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The Elemental Compositionin Aboveground and Underground Organs of Some *Agropyron* Species Grown in Different Salt Concentrations

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ABSTRACT

Salinity, which is more common in semi-arid and arid areas, is increasing every day with climate change, poor quality irrigation water, and soil structure. High salt concentration restricts plant production and causes productivity loss in agriculture. To sustain agriculture in saline soils, the determination of plant species resistant to salinity comes into prominence in areas with salinity problems. For this reason, the research was performed to determine the nutrients (Ca, Mg, P, S, B, Cu, Fe, Mn, and Zn) accumulating at aboveground and underground parts of the three different *Agropyron* species, namely *Agropyron cristatum*, *A.desertorum* and *A. elongatum* (Syn. *Elymus elongatus)* under different salt concentrations (control, 5, 10 and 15 EC dS m^{-1}NaCl). *A. cristatum*, *A.desertorum*, and *A. elongatum*species, which are quality forage crops grown in drought and salinity conditions, were determined to Ca content 1.03%, 1.01%, and 1.49% respectively, and Mg content. 0.13%, 0.11% and 0.20% respectively. As salt concentrations increased, Ca, Mg, Cu, Fe, Mn, and Zn in the aboveground organ has increased compared to the control treatment but decreased in the underground organs. Ca and Mg content of the aboveground organs of *A. elongatum* grown at 10 EC dS m^{-1}NaCl increased by 204% and 98%, respectively, compared to the control. Fe content of the wheatgrassspecies in saline conditions was found quite high, and an average of 788 mg kg^{-1} of Fe was found in underground organswhile this value was as 430mg kg^{-1} in aboveground organs. The results showed that *A. elongatum* had more nutrient elements in both underground and aboveground parts of the crop by comparison to the other two *Agropyron* speciesunder increased salinity levels.

1. Introduction

The salinity problem occurs in 6.5% of the world's total areas, and 3.4% (9 million ha) of irrigated farmland. This problem, which is more common in semi-arid and arid regions, is increasing every day with the effect of climate change, poor quality irrigation water and soil structure (Tuteja 2007; Çulha & Çakırlar 2011; FAO 2015).

The high concentrations of ion that cause toxic effects due to the excess of dissolved salts in the root impact area are among the essential causes of salt stress in plants (Kaçar et al 2013). High salt concentration disturbs the balance between ions and objects to intake inadequately plant nutritional elements by plants under salt stress by resulting in the antagonism between plant nutrients (Taban & Katkat 2000). This situation restricts plant production from the early seedling stage and causes productivity loss in agriculture (Demiroğlu Topçu et al 2015; Özkan & Demiroğlu Topçu 2017).Salinity also damages the soil's aggregate structure and harms the water and air permeability of the soil. Soils with excessive NaCl salinity become exposed to erosion. To sustain agriculture in saline soils, the determination of plant species that are resistant to salinity and the ones with high yield potential in salty conditions come into prominence in areas with salinity problems (Güneş et al 2000).

As wheatgrass species (*Agropyron* sp.) differ in terms of feed value, they also differ in salt resistance (Dewey 1960; Sedivec et al 2010). *Agropyron* species grow naturally in rangelands with salinity problems in Turkey (Acar et al 2016). As a result of the researches conducted on salt resistance of the plants, it is expressed that the elemental compositionof the plants

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grown in different salt concentrations were examined. Differences occurred in the elemental compositionin their plant parts (root, stem, young and old leaves, etc.) (Greenway & Rogers 1963; Ueng et al 1994; Kılıç et al 2015; Niu et al 2015; Koç & Acar 2018). This research has been carried out aim to examine the differences occurring in the elemental compositionof the underground and aboveground organs of three wheatgrass species (*Agropyron cristatum*, *A. desertorum*, and *A. elongatum*) grown in different salt concentrations.

2. Materials and Methods

This research was established as a pot experiment in Selçuk. University. Faculty of Agriculture Department of Field Crops, Plant Breeding Greenhouse, on October 21, 2015. While *A. cristatum* and *A. desertorum* population collected from KOP Region (Turkey) were used, seeds belonging to *Agropyron elongatum* Szarvasi-I variety were used. This trial, which was set with three replications according to the Completely Randomized Design, was planted in pots of 30 x 30 cm in size, with six plants in each cup.

The turf's chemical properties used in the research had pH 5.5-6.5; fertilizer ratio 0.30 g l^{-1}; 30-70 mg l^{-1} N; 30-70 mg l^{-1} P_2O_5 and 40-80 mg l^{-1} K_2O. The turf's physical properties had that degree of dissociation was H2-H8; porosity weight was 96%, moisture content was between 40 and 50%. Electrical Conductive of turf was between 0.12 and 0.22 dS m^{-1}.

In the study, salt concentration [control (0 dS m^{-1} NaCl), 5, 10, 15 EC dS m^{-1} NaCl] applied to three different wheatgrass species was started after tillering and were given to plants with irrigation water 1 liter per week until harvest. In this study, which continued until the grain filling period, while the production of the *A. cristatum* and *A. desertorum* was done on May 16, 2016, *A. elongatum* was done on June 22, 2016, as it matures later than the other two species. During the harvest, the harvests of underground (root) and aboveground (leaf and stem) of the plant were done separately, and the content of Ca, Mg, P, and S contained in both organs was determined as %; B, Cu, Fe, Mn, and Zn content was determined as mg kg-1.

Elemental Analysis: The sample taken from 0.2 mg of the dry plant was weighed and put into a tube. 5 ml of HNO_3 and 2 ml of H_2O_2 were added into each tube. The digesting process was done in a micro oven, and as soon the material was shredded, it was transferred into 25 ml tubes, and the sample was filled with 25 ml of pure water. The solution was filtered afterward, and each sample transferred to the tube was analyzed in ICP-AES (Kaçar & İnal 2010).

Statistical analyses of all the properties that were examined in the trial were made using JMP 7 package program. In the study, the values of statistically significant "Salt concentrations x *Agropyron* Species x Organ" interaction were only grouped, and the MSTAT-C package program was used for groupings.

3. Results and Discussion

The content of the nutrients (Ca, Mg, P, S, B, Cu, Fe, Mn, and Zn) that they accumulate in the underground (root) and aboveground (leaf and stem) organs in different saline concentrations were examined, and the average values and groupings of the triple interaction (Salt concentrations x *Agropyron* species x Organ) in the research are given in Table 1. As the salt concentration increased, Ca, Mg, Cu, Fe, Mn, and Zn content in the aboveground organ increased compared to the control. Still, in the presence of increasing salinity, the content of these elements decreased in the underground organs compared to control.

As the result of research, Ca content in aboveground organs of *A. cristatum* and *A. elongatum* increased while *A. desertorum*'s Ca content decreased by increasing salt concentration. Ca content in the roots of three *Agropyron* species was shown to reduce in the face of increased salt dose, except for underground organs of *A. desertorum* grown in the application of 5 EC dS m^{-1} NaCl (Figure 1).

A. cristatum, *A.desertorum*, and *A. elongatum* species, which are quality forage crops grown in drought and salinity conditions, were determined to Ca content 1.03%, 1.01%, and 1.49% respectively, and Mg content. 0.13%, 0.11% and 0.20% respectively (Figure 2). Minimum Mg content was obtained from aboveground (15 EC dS m^{-1}NaCl) and underground organs (control groups and 15 EC dS m^{-1}NaCl^{-1}) while the maximum Mg content was determined from the roots of *A. elongatum* grown at 15 EC dS m^{-1}NaCl. Ca and Mg content of the aboveground organs of *A. elongatum* grown at 10 EC dS m^{-1}NaClwere shown to increase by 204% and 98%, respectively, compared to the control.P content was higher in the aboveground organs than the underground organs. Aboveground organs of *A. cristatum* and *A. elongatum* hadthe highest P content. The S content of *Agropyron* species gave changeable results in aboveground and underground organs in different salt concentrations in the research. As a result of the study, as the salt concentrations increased, the boron content of the underground and aboveground organs decreased compared to the control groups. The lowest boron content was detected in the aboveground part of *A elongatum* that was grown in EC dS m^{-1}NaClsalt application.

Cu content was increased in aboveground organs while in underground organs' Cu content was decreased with increased salt concentration. The maximum Cu content was obtained from 17.33 mg kg^{-1} the roots of *A. desertorum* (5 EC dS m^{-1} NaCl) while the minimum Cu content (6.00 mg kg^{-1}) was obtained from aboveground organs of this *Agropyron* species grown in control groups.

Table 1
Average values and groupings belonging to the nutrient elements content in the aboveground (leaf and stem) and underground (root) organs in different saline concentrations

Organ	*Agropyron.* Species	Salt Con. (EC dSm^{-1})	Ca (%)	Mg (%)	P (%)	S (%)	B (mg kg^{-1})	Cu (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})
Aboveground (Leaf and Stem)	*A.cristatum*	Cont.	0.42^{T}	0.106^{G}	0.241^{EF}	0.12^{D}	14.94^{E}	6.23^{S}	58.93^{T}	38.21^{M}	47.02^{M}
		5	0.51^{R}	0.111^{FG}	0.269^{CD}	0.14^{B}	10.80^{M}	7.21^{Q}	211.00^{P}	34.92^{O}	72.36^{G}
		10	0.82^{O}	0.149^{E}	0.341^{A}	0.13^{C}	11.97^{I}	7.78^{O}	230.42^{O}	75.68^{G}	76.03^{E}
		15	0.96^{L}	0.155^{E}	0.343^{A}	0.14^{B}	14.25^{F}	8.44^{M}	404.41^{K}	136.43^{C}	96.29^{B}
	A.desertorum	Cont.	0.57^{P}	0.076^{H}	0.256^{DE}	0.10^{F}	15.33^{C}	6.00^{T}	151.60^{Q}	49.71^{L}	67.52^{I}
		5	0.56^{P}	0.108^{G}	0.252^{DE}	0.11^{E}	11.14^{L}	7.55^{P}	135.33^{R}	51.20^{K}	70.84^{H}
		10	0.54^{Q}	0.109^{G}	0.236^{FG}	0.12^{D}	11.33^{KL}	7.93^{N}	263.51^{N}	74.22^{H}	70.50^{H}
		15	0.53^{Q}	0.079^{H}	0.237^{FG}	0.09^{G}	13.10^{H}	7.03^{R}	144.79^{QR}	87.93^{E}	75.04^{F}
	A.elongatum	Cont.	0.48^{S}	0.114^{FG}	0.233^{FG}	0.12^{D}	19.38^{A}	7.16^{QR}	80.83^{S}	88.01^{E}	39.35^{N}
		5	0.94^{M}	0.215^{B}	0.352^{A}	0.15^{A}	15.15^{CD}	11.32^{I}	791.84^{F}	112.58^{D}	93.52^{C}
		10	1.46^{G}	0.226^{B}	0.298^{B}	0.15^{A}	14.35^{F}	11.34^{I}	1593.61^{C}	197.00^{A}	138.07^{A}
		15	0.89^{N}	0.215^{B}	0.302^{B}	0.14^{B}	13.50^{G}	11.41^{I}	1094.70^{E}	173.20^{B}	74.54^{F}
Underground (Root)	*A.cristatum*	Cont.	1.57^{F}	0.175^{D}	0.214^{H}	0.13^{C}	13.13^{H}	13.09^{E}	1494.92^{D}	51.45^{JK}	55.66^{K}
		5	1.33^{H}	0.120^{F}	0.302^{B}	0.13^{C}	13.41^{G}	12.15^{H}	358.75^{L}	16.93^{T}	21.31^{S}
		10	1.31^{I}	0.118^{FG}	0.308^{B}	0.12^{D}	10.14^{N}	12.94^{F}	311.94^{M}	18.07^{T}	20.01^{T}
		15	1.28^{J}	0.125^{F}	0.244^{EF}	0.11^{E}	11.76^{J}	10.60^{K}	463.24^{J}	29.45^{P}	50.78^{L}
	A.desertorum	Cont.	1.86^{D}	0.196^{C}	0.176^{J}	0.12^{D}	13.12^{H}	12.80^{G}	1984.31^{B}	54.05^{I}	60.31^{J}
		5	1.97^{B}	0.149^{E}	0.234^{FG}	0.14^{B}	11.96^{I}	17.33^{A}	469.80^{J}	25.18^{Q}	28.79^{Q}
		10	1.22^{K}	0.109^{G}	0.187^{IJ}	0.10^{F}	11.99^{I}	11.32^{I}	233.99^{O}	21.02^{R}	25.69^{R}
		15	0.82^{O}	0.086^{H}	0.228^{GH}	0.08^{H}	11.42^{K}	10.89^{J}	211.72^{P}	19.47^{S}	32.97^{P}
	A.elongatum	Cont.	2.74^{A}	0.220^{B}	0.178^{J}	0.13^{C}	16.84^{B}	15.53^{B}	2354.51^{A}	80.00^{F}	77.03^{D}
		5	1.66^{E}	0.142^{E}	0.276^{C}	0.12^{D}	15.11^{DE}	13.89^{D}	519.52^{H}	36.65^{N}	35.38^{O}
		10	1.89^{C}	0.192^{C}	0.196^{I}	0.15^{A}	13.09^{H}	14.54^{C}	543.36^{G}	52.63^{J}	29.15^{Q}
		15	1.87^{D}	0.244^{A}	0.249^{EF}	0.12^{D}	11.91^{IJ}	9.57^{L}	508.98^{I}	75.80^{G}	17.49^{U}
$LSD_{SALT*AGRO.*ORGAN}$			0.016	0.015	0.0199	0.009	0.197	0.139	9.683	1.183	0.947

Fe content of the wheatgrassspecies in saline conditions was found quite high, and an average 788 mg kg^{-1} of Fe was found in underground organs, while this value was as 430mg kg^{-1} in aboveground organs (Figure 3). The minimum Fe content (58.98 mg kg^{-1}) was obtained from aboveground organs of *A. cristatum* grown in control groups. In contrast, the maximum Fe content (2354.51 mg kg^{-1}) was obtained from underground organs of *A. elongatum* at control group conditions. The aboveground organs of *A. elongatum* grown at 10 EC dS m^{-1} NaCl salt concentration were the interaction having the maximum Mn (197.00 mg kg^{-1}) and Zn (138.07 mg kg^{-1}) contents.

Plants can respond differently to salinity based on species, type, and genotype. Kılıç et al (2015) examined the Ca and Mg content of different forage crops belonging to the *Poaceae* family grown in areas with varying salinity levels. In the study, while results regarding Ca differed from our findings, results regarding Mg showed similarity. Thus, Çulha & Çakırlar (2011) stated that a high quantity of NaCl in the setting unbalanced the ion in the cell, caused Na^{+} and Cl levels to increase and Ca^{+2} and Mg^{+2} concentrations to decrease in the cell.

Ueng et al (1994) grew *Agropyron smithii* in different salt concentrations and analyzed its chemical content. In the study, while Mg content decreased in increasing salinity levels, an increase in Ca content was determined compared to the control as in our study. High Na^{+} concentration causes emptying of internal Ca^{+2} stores by setting $Ca^{+2,}$ which are bound in the inner membrane of the cell-free and increases free Ca^{+2} in the cell. The increase of Ca^{+2} in cytosol starts the stimulation of signal transmission paths associated with salt tolerance (Çulha & Çakırlar 2011).

The plant-affected salt was decreased or limited to intake water and nutrient elements via roots (Ekmekçi et al 2005). Nutrient element uptake in the roots also reduced with an increased salt concentration in our results. Yorgancılar&Yeğin (2012) stated that nutrient elements in the pea root fell under salinity conditions, but Ca and Mg in the stem improved with increased salt concentration. Stragonov (1971) expressed that cotton grown under salinity had more mineral matter in leaves than in roots. As it was similar in our research, Kovda (1947) and Kovda (1949) detailed that some plants grown under salinity could adequately absorb the essential elements such as Ca, Fe and Mn, etc. (Stragonov 1971).

In a research Yorgancılar & Yeğin (2012) conducted on the root and stem of a pea, while P content in the stem increased with increased salinity, no difference was detected in P content in the root. In the same study, as the salinity increased, S content in the stem and root increased. Boron content in the root and stem was stated to have increased with the increasing salinity.

When the Fe concentration in the root and stem of barley grown in salinity conditions, the iron concentration in the roots were found higher compared to the stem in saline conditions (Yausfi et al 2007). *Poaceae* family plants, especially meadow and pasture plants, take the iron from the soil by making the iron in the rhizosphere region beneficial with the phytosiderophores excreted with their roots (Kaçar & Katkat 2007;Taiz & Zeiger 2008).

Similar to our research results, copper, zinc, and manganese intakes were determined to increase in plants in salt stress. However, the mechanism of this situation has not been completely explained (Alparslan et al 1998; Kaçar & Katkat 2007).

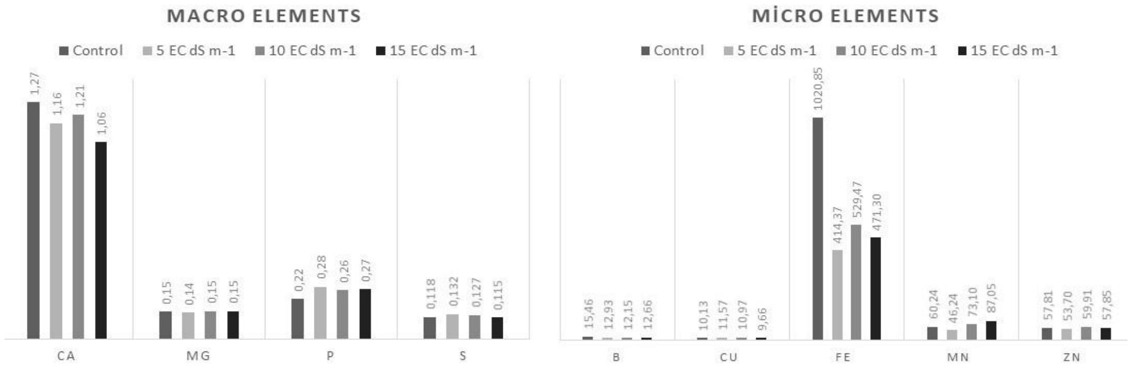

Figure 1

Content of macro elements (%) and micro elements (mg kg^{-1})in different salinity levels

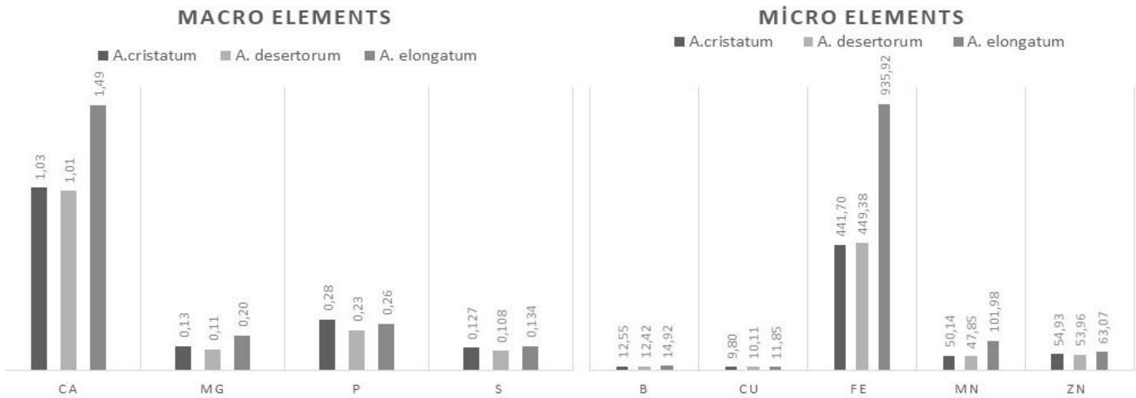

Figure 2

Content of macro elements (%) and micro elements (mg kg^{-1})in *Agropyron* species

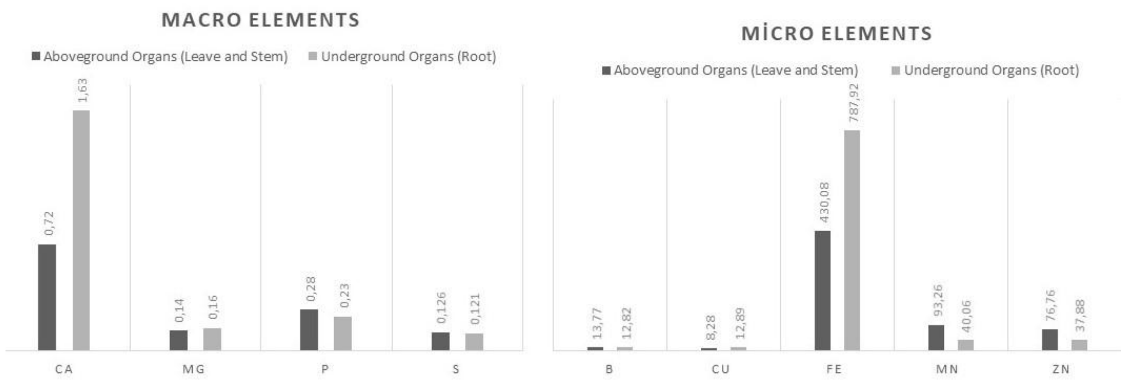

Figure 3
Content macro elements (%) and micro elements (mg kg^{-1})in aboveground (leaf and stem) and underground (root) organs

The plants have different mechanisms regarding salt tolerance and can show different responses at the level of leaves, stem, and root (Lüttge & Smith 1984). While some plants decreased salt density in the meristem area by distributing to salt on the whole body like root, stem, leave, and pedicel, some plants keep Na+ amount transported to xylem from roots at a minimum level by inhibiting to salt in the root zone (Çulha & Çakırlar 2011). Koç & Acar (2018) indicated that while Na content in the root and the stem increased with an increased salt concentration in the *Agropyron* species, these species were accumulated to chlorine in the root zone and decreased to Cl content in aboveground organs with increased salinity. Qiao et al (2007) stated that the growth and development of *A. elongatum* having Na+/H+ antiporter gene transported to salt in the vacuoles weren't affected by salinity at different levels.

4. Conclusions

As a result of the research, the elemental content of the three wheatgrass species has been determined to have changed in the presence of increased salt concentrations in the underground and aboveground parts. Ca, Mg, Fe, Mn, and Zn uptakes in the roots showed decreased while P, S, and Cu uptakes responded varying as increased salt concentration. Boron and Zinc uptakes in the aboveground organs decreased while Cupper uptake differed in the aboveground organs (leaf and stem). However, Ca, Mg, P, S, Fe, and Mn uptakes in the aboveground organs showed an opposite effect by increasing salinity. The maximum element uptakes regarding Ca, Mg, and P were found at a salt concentration of 10 EC dS m^{-1} NaCl. Although salt concentrations increased, *A. elongatum* was found to have higher elemental content than the other two *Agropyron* species.

It can be stated that three wheatgrass species grown at different salt concentrations provide a quality forage source to livestock with elements taken in their organs. The economical product can be obtained from pastureland using these wheatgrass species in rangeland improvement because of being qualified forage of these species at salinity conditions. Furthermore, these species can provide an opportunity to sustainable farming in pastureland as contributing erosion prevention owing to occupy to vegetation in problem (salinity, drought, etc.) areas.

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