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MINERAL CONTENT CHANGES OF SOME HALOPHYTE SPECIES EVALUATED AS ALTERNATIVE FORAGE CROPS FOR RUMINANTS' NUTRITION

Suleyman Temel[1,*], Mustafa Surmen[2]

[1]Department of Field Crops, Faculty of Agriculture, Igdir University, Igdir, Turkey
[2]Department of Field Crops, Faculty of Agriculture, Adanan Menderes University, Aydin, Turkey

ABSTRACT

Mineral contents of herbaceous produced in rangelands with intensive composition of species are usually high and can meet the requirements of ruminants. However, it has been reported that mineral contents of the herbs produced in especially disturbed rangelands due to different reasons such as salinity and drought were less than the levels required by the grazing ruminants. Our aim was to determine whether *Salsola dendroides*, *Salsola nitraria*, *Seidlitzia florida*, *Suaeda microphylla*, *Suaeda altissima*, *Petrosimonia brachiata*, *Kalidium caspicum* and *Alhagi pseudalhagi* harvested in late autumn periods are adequate for ruminants' mineral demands, and to reveal the potential P, K, Ca, Mg, Na, B, Cu, Fe, Mn and Zn contens of the browse grazed. This is the first scientific report on the mineral composition of the present species. For this purpose, a research was planned in a completely randomized block design with three replications in saline rangelands of Turkey's Igdir Province between the years of 2012-2013. Results showed that there was a significant difference in mineral contents among species, and *K. caspicum*, *S. dendroides* and *S. nitraria* had a higher mineral contents compared to other species. While Ca, B, Fe, Cu, Mn and Zn contens of forages were adequate for ruminants' demands, it was found that K content was low and P, Mg and Na were higher than the recommended values.

KEYWORDS:
Mineral composition, halophytes, saline rangelands, ruminants, seed maturity stage

INTRODUCTION

Rangelands provide about 70% of feed requirements of domestic ruminants in many countries and an important part of mineral needs [1]. Especially, whether climax plant communities are rich in terms of mineral contents because of having the different species devirsities, it plays an important role in meeting the mineral requirements of ruminats. However, the conducted experiments have shown that the feeding of *Atriplex nummularia* as the sole source of feed can cause mineral imbalances in sheep [2]. In addition, in degraded pasture land with low productivity, macro and micro mineral compositions of grass grown were reported to be lower than the levels required by the grazing ruminants [3]. These areas used for grazing also fail to provide enough quantity and quality fodder production for livestocks in order to locate generally in arid and semi-arid regions [4]. However, the browse plants maintaining their nutritive value and greenness even during the dry season when grasses dry up and decline in both quantity and quality compose one of the cheapest sources of feed for animals in many parts of the World [5, 6, 7]. For instance, in regions which summer drought dominated, halophyte plants and herbaceous species adapted to drought areas Gokkus et al. [8]; Temel [9] beside drought resistant shrubs compose the important plant groups used to this end [10, 6]. In addition, halophyte species come into prominence in marginal areas where soil salinity posed a problem, and continental climate dominated [11, 7].

Halophytes, repsenting ~1% of the world's flora, are plants that can grow and complete their lifecycles in environments with high concentrations (greater than 200 mM) of electrolytes (mostly Na+ and Cl-) in the root medium [12]. In the previous studies, it has been stated that halophyte species having their multiple uses such as the lowering of the watertables causing secondary salinity and improving soil stability in many parts of the World Le Houérou [13]; Barrett-Lennard et al. [14] are often used as a drought reserve or to fill the summer, autumn and early winter feed shortages within grazing systems [15, 16]. Consequently, it has been reported that these species could be used as a good alternative forage resource in terms of meeting their nutritional and mineral requirements of grazing livestocks [17, 7, 9].

The aim of rangeland management is to obtain the highest animal product per unit area without damaging to the natural resources. This is possible with meeting the daily energy and mineral needs required by the animals grazing on pasture to fulfill the physiological functions and to make animal

products [18]. This situation is related to the components or diversities of fodders used for animal feeding [19]. Regarding this issue, Ganskopp and Bohnert [18] stated that the mineral and nutritional contents of species on areas that animals grazed should be known for sustainablility of livestocks to reproduction, growth and production activities. Accordingly, the mineral contents and rates on the basis of species should be known beside fodder quality properties of the plants growing naturally on rangelands. Because mineral deficiencies may cause the some feeding disorders in both animals and plants [20].

As it is known, chemical contents of rangeland plant communities vary depending on speceis, soil types, climate and development stages of the plants [3, 6, 9]. Generally, in plants with high mineral content at the beginning of growth, reductions occur in mineral contents due to the organic mass increasing with progress of their development [21, 22]. Moreover, rangeland plants don't have constantly the same amount of mineral elements during the growing stages while varying according to species. Therefore, there is a close relationship between mineral nutrient content of the soils and mineral composition of the plants grown in these lands, and the mineral needs of the animals and the mineral composition of the produced forage [23].

Considering the topography of Igdir province with the annual total precipitation and evaporation rate, it is one of the areas experiencing maximum salinity in Turkey [24]. Therefore, a large part of the total available cultivated lands and grazings have been affected by salinity [25]. However, halophytes species have been seen as a big potential for providing food and mineral requirement of these animals adapted to these areas where many cultivars cannot be cultivated in an economical manner, feed material cannot be provided in sufficient quantity and quality. In this study, the potential effects of halophytes types used as alternative feed sources in terms of both meeting the needs of feed of the animals grazing in these areas and extending the period of green feed should extend the period of green forage mineral have been examined. As a result, both bio-accumulate features of halophytes types and the additives to animal nutrition as well as the possible effects on animal health have been identified.

MATERIALS AND METHODS

Climate and soil properties of research area. Research was carried out on the saline-alkaline grazing areas of the Igdir plain, located at an altitude of 825 m in the eastern part of Turkey which have arid climatic conditions. According to the long years average, the mean annual temperature was 12.5 ºC, average relative humidity was 51.2%, and annual precipitation was 264.0 mm [26]. In 2012 which the trial was conducted, while annual average precipitation, temperature and relative humidity were 237.2 mm, 13.5 ºC and 53.6%, respectively, these values were calculated as 226.9 mm, 14.1 ºC and 51.4%, respectively in 2013 [26]. Some chemical and physical characteristics of the soil (0-30 cm) samples taken from the trial area were presented in Table 1.

Experimental design. One hectare area where halophyte species intensively grown was selected for plant samples and trial around was fenced. The experiment was established in a completely randomized block design with three replications between the years of 2012-2013. Eight halophyte species (*Kalidium caspicum* (L.) Ung.-Sternb., *Salsola dendroides* Pall, *Salsola nitraria* Pall, *Seidlitzia florida* (Bieb.) Bunge., *Suaeda microphylla* Pall, *Suaeda altissima* (L.) Pall, *Petrosimonia brachiata* (Pall.) Bunge, *Alhagi pseudalhagi* (Bieb). Desv.) in per block and five random plants for per species in each block were selected. All the other species examined except for *Alhagi pseudalhagi* (*Fabaceae*) was belong to the family of *Chenopodiaceae*. While *P. brachiata*, *S. nitraria*, *S. florida* and *S. Altissima* were annual herbaceous plants, *K. caspicum*, *S. dendroides*, *S. microphylla* and *A. pseudalhagi* were perennial half-shrub forming.

Data collection and analysis. For each of the two years, browse samples were collected at the end of growth period (in seed maturuity stage). In this period, plants generally had the yellow and green images. All the species was cut 10 cm above ground and transported immediately to the laboratory after the harvest. The harvested plant materials were first washed with tap water, and later with pure water. After washed, the forage samples were first air dried and then dried in an oven at 65 °C until constant weight was obtained. After measured dry weight, samples were ground in a Wiley mill to pass through a 1 mm screen and made prepared for the mineral analyses. For mineral analysis, the plant

TABLE 1
Some characteristics of the study area soil

Texture	EC	pH	OM	P_2O_5	Ca	Mg	Na	K	B	ESP
	dS/m	½. 5	%	ppm		me/100g			ppm	%
Clayed	10.50	8.98	0.31	50.36	22.30	3.39	11.40	3.71	10.67	50.16

samples were prepared by wet digestion method using H_2SO_4 and H_2O_2 [27]. Mineral element (Ca, K, Mg, Na, P, B, Cu, Fe, Mn and Zn) contents of each sample solution were determined by inductively coupled plasma optical emission spectrometry (ICP-OES, Thermo Scientific, Cambridge, United Kingdom). Mineral contents of the plant samples were calculated as mg/100 g dry weight. All the analyses were performed in duplicate.

Statistical analysis. The results were subjected to one-way analysis of variance using MP 5.1 software (JMP, A Business Unit of SAS, Cary, NC, 2003). There were no significant differences between years. Therefore, the data from the two years were pooled. Differences between individual means were evaluated by LSD test at the 0.05 significance level.

RESULTS AND DISCUSSION

Macro-minerals. In this study conducted on the saline grazing areas, all the macro mineral contents examined showed significiant differences ($P<0.01$) among halophyte species (Table 2).

Potassium (K). According to these results, the highest value of K was found in *S. dendroides* and *S.nitraria*, and the K contents of two species included under the same statistical group (Table 2). The lowest K content was determined in *A. mannifera*. The variation of potassium content among species may be resulted from low soil moisture, drought, and availability of high Na concentration in the soil and water use efficiency of plants and differring the potassium absorption abilities of roots [28]. Indeed, Sultan et al. [29] have reported that there is deficiency of K in the types of different forage and grazing species due to these reasons. For example, in another study carried out, it was reported that Na in increased quantities negatively affected K^+ content of the alfalfa plant [30, 31]. When the species of halophytes that are the materials of the research were examined, it was detected not to be at levels that pose risks for ruminants. The recommended range of K for all classes of ruminants as suggested by NRC [32] was 0.5 to 1.0%. According to these results, the species other than *S. dendroides* and *S.nitraria* are seen to be insufficient to meet the needs of ruminants in terms of their potassium contents. About the subject, Abdullah et al. [3] also indicate that K concentration in browse species that naturally grows in degraded pasture are less than the levels required by ruminants. The most important reason for this is reduction potassium rate in dry matter with the differentiation of maturation periods of the species and being harvested of the species in late maturation periods. In our study, having low K concentration of halophyte species may have resulted from the poor soil moisture, high Na contents, drought conditions, and that the species were harvested in late growth stage. Other studies have indicated that the nutritional contents of species varied based on the phenological stages and, as plants became older, the desired nutritional contents decreased [33, 5].

Phosphorus (P). The P values obtained from the examined halophytes were significantly found to be higher than many legumes (0.30%) and poaceae (0.32%) forage used as feed source (Table 2). The highest value of P was determined in *K. caspicum* (2.19%) and lowest in *A. mannifera* (0.54%), and the mean P value of all the species was found as 1.24%. Considering the properties of halophytes type accumulators, these values are seen normally [34, 35]. Because, these species adopt macro and micro elements and other heavy metals in the soil such as macros in the soil, especially as physiological [12]. Phosphorus that is one of the most important in the macro elements has been observed to be available in the composition of the analyzed species in hig proportion and that this proportion is more than the need of ruminants and even than the maximum tolerable rate [36]. Toxic levels of phosphorus can be considered to adversely affect the health of ruminants grazing in the grasslands. But other species growing in similar areas and the sum of the daily dry feed resources applied outside the pasture are taken into account, it is understood that these rates will not create problems in ruminants.

TABLE 2
P, K, Ca, Mg and Na contents of halophyte species (%)

Species	K	P	Ca	Mg	Na
K. caspicum	0.37±0.05 c	2.19±0.36 a	0.59±0.08 cd	0.85±0.11 a	1.95±0.29 a
S. dendroides	0.65±0.10 a	1.04±0.22 d	1.08±0.11 a	0.48±0.06 b	1.26±0.19 b
S. nitraria	0.63±0.07 a	1.13±0.20 cd	0.58±0.09 cd	0.43±0.06 bc	1.87±0.28 a
S. florida	0.34±0.02 c	0.79±0.05 e	0.49±0.03 de	0.44±0.03 b	1.27±0.08 b
S. microphylla	0.24±0.03 d	1.34±0.14 c	0.64±0.06 bc	0.43±0.04 bc	1.34±0.12 b
S. altissima	0.47±0.03 b	1.89±0.10 b	0.37±0.02 f	0.36±0.02 c	0.85±0.05 cd
P. brachiata	0.27±0.03 d	0.99±0.07 de	0.41±0.03 ef	0.42±0.03 bc	0.89±0.08 c
A. mannifera	0.08±0.02 e	0.54±0.12 f	0.72±0.12 b	0.20±0.05 d	0.64±0.16 d
Mean	0.38±0.04	1.24±0.16	0.61±0.07	0.45±0.05	1.26±0.16
LSD (%5)	0.06**	0.23**	0.10**	0.08**	0.24**
CV(%)	14.32	15.97	14.69	14.58	15.91

Means in the same column with different superscript are significantly different at $P<0.01$

Calcium (Ca). Ca content of the species was found to be 0.61% and the highest Ca content was identified in *S. dendroides* (1.08%) plant following *A.mannifera* (0.72%) species and the lowest value was identified in *S.altissima* (0.37%). These differences that occur between plants may be resulted from the features of receiving Na ion by the species from the soil and being able to accumulate them. Because, the concentration of Ca were all inversely related to the concentration of Na in the plant tissue [37]. Considering the average calcium content of the species evaluated in the research, they were found to be lower than Minson [38] values (0.63%) and higher than the average level (0.30%) identified by Abdullah et al. [3]. According to NRC [32] records, Ca needs of ruminants range from 0.19 to 0.82% in dry matter. According to these results, calcium content of all halophytes other than *S. dendroides* (1.08%), were found to be lower than the toxic limits. In addition, calcium needs of the animals vary according to the age, species and breed of animals [23]. Thus, our findings indicate that calcium needs of the animals grazing in this area can be met.

Magnessium (Mg). In study, the concentration of magnesium (Mg) among species was varied from 0.20% to 0.85% with mean value 0.45%. Accordingly, the highest value of Mg was noted in *K. caspicum* (0.85%) and lowest in *A. mannifera* (0.20%). The obtained results indicate that conventional feed sources are higher than the Mg content. The high Mg content of the examined species is normal in saline and acidic soil conditions [39]. Therefore, the high Mg content of the species may be resulted from being conducted of the experiment in saline grassland. Indeed, Suyama et al. [40] reported in their study that Mg content of the alfalfa plant increased due to increased salinity of NaCl. Furthermore, the different types of magnesium may be due to the content of chlorophyll physiologically. Generally plants are rich in magnesium due to the chlorophyll content. The upper limit of magnesium contents of ruminants varies depending on the types of animals, but while it is 0.60% in sheep and cattle, this limit is 0.80% in horses [36]. Magnesium content of only *K. caspicum* among examined types (0.85%) was found to be higher than the proposed limits. However as it is known, the animals do not graze on the pastures as monotonous [41]. Thus, considering the other species in these area, it is thought that magnesium rate will not pose a risk in total dry matter.

Sodium (Na). The contents of sodium (Na) the species studied ranged from 0.64% to 1.95%. According to these results, the highest Na content was determined in *K. caspicum* (1.95%) and *S.nitraria* (1.87%), and the Na values of two species included under the same statistical group. However, the lowest content of Na was determined in *A.mannifera* (0.64%). Showing variation by Na contents of the species may be resulted from better adaptation of the species having Na ratio to salty areas and the soil rich in Na [42]. The results also show that Na content of halophytes is higher than conventional forage crops. As is known, increase in the precipitation reduces Na ratio in the soil. But, Na content increases depending on low precipitation in the pasture soils located in arid climates and this situation causes more Na intake in the body of halophytes [3]. Na is one of the important macro elements for livestock. In the lack of Na, weight loss, slowdown in growing up, and reduction in milk yield in animals are observed [43]. Whereas, the average of the Na content of halophytes species examined in our study (1.26%) seems to be over the needs of farm animals (0.06%).

Micro-minerals. In this study conducted on the saline grazing areas, significiant differences ($P<0.01$) were found among the species in terms of the examined micro minerals (B, Cu, Fe, Mn and Zn) (Table 3).

Boron (B). When Table 3 is examined, the mean boron (B) contents of halophyte species were measured as 10.73 ppm, and the highest boron content was determined in *K. caspicum* (24.96 ppm), and the boron concentration of this plant was found to be twice higher than both the average and the other species (Table 3). This can be said to be

TABLE 3
B, Cu, Fe, Mn and Zn contents of halophyte species (ppm)

Species	B	Cu	Fe	Mn	Zn
K. caspicum	24.96±4.93 a	11.66±1.61 a	73.40±10.60 a	25.55±3.28 bc	37.61±5.59 a
S. dendroides	11.82±1.63 b	11.47±1.62 a	50.17±7.20 bcd	40.00±5.67 a	24.76±3.84 b
S. nitraria	11.24±1.93 b	9.35±1.50 b	44.08±5.69 cd	23.90±3.12 c	17.93±2.82 c
S. florida	5.67±0.46 cd	7.55±0.51 cd	51.94±3.07 bc	12.81±0.92 f	38.14±2.49 a
S. microphylla	12.32±1.26 b	9.60±0.97 b	65.36±6.46 a	28.76±2.72 b	14.91±1.55 cd
S. altissima	6.73±0.92 cd	8.79±0.51 bc	42.32±2.77 d	19.16±1.57 d	15.21±0.78 cd
P.brachiata	4.95±0.37 d	6.89±0.66 d	56.46±4.77 b	14.77±1.17 ef	12.88±1.36 d
A.mannifera	8.17±1.98 c	6.85±1.63 d	29.41±6.94 e	17.21±4.04 de	23.46±5.50 b
Mean	10.73±1.68	9.02±1.13	51.64±5.94	22.77±2.81	23.11±2.99
LSD (%5)	2.73**	1.61**	8.32**	4.18**	4.59**
CV(%)	21.57	15.19	13.66	15.56	16.88

Means in the same column with different superscript are significantly different at $P<0.01$

resulted from that the present species is abundant leaved according to other species. Because, boron is a mineral that accumulates on leaves mostly [44]. In general, the lack or redundancy of boron is dangerous for particularly plants and also for the animals and humans. However, in our present research, it can be said that boron concentration of halophytes is seen to not to be in toxic levels. This can be said to be resulted from soil reaction. Because its reception in toxic levels does not take place by plants on toxic levels since when soil reaction is alkaline, it is connected by B and in the soil by Na [45]. The recommended range of P for all classes of ruminants as suggested by NRC [32] was 5 to 150 ppm. According to these results, boron contents of halophyte species were sufficient, but not constitute toxicity for livestock. Indeed, Abdullah et al. [3] reported that Na content of browse species naturally grown in degraded pastures can meet the need of grazing ruminants. In addition, these results obtained are consistent with the reports of Gokkus et al. [46] revealing the mineral content of different types in pastures.

Copper (Cu). The mean Cu contents of the species were found to be significantly different and ranged from 6.85 ppm to 11.66 ppm (Table 3). This may resulted from being different of the leaf-to-stem ratio in period when plants harvested. Because leaves contain a higher proportion of Cu relative to the stems [47]. In addition, it may be resulted from the species and genotype differences depending on the adaptability of plants to saline soils. In a study conducted, it is revealed that tropical grass has higher Cu content than tropical legumes [48]. Again, it is reported that the different forage species and varieties grown in the same soil have significant variations in Cu levels [49, 50]. For example, Abdullah et al. [3] states in their study conducted on the species of seven shrubs and three trees that average Cu contents of the species is 1.39 ppm and it ranges from 0.66 ppm to 2.24 ppm. The presence of 6.00-12.00 ppm copper in the feed in ration is recommended in order that animals can fulfill their physiological functions [36]. Cu content of the examined species in this research was found in the specified range (Table 3) and that the grazing ruminants can meet their requirements has been revealed.

Iron (Fe). Significiant different was noticed in the iron composition of halophyte plants (Table 3). While maximum Fe content was found in *K. caspicum* (73.40 ppm) and *S. microphylla* (65.36 ppm), the lowest Fe content was determined in *A. mannifera* (29.41 ppm). This variation may be due to the differences in their genus and species level, genetic factors and growth stage of the plant during collection [51]. In addition, Jalali-Honarmand et al. [52] stated that Fe^{2+} ion amounts removed by the plants differed even among the varieties belonging to the same species. The obtained results was found to be higher than Fe contents of shrub and tree species collected in Cholistan pastures of Pakistan [3], and within Fe value limits of conventional forages (alfalfa, sainfoin, vetch, meadow grass, sudan grass) collected in fall period in The Marmara Region of Turkey [53]. As it is known, the redundancy and deficiency of iron leads to some nutritional problems and disease in animals [54]. Therefore, it is necessary to ensure Fe mineral needed by ruminants. According to NRC [36] records, Fe needs of ruminants range from 30 to 60 ppm in dry matter. Accordingly, no species examined constitute a problem in terms of Fe content obtained from the present study. Because, that Fe content reach up to 1000 ppm doesen't pose a problem for ruminants [55]. Therefore, these values obtained from the study have been revealed to be at the level to meet the requirements of Fe of animals recommended by the NRC [36].

Manganese (Mn). The mean Mn contents of halophyte species ranged from 12.81 ppm to 40.00 pmm, and *S. dendroides* had the highest Mn followed by *S. microphylla* (Table 3). This may be resulted from the differences in species and varieties. The researches reveal that there are significant differences among the families, genius, species and varieties [3]. The deficiency of Mn leads to abnormal development and bone disorder in animals [56]. In the redundancy of it, the palatability of the hay reduces. The recommended range of P for all classes of ruminants as suggested by NRC [36] was 5 to 150 ppm, and NRC [32] reported that toxic level of this element is 1000 ppm. According to these results, Mn content of halophyte species found in saline pastures was found to be lower than these critical values, and it has been demonstrated to be sufficient for ruminants.

Zinc (Zn). The highest Zn values were obtained from *K. caspicum* and *S. florida*, and no significance difference was found between two species in terms of Zn content. The lowest Zn content was detected in the species of *P. brachiata* (12.88 ppm) (Table 3). This may be resulted from leaf/stem ratio of the species in harvest period. Because, leaves have higher Zn content than the stems. In addition, the studies conducted have revealed that there are big variations in Zn contents among the different plant species grown in the same soil [38, 3]. Zinc element takes over an important duty in the activation of enzymes. In addition, the deficiency of Zn may lead to anemia, negative effects on immune system and infertility [57]. The recommended range of Zn for all classes of ruminants as suggested by NRC [36] was 7 to 100 ppm. Therefore, this study reveals that the Zn content of the species examined is in the defined range and at

the level of meeting Zn requirements of the animals recommended by NRC.

CONCLUSIONS

As a result of the study, it is revealed that halophyte plants that can maintain the greens and biomass production in the pastures with high salinity have high mineral content even in autumn period when herbaceous plants are dormant even if it differs in terms of mineral content. It has been identified that these species developing and spreading especially in arid climates and adverse soil conditions can meet the mineral requirements of the animals grazing in these areas where legumes and poaceae forages are not very common and the mineral content is not at the level that adversely affect animal health.

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CORRESPONDING AUTHOR

Suleyman Temel
Iğdır University Faculty of Agriculture
Department of Field Crops,
Iğdır – Turkey

e-mail: stemel33@hotmail.com