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Research Article

THE EFFECTS OF POTASSIUM APPLICATIONS ON DROUGHT STRESS IN SUGAR BEET: PART II. PLANT NUTRITION CONTENT

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ABSTRACT

This is the second in a series of papers describing the effects of potassium applications on drought stress in sugar beet. Drought is a natural phenomenon that can affect water resources and agriculture. In this research, the effect of potassium applications under drought stress on some plant nutrition of sugar beet, which is a strategic plant, was investigated. In the experiment, irrigation levels were kept at 33%, 66% and 100% of field capacity. Different doses (10-20-40-80 mg kg-1) of potassium were applied to the plants. The plants were grown in the growth chamber under controlled conditions (day/night 16/8 hours, 25/15 0C, 60-70% humidity). According to the results, the effect of irrigation x potassium interaction on the shoot and root sodium (Na) potassium (K) calcium (Ca) and phosphorus (P) content Na/K and Na/K ratio was found to be statistically significant. Shoot and root sodium content decreased with potassium applications under drought conditions (33%). Shoot and root potassium, phosphorus content increased with potassium applications in both drought and sufficient water conditions. Shoot calcium content change irregular with potassium application while root calcium decreased with potassium application under drought conditions (33%). Shoot and root sodium/potassium ratio decreased with potassium applications in both drought and sufficient water conditions. Shoot and root sodium/calcium ratio change irregular with potassium applications. Therefore, it can be said that potassium may play a critical role in reducing the negative effect of drought stress and uptake plant nutrition in sugar beet.

Key Words: *Drought, Irrigation, Potassium, Sugar Beet.*

1. INTRODUCTION

Drought is a natural phenomenon that can affect water resources and agriculture. Drought is also the slowest growing, most insidious, most dangerous natural disaster that causes the most extensive socio-economic damages (Kadıoğlu 2012). Drought is one of the most costly disasters that do not occur abruptly, but can harm more people than other natural disasters, with an average annual loss of $ 8-10 billion (Wilhite, 2000). Drought stress means that the amount of water present in the soil during vegetation is less than the amount of water required for plant growth and development. Arid and semi-arid areas in Turkey are 51 million hectares. Therefore 37.3% of Turkey said that under the influence of mostly semi-arid climatic conditions (Kadıoğlu, 2012). A large part of the water taken from the soil through plant roots is given to the atmosphere by transpiration from the plant leaves. A small amount is retained in tissues and used for various compounds. In order to obtain high yields and high quality products from plants, this water flow should not slow down or be interrupted. The lack of moisture in the soil causes a decrease in turgor pressure, closure of stomata, slow growth and decrease in yield.

Sugar cane and sugar beet are the two most important sources of sugar production in the world. Sugar beet is one of our strategically important products due to its great contribution to the agriculture and economy of our country. In addition to its contributions to the agricultural sector, sugar beet also contributes to the food and chemical industry with its by-products. The ground and surface water resources of the Central Anatolia Region, where approximately 60% of Turkey's sugar beet cultivation areas are located, are rapidly decreasing. The aim of this research is to determine the effect of potassium applications on some plant nutrition of sugar beet, which is a strategic plant, under drought stress and to try to clarify the relationship between drought stress and potassium.

2. MATERIAL METHOD

2.1 Plant Growth

In this study, washed sand, with a pH of 8.2 and electrical conductivity of 75 µM cm^{-1}, was used. The sand was filled into 25X50 cm plastic sapling production bags. Resistive soil moisture sensors were put inside the sand to control the moisture level. Moisture sensors were calibrated with a device designed using an Arduino developer card, and irrigation was carried out according to the data received from that device (Kızıl et al., 2018). Irrigation levels were kept at 33%, 66% and 100% of field capacity. Serenad varieties of sugar beet (*Beta vulgaris* L.) plants were grown in the climate room under controlled conditions (day/night 16/8 hours, 25/15 ^{0}C, 60-70% humidity). Different doses (10-20-40-80 mg kg^{-1}) of potassium were applied to the plants with a potassium phosphate source. Plants were grown considering the 1: 0.8: 1.2, N: P: K ratio (Adiloglu and Guler, 2002), with 3 replicates for 4 months. Plants were harvested after sampling the leaves for relative water content and membrane damage.

2.2 Ion analysis

The plant shoot and root samples were dried in the oven at 65 ºC for 48 hours and then ground. Samples of 500 mg were taken and nitric acid and hydrogen peroxide was added for wet digestion. The samples were read in flame photometer for Calcium (Ca), potassium (K) and sodium (Na) concentrations while phosphorus (P) concentration was determined by spectrophotometer (Jones et al., 1991).

2.3 Statistical analysis

Analysis of variance (ANOVA) was performed using the general linear model (PROC GLM) procedure of R program. The variance analysis was done based on the following model:

$$Yijk = \mu + Mi + Fj + (MF)ij + Gk + eijk$$

Where:

Yijk: observed value

μ: grand mean

Mi: effect of irrigation i (i=1, 2, 3)

Fj: effect of potassium j (j=1, 2, 3, 4)

(MF)ij: effect of irrigation x effect of potassium

Gk: effect of replication k (k = 1, 2, 3)

eijk: random error term

Variance analysis (ANOVA) was performed by using the statistical package program using the GLM procedure. Differences between applications were determined by the Tukey multiple comparison test (P <0.05).

4. RESULTS

According to the results of variance analysis, the effect of irrigation x potassium interaction shoot and root sodium (Na) and potassium (K) content were statistically significant ($P \leq 0.01$). In addition, it was determined that the effect of irrigation and potassium applications on shoot and root sodium (Na) and potassium (K) content were statistically significant (Table 1).

Table 1. Mean squares for shoot and root Na and K content

Source of Variation	Df	Shoot Na content	Root Na content	Shoot K content	Root K content
Irrigation	2	0.222714**	0.000006**	4.90103**	3.75618**
Potassium (K)	3	0.004490**	0.000076**	2.69259**	1.55553**
Irrigation * K	6	0.003206**	0.000009*	0.04135**	0.03491**
Error	22	0.000010	0.000001	0.00001	0.00008

* . ** Indicates significant difference at $P \leq 0.05$. $P \leq 0.01$ respectively. Df: Degrees of freedom.

Shoot sodium content increased with the increase of irrigation levels to 0.058, 0.375 and 0.329% respectively. Shoot sodium content increased with potassium applications up until the 80 mg kg^{-1} potassium application (Table 2). The lowest shoot sodium content (0.51%) was obtained at the 33% irrigation level and 20 mg kg^{-1} potassium application, the highest shoot sodium content (0.438%) at the 66% irrigation level and 40 mg kg^{-1} potassium application (Table 2). When the root sodium content is considered, it is observed that root sodium content decreases with increasing irrigation levels and increasing potassium applications. The lowest root sodium content (0.012%) was obtained at the 66% irrigation level and 40 mg kg^{-1} potassium application, the highest root sodium content (0.022%) at the 33% irrigation level and 10 mg kg^{-1} potassium application (Table 2).

Table 2. Mean values of shoot and root Na content

	Irrigation (Field Capacity)				Irrigation (Field Capacity)			
K (mg kg^{-1})	**33%**	**66%**	**100%**	**Mean**	**33%**	**66%**	**100%**	**Mean**
	Shoot Na content (%)				**Root Na content (%)**			
10	0.077 g	0.312 e	0.292 f	0.227 D	0.022 a	0.020 a	0.016 b	0.019 A
20	0.051 h	0.331 d	0.329 d	0.237 C	0.013 bc	0.015 bc	0.014 bc	0.014BC
40	0.052 h	0.438 a	0.350 c	0.280 A	0.013 bc	0.012 bc	0.013 bc	0.013 C
80	0.052 h	0.418 b	0.346 c	0.272 B	0.014 bc	0.014 bc	0.014 bc	0.014 B
Mean	0.058 C	0.375 A	0.329 B		0.016 A	0.015 A	0.014 B	

*The differences between the interaction potassium and Irrigation means having different lower case letters in a column are statistically significant at 0.05. **The differences between the potassium means having different capital letters in a column are statistically significant at 0.05. The differences between the irrigation means having different capital letters in a line are statistically significant at 0.05.

Potassium content of shoots and roots are given in Table 3. Potassium content of shoots and roots increased with the increase of irrigation levels and potassium applications The lowest shoot potassium content (1.552%) was obtained at 33% irrigation level and 10 mg kg^{-1} potassium application, the highest shoot potassium content (4.467%) at 100% irrigation and 80 mg kg^{-1} potassium application. Similarly the lowest root potassium content (0.550%) was obtained at 33% irrigation level and 10 mg kg^{-1} potassium application, the highest root potassium content (2.355%) at 100% irrigation and 80 mg kg^{-1} potassium application.

Table 3. Mean values of shoot and root K content

	Irrigation (Field Capacity)				Irrigation (Field Capacity)			
K (mg kg^{-1})	**33%**	**66%**	**100%**	**Mean**	**33%**	**66%**	**100%**	**Mean**
	Shoot K content (%)				**Root K content (%)**			
10	1.552 l	2.537 ı	2.852 g	2.314D	0.550 l	0.733 j	1.639 e	0.974 D
20	1.922 k	3.027 f	3.262 e	2.737 C	0.611 k	0.809 ı	1.850 c	1.090 C
40	2.240 j	3.499 d	3.761 c	3.166 B	1.053 h	1.250 g	2.131 b	1.478 B
80	2.630 h	4.073 b	4.467 a	3.723 A	1.545 f	1.774 d	2.355 a	1.891 A
Mean	2.086 C	3.284 B	3.585 A		0.940 C	1.141 B	1.994 A	

*The differences between the interaction potassium and Irrigation means having different lower case letters in a column are statistically significant at 0.05. **The differences between the potassium means having different capital letters in a column are statistically significant at 0.05. The differences between the irrigation means having different capital letters in a line are statistically significant at 0.05.

According to the results of variance analysis, the effect of irrigation x potassium interaction shoot and root calcium (Ca) and phosphorus (P) content were statistically significant ($P \leq 0.01$). In addition, it was determined that the effect of irrigation and potassium applications on shoot and root calcium (Ca) and phosphorus (P) content were statistically significant (Table 4).

Table 4. Mean squares for shoot and root Ca and P content

Source of Variation	Df	Shoot Ca content	Root Ca content	Shoot P content	Root P content
Irrigation	2	0.007457**	0.000044**	0.086119**	0.067584**
Potassium (K)	3	0.000424**	0.000091**	0.202020**	0.265640**
Irrigation * K	6	0.000427**	0.000028**	0.014816**	0.012924**
Error	22	0.000002	0.000001	0.000159	0.000016

** Indicates significant difference at $P \leq 0.01$. Df: Degrees of freedom.

Shoot calcium content increased with the increase of irrigation levels to 0.033, 0.077 and 0.092% respectively. Shoot calcium content increased with potassium applications up until the 40 mg kg^{-1} potassium application (Table 5). The lowest shoot calcium content (0.026%) was obtained at the 33% irrigation level and 40 mg kg^{-1} potassium application, the highest shoot calcium content (0.113%) at the 100% irrigation level and 20 mg kg^{-1} potassium application (Table 5). When the root calcium content is considered, it is observed that root calcium content increases with increasing irrigation levels. The lowest root calcium content (0.006%) was obtained at the 33% irrigation level and 40 and 80 mg kg^{-1} potassium application, the highest root calcium content (0.021%) at the 100% irrigation level and 20 mg kg^{-1} potassium application (Table 5).

Table 5. Mean values of shoot and root Ca content

	Irrigation (Field Capacity)				Irrigation (Field Capacity)			
K (mg kg^{-1})	**33%**	**66%**	**100%**	**Mean**	**33%**	**66%**	**100%**	**Mean**
	Shoot Ca content (%)				**Root Ca content (%)**			
10	0.036 f	0.076 cde	0.072 e	0.062 C	0.011 de	0.011 de	0.011 de	0.011 B
20	0.037 f	0.079 cd	0.113 a	0.076 A	0.017 b	0.013 cd	0.021 a	0.017 A
40	0.026 g	0.080 c	0.075 cde	0.060 C	0.006 f	0.014 c	0.010 e	0.010 C
80	0.033 f	0.075 de	0.107 b	0.071 B	0.006 f	0.012 de	0.013 cd	0.010 BC
Mean	0.033 C	0.077 B	0.092 A		0.010 C	0.012 B	0.014 A	

*The differences between the interaction potassium and Irrigation means having different lower case letters in a column are statistically significant at 0.05. **The differences between the potassium means having different capital letters in a column are statistically significant at 0.05. The differences between the irrigation means having different capital letters in a line are statistically significant at 0.05.

Shoot phosphorus content increased with the increase of potassium application to 1.179, 1.432, 1.456 and 1.552% respectively (Table 6). The lowest shoot phosphorus content (1.138%) was obtained at the 33% irrigation level and 10 mg kg^{-1} potassium application, the highest shoot phosphorus content (1.607%) at the 33% irrigation level and 40 mg kg^{-1} potassium application (Table 6). When the root phosphorus content is considered, it is observed that root phosphorus content decreases with increasing irrigation levels. The lowest root phosphorus content (0.346%) was obtained at the 100% irrigation level and 20 mg kg^{-1} potassium application, the highest root phosphorus content (0.903%) at the 33% irrigation level and 40 mg kg^{-1} potassium application (Table 6).

Table 6. Mean values of shoot and root P content

	Irrigation (Field Capacity)				Irrigation (Field Capacity)			
K (mg kg^{-1})	**33%**	**66%**	**100%**	**Mean**	**33%**	**66%**	**100%**	**Mean**
	Shoot P content (%)				**Root P content (%)**			
10	1.138 f	1.145 f	1.254 e	1.179 D	0.440 g	0.396 h	0.372 ı	0.402 D
20	1.496 bc	1.315 d	1.485 c	1.432 C	0.608 f	0.446 g	0.346 j	0.467 C
40	1.607 a	1.237 e	1.524 b	1.456 B	0.903 a	0.710 c	0.692 d	0.768 A
80	1.597 a	1.498 bc	1.562 a	1.552 A	0.734 b	0.628 e	0.734 b	0.699 B
Mean	1.460 A	1.299 B	1.456 A		0.671 A	0.545 B	0.536 C	

*The differences between the interaction potassium and Irrigation means having different lower case letters in a column are statistically significant at 0.05. **The differences between the potassium means having different capital letters in a column are statistically significant at 0.05. The differences between the irrigation means having different capital letters in a line are statistically significant at 0.05.

According to the results of variance analysis, the effect of irrigation x potassium interaction shoot and root Na/K and Na/K ratio were statistically significant ($P \leq 0.01$). In addition, it was determined that the effect of irrigation and potassium applications on shoot and root Na/K and Na/K ratio were statistically significant (Table 7).

Table 7. Mean squares for shoot and root Na/K and Na/K ratio

Source of Variation	Df	Shoot Na/K ratio	Root Na/K ratio	Shoot Na/Ca ratio	Root Na/K ratio
Irrigation	2	0.015103**	0.000556**	18.9274**	1.55149**
Potassium (K)	3	0.000794**	0.000598**	1.5771**	1.32691**
Irrigation * K	6	0.000134**	0.000114**	0.7987**	0.47641**
Error	22	0.000001	0.000002	0.0070	0.02270

** Indicates significant difference at $P \leq 0.01$. Df: Degrees of freedom.

Shoot Na/K ratio increased with the increase of irrigation levels to 0.030, 0.115 and 0.093 respectively. Shoot Na/K ratio decreased with potassium applications (Table 8). The lowest shoot Na/K ratio (0.020) was obtained at the 33% irrigation level and 80 mg kg^{-1} potassium application, the highest shoot Na/K ratio (0.125) at the 66% irrigation level and 40 mg kg^{-1} potassium application (Table 8). When the root Na/K ratio is considered, it is observed that root Na/K ratio decreases with increasing irrigation levels and potassium applications. The lowest root Na/K ratio (0.006) was obtained at the 100% irrigation level and 40 and 80 mg kg^{-1} potassium application, the highest root Na/K ratio (0.040) at the 33% irrigation level and 10 mg kg^{-1} potassium application (Table 8).

Table 8. Mean values of shoot and root Na/K ratio

	Irrigation (Field Capacity)				Irrigation (Field Capacity)			
K (mg kg^{-1})	**33%**	**66%**	**100%**	**Mean**	**33%**	**66%**	**100%**	**Mean**
	Shoot Na/K ratio				**Root Na/K ratio**			
10	0.050 f	0.123 a	0.102 c	0.092 A	0.040 a	0.028 b	0.010 def	0.026 A
20	0.027 g	0.109 b	0.101 c	0.079 B	0.021 c	0.018 c	0.008 ef	0.016 B
40	0.023 gh	0.125 a	0.093 d	0.080 B	0.013 d	0.010 de	0.006 ef	0.010 C
80	0.020 h	0.103 c	0.077 e	0.067 C	0.009 def	0.008 ef	0.006 f	0.008 D
Mean	0.030 C	0.115 A	0.093 B		0.021 A	0.016 B	0.007 C	

*The differences between the interaction potassium and Irrigation means having different lower case letters in a column are statistically significant at 0.05. **The differences between the potassium means having different capital letters in a column are statistically significant at 0.05. The differences between the irrigation means having different capital letters in a line are statistically significant at 0.05.

Shoot Na/Ca ratio increased with the increase of irrigation levels to 1.786, 4.841 and 3.706 respectively (Table 9). The lowest shoot Na/Ca ratio (1.408) was obtained at the 33% irrigation level and 20 mg kg^{-1} potassium application, the highest shoot Na/Ca ratio (5.609) at the 66% irrigation level and 80 mg kg^{-1} potassium application (Table 9). When the root Na/Ca ratio is considered, it is observed that root Na/Ca ratio decreases with increasing irrigation levels (Table 9). The lowest root Na/Ca ratio (0.676) was obtained at the 100% irrigation level and 20 mg kg^{-1} potassium application, the highest root Na/Ca ratio (2.269) at the 33% irrigation level and 80 mg kg^{-1} potassium application (Table 9).

Table 9. Mean values of shoot and root Na/Ca ratio

	Irrigation (Field Capacity)				Irrigation (Field Capacity)			
K (mg kg^{-1})	**33%**	**66%**	**100%**	**Mean**	**33%**	**66%**	**100%**	**Mean**
	Shoot Na/Ca ratio				**Root Na/Ca ratio**			
10	2.148 f	4.088 c	4.036 c	3.424 B	1.993 a	1.833 ab	1.416 bc	1.748 A
20	1.408 g	4.185 c	2.906 e	2.833 C	0.776 e	1.101 cde	0.676 e	0.851 C
40	2.030 f	5.484 a	4.641 b	4.052 A	2.177 a	0.881 de	1.333 c	1.464 B
80	1.558 g	5.609 a	3.240 d	3.469 B	2.269 a	1.248 cd	1.061 cde	1.526 B
Mean	1.786 C	4.841 A	3.706 B		1.804 A	1.266 B	1.122 B	

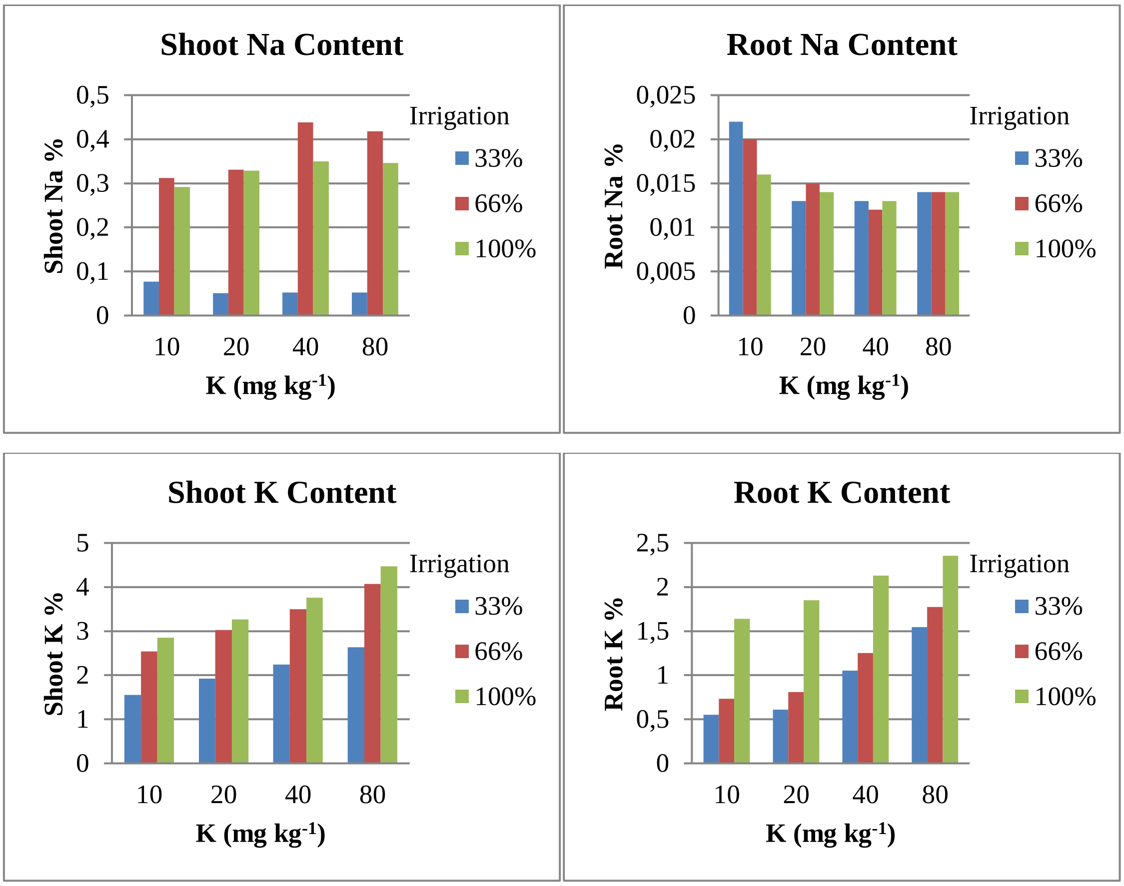
*The differences between the interaction potassium and Irrigation means having different lower case letters in a column are statistically significant at 0.05. **The differences between the potassium means having different capital letters in a column are statistically significant at 0.05. The differences between the irrigation means having different capital letters in a line are statistically significant at 0.05.

5. DISCUSSION

Sodium and potassium ions are very important in sugar beet cells for osmotic adjustment they are major vacuolar osmolyte factors (Choluj et al. 2008). According to the results, shoot sodium content has increased with increasing irrigation levels (Figure 1). Shoot sodium content is lower in stressed plants than plants grown under normal conditions. Contrarily root sodium content decreased with irrigation levels. Wu et. al., (2013) stated in his study that drought condition decreased shoot and root sodium content the results obtained were in partly compatible with this study. In Raza's study (2013) drought increased the sodium content in contrast to this study drought decreased shoot sodium content in our study (Figure 1). According to Abd-El-Motagally et.al., (2004) sodium is translocated to the shoots, where it replaces potassium in various metabolic functions in sugar beet. It has been suggested that sugar beet plants increase potassium and sodium content in the leaves than in the roots under drought stress for protects itself (Ghoulam et al., 2002; Li et. al., 2009).When we compare the shoot and root sodium contents, it is seen that there is more sodium in the shoot than the root (Table 2).

When Table 2 and Figure 1 are examined, it is seen that shoot sodium content increases with increasing potassium application which is not in parallel with previous studies. According to Bee et al.,(1997), potassium did not affect sodium content of sugar beet and on the other hand according to many researchers, potassium application decreased sodium content of sugar beet (Huijbregts et. al., 1996; Turhan and Piskin, 2005; Mubarek et.al., 2016). In this study root sodium content decreased with potassium application (Table 2) in parallel with previous studies. When results are examined in terms of the interaction between irrigation levels and potassium the lowest shoot sodium content (0.51%) was obtained at the 33% irrigation level and 20 mg kg^{-1} potassium application, the highest shoot sodium content (0.438%) at the 66% irrigation level and 40 mg kg^{-1} potassium application (Table 2). The lowest root sodium content (0.012%) was obtained at the 66% irrigation level and 40 mg kg^{-1} potassium application, the highest root sodium content (0.022%) at the 33% irrigation level and 10 mg kg^{-1} potassium application (Table 2).

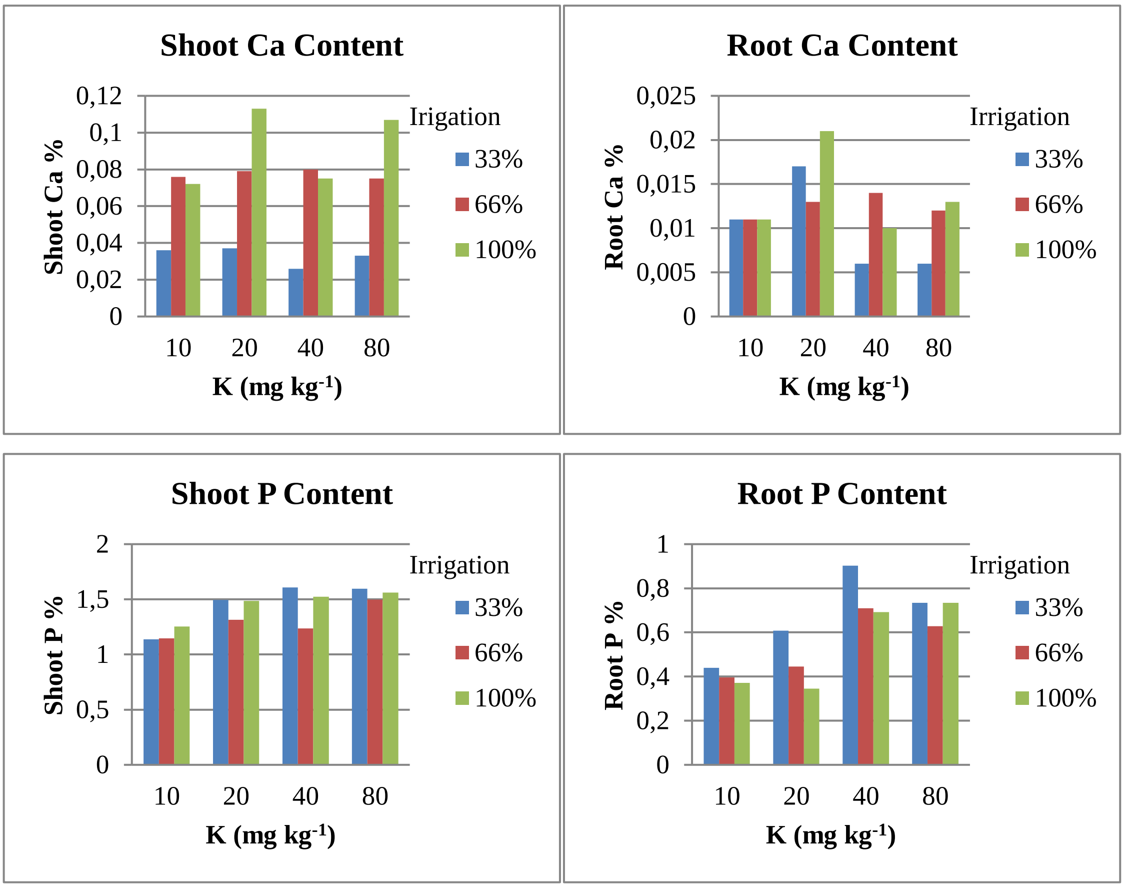
Figure 1. Shoot and root sodium (Na) and potassium (K) content (%) changes



According to the results, shoot and root potassium content has increased with increasing irrigation levels (Table 3). In this study, the highest shoot and root potassium content (3.585% and 1.994% respectively) was obtained at the 100% irrigation level, while the lowest (2.086% and 0.940% respectively) was obtained at the 33% irrigation level. According to Hu and Schimidhalter (2005) the lack of water under salt and drought stress conditions causes reduces the turgor pressure thus the potassium concentration reduce under these stress conditions. Previous studies have emphasized that potassium accumulation is very important under drought and salt stress condition for protect osmotic adjustment (Ashraf et. al., 2003). Contrary to our study plants can absorb 2-3 times of potassium under stress (Nejad et. al., 2010). Increasing the dose of potassium application resulted in significant increase shoot and root potassium content (Figure 1). Similarly our results other researcher (Huijbregts et. al., 1996; Bee et al.,1997; Mubarek et. al., 2016; Abd-El-Motagally 2004) stated that plant potassium content increased with potassium application dose.

When results are examined in terms of the interaction between irrigation levels and potassium the lowest shoot potassium content (1.552%) was obtained at the 33% irrigation level and 10 mg kg^{-1} potassium application, the highest shoot potassium content (4.467%) at the 100% irrigation level and 80 mg kg^{-1} potassium application (Table 3). The lowest root potassium content (0.550%) was obtained at the 33% irrigation level and 10 mg kg^{-1} potassium application, the highest root potassium content (2.355%) at the 100% irrigation level and 80 mg kg^{-1} potassium application (Table 3). According to Ashraf (1998) potassium application increased potassium content of plan under drought condition.

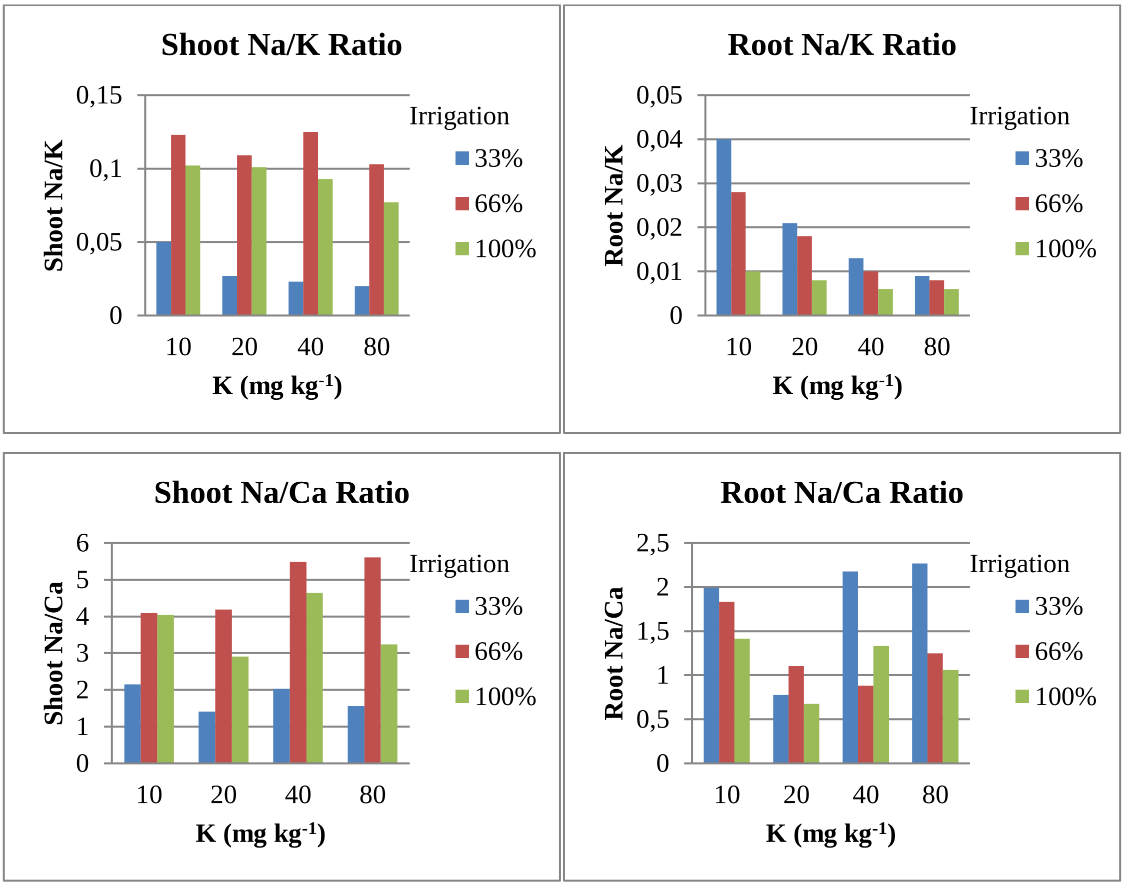
Figure 2. Shoot and root calcium (Ca) and phosphorus (P) content (%) changes



Calcium is a macronutrient and absolutely necessary for plant growth. According to the results, shoot and root calcium content has increased with increasing irrigation levels (Figure 2). Shoot and root calcium content is lower in stressed plants than plants grown under normal conditions. According to Abdalla and El-Khohiban (2007), drought causes a decrease in calcium concentration in wheat plants. Kusvuran (2010) stated in her study that drought condition decreased plant calcium content depending on the duration of stress and plants increase calcium content in the leaves than in the roots under drought stress for ion balance. When we compare the shoot and root calcium contents in our study, it is seen that there is more calcium in the shoot than the root (Table 5). In this study contrary to some studies shoot calcium content increased under drought condition (Wu et.al., 2013). According to Abd-El-Motagally (2004) shoot and root calcium content of sugar beet decreased by increasing potassium our results are partially parallel with this study. Shoot and root calcium content increased in parallel with the increasing potassium doses while it decreased at 40 mg kg^{-1} (Figure 2).

Other researcher stated before that plants can uptake more phosphorus in under drought condition (Khondakar et al. 1983) and our results in parallel with this study. Shoot and root phosphorus content decreased with the increase of irrigation levels to 1.460, 1.299, 1.456% and 0.671, 0.545, 0.536% respectively. It has been suggested that potassium application increased wheat phosphorus uptakes (Raza et. al., 2013). Similar results were obtained in our study shoot and root phosphorus content increased with the increase of potassium application (Table 6).

Figure 3. Shoot and root Na/K and Na/Ca ratio changes



Shoot Na/K ratio increased with the increase of irrigation levels to 0.030, 0.115 and 0.093 respectively (Table 8). According to Al-Jbawi and Abbas (2013) depend on the duration of stress Na decreases while K increases, as a result Na/K ratio decreases. It has been suggested that root Na/K ratio significantly increased under drought (Wu et. al., 2013) and our results not in parallel with this study. When the root Na/K ratio is considered, it is observed that root Na/K ratio decreases with increasing irrigation levels. It has been emphasized that the impaired intracellular electrolyte balance is improved, the amount of potassium to compete with sodium is increasing and the disturbed intracellular Na/K balance is readjusted by additional potassium (Kabay and Sensoy, 2017). Our results are consistent with previous studies it is observed that root Na/K ratio decreases with increasing potassium applications (Figure 3).

Plants prefer calcium instead of sodium under stress condition to balance ion regulation and osmotic pressure for increase the tolerance level. Therefore Na/Ca ratio is an important parameter under stress (Koc, 2005; Dasgan et. al., 2006). Under stress, sodium replaces calcium in the cell membrane, thereby Na/Ca ratio in the apoplast increasing (Kaya and Tuna, 2010). Drought increased shoot Na/Ca ratio while reducing root Na/Ca ratio (Wu et. al., 2013). Contrary to this study shoot Na/Ca ratio increased with the increase of irrigation levels to 1.786, 4.841 and 3.706 respectively (Table 9) while the root Na/Ca ratio decreases with increasing irrigation levels. The lowest root Na/Ca ratio (0.676) was obtained at the 100% irrigation level and 20 mg kg^{-1} potassium application, the highest root Na/Ca ratio (2.269) at the 33% irrigation level and 80 mg kg^{-1} potassium application (Table 9).

6. CONCLUSION

According to the results of variance analysis, the effect of irrigation x potassium interaction on the shoot and root sodium (Na) potassium (K) calcium (Ca) and phosphorus (P) content Na/K and Na/K ratio was found to be statistically significant.

Shoot and root sodium content decreased with potassium applications under drought conditions (33%). Shoot and root potassium content increased with potassium applications in both drought and sufficient water conditions. Shoot calcium content change irregular with potassium application while root calcium decreased with potassium application under drought conditions (33%). Shoot phosphorus content increased with potassium applications in both drought and sufficient water conditions. Root phosphorus content increased with potassium applications up until the 40 mg kg^{-1} potassium application under drought condition. Shoot and root sodium/potassium ratio decreased with potassium applications in both drought and sufficient water conditions. Shoot and root sodium/calcium ratio change irregular with potassium applications.

In summary, applying potassium to the plants under drought stress led to an increase in the shoot and root potassium and phosphorus content while decrease in the shoot and root sodium, sodium/potassium ratio and root calcium. Thus, it can be said that potassium may play a critical role in reducing the negative effects of drought stress in sugar beet. Therefore, it is thought that keeping the K nutrition at a sufficient level for the plants grown in the regions where irrigation may be a problem can be beneficial in reducing the damage of drought stress.

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