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Research Article

MACRO AND MICRO ELEMENT CONTENTS OF THE HERBAGE OF SIX DIFFERENT FENNEL (*Foeniculum vulgare* Mill. *var. dulce*) POPULATIONS USED AS FEED ADDITIVE SUBSTANCES

Omer Suha Uslu[1,*], Osman Gedik[1], Ali Riza Demirkiran[2], Mahmut Tepecik[3], Ali Riza Ongun[3], Kubra Karatayli[1]

[1]*Kahramanmaraş Sütçü İmam University, Faculty of Agriculture, Department of Field Crops, Kahramanmaraş, Turkey*
[2]*Bingöl University, Faculty of Agriculture, Soil Science and Plant Nutrition Department, Bingöl, Turkey*
[3]*Ege University, Faculty of Agriculture, Soil Science and Plant Nutrition Department, İzmir, Turkey*

**Corresponding Author:*
E-mail: suhauslu@ksu.edu.tr

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ABSTRACT. This study was carried out to determine the mineral element contents of the fennel herbage which can be used as an additive in animal feeds. The research was investigated in the experimental area of Kahramanmaraş Sütçü İmam University, Faculty of Agriculture and Department of Field Crops in 2017-2018 winter season and established according to the completely randomized block design (CRD) as three replications. Six fennel populations collected from different regions in Turkey Tokat1, Tokat2, Tokat3, Urfa, Burdur and Konya were used in the study. According to the research results; It was determined the mean nitrogen (2.11-2.78%), phosphorus (0.31-0.39%), calcium (1.39-1.68%), potassium (2.30-2.92%), sodium (1392-8328 mg kg^{-1}), magnesium (0.54-0.61%), iron (215–623 mg kg^{-1}), copper (16.83-19.87 mg kg^{-1}). zinc (44.22- 53.68 mg kg^{-1}), manganese (35.77-58.53 mg kg^{-1}) content of fennel plant. Ca/P, K/Ca+Mg, Ca/Na, and K/Na ranged from 3.99-4.59, 1.20-1.38, 1.83-2.38, and 3.44-3.86, respectively. The macro elements for growth in the fennel plants as N, K, and P content had founded positively significant with all elements except Ca and Na content. The micro elements which are Fe, Cu, Zn, and Cu contents were also positively correlated with each other.

Keywords: *Foeniculum vulgare var. dulce, fennel, hay, macro and micro mineral elements*

INTRODUCTION

A quality animal feed has a direct impact on animal performance and operational gain. The quality of the feed can be defined in different ways. Feed quality is related to mineral element contents, energy value, protein ratio and quality, digestible ratio, fiber ratio, amount of mineral substances, vitamins and ratios, and sometimes animal yields. In practice, the consumption performance of animals reflects the quality of the feed. Feed quality is determined by the milk yield and increase of the animals, the increase in body weight and the performance of the animals. To achieve this quality, a number of additives may be included in the feed rations [1].

Many of aromatic and medicinal plants synthesize substances as secondary metabolites that are useful to the maintenance of health in animals and human [2, 3]. Plant growth and secondary metabolites which are contained depend on plant nutrition and its management which is an important factor in success of agriculture. For optimum plant production, macro and micro mineral elements must be balanced and should be sufficient for plants. In other words, the soil nutrition has that are needed for plants [4].

Minerals are nutrients that exist in the body of ruminants and are essential for sustaining life. They are the most important factors in maintaining all physiological processes. A lack of minerals is one of the most common nutritional deficiencies. The balance between minerals, as well as the mineral content of forages, are very important in animal nutrition. Tetany (hypomagnesia) and milk fever (hypocalcemia) incidences are among the most important. Therefore, it is important to know such balances in the forages of animal feed [5].

Plant nutrition is one of the most important factors for plant production. Nitrogen (N) is one of the most critical elements that affect plant growth and development [6]. N is the most recognized in plants for its presence in the protein molecule. Also, it is known to promote production, partitioning and accumulation of dry matter [7]. Potassium (K) is other one of the main mineral elements [8]. K is important in many plant physiological functions like energy metabolism, enzymatic activation, osmotic adjustment, water relations, stomatal regulation, carbohydrates synthesis and resistance against plant stress [9, 10, 11, 12]. Abou El-Magd et al. [13] reported that application of K improved plant length, leaf number, bulb dimensions, fresh and dry weight of leaves and bulbs and macro mineral element contents in leaf and bulb tissues of sweet fennel.

Feed additives are use in modern animal nutrition. They are products which are fed separately or as a component in feed mixture for animal performance improving [14]. According to the information given by Gálik et al. [15] from the studies of some researchers, feed additives are used in animal nutrition for their positive effect on health status and quality of animal production [16, 17]. Capcarová and Kolesárová [18] reported that feed additives are products with positive effects on animal performance. Fennel seed is one of these substances. Aromatic plants are being explored as options to antimicrobials, due to their different active substances [1]. In the Gálik et al. [15]'s study analyzed the effect of some fruits essential oils on biochemical indicators and nutrients digestibility in the nutrition of horses. The fruits essential oils can significantly affect some biochemical indicators as cholesterol and triglycerides. However, this additive has significant effect on dry matter and organic matter digestibility as well as in Mg and K apparent digestibility. Uslu ve Gedik [1] reported that the fennel herbage was found to be rich in nutritive value. The use of feed additives in animal husbandry is expected to provide advantages in terms of nutritional value and digestibility. In the light of all this information, determining the mineral element contents of the herbage obtained after the harvest is expected to provide a multifaceted benefit.

The regional plants are more adapted to its local environmental conditions. A considerable number of medicinal and aromatic plants are locally adapted and considered as native to arid zones of the world [19]. Fennel (*Foeniculum vulgare* Mill.) is one of the most important medicinal plants grown within the Mediterranean region, in Europe and North Africa [20].

Fennel (*Foeniculum vulgare* Mill.) is a short lived aromatic herb, indigenous to Europe and cultivated mostly in India, China and Egypt [21]. It does also contain essential oil which is used for many purposes by human [22]. Fennel (*Foeniculum vulgare*), is a hardy and perennial herb [23, 24]. Fennel is a well-known aromatic medicinal plant which is used in traditional medicine as spice and substrate in industry [25]. In Mediterranean region, it is cultivated and also widespread such as Italy, Turkey and Iran [26]. In Turkey, fennel cultivation area was approximately 1551 ha in 2019 [27]. The fruits of sweet fennel contain essential oil which is containing anethole, limonene, fenchone, estragole and camphene among of the essential oil of seeds [28]. The constituents of plants depend upon internal and external factors affecting the plant such as genetic structures and ecological conditions [25].

There are very few studies on the mineral element contents of the herbage of these plants and their effect and benefit on animal nutrition. The studies on the mineral composition and mineral balance of fennel herbage are very important because of the potential use of the forage plant in animal nutrition. Some of the studies mentioned above are summarized below:

N, P, K, Ca and Mg contents of fennel were significantly influenced by different cropping patterns and humic acid application. The highest concentration of N (3.88%), P (0.38%), Ca (1.08%), K (2.89%) and Mg (1.02%) was observed with the lowest P (0.29%) and Ca (0.81%) concentration of fennel [29]. A greenhouse experiment was conducted to assess the effect of NaCl on growth in 67-d-old plants of *Foeniculum vulgare* Mill. Mineral element concentrations of *Foeniculum vulgare* were subjected to varying concentrations of NaCl in sand culture. Mean shoot Na^+, root Na^+, shoot K^+, root K^+, shoot Ca^{2+}, and root Ca^{2+} contents, and shoot K^+/Na^+, root K^+/Na^+, shoot Ca^{2+}/Na^+, and root Ca^{2+}/Na^+ ratios were determined as 12.00, 10.70, 58.75, 27.20, 15.25, 5.72 mg g^{-1}(d.m.), 5.06, 2.56, 1.31, and 0.52 respectively [30]. A field experiment during two seasons (2003-2004 and 2004-2005), the effects of biofertilization on growth, fruit yield, and oil composition of fennel plants were investigated. The amounts of N (0.96-1.27%), P (0.23-0.38%) and K (3.05-4.00%) in the plant tissue were occurred [31]. Younis et al. [20] reported that the mean values of N (1.98-3.20%), P (0.14-0.37%) and K (2.03-3.99%) of fennel herbages in the two growing seasons.

Na, K, Mg, Ca contents of fennel are among to 0.07-1.32, 2.45-40.60, 0.57-5.37, 1.00-16.78 mg g^{-1} respectively which by Yaldiz and Camlica [32] who are reported. Abou El-Magd et al. [13], Barzegar et al. [33] and Sadanandan et al. [34] who reported that N, P, and K content in leaves and bulbs of sweet fennel plants were enhanced by increasing potassium fertilizer levels. Rai et al. [35] suggested that N fertilizer improved K utilization by the plant. In general, the uptake of N and K by sweet fennel significantly increased with increasing levels of application of nutrients. Also, the higher content of mineral elements under higher N and K levels can be attributed to increase in root proliferation, activate on cell, increase root cation exchange capacity, growth stimulating compounds to roots and absorb other mineral elements from the soil [36, 37]. The soil application of N and K increased yield and quality. N and K fertilizer increased macro mineral elements in tissue of fennel, although K had adverse effect on Ca and Mg content of sweet fennel [33].

The differences specific to fennel herbs but can be also attributed to agro technical and weather conditions [38, 39]. In particular, the content of microelements in herbal material can be subject to considerable fluctuations [40]. The deficiency of iron in food rations is a common problem. It is most often due to the presence of its poorly assimilable forms in food. Herbal products contain Fe in a form easily available to the organism [41]. Copper is an important microelement accompanying iron [42]. Manganese is another microelement increasing the utilization of Fe from food. Fennel flower proved to be the herb which accumulated twice as much of zinc (74.53 μg g^{-1}) as the other herbs. Apart from many catalytic, structural and regulatory functions, zinc has a significant effect on the assimilability of basic nutrients [41]. In a survey research in Kahramanmaraş region, mineral contents of wheat and corn grains in the 16 different regions in there were determined. As results, Fe, Zn and Cu contents of wheat grain ranged from 60.41-424.30, 23.25-41.76, and 1.80-5.39 mg kg-^{1}, respectively. Also Fe, Zn and Cu contents of corn grain ranged from 2.71-313.36, 16.31-130.56, and 1.80-3.59 mg kg^{-1}, respectively [43].

Medicinal, aromatic or as using additively plants production is mainly under condition of sustainable agriculture. Management of environmental parameters is very critical in the plant growths system. By using correct nutritional sources through organic manures and bio fertilizers, quantity and quality of active substances of medicinal plants can be maximized [44, 45]. Even small amounts of herbs in animal food can provide a good source supplementing mineral deficiencies. In this study, the fennel herbage nutrient content which can be used as an additive in animal feeds were determined which obtained from fennel which had grown between 30-50 cm. The aim of this study was to determine nutritional quality of fennel herbage (*Foeniculum vulgare*) which collected from different regions of Turkey.

MATERIALS AND METHODS

This research was carried out in the experimental area of Kahramanmaraş Sütçü İmam University, Faculty of Agriculture and Department of Field Crops in 2017-2018 production seasons. The research was conducted in 2017 winter growing season. Six fennel populations collected from different regions in Turkey Tokat1, Tokat2, Tokat3, Urfa, Burdur and Konya were used in the study. The research was established according to completely randomized block design (CRBD) as three replications. In this study, fennel herbage nutrient content which can be used as an additive in animal feeds was investigated. There was no disease and pest control in the parcels. Four green fodder samples were taken from the production parcels in each of three replications. The samples were taken from each parcel separately during the flowering stage. The fennels were cut with sickle. The mown fennels were dried in the oven at 70 °C for 48 hours. Then it was milled and passed through a 1 mm sieve.

Some physical and chemical properties determined as a result of the analysis applied to the samples taken from 0-30 depths of the experiment area of the research place. According to the soil analysis, soil pH was found as nötral at a depth of 0-30 cm. Experiment area soil has clay, slightly alkaline (pH 7.66), low organic matter (1.66%), calcareous (3.91%), low salt (0.86%), medium phosphorus (P2O5) ratio medium (6.29 kg^{-1}) and high potassium (K_2O) ratio (53 kg da^{-1}).

The research area is in a region where the summer months are hot and dry and the winter months are warm and rainy. During the ryegrass growing season in Kahramanmaraş, the total amount of precipitation for was 523.5 mm in the period when the experiment was carried out, compared to the average of many years (650.8 mm), there was less rainfall in the 2017-2018 period. The average temperature was 14.7 °C during the 2017-2018 cultivation periods when the research was conducted, and it was higher than the average for many years (12.6 °C). The humidity value was determined as 59.97% lower than in the 2017-2018 periods by comparing the average relative humidity of the average of long years (63.04%).

Fertilization was carried out in pure conditions at 60 kg ha^{-1} N and 60 kg ha^{-1} P_2O_5. 30 kg of nitrogen and all of phosphorus were given with planting time (with 21% Ammonium Sulphate and 25% Super Phosphate), the remaining 30 kg of nitrogen was given at the tillering time (with 21% Ammonium Sulphate). Weed control was done manually. Disease and pest fight has not been made. The parcel length of the experiment was planted as 3 m and the parcel width was 1.2 m. Seeds sown in the parcel were calculated as 40 kg ha^{-1}. The experiment was carried out in dry conditions. Herbage harvest was made for each plot in the grain filling period.

The fennel samples used in the experiment were made ready for plant nutrient analysis by wet burning. According to the modified Kjeldahl method [46] in N samples in forage samples were determined. K, Ca, Mg, Na, Fe, Cu, and Zn nutrient elements after burning with wet burning (HNO_3; $HClO_4$; 4:1), P with vanadomolibdo phosphoric yellow colour, spectrophotometrically [47], K, Na and Ca were determined by flame photometer, Mg, Fe, Zn, Mn and Cu were determined by Atomic Absorption Spectrophotometer [48]. The data obtained were analysed according to randomised complete block design (RCBD) using the SAS V.9.3 statistical program [49]. The differences between the averages were compared according to the LSD test [50].

RESULTS AND DISCUSSION

In this research, the properties of different fennel varieties in terms of some mineral elements (N, K, Ca, P, Mg, Na, and Fe in Table 1, Cu, Zn and Mn contents with Ca/P, K/Ca+Mg, Ca/Na, and K/Na ratios in Table 2) were examined in terms of macro and micro elements and theirs ratios.

Table 1. *Average N, K, Ca, P, Mg, Na and Fe values of different fennel herbs*

	N (%)	K (%)	Ca (%)	P (%)	Mg (%)	Na (mg kg^{-1})	Fe (mg kg^{-1})
Tokat 1	2.67	2.80	1.48	0.38	0.55	8328	413
Tokat 2	2.78	2.92	1.68	0.39	0.61	7733	523
Tokat 3	2.31	2.66	1.67	0.34	0.58	7142	623
Urfa	2.45	2.66	1.50	0.37	0.56	7819	533
Burdur	2.19	2.63	1.49	0.33	0.54	7343	282
Konya	2.11	2.30	1.39	0.31	0.54	6527	215
Mean	2.42	2.66	1.55	0.36	0.564	7481	431
LSD	0.80	0.53	0.37	0.11	0.12	1392	352
CV (%)	18.23	10.93	13.09	17.09	11.21	10.23	44.86
F Value	1.08	1.55	0.92	0.88	0.64	1.99	2.00
Probability	ns	ns	ns	ns	ns	ns	ns

ns: non significant statistically

The mean nitrogen (mean 2.42%) and phosphorus (0.36%), contents of fennel plants are determined in accordance with those reported by [20], but more than result of [31] and lower than result of [29]. These results as mean Ca (1.55%) content of fennel herbages is in accordance with those reported by [30] and [29] with more than result of [29]. Potassium (2.66%) and sodium (7481 mg/kg) contents are low as compared with research reported by [20], [31] and [29]. The fennel herbs contained different amounts of macro and micro elements (in Table 1 and 2) can be a result of differences specific to fennel herbs but can be also attributed to agro technical and weather conditions of Turkey country.

Table 1 shows that element content of fennel fruits were not significantly changed among the all genotypes ($P<0.05$). The concentration of nitrogen ranged from 2.11

(Konya genotype) to 2.78% (Tokat 2 genotype). Phosphorus (P) ranged from 0.31 (Konya genotype) to 0.39% (Tokat 2 genotype). Potassium concentrations of fennel varied between 2.30 (Konya genotype) and 2.92% (Tokat 2 genotype). Calcium concentrations determined between 1.39 (Konya genotype) - 1.68% (Tokat 2 genotype). Magnesium concentrations determined between 0.54 (Konya and Burdur genotypes) and 0.61% (Tokat 2 genotype). Sodium concentrations determined between 6527 (Konya genotype) and 8328 mg kg^{-1} (Tokat 1 genotype). The mean Na concentration (7481 mg kg^{-1}) of fennel plant was founded more than [32] who reported that fennel fruits content (1.32 mg g^{-1}) in Antalya genotype which is originated from local genotypes, while PI174213 which is USDA genotypes (0.07 mg g^{-1}) have the lowest Na content. The concentration of iron (Fe) changed between 215-623 mg kg^{-1}. Tokat 3 had the highest value and Konya genotype had the lowest value.

Table 2. *Average Cu, Zn, Mn values with Ca/P (milk fever), K/Ca+Mg (tetany), Ca/Na and K/Na ratios of different fennel herbs*

	Cu (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})	Ca/P	K/Ca+Mg	Ca/Na	K/Na
Tokat 1	19.87	47.77	49.30	3.99	1.38	1.83	3.46
Tokat 2	19.48	53.68	58.53	4.30	1.28	2.19	3.86
Tokat 3	17.70	47.38	54.93	4.88	1.20	2.38	3.74
Urfa	18.73	47.65	51.97	4.33	1.25	2.03	3.44
Burdur	16.83	44.22	39.80	4.52	1.29	2.08	3.70
Konya	16.83	46.16	35.77	4.59	1.21	2.14	3.57
Mean	18.24	47.81	48.38	4.43	1.27	2.11	3.63
LSD	2.99	18.01	24.45	1.19	0.31	0.71	1.33
CV (%)	9.04	20.71	27.78	14.81	13.31	18.53	20.08
F Value	1.91	0.31	1.30	0.63	0.45	0.65	0.16
Probability	ns	ns	ns	ns	ns	ns	ns

ns: non significant statistically

In Table 2, the concentration of copper (Cu) ranged from 16.83 to 19.87 mg kg^{-1}. The highest Cu content was found from Tokat 1 genotype compared with other genotypes. The lowest Cu value was determined from Burdur and Konya genotypes. The concentration of zinc (Zn) ranged from 44.22 to 53.68 mg kg^{-1}. The highest Zn content was found from Tokat 2 genotype compared with other genotypes. The lowest Zn value was determined from Burdur genotype. The concentration of manganese (Mn) ranged from 35.77 to 58.53 mg kg^{-1}. The highest Mn content was found from Tokat 2 genotype compared with other genotypes. The lowest Mn value was determined from Burdur genotype. The mean micro elements as Fe and Zn contents of fennel plants are determined in accordance with those reported by [43] determined in corn and wheat, but Cu contents of fennel plant were founded more than result of mentioned above research.

The ratio of Ca/P ranged from 3.99 to 4.59. The highest ratio of Ca/P (milk fever incidences) was found from Konya genotype compared with other genotypes (Table 2). The lowest ratio of Ca/P was determined from Tokat 1 genotype. The ratio of K/Ca+Mg (tetany incidences) ranged from 1.20 to 1.38. The highest ratio of K/Ca+Mg was found from Tokat 1 genotype compared with other genotypes. The lowest ratio of K/Ca+Mg was determined from Tokat 3 genotype. The ratio of Ca/Na ranged from 1.83 to 2.38. The highest ratio of Ca/Na was found from Tokat 3 genotype compared with other genotypes. The lowest ratio of Ca/Na was determined from Tokat 1 genotype. The ratio of K/Na ranged from 3.44 to 3.86. The highest ratio of Ca/P was found from Tokat 2 genotype compared with other genotypes. The lowest ratio of Ca/P was determined from Urfa genotype.

Table 3. *Correlation analysis of nutrient contents and ratios of fennel genotypes*.

	N	K	Ca	P	Na	Mg	Fe	Cu	Zn	Mn	Ca/P	K/Ca+Mg	Ca/Na	K/Na
N	1													
K	0.763**	1												
Ca	0.356	0.393	1											
P	0.843**	0.814**	0.551*	1										
Na	0.103	-0.045	0.062	0.139	1									
Mg	0.555*	0.493*	0.817**	0.712**	0.215	1								
Fe	0.622**	0.624**	0.614**	0.617**	-0.092	0.561*	1							
Cu	0.674**	0.606**	0.588*	0.767**	0.315	0.637**	0.579*	1						
Zn	0.702**	0.521*	0.577*	0.805**	0.169	0.767**	0.527*	0.733**	1					
Mn	0.841**	0.750**	0.594**	0.822**	0.034	0.714**	0.903**	0.687**	0.755**	1				
Ca/P	-	-0.559*	0.251	-	-0.120	-0.052	-0.116	-0.319	-0.409	-0.353	1			
K/Ca+Mg	0.289	0.503*	-0.583*	0.159	-0.149	-0.395	-0.039	-0.074	-0.148	0.058	-	1		
Ca/Na	0.176	0.340	0.653**	0.287	-	0.406	0.493*	0.183	0.263	0.387	0.264	-0.264	1	
K/Na	0.403	0.657*	0.156	0.383	-	0.109	0.421	0.135	0.165	0.408	-0.249	0.443	0.738**	1

* $P < 0.05$; ** $P < 0.01$

Correlations analysis (Table 3) showed that the highest positive correlation coefficient was found between K and N (r=0.763) P and N (r=0.843), P and K (r=0.814), Mg and Ca (r=0.817), Mg and P (r=0.712), Fe and N (r=0.622), Fe and K (r=0.624), Fe and Ca (r=0.614), Fe and P (r=0.617), Cu and N (r=0.674), Cu and K (r=0.606), Cu and Ca (r=0.588), Cu and P (r=0.767), Cu and Mg (r=0.637), Zn and N (r=0.702), Zn and P (r=0.805), Zn and Mg (r=0.767), Zn and Cu (r=0.733), Mn and N (r=0.841), Mn and K (r=0.750), Mn and Ca (r=0.5943), Mn and P (r=0.822), Mn and Mg (r=0.714), Mn and Fe (r=0.903), Mn and Cu (r=0.687), and Mn and Zn (r=0.755) contents of fennel plant. It was also seen that other positive correlations were observed between P and Ca (r=0.551), Mg and N (r=0.555), Mg and K (r=0.493), Fe and Mg (r=0.561), Cu and Fe (r=0.579), Zn and K (r=0.521), Zn and Ca (r=0.577) contents of fennel plant. Ca/P ratio was correlated with N (r=0.614), P (r=0.651), and K (r=0.559) were correlated as negatively. It was also seen that other negative correlations were observed between K/Ca+Mg ratio with Ca content (r=0.583) and Ca/P ratio (r=0.691). K/Na ratio was correlated with Na content (r=0.772) and Ca/Na ratio (r=0.738) as negatively, but with K content (r=0.657) as positively.Ca/Na ratio was correlated with Ca (r=0.653) and Cu content (r=0.493) as positively, but with Na (r=0.710) as negatively. Ca content of fennel genotypes was not found any important correlation between N and K. Na content of fennel genotypes was also not found any important correlation between N, K, Ca, P, Mg, Fe, Cu, Zn and Mn contents of fennel genotypes.

CONCLUSION

Comparison of the means of different genotypes on the content of the N, K, and P elements which are major elements for growth in the fennel plants had founded positive significant difference with all elements except Ca and Na content. The micro elements which are Fe, Cu, Zn, and Cu contents of fennel plants were positively correlated with each other elements. Significant differences were not found among the fennel genotypes from different origin of Turkey based on the macro and micro mineral elements and ratios of them. Local Tokat genotypes were higher in its content of elements in compare to the other genotypes. Local Konya genotype showed lower element contents of fennel. The lowest ratios of Ca/P (milk fever) and K/Ca+Mg (tetany) were determined from Tokat 1 and Tokat 3 genotypes, respectively. Also, the lowest ratios of Ca/Na in Tokat 1 genotype and K/Na in Urfa and Tokat 1 genotypes were determined. In the results of present research were found available and high element contents in local Tokat genotypes and the available ratio of them. But the lowest nutrient element of fennel plant was founded in local Konya genotypes. It can be concluded that differences are in climate condition of Konya (dry-subhumid/semiarid) in the central Anatolia of Turkey and Tokat (mid-latitude humid transitional climate between the coastal and step) in the Black Sea region. Determination of mineral contents of different fennel in the regions is also important to understand the basic features of the agricultural practices and animal feedings in these different geographical environment and climates. It can be said that with knowing the properties and contents of plant of a certain region, makes it easier to manage to agricultural strategies and practices more sustainably.

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