFV) of foreign-origin alfalfa cultivars under semi-arid conditions are presented in Table 2.

Differences among cultivars and cultivar x year interactions were not statistically significant for CP, ADF, NDF and RFV, whereas year effects were significant except for CP.CP ranged between 19.8 and 21.3%, ADF between 31.0 and 36.0%, NDF between 39.7 and 45.8% and RFV between 125 and 152. No significant year effect was observed for crude protein. However, ADF and NDF were higher in the first year and lower in the second year, whereas RFV showed the opposite trend. This indicates improved forage quality in the second year (Table 2). Similar findings were reported by Engin and Mut (2017; 2018).In terms of quality parameters (CP, ADF, NDF and RFV), foreign-origin cultivars did not differ significantly from the standard cultivar. Therefore, these cultivars can be considered suitable alternatives under the semi-arid conditions of Turkey.

Mean CP, ADF, NDF and RFV values were 20.4, 33.0, 42.4% and 140, respectively. Based on the classification of Lacefield (1988), CP was in the premium class and ADF, NDF and RFV were in the first-quality class, indicating that the cultivars produced high-quality forage. Similar results were reported by Seydosoglu *et al.*(2025) and Engin and Mut (2017) under comparable conditions.

According to Dunnett's test, Emiliana and Queen cultivars gave lower values for CP and RFV, while the

Table 2. Crude protein, ADF, NDF content and RFV of alfalfa cultivars

Cultivars	CP (%)			ADF (%)		
	2020	**2021**	**Mean**	**2020**	**2021**	**Mean**
Bilensoy 80	18.8	20.8	19.8	37.3	30.6	34.0
Banat vs	20.3	21.0	20.7	37.8	28.5	33.1
Diane	21.0	20.5	20.8	35.2	31.0	33.1
Emiliana	19.3	19.0	19.1	37.3	34.8	36.1
Escorial	21.3	20.6	20.9	31.4	30.7	31.0
Ezzelina	20.2	19.8	20.0	35.2	32.1	33.7
Iside	20.5	20.8	20.6	33.8	31.3	32.6
La Torre	21.3	20.1	20.7	33.5	30.1	31.8
Osjecka 99	21.7	20.9	21.3	32.8	30.5	31.7
Prosementi	20.1	20.7	20.4	34.6	31.0	32.8
Queen	19.7	19.2	19.5	36.4	33.2	34.8
Riviera vicentina	19.9	20.6	20.3	35.2	30.5	32.8
Sabrina	21.4	21.0	21.2	33.2	29.9	31.6
Mean	20.4	20.3	20.4	34.9 A	31.1 B	33.0
	CV: %6.29, Year (Y): ---, Cultivar (C): ---, Y*C: ---			CV: %9.05, Year (Y):**, Cultivar (C):---, Y*C: ---		
	NDF (%)			**RFV**		
Cultivars	**2020**	**2021**	**Mean**	**2020**	**2021**	**Mean**
Bilensoy 80	47.4	39.9	43.7	118	152	135
Banat vs	47.9	37.9	42.9	117	164	140
Diane	44.0	40.0	42.0	131	154	142
Emiliana	47.3	44.3	45.8	118	132	125
Escorial	41.3	39.6	40.5	146	154	150
Ezzelina	45.0	41.7	43.4	128	143	135
Iside	45.0	41.0	43.0	131	147	139
La Torre	43.2	39.5	41.3	135	154	145
Osjecka 99	41.2	40.1	40.7	144	151	148
Prosementi	42.6	40.3	41.5	137	150	144
Queen	45.9	43.1	44.5	124	137	131
Riviera vicentina	44.9	39.9	42.4	128	152	140
Sabrina	40.8	38.6	39.7	144	161	152
Mean	44.4 A	40.5 B	42.4	131 B	150 A	140
	CV: %8.30, Year (Y): **, Cultivar (C): ---, Y*C: ---			CV: %12.06, Year (Y): **, Cultivar (C): ---, Y*C: ---		

**: P≤0.01.

rest of the cultivars gave higher values compared to the Bilensoy cultivar.ADF and NDF, Emiliana and Queen cultivars gave higher values and the rest of the cultivars gave lower values compared to the Bilensoy cultivar. However, none of the cultivars differed significantly from the standard cultivar (Bilensoy) in terms of CP, ADF, NDF or RFV (Fig 2).

Ca, Mg, P and K contents: Ca, Mg, P and K contents of foreign-origin alfalfa cultivars under semi-arid conditions were recorded (Table 3). Differences among cultivars were not statistically significant for Ca, Mg and P, and cultivar x year interactions were also insignificant. However, year effects (except for Ca) and cultivar effects for K were significant.

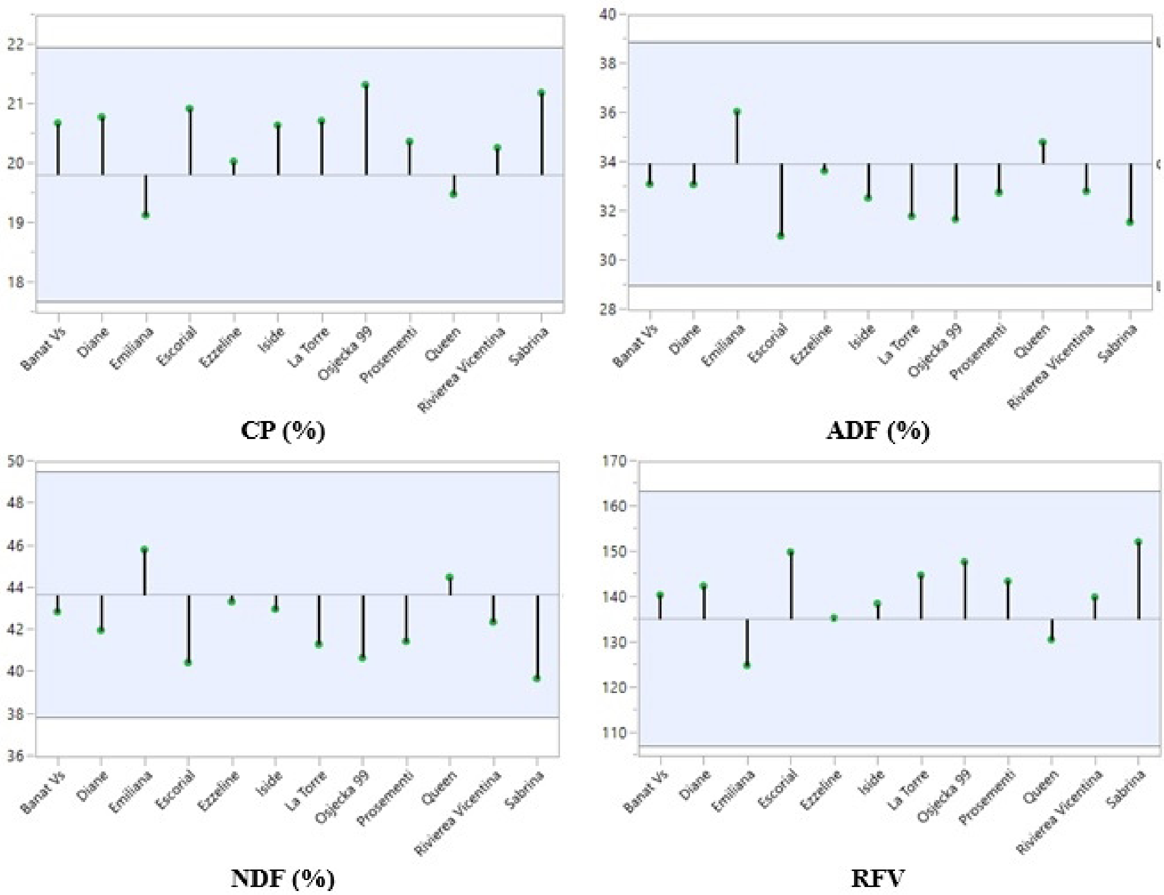

Fig 2: Comparison of foreign-origin cultivars with Bilensoy cultivar in terms of CP, ADF, NDF and RFV according to Dunnett's test

Ca ranged between 1.503 and 1.636%, Mg between 0.375 and 0.401%, P between 0.323 and 0.352%, and K between 1.872 and 2.217%. No significant year effect was observed for Ca, whereas Mg was lower and P and K were higher in the second year. The highest K value was obtained from Diane (2.217%) and the lowest from La Torre (1.872%), while the remaining cultivars were included in the statistically higher group (Table 3).

According to Dunnett's test, none of the foreign-origin cultivars differed significantly from the standard cultivar (Bilensoy) in terms of Ca, Mg, P, or K contents (Fig 3). Calcium is involved in protein formation, carbohydrate transport and membrane stability, contributing to plant stress tolerance. Magnesium is essential for photosynthesis as a structural component of chlorophyll and plays a role in protein synthesis and nutrient uptake. Phosphorus is required for cell division and energy transfer, whereas potassium regulates photosynthesis, carbohydrate transport and water balance (Karaman, 2012; Kutlu, 2015; Bolat and Kara, 2017).

In terms of animal nutrition, the Ca content of alfalfa plants should be between 0.80-3.00%, Mg content between 0.25-1.00%, P content between 0.25 to 0.70% and K content between 2.00 to 3.50% (Jones *et al*., 1991; Plank and Kissel, 2025). The mean Ca content of the cultivars was 1.566%, Mg content was 0.390%, P content was 0.338% and K content was 2.044%. It is seen that the Ca, Mg and P contents obtained for all cultivars in the study were within the determined limit values. Although Bilensoy, Emiliana, Escorial, La Torre and Queen cultivars were slightly below the determined limit values, it is possible to state that alfalfa cultivars were at or close to a sufficient level in terms of K.

In previous studies, Ca, Mg, P and K contents in alfalfa were reported within ranges similar to those obtained in the present study. Engin and Mut (2018) reported Ca values of 1.57 to 1.58%, Mg 0.29 to 0.30%, P 0.38 to 0.41% and K 2.44 to 2.86% as a five-cutting average of 10 cultivars. Çaçan and Kökten (2024a) reported corresponding values of 2.13, 0.45, 0.39 and 1.65%, respectively, as a three-year average in 16 cultivars, while in 29 alfalfa populations the values were 1.67% for Ca, 0.39% for Mg, 0.40% for P and 2.49% for K (Çaçan and Kökten, 2024b). Similarly, Çaçan and Arslan (2024) reported average Ca, Mg, P and K contents of 1.81, 0.40, 0.39, and 2.35%, respectively, across 39 alfalfa fields. Overall, these findings were consistent with the results of the present study.

Table 3. Ca, Mg, P and K contents of alfalfa cultivars

	Ca (%)			**Mg (%)**		
Cultivars	**2020**	**2021**	**Mean**	**2020**	**2021**	**Mean**
Bilensoy 80	1.504	1.563	1.533	0.388	0.381	0.385
Banat vs	1.470	1.592	1.531	0.385	0.382	0.383
Diane	1.551	1.454	1.503	0.393	0.358	0.375
Emiliana	1.501	1.509	1.505	0.387	0.368	0.378
Escorial	1.656	1.616	1.636	0.414	0.388	0.401
Ezzelina	1.550	1.608	1.579	0.396	0.400	0.398
Iside	1.545	1.585	1.565	0.391	0.392	0.391
La Torre	1.584	1.591	1.587	0.401	0.379	0.390
Osjecka 99	1.639	1.591	1.615	0.394	0.394	0.394
Prosementi	1.622	1.532	1.577	0.420	0.378	0.399
Queen	1.613	1.553	1.583	0.403	0.393	0.398
Riviera vicentina	1.510	1.628	1.569	0.386	0.386	0.386
Sabrina	1.571	1.573	1.572	0.398	0.380	0.389
Mean	1.563	1.569	1.566	0.397 A	0.383 B	0.390
	CV: %5.60, Year (Y): ---, Cultivar (C): ---, Y*C: ---			CV: %4.92, Year (Y): **, Cultivar (C): ---, Y*C: ---		
	P (%)			**K (%)**		
Cultivars	**2020**	**2021**	**Mean**	**2020**	**2021**	**Mean**
Bilensoy 80	0.313	0.345	0.329	1.694	2.301	1.998 ab
Banat vs	0.348	0.343	0.345	1.839	2.192	2.015 ab
Diane	0.344	0.350	0.347	1.912	2.521	2.217 a
Emiliana	0.314	0.332	0.323	1.758	2.164	1.961 ab
Escorial	0.334	0.345	0.340	1.688	2.186	1.937 ab
Ezzelina	0.335	0.341	0.338	1.879	2.246	2.063 ab
Iside	0.331	0.343	0.337	1.940	2.336	2.138 ab
La Torre	0.344	0.343	0.344	1.822	1.923	1.872 b
Osjecka 99	0.350	0.344	0.347	1.999	2.359	2.179 ab
Prosementi	0.330	0.342	0.336	1.894	2.397	2.145 ab
Queen	0.320	0.328	0.324	1.714	2.240	1.977 ab
Riviera vicentina	0.324	0.345	0.335	1.828	2.266	2.047 ab
Sabrina	0.346	0.358	0.352	1.892	2.150	2.021 ab
Mean	0.333 B	0.343 A	0.338	1.835 B	2.252 A	2.044
	CV: %4.77, Year (Y): *, Cultivar (C): ---, Y*C: ---			CV: %8.17, Year (Y): **, Cultivar (C): *, Y*C: ---		

*: P≤0.05, **: P≤0.01.

Fe, Cu, Mn and Zn contents: Fe, Cu, Mn and Zn contents of foreign-origin alfalfa cultivars under semi-arid conditions were recorded (Table 4). Year and cultivar effects were statistically significant for all four microelements, whereas the cultivar × year interaction was not significant.

Fe ranged between 357 and 535 mg kg^{-1}, Cu between 8.46 and 11.32 mg kg^{-1}, Mn between 34.5 and 54.4 mg kg^{-1} and Zn between 14.73 and 19.96 mg kg^{-1}. Fe, Cu and Mn contents were higher in the first year, whereas Zn was higher in the second year. The highest Fe value was recorded in Iside (535 mg kg^{-1}) and the lowest in La Torre (357 mg kg^{-1}), Sabrina (367 mg kg^{-1}), Emiliana (370 mg kg^{-1}) and Diane (385 mg kg^{-1}). The remaining cultivars were in the group with the highest Fe content. The overall mean Fe content was 431 mg kg^{-1}. The highest Cu content was observed in Riviera vicentina (11.32 mg kg^{-1}), Bilensoy (11.25 mg kg^{-1}) and Iside(11.21 mg kg^{-1}),

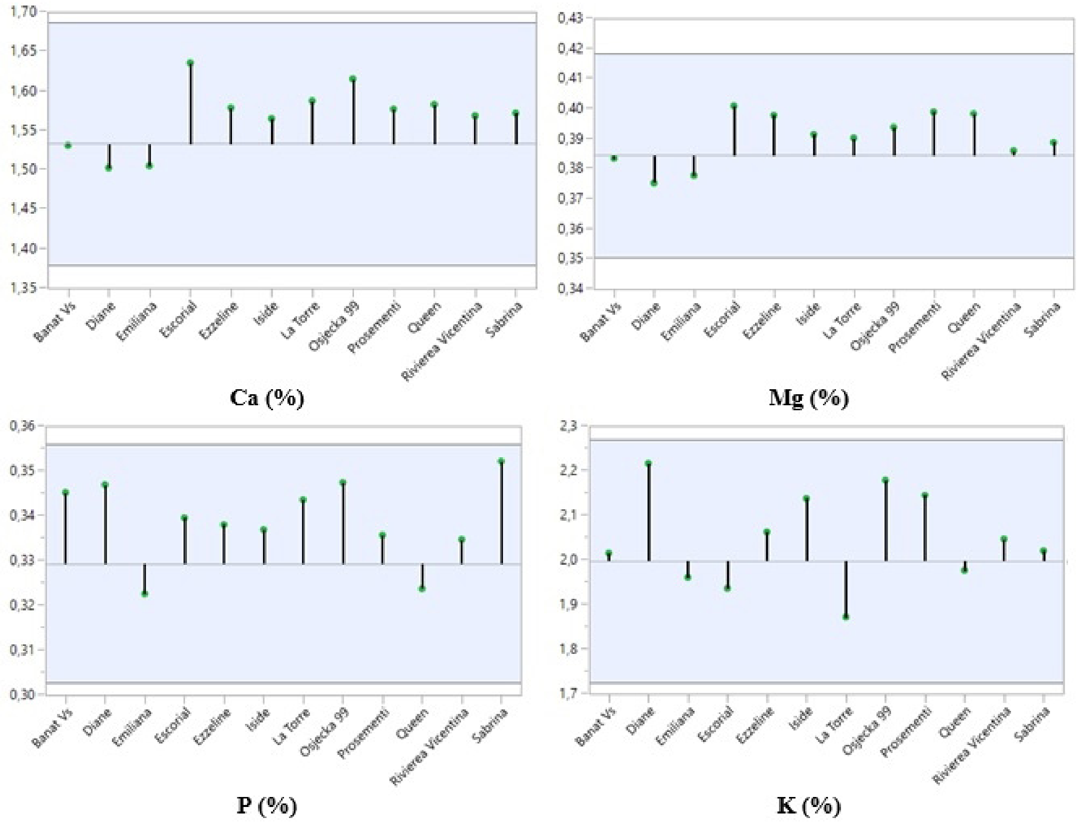

Fig 3: Comparison of foreign-origin cultivars with Bilensoy cultivar in terms of Ca, Mg, P and K contents according to Dunnett's test

whereas the lowest values were recorded in Diane (8.46 mg kg^{-1}), Banat vs (8.50 mg kg^{-1}) and Prosementi (8.69 mg kg^{-1}). The remaining cultivars were in the group that gave the highest value in terms of Cu content. The mean Cu content was 9.87 mg kg^{-1} (Table 4).

For Mn, the highest values were obtained from Sabrina (54.4 mg kg^{-1}) and Iside (54.0 mg kg^{-1}), and the lowest from Diane (34.5 mg kg^{-1}) and Emiliana (35.1 mg kg^{-1}). The remaining cultivars were in the group with the highest Mn content. The mean Mn content was 46.0 mg kg^{-1}. The highest Zn value was recorded in Iside (19.96 mg kg^{-1}) and the lowest in Prosementi (14.73 mg kg^{-1}). The rest of the cultivars were in the group with the highest Zn content and the mean Zn content was 17.68 mg kg^{-1} (Table 4).

According to Dunnett's test, foreign-origin alfalfa cultivars were compared with the standard cultivar (Bilensoy) for Fe, Cu, Mn and Zn contents (Fig 4). Iside and Queen showed higher Fe values than Bilensoy, whereas the remaining cultivars had lower values. The lower Fe values of Emiliana, La Torre and Sabrina were statistically significant. For Cu, only Riviera vicentina exceeded Bilensoy, while all other cultivars had lower values. The reductions observed in Banat vs Diane, La Torre and Prosementi were statistically significant. Regarding Mn and Zn, Escorial, Iside, Riviera vicentina and Sabrina had higher values than Bilensoy, whereas the other cultivars were lower. Among these, only the lower Mn value of Diane differed significantly from the standard cultivar (Fig 4).

Iron (Fe) is an essential micronutrient involved in respiration, photosynthesis and chlorophyll synthesis; therefore, its deficiency reduces chlorophyll production and plant growth. Fe deficiency is common in arid and semi-arid soils with high pH, where Fe becomes less available, whereas excess Fe may reduce the uptake of Cu, Zn, Mg and Mn. Copper (Cu) functions in chlorophyll synthesis, respiration and protein metabolism and is involved in symbiotic nitrogen fixation (Bolat and Kara, 2017). In the present study, lower Cu levels in the second year may be related to plant maturation, as Cu concentration generally decreases with advancing growth stages (Kutlu, 2015). Manganese (Mn) is associated with enzyme activation and photosynthetic processes, while zinc (Zn) plays roles in nitrogen metabolism and growth regulation (Karaman, 2012; Kutlu, 2015; Bolat and Kara, 2017).

In animal nutrition, recommended ranges are 30 to 250 mg kg^{-1} for Fe, 5 to 30 mg kg^{-1} for Cu, 25 to 100 mg kg^{-1} for Mn and 20 to 70 mg kg^{-1} for Zn (Plank and Kissel, 2025). In the present study, mean values were 431 mg

Table 4. Fe, Cu, Mn and Zn content of alfalfa cultivars

Cultivars	Fe (mg kg^{-1})			Cu (mg kg^{-1})		
	2020	**2021**	**Mean**	**2020**	**2021**	**Mean**
Bilensoy 80	525	447	486 AB	11.60	10.89	11.25 A
Banat vs	466	337	401 AB	8.81	8.19	8.50 B
Diane	421	349	385 B	9.24	7.69	8.46 B
Emiliana	393	347	370 B	10.65	8.26	9.45 AB
Escorial	506	427	467 AB	10.45	10.07	10.26 AB
Ezzelina	502	356	429 AB	9.83	9.34	9.58 AB
Iside	596	475	535 A	11.32	11.09	11.21 A
La Torre	368	345	357 B	9.75	8.88	9.31 AB
Osjecka 99	540	417	478 AB	11.63	9.09	10.36 AB
Prosementi	425	395	410 AB	8.98	8.40	8.69 B
Queen	531	443	487 AB	10.04	8.98	9.51 AB
Riviera vicentina	441	415	428 AB	11.38	11.27	11.32 A
Sabrina	398	335	367 B	11.99	8.89	10.44 AB
Mean	470 A	391 B	431	10.44 A	9.31 B	9.87
	CV: %15.9, Year (Y): **, Cultivar (C): **, Y*C: ---			CV: %11.8, Year (Y): **, Cultivar (C): **, Y*C: ---		
Cultivars	**Mn (mg kg^{-1})**			**Zn (mg kg^{-1})**		
	2020	**2021**	**Mean**	**2020**	**2021**	**Mean**
Bilensoy 80	67.0	33.4	50.2 AB	18.11	19.65	18.88 AB
Banat vs	49.0	33.2	41.1 AB	14.90	18.59	16.74 AB
Diane	40.2	28.8	34.5 B	15.28	18.96	17.12 AB
Emiliana	39.9	30.3	35.1 B	13.83	19.59	16.71 AB
Escorial	61.9	39.9	50.9 AB	18.96	19.21	19.09 AB
Ezzelina	50.3	36.5	43.4 AB	15.48	19.23	17.35 AB
Iside	70.1	37.9	54.0 A	19.13	20.78	19.96 A
La Torre	60.5	38.3	49.4 AB	15.92	18.12	17.02 AB
Osjecka 99	63.4	31.8	47.6 AB	16.30	16.44	16.37 AB
Prosementi	49.7	32.9	41.3 AB	12.79	16.67	14.73 B
Queen	51.0	35.6	43.3 AB	16.33	18.17	17.25 AB
Riviera vicentina	64.7	41.3	53.0 AB	18.30	20.40	19.35 AB
Sabrina	73.8	35.0	54.4 A	18.95	19.70	19.33 AB
Mean	57.0 A	35.0 B	46.0	16.48 B	18.88 A	17.68
	CV: %18.9, Year (Y): **, Cultivar (C): **, Y*C: ---			CV: %14.1, Year (Y): **, Cultivar (C): *, Y*C: ---		

**: P≤0.01, *: P≤0.05.

kg^{-1} for Fe, 9.87 mg kg^{-1} for Cu, 46.0 mg kg^{-1} for Mn and 17.68 mg kg^{-1} for Zn. Accordingly, Cu and Mn levels were within the recommended limits, Fe was above the commonly suggested range and Zn was slightly below the 20 mg kg^{-1} threshold. Although the optimal Fe range is reported as 30 to 250 mg kg^{-1}, Fe toxicity is considered to begin at approximately 500 mg kg^{-1} (Karaman, 2012); this threshold was exceeded only in the Iside cultivar. For Zn, while Plank and Kissel (2025) suggest a range of 20 to 70 mg kg^{-1}, Karaman (2012) reports a broader normal range of 5 to 100 mg kg^{-1} and toxicity beginning at 400 mg kg^{-1}. Based on this broader range, Zn levels in all cultivars can be considered adequate.

Previous studies have reported Fe, Cu, Mn and Zn contents in alfalfa within ranges comparable to those observed in the present study. Research conducted on different cultivars and populations under varying ecological conditions has shown considerable variability

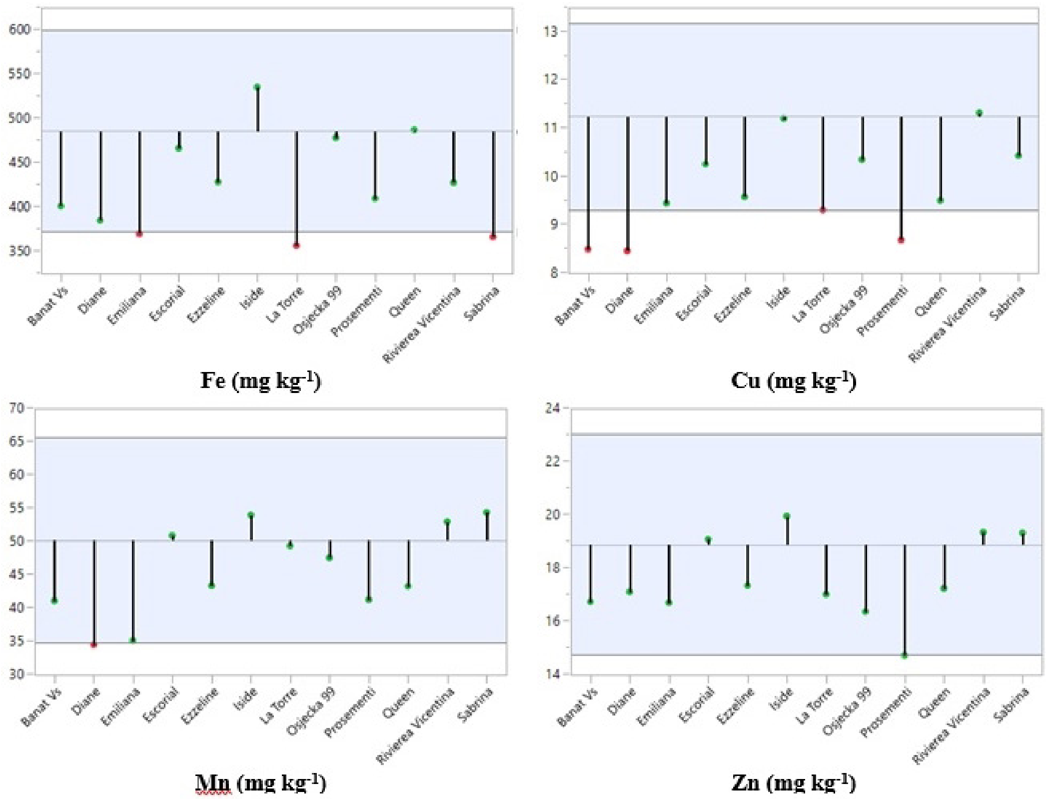

Fig 4: Comparison of foreign-origin cultivars with Bilensoy cultivar in terms of Fe, Cu, Mn and Zn contents according to Dunnett's test

in microelement concentrations (Çaçan and Kökten, 2023a; 2023b; Petković *et al.*, 2019; Lakic *et al.*, 2020; Samoraj *et al.*, 2023). Overall, the values obtained in this study fall within the previously reported ranges, indicating that the microelement composition of the evaluated cultivars is consistent with findings from similar environments.

Conclusion

In this study, the effects of foreign-origin alfalfa cultivars on quality traits and macro- and microelement contents under semi-arid climatic conditions of Turkey were evaluated. No statistically significant differences were detected among cultivars for CP, ADF, NDF, or RFV. Year effects were not significant for CP; however, ADF and NDF were lower and RFV was higher in the second year. For macro-elements, no significant cultivar differences were observed for Ca, Mg, or P, whereas K differed among cultivars, with all cultivars except La Torre showing higher values. Year effects were not significant for Ca; Mg was higher in the first year, while P and K were higher in the second year. Regarding microelements, the highest Fe content was recorded in Iside; the highest Cu values in Iside, Bilensoy and Riviera vicentina; the highest Mn in Iside and Sabrina; and the highest Zn in Iside. Fe, Cu and Mn were higher in the first year, whereas Zn was higher in the second year. Overall, although minor differences were observed in microelement contents, cultivars did not differ significantly in macro-elements (except K) or in CP, ADF, NDF and RFV, which are critical quality parameters in animal nutrition. Therefore, it was concluded that all alfalfa cultivars of foreign origin considered in this study produced quality forage at the level of standard cultivars and can be considered suitable alternatives to standard cultivars in semi-arid climatic conditions of Turkey.

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