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Research Article

EVALUATION OF GERMINATION, EMERGENCE AND PHYSIOLOGICAL PROPERTIES OF SUGAR BEET CULTIVARS UNDER SALINITY

Engin Gökhan KULAN[1*], Alper ARPACIOĞLU[1], Nurgül ERGİN[2], Mehmet Demir KAYA[1]

[1] Department of Field Crops, Faculty of Agriculture, Eskişehir Osmangazi University, Eskişehir, TURKEY
[2] Department of Field Crops, Faculty of Agriculture and Natural Sciences, Bilecik Şeyh Edebali University, Bilecik, TURKEY

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Panagiotis Madesis

****Corresponding Author:***
Engin Gökhan Kulan
egkulan@ogu.edu.tr

ORCID iDs of the authors:
EGK. orcid.org/0000-0002-7147-6896
AA. orcid.org/0000-0002-1176-2866
NE. orcid.org/0000-0003-3105-7504
MDK. orcid.org/0000-0002-4681-2464

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Abstract: This study aimed to determine a useful selection criterion for salt tolerance during the early development stage of sugar beet. Four sugar beet cultivars (Orthega, Valentina, FD Shoot, and Mohican) were exposed to NaCl stresses (Control, 5, 10, and 15 dS m^{-1}), and morphological and physiological characteristics were investigated. Germination percentage, mean germination time (MGT), seedling length, and seedling fresh weight (SFW) in germination test; emergence percentage, mean emergence time (MET), root length, shoot length, plant fresh weight, relative chlorophyll content (Chl), relative water content (RWC) and electrolyte leakage of the plants grown in pod experiment were measured. The results showed that the maximum germination at control was recorded in FD Shoot, but it gave the lowest germination at 15 dS m^{-1}. In the pod experiment, the highest emergence rate was detected in Orthega and Mohican at all levels of NaCl. Increased salinity delayed MET and led to reduction in shoot length, root length, and RWC of sugar beet cultivars. Relative Chl content and electrolyte leakage enhanced from 32.7 SPAD and 21.6% in control to 38.5 SPAD and 35.6% in 10 dS m^{-1}, respectively. In general, there were significant differences among sugar beet cultivars, and they could keep the salinity up to 5 dS m^{-1} in terms of the investigated traits. It was concluded that relative Chl content and electrolyte leakage should be used a promising clue for selection of tolerant or sensitive sugar beet cultivars for salinity.

Özet: Bu çalışmada, erken gelişim döneminde şeker pancarının tuza toleransı için faydalı bir seçim kriteri belirlemek amaçlanmıştır. NaCl stresine (Kontrol, 5, 10 ve 15 dS m^{-1}) maruz bırakılan dört şeker pancarı çeşidinde (Orthega, Valentina, FD Shoot ve Mohican) morfolojik ve fizyolojik özellikler incelenmiştir. Çimlenme testinde; çimlenme yüzdesi, ortalama çimlenme süresi, fide uzunluğu ve fide yaş ağırlığı, çıkış testinde; çıkış yüzdesi, ortalama çıkış süresi, kök uzunluğu, sürgün uzunluğu, bitki yaş ağırlığı, bağıl su içeriği, bağıl klorofil içeriği ve elektrolit sızıntısı ölçülmüştür. Sonuçlar, FD Shoot çeşidinde en yüksek çimlenmenin kontrol, en düşük çimlenmenin ise 15 dS m^{-1} seviyesinde kaydedildiğini göstermiştir. Çıkış testindeki tüm NaCl seviyelerinde en yüksek çıkış yüzdesi Orthega ve Mohican çeşitlerinde tespit edilmiştir. Artan NaCl seviyeleri ile şeker pancarı çeşitlerinde ortalama çıkış süresi gecikmiş ve sürgün uzunluğu, kök uzunluğu ve bağıl su içeriği azalmıştır. Bağıl klorofil içeriği ve elektrolit sızıntısı, kontrol ve 10 dS m^{-1} seviyelerinde sırasıyla 32,7 SPAD ve %21,6; 38,5 SPAD ve %35,6 olarak belirlenmiştir. Genel olarak, şeker pancarı çeşitleri arasında önemli farklılıklar bulunmuş ve incelenen özellikler açısından çeşitler 5 dS m^{-1}'e kadar olan tuzluluğa tolerans göstermişlerdir. Bağıl klorofil içeriği ve elektrolit sızıntısının, tuzluluğa toleranslı veya hassas şeker pancarı çeşitlerinin seçiminde umut verici bir ipucu olarak kullanılması gerektiği sonucuna varılmıştır.

Introduction

Soil salinity occurs naturally in arid and semiarid regions where evapotranspiration is greater than precipitation. In irrigated areas, excessive amounts of irrigation water and low quality irrigation water use cause the accumulation of salts in soil. Salt stress is one of the most significant abiotic stresses inhibiting plant growth (Hampson & Simpson 1990, Neumann 1995) and resulting in a wide number of irregularities in morphological, physiological and biochemical processes from germination to harvest (Willenborg *et al*. 2004).

However, seed germination and early seedling growth are the most sensitive phases in many crops to salt stress (Almansouri *et al*. 2001).

Sugar used for human consumption is obtained from sugar beet and sugar cane in the world, while it is produced only from sugar beet in Turkey. Sugar beet is classified as a salt tolerant crop (Katerji *et al*. 2000, Yang *et al*. 2012), although it is sensitive to increased salinity at germination and early seedling stages (Ghoulam & Fares 2001). Routinely, germination and seedling development properties have been tested for salinity tolerance because they are the most sensitive stage in plant life cycle. Jamil & Rha (2004) recorded a significant reduction in germination percentage and a delay in required time to germination, but Jafarzadeh & Aliasgharzad (2007) indicated that there was genotypic variation for germination rate among sugar beet cultivars. Also, Higazy *et al*. (1995) and Mekki & El-Gazzar (1999) reported that salinity stress caused a depressed seedling growth, especially in the seedling fresh and dry weights of sugar beet. Moreover, relative water content, electrolyte leakage and chlorophyll content were recently used for indicators of salinity in barley (Ashraf 2004), in wheat (Farooq & Azam 2006, Jamali *et al*. 2015). In sugar beet, decreased relative water content and chlorophyll content in leaves (Khorshid *et al*. 2018) and increased electrolyte leakage under NaCl were reported by Wang *et al*. (2017) but Skorupa *et al*. (2019) determined no changes in chlorophyll content. Due to the controversial reports and lack of sufficient researches, physiological traits needs to be confirmed by comparing salt stress sensitive and tolerant cultivars in sugar beet. This study aimed to investigate for any potential characteristics to be used for salt-tolerant sugar beet cultivars considering germination, early seedling development traits, relative water content, chlorophyll content and electrolyte.

Materials and Methods

The study was carried out at the Department of Field Crops, Faculty of Agriculture, Eskişehir Osmangazi University, Turkey in 2019. Extensively preferred four sugar beet cultivars (Orthega, Valentina, FD Shoot, and Mohican) from three seed companies and NaCl (Merck) were used in the experiments. Salinity levels were arranged as decreasing in germination and emergence percentage and they were constituted as low (5 dS m^{-1}), medium (10 dS m^{-1}), and high (15 dS m^{-1}) salinity with WTW 3.15 conductivity meter (Germany). Distilled water (0 dS m^{-1}) was used as control.

In the germination experiment, it was aimed to simulate the soil salinity because the seeds were directly placed into salt-contaminated soils. Two hundred seeds as four replicates (4×50) were employed for each cultivar and salinity level. The fifty seeds were counted and inserted into three layers of sterile filter paper with 21 mL of respective salt solutions. As soon as the papers were gently rolled, they were put into sealed plastic bags to prevent water loss. These bags were transferred to the incubator at a constant temperature of 25±1°C in the dark. Germinated seeds with a 2 mm radicle were counted every day for 14 days period. The mean germination time (MGT) was calculated as described in Anonymous (2003). Seedling length and seedling fresh weight were measured at the end of the experiment.

The emergence experiment was designed for simulation of irrigation water salinity under laboratory conditions. It was conducted in peat-filled plastic containers with 100 seeds (4×25) and the seeds of each sugar beet cultivar were sown individually at a depth of 2 cm. The plastic containers were placed in the growth chamber after they were irrigated with respective salt solutions. Emergence percentage, mean emergence time (MET), fresh plant weight, root length, shoot length, relative chlorophyll content (Chl), relative water content (RWC) and electrolyte leakage were measured at 28th day after sowing. Leaf relative Chl was measured at the third leaf from the top of plants by using Konica Minolta SPAD-502 meter. Leaf RWC was assessed on fully enlarged leaves of five plants per replicate. Five leaves were pulled out from each replication and immediately weighed fresh weight (FW). They were immersed in distilled water in a falcon tube for 24 h to regain turgidity, and then turgor weight (TW) was weighted. The samples were dried at 70°C for 48 h in order to determine the dry weight (DW). RWC of the leaves was calculated following the formula (Ghoulam *et al*. 2002) (Eq. 1).

$$RWC\ (\%) = [(FW-DW)/(TW-DW)] \times 100 \quad (Eq.\ 1)$$

After the plants were harvested, the electrical conductivity (EC) values of the growing medium were determined. The saturated paste extract was prepared with a 1:10 medium to water ratio and the EC was measured with the EC meter at 25°C after 24 h with three replicates for each treatment.

Electrolyte leakage was analyzed by using young leaf discs of five plants from each treatment. Leaf samples were washed with deionized water to eliminate electrolytes on the surface of the leaves. Five leaf disks with 10 mm diameter were excised, weighed and placed into glass tubes filled with 20 mL of deionized water. After the incubation period for 24 h at 25°C, the solution's electrical conductivity (L_t) was directly read by the EC meter. They were then autoclaved for 20 min at 121°C, and the electrical conductivity (L_o) was recorded again at 25°C after equilibration (Yadav *et al*. 2012). The electrolyte leakage was calculated by the formula of Ghoulam *et al*. (2002) as follows (Eq. 2).

$$Electrolyte\ leakage\ (\%) = (L_t / L_o) \times 100 \quad (Eq.\ 2)$$

The experimental design was a 2-factor factorial, arranged in a completely randomized design with 4 replications. Analysis of variance was performed by the MSTAT-C software program (Michigan State University, v 2.10). Significant differences among the mean values were compared by Duncan's Multiple Range test ($p<0.05$).

Results

Germination performance and seedling development of sugar beet cultivars in the germination experiment were negatively influenced by increasing NaCl levels (Table 1). Mean values of sugar beet cultivars showed that differences were detected for the investigated traits. Among the cultivars, Mohican gave the highest germination percentage and seedling length, while Ortega produced the heavier fresh weight. At the highest NaCl level of 15 dS m^{-1}, Mohican had the maximum germination percentage, while a dramatic decrease in germination rate of FD Shoot was observed. Considering mean values of NaCl levels, increased NaCl caused a significant reduction in germination, seedling length and seedling fresh weight, but MGT was retarded. Mean values obtained from four cultivars showed higher germination, seedling length and seedling fresh weight; however, the interaction between cultivar and salinity was significant.

Interaction of cultivar × NaCl levels showed that germination percentage of cultivar FD Shoot linearly declined due to an increase in NaCl (Fig. 1a). Under salt stresses, Orthega and Valentina germinated higher than the other cultivars, while the germination rate of Mohican did not change. MGT was clearly delayed by increasing salinity; the most rapid germination was obtained from Valentina (Fig. 1b). The response of seedling length of sugar beet cultivars to salinity levels was different and FD Shoot had the shortest seedling at 15 dS m^{-1} (Fig. 1c).

Table 1. Analysis of variance and mean values of germination and early seedling growth parameters of sugar beet cultivars under salinity conditions in the germination experiment. The means ± SD of four replicates were given. Different letters denote statistically significant differences by Duncan's Multiple Range test (p<0.05) among all treatments respectively.

Factors	Germination percentage (%)	Mean germination time (day)	Seedling length (cm)	Seedling fresh weight (mg plant^{-1})
Cultivars				
Orthega	62.7^{b}±9.50	4.61^{b}±1.27	7.06^{b}±0.46	44.4^{a}±5.39
Valentina	61.1^{b}±6.37	3.89^{c}±0.75	7.49^{b}±0.94	33.2^{c}±5.73
FD Shoot	49.3^{c}±28.5	5.50^{a}±1.90	6.95^{b}±2.29	42.5^{ab}±12.9
Mohican	66.3^{a}±3.04	4.07^{c}±1.06	8.62^{a}±1.14	40.8^{b}±5.84
NaCl (dS m^{-1})				
Control	71.8^{a}±6.77	3.30^{d}±0.35	7.24^{b}±0.57	38.6^{c}±6.17
5	63.3^{b}±3.42	3.71^{c}±0.40	8.97^{a}±1.09	49.1^{a}±6.90
10	57.1^{c}±12.1	5.08^{b}±1.02	7.61^{b}±0.60	41.4^{b}±5.04
15	47.2^{d}±23.1	5.97^{a}±1.26	6.30^{c}±1.80	31.8^{d}±6.62
Analysis of Variance				
D $_{Cultivars (A)}$	0.000	0.000	0.000	0.000
D $_{NaCl (B)}$	0.000	0.000	0.000	0.000
D $_{A×B}$	0.000	0.000	0.000	0.000

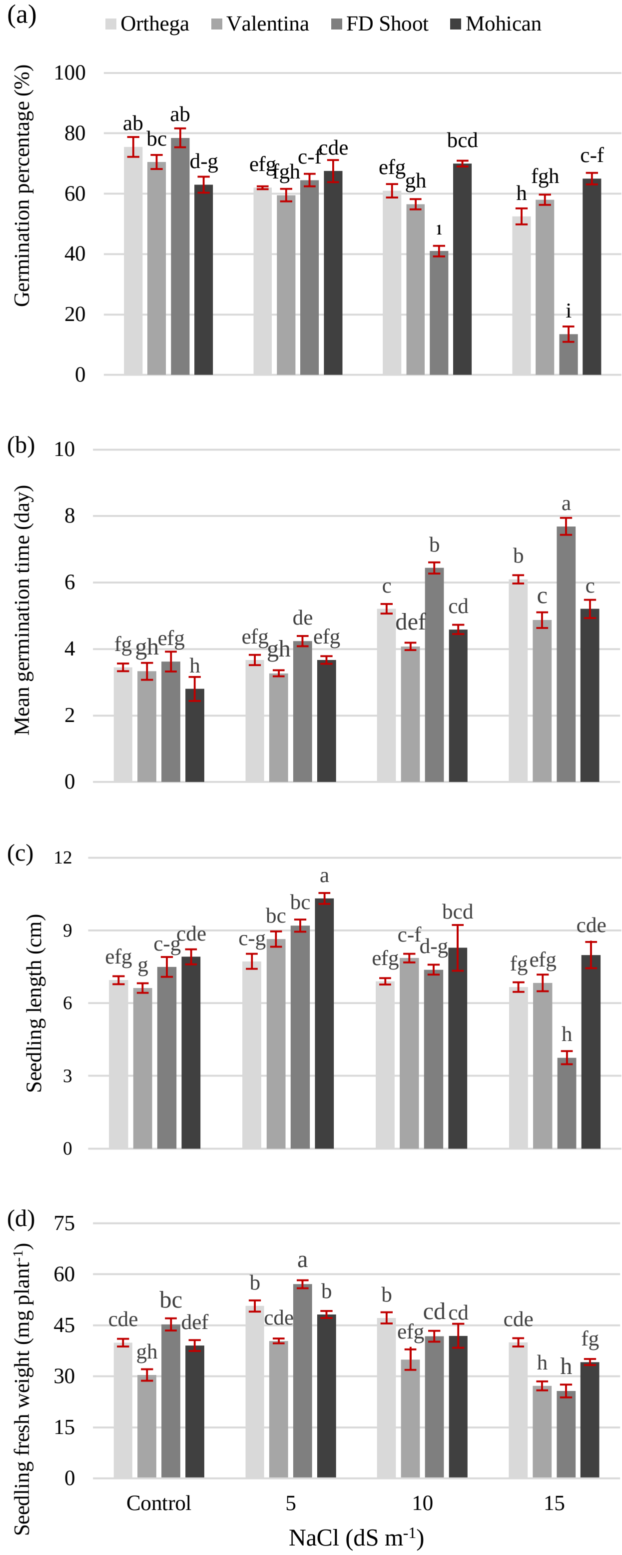

Fig. 1. Interaction of cultivar x NaCl level for a) germination percentage, b) mean germination time, c) seedling length, d) seedling fresh weight of sugar beet cultivars in the germination experiment. The means ± SD of four replicates were given. Different letters denote statistically significant differences by Duncan's Multiple Range test (p<0.05) among all treatments respectively.

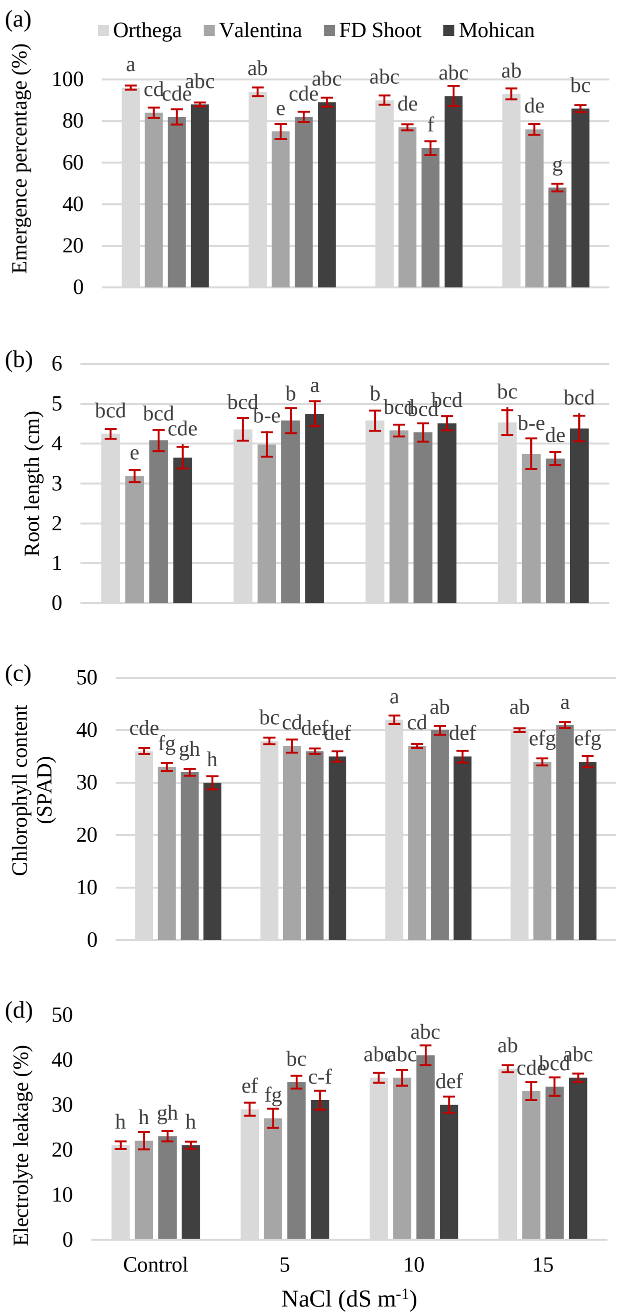

Fig. 2. Interaction of cultivar x NaCl level for a) emergence percentage, b) root length, c) relative chlorophyll content, d) electrolyte leakage of sugar beet in the pod experiment. The means ± SD of four replicates were given. Different letters denote statistically significant differences by Duncan's Multiple Range test ($p<0.05$) among all treatments respectively.

Similar results were obtained from the other sugar beet cultivars and the minimum level of NaCl promoted the seedling growth. Seedling fresh weight evidently increased at NaCl levels of 5 dS m^{-1}; that is why low doses of salts act as plant nutrition during short periods at early development stage. A remarkable reduction in SFW occurred at 15 dS m^{-1} along with significant changes among cultivars. Seedling fresh weight of Orthega did not change from control to 15 dS m^{-1}, but FD Shoot was clearly depressed (Fig. 1d).

In the pod experiments, main factors and interaction effects of the investigated characters of sugar beet cultivars subjected to different NaCl levels were given in Table 2. A two-way interaction was significant for emergence percentage, root length, relative chlorophyll content and electrolyte leakage, and the interactions were displayed in Fig. 2. Orthega had the highest emergence percentage of 92.8%, while FD Shoot had the lowest emergence with 69.3%. Increasing NaCl levels resulted in decreased emergence percentage from 87.0% in control to 75.5% at 15 dS m^{-1}. FD Shoot was the most severely affected by NaCl and its emergence percentage was dramatically decreased at 10 dS m^{-1} and above (Fig 2a). MET was adversely affected by increasing NaCl and the shortest time to emergence was recorded in Orthega. Among the cultivars, Mohican had the longest root length with 4.57 cm, followed by Orthega with 4.43 cm. Under all NaCl levels, sugar beet seedlings produced longer root length than control. Shorter root length at 15 dS m^{-1} than control was attained in FD Shoot and the other cultivars produced the longest root length (Fig 2b).

Shoot length varied between 2.73 cm and 3.27 cm, Orthega and Valentina had the higher values compared to FD Shoot and Mohican. Shoot length was severely decreased when NaCl levels increased. On the other hand, NaCl dose of 5 dS m^{-1} showed a promoter effect on fresh plant weight, significant reductions were observed at 10 and 15 dS m^{-1}.

Physiological parameters were apparently changed by sugar beet cultivars and NaCl levels. Orthega had the highest Chl, while the maximum RWC and electrolyte leakage was obtained from FD Shoot. Increasing salinity levels led to an increase in Chl and electrolyte leakage, and the highest values were detected at 10 dS m^{-1} and dropped at 15 dS m^{-1}. An apparent increase in Chl content of Orthega and FD Shoot was observed under NaCl, but this increase was at minimal level in Mohican and Valentina (Fig. 2c). Considerable variations were found for RWC and electrolyte leakage. RWC reduced by increasing salinity and decreased from 76.7% to 64.9%. FD Shoot exhibited the highest RWC with 72.3%. Salinity induced significant decrease in RWC at higher salinity levels compared to the control. Salt treatment caused a highly significant decrease in RWC of the investigated cultivars. RWC decreased with the increase of salt concentration and less effect was recorded in FD Shoot. Electrolyte leakage reached the maximum level at 15 dS m^{-1} except for Valentina and FD Shoot at 10 dS m^{-1}, whose electrolyte leakage values declined at 15 dS m^{-1}.

Comparison of electrical conductivity values of the growing medium at the end of the pod experiment was illustrated in Fig. 3. At control and 5 dS m^{-1}, no significant changes in EC values of growing medium were observed among sugar beet cultivars. The medium of Orthega and FD Shoot possessed lower EC values at 10 dS m^{-1}, while they were higher at 15 dS m^{-1} than that of Mohican and Valentina.

Table 2. Analysis of variance and main effects of sugar beet cultivars and NaCl levels for emergence percentage (EP), mean emergence time (MET), root length, shoot length, fresh plant weight (FPW), relative chlorophyll content (Chl), relative water content (RWC) and electrolyte leakage (EL) of 28-day old sugar beet plants in the pod experiment. The means ± SD of four replicates were given. Different letters denote statistically significant differences by Duncan's Multiple Range test ($p<0.05$) among all treatments respectively.

Factors	EP (%)	MET (day)	Root length (cm)	Shoot length (cm)	FPW (mg plant^{-1})	Chl (SPAD)	RWC (%)	EL (%)
Cultivars								
Orthega	$92.8^{a}\pm2.56$	$6.02^{c}\pm0.72$	$4.43^{ab}\pm0.15$	$3.27^{a}\pm0.72$	$1036^{a}\pm165$	$39.0^{a}\pm2.62$	$69.4^{ab}\pm4.51$	30.9^{b}†±7.98
Valentina	$77.6^{c}\pm4.01$	$6.29^{c}\pm0.79$	$3.81^{c}\pm0.48$	$3.16^{a}\pm0.84$	$820^{b}\pm221$	$35.1^{c}\pm2.09$	$66.2^{b}\pm5.28$	$29.2^{b}\pm6.15$
FD Shoot	$69.3^{d}\pm15.9$	$7.04^{a}\pm1.04$	$4.14^{bc}\pm0.40$	$2.77^{b}\pm0.65$	$1131^{a}\pm336$	$37.0^{b}\pm4.27$	$72.3^{a}\pm5.99$	$33.2^{a}\pm7.40$
Mohican	$88.5^{b}\pm2.74$	$6.65^{b}\pm0.76$	$4.57^{a}\pm0.87$	$2.73^{b}\pm0.45$	$1032^{a}\pm229$	$33.5^{d}\pm2.13$	$67.7^{ab}\pm6.90$	$29.6^{b}\pm6.15$
NaCl (dS m^{-1})								
Control	$87.0^{a}\pm6.19$	$5.81^{c}\pm0.33$	$3.79^{c}\pm0.47$	$3.77^{a}\pm0.42$	$1125^{b}\pm178$	$32.7^{c}\pm2.26$	$76.7^{a}\pm3.32$	$21.6^{c}\pm1.01$
5	$84.7^{ab}\pm8.55$	$5.97^{c}\pm0.43$	$4.67^{a}\pm0.76$	$3.06^{b}\pm0.50$	$1238^{a}\pm156$	$36.3^{b}\pm1.53$	$67.6^{b}\pm2.11$	$30.6^{b}\pm3.54$
10	$81.1^{b}\pm11.8$	$6.61^{b}\pm0.54$	$4.42^{ab}\pm0.14$	$2.86^{b}\pm0.22$	$960^{c}\pm147$	$38.5^{a}\pm3.00$	$66.4^{b}\pm4.57$	$35.6^{a}\pm4.30$
15	$75.5^{c}\pm19.5$	$7.60^{a}\pm0.61$	$4.07^{bc}\pm0.44$	$2.23^{c}\pm0.21$	$696^{d}\pm106$	$37.2^{b}\pm3.99$	$64.9^{b}\pm2.96$	$35.2^{a}\pm2.37$
Analysis of Variance								
D $_{Cultivars (A)}$	0.000	0.000	0.001	0.001	0.000	0.000	0.050	0.004
D $_{NaCl (B)}$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D $_{A\times B}$	0.000	0.312	0.010	0.160	0.252	0.000	0.332	0.004

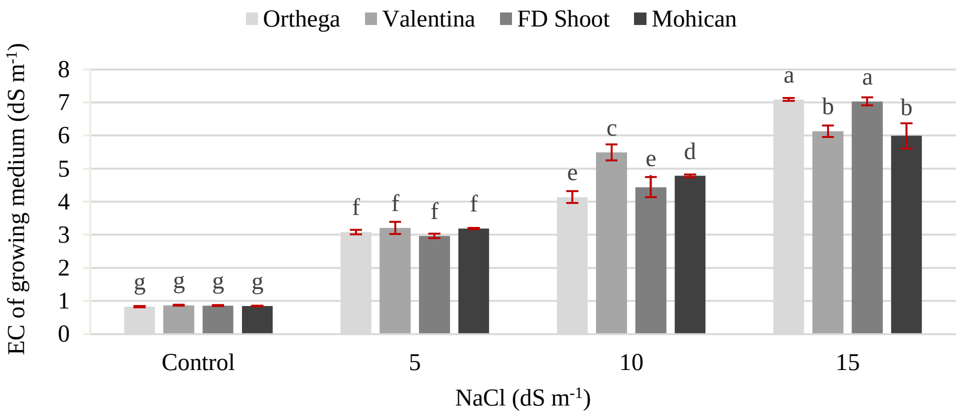

Fig. 3. Electrical conductivity values (1:10) of growing medium after the pod experiment according to NaCl levels and sugar beet cultivars. The means ± SD of four replicates were given. Different letters denote statistically significant differences by Duncan's Multiple Range test ($p<0.05$) among all treatments respectively.

Discussion

The primary effect of salinity stress in plants is restriction of water uptake, ion imbalance and toxicity. Sugar beet is often exposed to salinity by means of irrigation water or naturally saline soils in arid and semiarid regions in Turkey. For this reason, it is necessary to improve salt tolerant sugar beet cultivars or to select the tolerant cultivars. Our results showed that germination performance was reduced and delayed due to increasing NaCl levels with significant variation among sugar beet cultivars. The inhibitory effect of salinity on germination was not determined in Mohican, but MGT was delayed. The results are in agreement with Mostafavi (2012), Khayamim *et al*. (2014) and Pinheiro *et al*. (2018) who observed that sugar beet cultivars were adversely affected by high salt doses and their MGT was prolonged. Kandil *et al*. (2014) found that increasing salinity levels significantly decreased germination percentage, while the shortest MGT was recorded in control. They confirmed that there was genotypic variation among sugar beet cultivars in terms of germination rate and MGT under salinity. Early seedling development was not inhibited up to NaCl level of 15 dS m^{-1}, while sugar beet cultivars showed different responses to salinity. FD Shoot was the most adversely influenced with respect to seedling length and seedling fresh weight. On the other hand, Mohican and Orthega exhibited better performance as NaCl levels increased. Our results confirmed the findings of Mostafavi (2012), Jamil & Rha (2004) and Khorshid *et al*. (2018). They determined a significant reduction in root, shoot length and seedling fresh weight due to increasing salinity. Similar results were obtained from several plants such as soybean (Amirjani 2010) and nine vegetables (Shannon *et al*. 2000). Decreased emergence percentage and retarded MET were determined under NaCl stresses. Mahmoud & Hill (1981) indicated that higher salt levels resulted in reduced and delayed emergence compared to control. Generally, emergence performance was confirmed by germination percentage and MGT. However, germination percentage was observed lower than the emergence percentage in our study. That is why sugar beet seeds have germination inhibitors (Salimi & Boelt 2019) and pleated papers are advised for germination test. On the other hand, flat papers were employed in this study in order to prevent the leakage of salt ions from germination medium and lower germination rate were achieved than emergence rate.

Root length is considered as an important clue to the response of plants to salt stress, so that they are in contact with soil and absorb water and nutrients from the soil (Kaya *et al*. 2003). Taghizadegan *et al*. (2019) reported that the root length increased by salinity compared to control. Root length showed differences among sugar beet cultivars. Orthega and Mohican were the least affected cultivars by NaCl. Jafarzadeh & Aliasgharzad (2007) recorded a decrease in root length at 16 dS m^{-1} and no considerable change was observed up to 14 dS m^{-1}. Shoot length was the most sensitive character and it was gradually decreased with increasing NaCl. Orthega and Valentina produced longer shoot than the others. Jamil & Rha (2004) reported that salinity significantly reduced shoot length of sugar beet, and shoot length was more sensitive than root length (AboKassem 2007). Depending on the decrease in root and shoot length, FPW was reduced by NaCl levels. The findings of Mostafavi (2012), Jamil *et al*. (2012) and Khayamim *et al*. (2014) confirmed these results. Chl under increasing salinity was changed by sugar beet cultivars. FD Shoot showed linear increases up to 15 dS m^{-1}, while Valentina gradually increased at 10 dS m^{-1} and decreased at 15 dS m^{-1}. Contrarily, Wang *et al*. (2017) stated a clear reduction in Chl in sugar beet as NaCl increased. Skorupa *et al*. (2019) determined that no change was recorded in Chl under saline conditions. The difference in Chl could be resulted from genotypic variation or their tolerance levels and duration of exposure to salinity. RWC diminished when the salinity level increased. Mensah *et al*. (2006) found that the RWC of the pea cultivars under salt stress decreased. Similarly, Ghoulam *et al*. (2002), Wang *et al*. (2017), Skorupa *et al*. (2019), Taghizadegan *et al*. (2019), Tahjib-Ul-Arif *et al*. (2019) and Wang *et al*. (2019) reported that increasing salinity resulted in a decrease in RWC in sugar beet. The decline in RWC stated a loss of turgor leading to limited available water for the cell extension process (Ghoulam *et al*. 2002); consequently, inhibition of growth in FD Shoot might be linked to a decline in RWC caused by salinity stress. Our results showed that salinity induced electrolyte leakage from the leaves of all sugar beet cultivars. This finding was supported by Ghoulam *et al*. (2002), Dadkhah (2011) and Romano *et al.* (2019), who reported that the electrolyte leakage was raised with higher salinities. Excessive accumulation of Na^{+} and Cl^{-} ions in plant tissue causes ion imbalance and deformation, even resulted in killing the cells, which led to improve the ionic leakage from leaves; therefore, higher electrolyte leakage was observed in lower salt tolerant plants. It is used to measure the stability of the cellular membranes against any stress factors. In previous studies, enhanced salinity levels caused by cell membrane injury and electrolyte leakage were supported by Dadkhah (2011) in sugar beet and Dkhil & Denden (2012) in okra.

Conclusion

Sugar beet is considered to be a salinity tolerant plant; however, its tolerance level depends on two main factors, the cultivar and the plant development stage. The seeds of sugar beet are firstly exposed to salinity when they are sown into soils contaminated by salinity or irrigated with water with low quality for emergence. Improvement of salt tolerant cultivars is necessary and/or tolerant cultivars should be selected for successful production in saline soils. In this study, four sugar beet cultivars were imposed to germinate under saline conditions and allowed to grow seedlings. Among the investigated cultivars, Mohican and Orthega were found to be more salt tolerant than the others and the most sensitive cultivar was FD Shoot. Similar trends between germination results and the findings of the emergence experiment were identified. The results of relative chlorophyll content and electrolyte leakage were prominently changed according to salt-tolerant and sensitive cultivars, and consequently, they should be considered for suitable selection criteria for salinity in sugar beet. However, further research should be conducted with more sugar beet cultivars in order to explain precisely the relationship between the germination and physiological properties, and to determine their responses to salinity at successive development stages under field conditions.

Ethics Committee Approval: Since the article does not contain any studies with human or animal subject, its approval to the ethics committee was not required.

Author Contributions: Concept: A.A., M.D.K., Desing: A.A., M.D.K., Execution: A.A., E.G.K., Material supplying: A.A., M.D.K., Data acquisition: M.D.K., N.E., E.G.K., Data analysis/interpretation: M.D.K., N.E., E.G.K., Writing: M.D.K., N.E., E.G.K., Critical review: M.D.K.

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