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Original article

The Effect of Potassium Application on Sugar Beet (*Beta vulgaris* L.) under Salt Stress

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Abstract

Salt stress is an important type of abiotic stress that limits vegetative production in the world, particularly in arid and semi-arid climatic areas. The aim of this study is to mitigate salt stress damage in the sugar beet plant, which is an important part of crop production, with potassium application. An experiment was designed according to a design of random blocks with 4 different doses (10, 20, 40, 80 mg kg-1 K) of potassium and 3 different salt levels (0, 100, 150 mM NaCl) and 3 replicates. Leaf length, leaf width, fresh weight, malondialdehyde (MDA) content, membrane damage, relative water content was determined after harvest. The data obtained from the experiment were evaluated by one-way analysis of variance (One-Way ANOVA). According to the results of variance analysis, leaf width, leaf length, fresh weight, MDA content, membrane damage, relative water content were found to be statistically significant in salt x potassium interaction. Due to the positive effects of potassium on the parameters known to increase the plants' stress tolerance, it is thought that it may be beneficial in reducing the salt stress in order to make the sugar beet less affected by salt stress.

Keywords: Potassium, Salt Stress, Sugar Beet (*Beta vulgaris* L.).

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INTRODUCTION

Salt stress is an abiotic stress that occurs especially in arid and semi-arid climatic zones and significantly limits plant productivity. More than 800 million hectares of terrestrial areas are affected by salt stress (Ghanem et al., 2012). While 50% of the productive areas and 20% of the agricultural lands in the world face the salinity problem, according to the United Nations Environment Program, approximately 1.5 million hectares of land in Turkey are faced with the problem of salinity and alkalinity (Ekmekçi et al., 2005). Approximately 50% of cultivable land will experience salinity stress by 2050 (Shrivastava and Kumar, 2015). The rapid increase in the world population increases the need for agricultural products, whereas agricultural areas are decreasing. For this reason, it is very important to get the highest efficiency per unit area and to keep plants away from stress. The problem of salinity is generally describe as the content of salts accumulating in the soil preventing the development of the plant and leading to the exclusion of cultivable land from agriculture. Salinity in general causes a reduce in the number and area of leaves of the plant; shrinking in the size of the plant, suppression of the growth and differentiation of tissues and organs, and the inability to balance the root and stem weight, in turn causing slower growth by showing itself as a weak root. At the same time, it shows its effect through decreases in salinity, the fresh and dry weight of the plant, decreases in chlorophyll content, a decrease in fruit quality and a consequent decrease in yield (Asraf, 2004; Yu et al., 2012). In arid and semi-arid lands where the drainage is not good in Turkey, when the salts from irrigation water cannot be washed away sufficiently with rainfall, excessive salinization occurs in the soils (Uygan et al., 2006). Ion imbalances occur in plants due to salt stress; one of these ions is potassium (Hirpara et al., 2005). Potassium concentration decreases in the tissues of plants under salt stress (Othman et al., 2006; Kuşvuran et al., 2008). In this context, the potassium nutrition of plants under salt stress is importance. As the potassium concentration of the plant enhancements, the strength of the plants to salt stress increases (Hsiao and Lauchli, 1986). It has been demonstrated in previous studies that a high K^+/Na^+ ratio of plants and tolerance to salt stress are directly proportional (Ashraf et al., 1997; Sherif et al., 1998). In a study using forecasting models, according to the projections for the 2018-2022 period, It has been determined that the use of potassium and the amount needed tend to increase over the years. While 77% of sugar production in the world is obtained from sugar cane, 23% is obtained from sugar beet (Anonymous, 2018). Sugar beet is known to uptake potassium faster than sugar cane (Bellitürk, 2010). In Turkey, sugar beet is produced in five regions, excepting the South-eastern Anatolia and Mediterranean regions, and approximately 4.5% of the population works in sugar beet production (Er and Uranbey, 1998). According to TURKSTAT plant production statistics, sugar beet production increased by 3.7% compared to the previous year and reached 18.1 million tons in 2019. With the amount produced, it ranked 5th in the world after Russia, France, Germany and the USA. In the light of this information, the aim of this study is to prevent damage under salt stress to the sugar beet plant, which cannot be abandoned and has an important place in the economy of the country, through the application of potassium.

MATERIALS and METHODS

Serenada varieties of sugar beet were used in this experiment. Washed sand, with a pH of 8.2 and EC of 75 µM cm^{-1} was chosen as the medium. Plants were grown under controlled conditions with Hoagland solution. Potassium doses (10–20–40–80 mg kg^{-1}) were applied to the sugar beets and salt levels were kept at 0, 100, 150 mM NaCl.

The malondialdehyde (MDA) content was analysed according to Lutts et al., (2002) and calculated by the following formula:

MDA= (A 532- A 600) / 155mM/cm x Volume (ml)= mM/200 g

The membrane damage was analysed according to Dlugokecka and Kacperska-palacz (1978) and calculated by the following formula:

Membrane Damage (%) = (EC1-EC2 / 1-EC2)x100

The relative water content was analysed according to Barr and Weatherley (1962); Sairam and Srivastava (2002) and calculated by the following formula:

RWC % = [(FW– DW) / (TW– DW)] x 100

Variance analysis was performed using the GLM of the Minitab 17 program. Differences were determined by the Tukey multiple comparison test (P<0.05).

RESULTS and DISCUSSION

According to the results, the salt x potassium interaction effect was statistically significant (P 0.01) in terms of leaf width (LW), leaf length (LL) and fresh weight (FW), Malondialdehyde (MDA) content, membrane damage, and relative water content (RWC) of plants (Table 1).

Table 1. The effect of potassium on LW, LL, FW, MDA, membrane damage, RWC

Source of variation	Df	Leaf width	Leaf length	Fresh Weight	Malondialdehyde (MDA) Content	Membrane damage	RWC (%)
Salt	2	2,45**	5,07**	39,67**	0,72011**	1540,04**	114,19**
Potassium	3	0,08	2,00**	5,18**	0,07269**	18,53**	40,62**
Salt*Potassium	6	0,26**	0,60**	3,96**	0,04410**	61,64**	29,95**
Error	21	0,04	0,14	0,03	0,00013	0,67	1,84

df degrees of freedom *, ** and ***Significant difference at P<0.01

Salt stress causes reduce in leaf number and area (Shanannon and Grieve, 1999; Asraf, 2004). Plants under salt stress try to prevent water loss by closing their stomata and reducing transplant by shrinking the leaf areas. Lutts et al. (1996) reported that plants grown under stress conditions have smaller leaf area than control plants due to salt stress. When the plants under salt stress were compared with the control plants, the leaf width decreased by 14.60% and 16.72%, and leaf length by 8.15% and 16.25%, respectively, in 100 mM and 150 mM NaCl applications. Similar to the results obtained, Chartzoulakis and Klapaki (2000) stated in their study on pepper varieties that 100 and 150 mM NaCl doses caused reduce in leaf area. Salt x potassium interaction was found to be statistically significant (p <0.01) according to the variance analysis performed, with reference to LW and LL values obtained from the study. The highest LW and LL were detected at a potassium dose of 10 mg kg^{-1} at 0 mM NaCl salt level, while the lowest 100 mM NaCl salt level was detected at 20 mg kg^{-1} potassium dose (Table 2). As the potassium level increased in plants under stress, the decrease in LW and LL decreased. Consistent with the results obtained, Shirazi et al. (2005) and Sherif et al. (1998) stated that high doses of potassium fertilizer applied in potassium poor soils will protect the plant from the negative effects of salt.

Table 2. Effect of potassium on leaf width and leaf length of plant

	mM NaCl				**mM NaCl**			
K (mg kg^{-1})	**0**	**100**	**150**	**Mean**	**0**	**100**	**150**	**Mean**
	Leaf Width (cm)				**Leaf Length (cm)**			
10	5,500 a	4,167 de	4,111 de	4,593	8,944 a	7,722 bc	7,028 cd	7,898 A
20	4,944 ab	3,944 e	4,306 cde	4,398	7,833 bc	6,444 d	6,750 cd	7,009 B
40	4,833 bc	4,444 bcde	4,167 de	4,481	7,722 bc	7,667 bc	6,778 cd	7,389 B
80	4,889 abc	4,667 bcd	4,214 cde	4,590	8,556 ab	8,528 ab	7,130 cd	8,071 A
Mean	5,042 A	4,306 B	4,199 B		8,264 A	7,590 B	6,921 C	

The different letter are significantly different at α=0.01.

With the salt application, the fresh weights decreased compared to the control plants. Plant fresh weight averages were changed to 8.438 g, 6.234 g and 4.592 g at 0 mM, 100 mM, 150 mM NaCl salt levels, respectively (Table 3). Similarly, in previous studies on wheat, eggplant and pepper, a loss of fresh and dry weights of the plants has been reported as a result of stress (Daşgan et al., 2002; Yaşar, 2003). Salt x potassium interaction was found to be statistically significant (p <0.01) according to the variance analysis performed, with reference to the fresh weight values obtained from the study. The highest plant fresh weight was detected at a potassium dose of 10 mg kg^{-1} (11,035 g) at 0 mM NaCl salt level, while the lowest plant fresh weight was determined at a potassium dose of 40 mg kg^{-1} (4,485 g) at 150 mM NaCl salt level (Table 3). Similarly, Tuna et al. (2017) reported that the dry matter content of the leaves decreased with salt applications, and the maximum decrease was detected at 150 mM NaCl concentration and that the added potassium could increase the dry matter content of the leaves. Yakıt and Tuna (2006) also stated in their study that the negative effect of salt stress on plant height and stem diameter can be alleviated by potassium applications.

The malonialdehyde (MDA) content is a product of membrane lipid peroxidation and occurs by the breakdown of unsaturated fatty acids found in membranes. Malonialdehyde (MDA) is closely related to membrane permeability and increases under stress conditions (Dolatabadian et al., 2008). When Table

3 is investigated, it is seen that the mean of the plant MDA content of the salt levels changes 1.765%, 1.343% and 1.329% at 0 mM, 100 mM, 150 mM NaCl salt levels, respectively. Similar to these results, with their studies, Yaşar (2003) on eggplant, Kuşvuran et al. (2007) on melon, Wei et al. (2009) on eggplant, Yaşar et al. (2008) on beans, and Huang et al. (2009) on cucumber emphasized that the amount of MDA increased in plants as a result of high salt concentration. Salt x potassium interaction was found to be statistically significant (p <0.01) according to the variance analysis performed, with reference to the MDA values obtained from the study. The highest plant MDA content was detected at a potassium dose of 20 mg kg-1 (1.909%) at 0 mM NaCl salt level, while the lowest plant MDA content was detected at a potassium dose of 40 mg kg-1 (1.188%) at 150 mM NaCl salt level (Table 3). In a similar study, it has been reported that foliar application of potassium to a tomato plant under NaCl stress reduces the MDA content, which is elevated due to salinity, reduces stress damage, positively affects growth parameters and reduces oxidative damage (Amjad et al., 2016).

Table 3. Effect of of potassium on fresh weight and MDA content of plant

K (mg kg^{-1})	**mM NaCl**				**mM NaCl**			
	0	**100**	**150**	**Mean**	**0**	**100**	**150**	**Mean**
	Fresh Weight				**MDA**			
10	11,035 a	6,401 e	4,788 f	7,408 A	1,833b	1,522e	1,333f	1,563 A
20	7,397 c	4,532 f	4,495 f	5,475 C	1,909a	1,317 fg	1,253hı	1,493 B
40	8,173 b	6,720 de	4,485 f	6,459 B	1,581d	1,285gh	1,188j	1,351 C
80	7,147 cd	7,282 c	4,601 f	6,343 B	1,737c	1,247ı	1,541e	1,508 B
Mean	8,438 A	6,234 B	4,592 C		1,765 A	1,343B	1,329C	

The different letter are significantly different at α=0.01.

It has been reported that in many plants under salt stress, membrane permeability increases and membrane damage increases. Ghoulam et al. (2002) on sugar beet, Lutts et al. (1996) on rice, Yakıt and Tuna (2006) on corn reported an increase in membrane permeability values under salt stress. A membrane damage index is considered as an indicator of damage to plant cells in response to salt stress, and is expressed as an ion imbalance that develops in plants due to intracellular and extracellular osmotic incompatibility (Munns, 2002; Ghoulam et al., 2002). When Table 4 is examined, it is seen that salt levels change the plant membrane damage averages to 42.11%, 64.21% and 57.67% at 0 mM, 100 mM, 150 mM NaCl levels, respectively. Similar to these results, Zhu et al. (2008) on cucumber, and Perez-Lopez et al. (2008) on barley stated that cell damage increased under stress conditions with their salt studies. Salt x potassium interaction was found to be statistically significant (p <0.01) according to the variance analysis performed in terms of the membrane damage values obtained from the study. While the highest plant membrane damage was detected at a potassium dose of 20 mg kg-1 (67.16%) at 100 mM NaCl salt level, the lowest plant membrane damage was detected at a potassium dose of 40 mg kg-1 (38.44%) at 0 mM NaCl salt level (Table 4). It has been reported by some researchers that macro nutrients applied to plants under salt stress have an improving effect on membrane permeability. Kaya and Higgs (2003) reported that the potassium applied to the pepper plant and again, Kaya and Higgs (2002) reported that the calcium applied to the cucumber plant had a positive effect on the membrane permeability.

Table 4. Effect of potassium on membrane damage and RWC content of plant

	mM NaCl				**mM NaCl**			
K (mg kg^{-1})	**0**	**100**	**150**	**Mean**	**0**	**100**	**150**	**Mean**
	Membrane Damage				**RWC**			
10	48,83f	66,45 a	54,17e	56,48 A	91,81 a	83,15 bcd	80,55 def	85,17 A
20	40,45g	67,16 a	55,93 de	54,51 B	82,07 cde	77,42 f	82,88 bcd	80,79 C
40	38,44g	65,59 a	60,46 b	54,83 B	86,54 b	84,79 bc	78,67 ef	83,33 B
80	40,71g	57,64 cd	60,14 bc	52,83 C	83,95 bcd	78,18 ef	79,90 def	80,68 C
Mean	42,11C	64,21 A	57,67 B		89,09 A	80,88 B	80,50 B	

The different letter are significantly different at α=0.01.

When Table 4 is examined, it is seen that RWC values are the lowest in salt applications (100 mM, 80.88%, 150 mM, 80.50%); the highest (89.09%) is in the control group. Similarly, Yakıt and Tuna (2006) stated in their study that 100 mM NaCl application in corn dropped the relative water content of the leaves under stress conditions and reached the highest values in control plants. It has been reported by Aksu and Altay (2020) that RWC decreased under other abiotic stress factors such as drought. Salt x potassium interaction was found to be statistically significant ($p < 0.01$) according to the variance analysis made with regard to the relative water content values of the leaves obtained from the study. The highest RWC was detected at 0 mM NaCl salt level at 10 mg kg-1 potassium dose (91.81%), and the lowest RWC at 100 mM NaCl salt level at 20 mg kg-1 potassium dose (77.42%) (Table 4). The applied potassium doses did not affect the RWC under stress. Contrary to these results, Katerji et al. (1997) studying sugar beet, Srivastava et al. (1998) studying wheat, and Kaya and Higgs (2003) pepper plants, found that RWC values declined under salt stress and improved with additional nutrient supplements. In parallel with our results, in previous studies, it was recommended to apply fertilizers providing 81 kg K2O, 27 kg Mg and 46 kg S per hectare in addition to nitrogen and phosphorus in order to obtain optimum root and white sugar yield (Zengin et al., 2009).

Conclusion

According to the results, leaf width and leaf length decreased with salt application, compared to control plants. As discussed earlier, salt stress negatively impacts the yield. The leaf width and leaf length showed an important reduction in response to the increasing levels of salt. Potassium applications to plants under stress did not affect this decrease. As the amount of salt increased, the fresh weight of the plant decreased and the decrease in the fresh weight decreased as the potassium level increased. Malonialdehyde (MDA) content increased under stress conditions, and applied potassium increased MDA content. Cell membrane damage was increased under salt stress conditions. Potassium has a curative effect on potassium membrane permeability when applied to plants under salt stress. This demonstrates the role of potassium in reducing the damage of salt-dependent cell membranes. Relative water content decreased under stress conditions; the highest value was determined in control plants. Relative water content is lower in stressed plants than in plants grown under normal conditions. Potassium applications under salt stress did not affect this decrease. Because of the positive effects of potassium on parameters known to increase the stress tolerance of plants, it is thought that it may be beneficial to apply it to sugar beet to ensure that the plant is less affected by salt stress.

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