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Effects of Salt Stress on Early Seedling Development and Germination in Some Root Vegetables

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ABSTRACT: *The challenge of increasing soil salinity poses a serious problem for agricultural production and food security worldwide. This study aimed to investigate the effects of salt stress on germination and early seedling stage of carrot, red radish, black radish and red beetroot seeds. During the research, the development of seeds under different salt levels (25 mM, 50 mM, 75 mM, 100 mM, 125 mM, and 150 mM) was investigated and parameters such as germination rate, velocity and vigor, salt tolerance index, shoot and root length, shoot and root fresh and dry weight were evaluated at seed and early seedling stages. As a result of the study, carrot seeds exhibited no germination at 150 mM salt concentration, while red beetroot and radish varieties showed 36.67% and 86.67% germination, respectively. Consequently, knowledge of these processes and investigation of germination and early seedling performance of these crops under salt conditions can contribute significantly to sustainable agricultural productivity and food security in areas affected by soil salinization.*

Keywords: *Salt stress, root vegetables, germination, germination parameters.*

Tuz Stresinin Bazı Kök Sebze Türlerinde Çimlenme ve Erken Fide Gelişimi Üzerine Etkileri

ÖZ: *Artan toprak tuzluluğu tehdidi, dünya genelinde tarımsal üretim ve gıda güvenliği açısından ciddi bir sorun teşkil etmektedir. Bu çalışma, tuz stresinin havuç, fındık turp, siyah turp ve kırmızı pancar tohumlarının çimlenme ve erken fide dönemi üzerindeki etkilerini araştırmayı amaçlamaktadır. Araştırma sırasında tohumların çeşitli tuz seviyeleri (25 mM, 50 mM, 75 mM, 100 mM, 125 mM ve 150 mM) altında gelişimi incelenmiş, tohum ve fide aşamalarında; çimlenme oranı, hızı ve gücü, tuz tolerans indeksi, sürgün ve kök uzunluk, sürgün ve kökte taze ve kuru ağırlık gibi parametreler değerlendirilmiştir. Çalışma sonucunda havuç tohumları 150 mM tuz dozunda hiç çimlenme göstermezken, kırmızı pancarda %36,67, turp çeşitleri ise %86,67 oranında çimlenme görülmüştür. Sonuç olarak bu süreçlere ilişkin bilgiler, bu ürünlerin tuzlu koşullarda çimlenme ve erken büyüme performansının araştırılması, toprak tuzlanmasından etkilenen bölgelerde tarımsal verimin ve gıda güvenliğinin sürdürülmesine önemli ölçüde katkıda bulunabilir.*

Anahtar kelimeler: *Tuz stresi, kök sebze, çimlenme, çimlenme parametreleri.*

INTRODUCTION

Soil salinity is an important abiotic stress factor that negatively affects the growth and development of plants. This stress factor, which arises especially in arid or semi-arid climates, occurs as a result of salts mixed with groundwater rising to the soil surface and salt accumulates because of evaporation of water. Initially, salinity stress causes disruptions in the metabolic and physiological mechanisms of plants. This situation can lead to damage to plant organs, reduced crop quality and even plant death. It can also significantly reduce plant yield and quality by altering soil structure (Ekmekçi *et al*., 2005). Nowadays, the area of saline soils in the world continues to increase regularly (Athar and Ashraf, 2009). The threat of increasing soil salinity poses a serious problem to agricultural production and food security worldwide (Munns and Tester, 2008). Approximately 7% of the world's agricultural area and

20% of irrigated agricultural areas are affected by soil salinity (Yamaguchi and Blumwald, 2005).

Increased soil salinity reduces the uptake water capability of plants and absorption of excessive ions such as Na^+ and Cl^- by roots, damages plant growth by disrupting metabolic processes and reducing photosynthetic efficiency (Mäser *et al.*, 2002). The response of plants to salt stress not only varies among plant species but also within the same species. Since the remediation of saline soils is a difficult and costly process, it is more appropriate to grow salinity-resistant plants to increase crop production in these areas (Turhan and Şeniz, 2010). For this reason, researchers have focused on studies on the salinity resistance of plant species and varieties in recent years.

Carrot, radishes and red beetroot are not essential crops for human life, but they are recognized as providing micronutrients to our diets because they contain diverse phytochemical compounds. They have significant health benefits that include antioxidant, anti-inflammatory and anti-carcinogenic properties when they are consumed (Cemeroğlu, 2004; Butnariu and Butu, 2015; Tripathy *et al*., 2021; Ahmadi *et al*., 2022; Kalia and Selvakumar, 2023). Salt stress is an important environmental factor affecting the growth and yield of various crops, including root vegetables such as carrot, radishes and red beetroot. Understanding the molecular and physiological responses of these crops to salt stress is critical for developing strategies to improve their tolerance and yield under saline conditions. Seed germination, a critical stage in the life cycle of plants, is especially vulnerable to the negative effects of salt stress, which significantly inhibits the growth and development of many plants. Many studies to date have shown that salinity significantly reduces or even completely inhibits germination, but this effect varies depending on plant species, variety and salt concentration (Acar *et al.*, 2011; Şentürk and Sivritepe, 2015).

Several studies have indicated that salt stress is a limiting factor that negatively affects germination, fresh weight, health-promoting compounds and antioxidant activity in carrot (Bolton and Simon, 2019; Akbıyık and Aktaş, 2022), radish (Yuan *et al.*, 2010; Sun *et al.*, 2015; Sun *et al.*, 2017) and red beetroot (Yolcu *et al.*, 2021; Subbarao *et al.*, 2001; Vitali *et al*., 2021). These studies have collectively provided insight into the complexity of salt stress responses in these root vegetables and the potential for targeted interventions to improve their salt tolerance. Therefore, investigating the regulatory mechanism responding to salt stress will be important for designing salt-tolerant genetic materials. The aim of this study was to determine the physiological effects of different salt concentrations on the germination of carrot, radish (black radish and red radish) and red beet seeds.

MATERIAL AND METHODS

Plant material

Standard seeds of carrot (*Daucus carota*) of the nantes variety, radish (*Raphanus sativus* L. var. radicula) of the cherry belle variety, black radish (*Raphanus sativus* L.) and red beet (*Beta vulgaris* L.) were used as plant material in the study. In this study, the effects of different concentrations of salt stress (25 mM, 50 mM, 75 mM, 100 mM, 125 mM and 150 mM) on germination rate and early seedling growth of these plant species were examined. NaCl was used for preparing the salt solution in the study. One liter of 150 mM stock NaCl was prepared and diluted to desired concentrations.

Seed germination test

The plant seeds were surface sterilized first with 5% bleach solution and then with 80% ethyl alcohol (Çarpıcı *et al.*, 2009). In the trial setup, 25 seeds were planted at equal intervals in 3 replicates for control and salt stress concentration for each seed species and humidified with the corresponding salt solution (25 mM, 50 mM, 75 mM, 100 mM, 125 mM and 150 mM). For the control groups, the moisturizing process was completed using the same amount of pure water. Consistent environmental conditions were ensured during germination and early seedling stages so as to provide reliability and replicability of the results. Germination tests of the seeds were carried out in petri dishes with a double-layer of sterile filter paper (Çavuşoğlu, 2007; Turhan and Şeniz, 2010) and temperature of 20/25 ºC (day/night) (Khodarahmpour *et al.*, 2012) for 5 days.

Seed parameters measured

Germination rate of the seeds was determined daily and 0.5 mm protrusion of the radicle was considered as germination criterion (Abro *et al.* 2009; Datta *et al.* 2009). Germination percentage values obtained on the 5th day were used to compare germination rates. On the 5th day of germination, peduncle and root lengths of germinated seeds were also determined (Sekmen *et al.* 2005; Bahrani and Hagh Joo, 2012).

Germination percentage (rate): It was determined according to the formula given below (Erdoğan, 2008; Ologundudu *et al.*, 2014).

GR = (G/T)*100

GR: Germination rate, G: Numbers of germinated seeds, T: Total numbers of seeds used.

Germination speed: It was calculated according to the formula given below (Abazarian *et al.*, 2011; Güldüren, 2012).

GS = N1/T1+N2/T2+……+Nn/Tn

GS: Germination speed, N: Numbers of germinated seeds, T: Number of days germination occurred.

Salt tolerance index: It was calculated based on the formula given below (Güldüren, 2012; Khayatnezhad and Gholamin, 2011).

ST = (A/B)*100

ST: Salt tolerance index, A: Germination in treated seeds, B: Germination in control group.

Seedling parameters measured

After germination was completed, measurements were completed by carefully removing the seedlings from the germination medium without damaging their sensitive structures in order to evaluate early seedling growth.

Seedling vigor index (germination vigor): It was calculated using the following formula (Sivritepe, 2012; Karakaş *et al.*, 2013; Tatar *et al.*, 2018; Akay *et al.*, 2019).

Vigor index = [Germination rate x (radicle length + peduncle length)]

Root and shoot length (mm): It was measured with a digital caliper in mm.

Fresh and dry weights of root and shoot (mg): It was measured on a precision balance (Shimadzu/AY220) in mg. For the fresh weights of roots and shoots, the roots and shoots of 10 plants randomly selected from each petri dish were separated and weighed on the precision balance. Seedlings dried at 70 ºC for 48 hours were used for the dry weight experiment (Bilgin and Yıldız, 2008; Doğan *et al.*, 2009).

Statistical analyses

Statistical analysis was performed to compare germination and seedling growth parameters at different salt concentrations and control groups. The data were analyzed by one-way analysis of variance (ANOVA) using SPSS 21.0 statistical software (IBM, Chicago, IL., USA) at 5% and 1% level of significance (IBM, Chicago, IL., USA) to determine significant differences among treatments. In addition, the difference between means was determined by Duncan’s multiple comparison test.

RESULTS AND DISCUSSION

In this study, the physiological effects of salt stress on seed germination and early seedling stage of root vegetables such as carrot, red beetroot and radish cultivated in Türkiye and their salt tolerance levels were identified. Physiological parameters such as germination rate, velocity and vigor, root and shoot length, fresh and dry weight of root and shoot, and salt tolerance index were used to determine salt tolerance in comparison with control conditions. As a result of the analysis of variance, it was found that there were statistically significant differences between salt doses for all traits examined ($p<0.01$).

Germination rate (%)

Germination rates of all the studied plants were significantly ($P<0.01$) inhibited with increasing salt concentration compared to the control group (0.0 mM NaCl). When the effects of salt doses on germination rate were examined, it was observed that 150 mM salt dose completely inhibited germination in carrot, while radish varieties showed a germination rate of 86.67% and red beet 29.33% compared to the control (Table 1). Consequently, in our study, significant decreases in germination rates occurred in parallel with the increase in salinity. The findings of studies on leek (Yıldırım and Güvenç, 2005), pepper (Hassen *et al.*, 2014) and pea (Demirkol *et al.*, 2019) showed a low germination rate due to increasing salt concentration are in agreement with our findings.

Germination speed

The results of the variance analysis demonstrated that salt treatments had highly significant effects on the germination speed of all seeds investigated (P<0.01). Increasing salt concentration significantly decreased the germination speed at all salt doses. When the effects of salt concentrations on germination speed were examined, it was realized that salt treatments caused a significant decrease (P<0.01) in red beetroot and carrot compared to the control groups (0.0 mM NaCl). In 150 mM salt treatment, no germination was recorded in carrots, while the germination speed of radish varieties was 4.33 and 1.1 in red beetroot (Table 2). In a study in which leek varieties called İnegöl and Kalem were used, it was reported that there was a significant decrease in germination speed in both varieties due to increasing salt concentration compared to the control groups (Yıldırım and Güvenç, 2005). Similarly, the significant decrease in germination speed in parallel with increasing salt level in studies conducted with bean (Elkoca *et al.*, 2003) and pepper (Hassen *et al.*, 2014) is consistent with the data obtained in our study.

Salt tolerance index (%)

The variance analysis for the percentage of salt tolerance index in salt treatments at different concentrations is given in Table 3. When salt tolerance values were examined in the study, it was confirmed that there were statistically significant differences between salt concentrations (p<0.01). Increasing salt concentrations compared to the control groups displayed a statistically significant (P<0.01) decrease in all species for salt tolerance index. At 150 mM salt concentration, red beetroot and radish varieties tolerated salt by 36.67% and 86.67%, respectively, with a significant (P<0.01) decrease, while no germination was observed in carrot at 150 mM salt concentration. Especially in 150 mM salt treatments, a significant decrease was recorded in the salt tolerance index of all plant groups. The findings of salt tolerance indexes in lentil (Kökten *et al.*, 2010) and pepper (Hassen *et al.*, 2014) are similar to our results.

Table 1. Effects of different salt concentrations on seed germination rate (%).
Çizelge 1. Tuz konsantrasyonlarının tohum çimlenme oranı üzerine etkisi (%).

Germination Rate (%)								
Treatments	0/Control	25 mM	50 mM	75 mM	100 mM	125 mM	150 mM	P
Red Beetroot	80±0.00[a]	60±6.92[b]	56±6.92[bc]	49.33±8.32[cd]	44±4.00[d]	32±4.00[e]	29.33±6.11[e]	**
Black Radish	100±0.00[a]	100±0.00[a]	98.67±2.30[ab]	96±0.00[bc]	94.67±2.30[c]	93.33±2.31[c]	86.67±2.31[d]	**
Red Radish	100±4.00[a]	98.67±2.31[a]	96.00±4.00[a]	89.33±2.31[a]	88.00±4.00[b]	88.00±4.00[b]	86.67±2.31[b]	**
Carrot	92.00±4.00[a]	88.00±8.00[a]	76.00±8.00[a]	52.00±15,43[b]	21.33±2.31[c]	16.00±10.58[c]	0.00±0.00[d]	**

F values: p < 0.01 (**), Values are given as average and standard deviation of three independent composites
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Table 2. Effects of different salt concentrations on seed germination speed.
Çizelge 2. Tuz konsantrasyonlarının tohum çimlenme hızı üzerine etkisi.

Germination Speed (Days)								
Treatments	0/Control	25 mM	50 mM	75 mM	100 mM	125 mM	150 mM	P
Red Beetroot	2.86±0.00[a]	2.14±0.24[b]	2.00±0.24[bc]	1.76±0.29[bc]	1.66±0.20[c]	1.21±0.18[d]	1.10±.016[d]	**
Black Radish	6.94±1.20[a]	5.42±0.72[b]	4.93±0.12[bc]	4.80±0.01[bc]	4.73±0.12[bc]	4.67±0.12[bc]	4.33±0.12[c]	**
Red Radish	5.00±0.00[a]	4.93±0.11[a]	4.80±0.20[a]	4.47±0.12[b]	4.40±0.20[b]	4.40±0.20[b]	4.33±0.12[b]	**
Carrot	4.60±0.20[a]	4.40±0.40[ab]	4.40±0.40[b]	3.80±0.64[b]	2.73±0.29[c]	1.23±0.36[d]	0.00±0.00[e]	**

F values: p < 0.01 (**), Values are given as average and standard deviation of three independent composites
Ortalama ve Standart hata değerleri 3 örnek ortalama değerleridir.

Germination vigor (Seedling vigor index)

The data regarding the effect of different salt concentrations on germination vigor are given in Table 4. Increasing salt concentrations caused a significant ($P<0.01$) decrease in all cultivars compared to the control groups. At 150 mM salt concentration, the highest germination vigor was obtained in red radish (4593.71), while there was no germination in carrot seeds. As in our study, studies conducted by Kara *et al.* (2011) on triticale, Benlioğlu and Özkan (2015) on barley and Shams (2019) on pepper demonstrated a significant decrease in germination vigor due to increasing salt levels.

Seedling (Shoot+ Root) length (mm)

When the plant root lengths at the treated salt concentrations were investigated, values ranging from 3.21 mm to 64.94 mm were observed. The effect of salt treatments on root lengths is given in Table 5. Compared to the control groups, increasing salt concentrations caused a significant ($P<0.01$) decrease in all cultivars. At 150 mM salt concentration, these values were 9.20 mm in beet, 27.13 mm in black radish and 38.67 mm in red radish as compared to the control groups. Similarly, in a study conducted with pea, it was reported that the root was more affected due to increasing salt concentrations (Okçu *et al.*, 2005).

Seedling lengths in the treatment groups at different salt concentrations indicated values ranging from 7.36 mm to 32.14 mm (Table 6). Compared to the control groups, increasing salt treatments resulted in a significant ($P<0.01$) decrease of more than 50% in red beetroot and radish varieties, while no germination was observed in carrot. In the salt stress study by Aydın and Atıcı (2015) on some cultivated plant seeds, seedling lengths ranged from 4.80 mm to 114.61 mm and increased salt treatments caused a significant ($P<0.05$) decrease in all varieties compared to the control groups. In addition, it was reported that no seedling development occurred in tomato at 150 and 250 mM salt levels (Aydın and Atıcı, 2015).

Table 3. Effects of different salt concentrations on seed salt tolerance index (%).
Çizelge 3. Tuz konsantrasyonlarının tohum tuz tolerans indeksi üzerine etkisi (%).

Salt Tolerance (%)								
Treatments	0/Control	25 mM	50 mM	75 mM	100 mM	125 mM	150 mM	P
Red Beetroot	100.00±0.00^{a}	75.00±.866^{b}	70.00±8.66^{bc}	61.67±10.41^{cd}	55.00±5.00^{d}	40.00±5.00^{e}	36.67±7.63^{e}	**
Black Radish	100.00±0.00^{a}	100±0.00^{a}	98.67±2.30^{ab}	96.00±0.00^{bc}	94.67±2.31^{c}	93.33±2.31^{c}	86.67±2.31^{d}	**
Red Radish	100.00±0.00^{a}	98.67±2.30^{a}	96.00±4.00^{a}	89.33±2.31^{b}	88.00±4.00^{b}	88.00±4.00^{b}	86.67±2.30^{b}	**
Carrot	100.00±0.00^{a}	95.74±8.65^{a}	82.61±8.69^{a}	56.52±16.95^{b}	23.19±2.52^{c}	17.39±11.50^{c}	0.00±0.0^{d}	**

F values: $p < 0.01$ (**), Values are given as average and standard deviation of three independent composites.
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Table 4. Effects of different salt concentrations on plant germination vigor.
Çizelge 4. Tuz konsantrasyonlarının çimlenme gücü üzerine etkisi .

Germination Vigor (Seedling Vigor Index)								
Treatments	0/Control	25 mM	50 mM	75 mM	100 mM	125 mM	150 mM	P
Red Beetroot	4487.73±0.0^{a}	2926.89±112.3^{b}	2556.44±446.7^{bc}	2113.65±410.2^{c}	1489.15±136,0^{d}	1019.68±157.1^{e}	563.03±60.5^{f}	**
Black Radish	7990.00±685.5^{a}	7316.33±366.8^{b}	6456.16±94.7^{c}	5402.88±238.6^{d}	4913.63±143.2^{de}	4388.81±337.6^{e}	3321.64±362.1^{f}	**
Red Radish	9708.33±561.5^{a}	8293.89±604.5^{b}	7216.16±511.3^{c}	6157.96±584.5^{d}	5706.95±197.1^{de}	5134.77±191.3^{ef}	4593.71±147.6^{f}	**
Carrot	5733.85±775.9^{a}	3825.81±936.6^{b}	2752.68±583.7^{c}	1534.68±547.6^{d}	275.85±53.7^{e}	171.96±119.4^{e}	0,00±0.00^{e}	**

F values: $p < 0.01$ (**), Values are given as average and standard deviation of three independent composites
Ortalama ve Standart hata değerleri 3 örnek ortalama değerleridir.

Table 5. Effects of different salt concentrations on seedling root length (mm).
Çizelge 5. Tuz konsantrasyonlarının fide kök uzunluğu üzerine etkisi (mm).

Root Length (mm)								
Treatments	0/Control	25 mM	50 mM	75 mM	100 mM	125 mM	150 mM	P
Red Beetroot	24.73±0.28^{a}	21.08±2.30^{b}	20.90±2.40^{b}	20.37±2.70^{b}	15.93±1.38^{c}	13.91±0.49^{c}	9.20±1.75^{d}	**
Black Radish	50.94±5.95^{a}	46.73±3.11^{a}	40.29±0.99^{b}	39.40±2.21^{bc}	33.44±1.44^{cd}	30.59±2.31^{d}	27.13±2.50^{e}	**
Red Radish	64.94±6.60^{a}	53.99±3.80^{b}	48.47±2.46^{bc}	44.91±3.06^{cd}	41.91±1.25^{d}	41.00±1.13^{d}	38.76±1.83^{d}	**
Carrot	38.59±4.61^{a}	23.96±3.38^{b}	17.02±3.18^{c}	11.33±0.60^{d}	4.84±0.96^{e}	3.21±0.22^{ef}	0.00±0.00^{f}	**

F values: $p < 0.01$ (**), Values are given as average and standard deviation of three independent composites.
Ortalama ve Standart hata değerleri 3 örnek ortalama değerleridir.

Table 6. Effects of different salt concentrations on seedling shoot length (mm).
Çizelge 6. Tuz konsantrasyonlarının fide uzunluğu üzerine etkisi (mm).

Shoot Length (mm)								
Treatments	0/Control	25 mM	50 mM	75 mM	100 mM	125 mM	150 mM	P
Red Beetroot	31.36±2.29^{a}	28.01±3.96^{ab}	24.57±2.88^{bc}	22.55±2.32^{c}	17.97±2.03^{d}	17.88±0.92^{d}	10.31±1.49^{e}	**
Black Radish	28.96±1.83^{a}	26.43±0.94^{b}	25.16±0.78^{b}	19.88±0.29^{c}	18.48±0.59^{c}	16.41±1.13^{d}	11.14±0.92^{e}	**
Red Radish	32.14±1.14^{a}	30.04±1.19^{b}	26.66±0.71^{c}	23.94±1.77^{d}	22.98±0.69^{d}	17.37±0.62^{e}	14.27±0.74^{f}	**
Carrot	23.58±1.45^{a}	19.17±3.61^{b}	19.02±2.78^{b}	18.01±0.99^{b}	8.14±1.66^{c}	7.36±0.64^{c}	0.00±0.00^{d}	**

F values: $p < 0.01$ (**), Values are given as average and standard deviation of three independent composites
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Seedling fresh and dry weight (mg)

Rising salt concentrations decreased the fresh weights of all plant groups considerably compared to the control groups ($P<0.01$). It was observed that the stress started firstly at 25 mM in all the species when compared to the control groups, although it changed according to the species. The most negative effect on seedling and root fresh weights was found at 150 mM salt concentration (Tables 7 and 8). In parallel with fresh weight, dry weights of all groups were also negatively affected by increasing salt concentrations. Significant ($P<0.01$) differences were detected when all species were compared with their control groups. When the effects of salt treatments on seedling and root dry weight were examined, it was determined that the first stress began at 25 and 50 mM concentrations, depending on the species. In studies performed in pea, it was reported that the first negative effect of salt stress on germination and plant development was generally observed after 75 mM (Acar *et al.*, 2011; Şentürk and Sivritepe, 2015). These findings suggest that root vegetables such as carrot and red beetroot are more sensitive to salt.

Table 7. Effects of different salt concentrations on seedling fresh weight (mg).
Çizelge 7. Tuz konsantrasyonlarının fide taze ağırlık üzerine etkisi (mg).

Seedling Fresh Weight (mg)								
Treatments	0/Control	25 mM	50 mM	75 mM	100 mM	125 mM	150 mM	P
Red Beetroot	0.247±0.007^{a}	0.208±0.007^{b}	0.170±0.026^{c}	0.153±0.005^{c}	0.143±0.021^{c}	0.076±0.015^{d}	0.033±0.011^{e}	**
Black Radish	0.561±0.038^{a}	0.536±0.010^{a}	0.432±0.029^{b}	0.391±0.023^{bc}	0.360±0.014^{c}	0.350±0.035^{c}	0.242±0.052^{d}	**
Red Radish	0.642±0.004^{a}	0.608±0.025^{ab}	0.565±0.056^{cd}	0.526±0.027^{de}	0.496±0.010^{ef}	0.454±0.041^{e}	0.371±0.003^{f}	**
Carrot	0.069±0.005^{a}	0.062±0.006^{a}	0.060±0.008^{a}	0.045±0.003^{b}	0.031±0.003^{c}	0.022±0.002^{c}	0.00±0.00^{d}	**

F values: $p < 0.01$ (**), Values are given as average and standard deviation of three independent composites
Ortalama ve Standart hata değerleri 3 örnek ortalama değerleridir.

Table 8. Effects of different salt concentrations on seedling root fresh weight (mg)
Çizelge 8. Tuz konsantrasyonlarının kök taze ağırlık üzerine etkisi (mg)

Seedling Root Fresh Weight (mg)								
Treatments	0/Control	25 mM	50 mM	75 mM	100 mM	125 mM	150 mM	P
Red Beetroot	0.767±0,001[a]	0.700±0.015[a]	0.633±0.006[ab]	0.467±0.020[bc]	0.433±0.011[bc]	0.267±0.011[cd]	0.123±0.007[d]	**
Black Radish	0.200±0.014[a]	0.161±0.007[b]	0.148±0.017[bc]	0.140±0.008[c]	0.132±0.007[cd]	0.116±0.006[de]	0.108±0.012[e]	**
Red Radish	0.247±0.012[a]	0.205±0.017[b]	0.189±0.011[bc]	0.175±0.010[c]	0.151±0.009[d]	0.150±0.008[d]	0.140±0.004[d]	**
Carrot	0.033±0.003[a]	0.027±0.002[ab]	0.026±0.005[b]	0.021±0.002[b]	0.013±0.001[c]	0.010±0.002[c]	0.00±0.00[d]	**

F values: $p < 0.01$ (**), Values are given as average and standard deviation of three independent composites
Ortalama ve Standart hata değerleri 3 örnek ortalama değerleridir.

In our study, seedling and root wet/dry weights were affected more than the control groups with increasing salt dose. The most negative effect of salt dose on seedling and root dry weight values occurred at 150 mM salt dose in all plant groups. There was no germination in carrot at 150 mM salt concentration (Tables 9 and 10). The salt in the root zone reduces root elongation by inhibiting cell expansion and cell production in the root meristem tissue through osmotic stress and toxic ion effects (Rewald *et al.*, 2013). For these reasons, root and shoot development were negatively affected with increasing salt doses in the study. Again, in the salt stress study conducted in capia pepper, 50 mM salt concentration caused statistically significant decreases in the parameters on seedling development compared to the control groups (Altunlu, 2019). Many researchers have reported that salt stress has a negative effect on plant root and shoot length (Hakim *et al.*, 2010; Kökten *et al.*, 2010; Abazarian *et al.*, 2011; Hassen *et al.*, 2014). In our study, increasing salt concentrations significantly inhibited both root and shoot fresh and dry weights of all treatment group.

Table 9. Effects of different salt concentrations on seedling dry weight (mg)
Çizelge 9. Tuz konsantrasyonlarının fide kuru ağırlık üzerine etkisi (mg)

Seedling Dry Weight (mg)								
Treatments	0/Control	25 mM	50 mM	75 mM	100 mM	125 mM	150 mM	P
Red Beetroot	0.026±0.000[a]	0.021±0.000[b]	0.017±0.002[c]	0.015±0.000[c]	0.014±0.002[c]	0.008±0.002[d]	0.003±0.001[e]	**
Black Radish	0.084±0.005[a]	0.081±0.002[a]	0.065±0.004[b]	0.059±0.003[bc]	0.054±0.002[c]	0.052±0.005[c]	0.036±0.008[d]	**
Red Radish	0.096±0.000[a]	0.092±0.004[a]	0.085±0.008[bc]	0.079±0.004[cd]	0.075±0.002[de]	0.068±0.006[e]	0.056±0.001[f]	**
Carrot	0.046±0.000[a]	0.041±0.001[a]	0.040±0.001[a]	0.030±0.000[b]	0.021±0.000[c]	0.013±0.000[c]	0.00±0.00[d]	**

F values: $p < 0.01$ (**), Values are given as average and standard deviation of three independent composites
Ortalama ve Standart hata değerleri 3 örnek ortalama değerleridir.

Table 10. Effects of different salt concentrations on seedling root dry weight (mg)
Çizelge 10. Tuz konsantrasyonlarının fide kök kuru ağırlık üzerine etkisi (mg)

Seedling Root Dry Weight (mg)								
Treatments	0/Control	25 mM	50 mM	75 mM	100 mM	125 mM	150 mM	P
Red Beetroot	0.008±0.000[a]	0.007±0.002[a]	0.006±0.001[ab]	0.005±0.002[bc]	0.004±0.001[bc]	0.003±0.002[cd]	0.001±0.001[d]	**
Black Radish	0.030±0.002[a]	0.024±0.001[b]	0.022±0.003[bc]	0.021±0.001[c]	0.020±0.001[cd]	0.017±0.001[de]	0.016±0.002[e]	**
Red Radish	0.025±001[a]	0.021±0.002[b]	0.019±0.001[bc]	0.017±0.001[c]	0.016±0.000[d]	0.015±0.00[d]	0.014±0.00[d]	**
Carrot	0.022±0.000[a]	0.018±0.000[ab]	0.017±0.001[b]	0.015±0.000[b]	0.008±0.000[c]	0.007±0.000[c]	0.00±0.00[d]	

F values: $p < 0.01$ (**), Values are given as average and standard deviation of three independent composites
Ortalama ve Standart hata değerleri 3 örnek ortalama değerleridir.

CONCLUSION AND SUGGESTIONS

Germination of root vegetable seeds and seedling development are negatively affected by increasing salt concentrations. In this study, it was determined that all root vegetable species were significantly affected by the 150 mM salt concentration in the medium during the germination period. Germination and seedling development of the radish varieties examined in the study were less negatively affected by salt concentrations below 100 mM compared to other species, while no germination was observed in carrot at 150 mM salt concentration. Compared to other plant groups, high salt concentrations negatively affected root development more than shoot development in carrots. This indicates that carrot roots are more sensitive to salinity than shoots. Determining the performance of the studied species under field conditions in areas with salinity problems is important for the evaluation of saline areas. Therefore, further studies conducted under pot and field conditions would be beneficial. In addition, our research is important in terms of providing preliminary information to the producer at the point of preference of the plant species studied and being a source for further research.

REFERENCES

Abazarian, R., M. R. Yazdani, K. Khosroyar, and P. Arvin. 2011. Effects of different levels of salinity on germination of four components of lentil cultivars. African Journal of Agricultural Research 6 (5): 2761 – 2766.

Abro, S. A., A. R. Mahar, and A. A. Mirbahar. 2009. Improving yield performance of landrace wheat under salinity stress using on-farm seed priming. Pak. J. Bot. 41 (5): 2209-2216.

Acar, R., M. Yorgancılar, E. Atalay, ve C. Yaman. 2011. Farklı tuz uygulamalarının bezelyede (*Pisum sativum* L.) bağıl su içeriği, klorofil ve bitki gelişimine etkisi. Selcuk Journal of Agriculture and Food Sciences 25 (3): 42-46.

Ahmadi, M., Ș. A. Hulea, and I. Peț. 2022. Root vegetables: biology, nutritional value and health ımplications. IntechOpen. doi: 10.5772/intechopen.106240

Akay, H., E. Öztürk, İ. Sezer, ve M. C. Bahadır. 2019. Farklı tuz konsantrasyonlarının şeker mısır (*Zea mays* L. Var. sacharata sturt.) çeşitlerinde çimlenme ve erken fide gelişimi üzerine etkileri. Turkish Journal of Agriculture-Food Science and Technology 7 (2): 103-108.

Akbıyık, C., ve H. Aktaş. 2022. Asetil salisilik asit solüsyonlarında ön çimlendirmenin havuç tohumlarının tuz stresi altında çimlenme ve çıkışı üzerine etkileri. Eurasian Journal of Biological and Chemical Sciences 5 (2): 62-68.

Altunlu, H. 2019. Tuzlu koşullarda mikoriza uygulamasının kapya biberde (*Capsicum annuum* L.) fide gelişimi ve antioksidant enzimler üzerine etkisi. Ege Üniversitesi Ziraat Fakültesi Dergisi 56 (2): 139-146.

Athar, H. R., and M. Ashraf. 2009. Strategies for crop improvement against salinity and drought stress: An overview. Salinity and Water Stress: Improving Crop Efficiency. Springer Nature 1-16

Aydın, İ., ve Ö. Atıcı. 2015. Tuz stresinin bazı kültür bitkilerinde çimlenme ve fide gelişimi üzerine etkileri. Muş Alparslan Üniversitesi Fen Bilimleri Dergisi 3 (2): 1-15.

Bahrani, A., and M. Hagh Joo. 2012. Response of some wheat (*Triticum aestivum* L.) genotypes to salinity at germination and early seedling growth stages. World Applied Sciences Journal 16 (4): 599-609.

Benlioğlu, B., ve U. Özkan. 2015. Bazı arpa çeşitlerinin (*Hordeum vulgare* L.) çimlenme dönemlerinde farklı dozlardaki tuz stresine tepkilerinin belirlenmesi. Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi 24 (2): 109-114.

Bilgin, N., ve N. Yıldız. 2008. Besin kültüründe yetiştirilen (Kaya F1) domates çeşidinin (*Lycopersicon esculentum*) artan NaCl uygulamalarına toleransı ve tuzluluk stresinin kuru madde miktarı ile bitki mineral madde içeriğine etkisi. Atatürk Üniversitesi Ziraat Fakültesi Dergisi 39 (1): 15-21.

Bolton, A., and P. Simon. 2019. Variation for salinity tolerance during seed germination in diverse carrot (*Daucus carota* L.) germplasm. HortScience 54 (1): 38-44.

Butnariu, M., and A. Butu. 2015. Chemical composition of vegetables and their products. Handbook of Food Chemistry pp. 627-692.

Cemeroğlu, B. 2004. Meyve ve sebze işleme teknolojisi. Gıda Teknolojisi Derneği Yayınları 1. Cilt No. 35: 77-88 Ankara.

Çarpıcı, E. B., N. Çelik, ve G. Bayram. 2009. Effects of salt stress on germination of some maize (*Zea mays* L.) cultivars. J. Biotechnol. 8 (19): 4918–4922.

Çavuşoğlu, K. 2007. Tuzlu (Nacı) koşullar altındaki tohum çimlenmesi, fide büyümesi ve yaprak anatomisi üzerine triakontanol ön uygulamasının etkileri. Süleyman Demirel University Faculty of Arts and Science Journal of Science 2 (2): 136-145.

Datta, J. K., S. Nag, A. Banerjee, and N. K. Mondai. 2009. Impact of salt stress on five varieties of wheat (*Triticum aestivum* L.) cultivars under laboratory condition. Journal of Applied Sciences and Environmental Management 13 (3): 93–97.

Demirkol, G., N. Yılmaz, ve Ö. Aşçı-Önal. 2019. Tuz stresinin yem bezelyesi (*Pisum sativum* ssp. arvense L.) seçilmiş genotipinde çimlenme ve fide gelişimi üzerine etkileri. Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi 22 (3): 354-359.

Doğan, M., H. Kiliç, A. Aktan, ve N. E. Can. 2009. Tuz Stresi altındaki Domates (*Lycopersicon* sp.) fidelerinde kalsiyum miktarı değişimleri. Firat Unıversity Journal of Science 21 (2): 103–108.

Ekmekçi, E., M. Apan, and T. Kara. 2005. Tuzluluğun bitki gelişimine etkisi. Anadolu Tarım Bilimleri Dergisi 20(3): 118-125. https://doi.org/10.7161/anajas.2005.20.3.118-125

Elkoca, E., F. Kantar, ve İ. Güvenç. 2003. Değişik NaCl konsantrasyonlarının kuru fasulye (*Phaseolus vulgaris* L.) genotiplerinin çimlenme ve fide gelişmesine etkileri. Atatürk Üniversitesi Ziraat Fakültesi Dergisi 34 (1): 1-8.

Erdoğan, G. 2008. Değişik kimyasal uygulamalarının farklı İskenderiye üçgül (*Trifolium alexandrinum* L.) çeşidi tohumlarının düşük sıcaklıkdaki çimlenme ve çıkış performansları üzerine etkileri. Yüksek Lisans Tezi. K.S.Ü. Zir. Fak. Fen Bil. Ens. Tarla Bitkileri Ana Bilim Dalı Kahramanmaraş.

Güldüren, Ş. 2012. Kuzey Doğu Anadolu Bölgesi ve Çoruh Vadisi'nden toplanan bazı fasulye (*Phaseolus vulgaris* L.) genotiplerinin tuza toleransı. Yüksek Lisans Tezi. Atatürk Ü. Zir. Fak. Fen Bil. Ens. Tarla Bitkileri Ana Bilim Dalı, Erzurum.

Hakim, M. A., A. S. Juraimi, M. Begum, M. M. Hanafi, M. R. Ismail, and A. Selamat. 2010. Effect of salt stress on germination and early seedling growth of rice (*Oryza sativa* L.). African journal of biotechnology 9 (13): 1911-1918.

Hassen, A., S. Maher, and H. Cherif, 2014. Effect of salt stress (NaCl) on germination and early seedling parameters of three pepper cultivars (*Capsicum annuum* L.). Journal of Stress Physiology & Biochemistry 10 (1): 14-25.

Kalia, P., and R. Selvakumar. 2023. Root vegetables for nutrition and entrepreneurship. In Vegetables for Nutrition and Entrepreneurship pp. 481-532. Singapore: Springer Nature Singapore.

Kara, B., İ. Akgün, ve D. Altındal. 2011. Tritikale genotiplerinde çimlenme ve fide gelişimi üzerine tuzluluğun (NaCl) etkisi. Selcuk Journal of Agriculture and Food Sciences 25 (1): 1-9.

Karakaş, S., M. Çullu, ve M. Dikilitaş. 2013. In vitro koşullarinda NaCl stresinin domates çeşitlerinin çimlenmesi üzerine fizyolojik ve biyokimyasal etkileri. Harran Tarım ve Gıda Bilimleri Dergisi 17 (4): 25-33.

Khayatnezhad, M., and Gholamin, R. 2011. Effects of salt stress levels on five maize (*Zea mays* L.) cultivars at germination stage. African Journal of Biotechnology 10 (60): 12909-12915.

Khodarahmpour, Z., M. Ifar, and M. Motamedi. 2012. Effects of NaCl salinity on maize (*Zea mays* L.) at germination and early seedling stage. African Journal of Biotechnology 11 (2): 298-304.

Kökten, K., T. Karaköy, A. Bakoğlu, and M. Akçura. 2010. Determination of salinity tolerance of some lentil (*Lens culinaris* M.) varieties. Journal of Food, Agriculture &. Environ. 8 (1):140–143.

Mäser, P., B. Eckelman, R. Vaidyanathan, T. Horie, D. J. Fairbairn, M. Kubo, M. Yamagami, K. Yamaguchi, M. Nishimura, N. Uozumi, W. Robertson, M.S. Sussman, and J. I. Schroeder. 2002. Altered shoot/root Na^+ distribution and bifurcating salt sensitivity in *Arabidopsis* by genetic disruption of the Na^+ transporter AtHKT1. FEBS letters 531 (2): 157-161.

Munns, R., and M. Tester. 2008. Mechanisms of salinity tolerance. Annual Review of Plant Biology 59: 651-681.

Okçu, G., M. D. Kaya, and M. Atak. 2005. Effects of salt and drought stresses on germination and seedling growth of pea (*Pisum sativum* L.). Turkish journal of Agriculture and Forestry, 29(4): 237-242.

Ologundudu, A.F., A.A. Adelusı, and R.O. Akınwale. 2014. Effect of salt stress on germination and early seedling growth of rice (*Oryza Sativa* L.). Notulea Science Biology 6 (2): 237–243.

Rewald, B., O. Shelef, J. E. Ephrath, and S. Rachmilevitch. 2013. Adaptive plasticity of salt-stressed root systems. Ecophysiology and Responses of Plants Under Salt Stress, Springer, New York, NY. https://doi.org/10.1007/978-1-4614-4747-4_6.

Sekmen, A. H., T. Demiral, N. Tosun, H. Türküsay, ve İ. Türkan. 2005. Tuz stresi uygulanan domates bitkilerinin bazı fizyolojik özellikleri ve toplam protein miktarı üzerine bitki aktivatörünün etkisi. Ege Üniversitesi Ziraat Fakültesi Dergisi 42 (1): 85-95.

Shams, M. K. 2019. Tuz stresinin biberde bitki gelişimi, fizyolojik ve biokimyasal özellikler, dna metilasyonu ile tohum çimlenmesi üzerine etkisi. Doktora Tezi. Atatürk Ü. Zir. Fak. Fen Bil. Ens. Bahçe Bitkileri Ana Bilim Dalı Erzurum.

Sivritepe, H.Ö. 2012. Tohum gücünün değerlendirilmesi. Alatarım Dergisi 11 (2): 33-44.

Subbarao, G. V., R. M. Wheeler, L. H. Levine, and G. W. Stutte. 2001. Glycine betaine accumulation, ionic and water relations of red-beet at contrasting levels of sodium supply. Journal of Plant Physiology 158 (6): 767-776.

Sun, X., L. Xu, Y. Wang, R. Yu, X. Zhu, X. Luo, Y, Gong, R. Wang C. Limera, K. Zhang and L. Liu. 2015. Identification of novel and salt-responsive miRNAs to explore miRNA-mediated regulatory network of salt stress response in radish (*Raphanus sativus* L.). BMC genomics 16 (1): 1-16.

Sun, X., Y. Wang, L. Xu, C. Li, W. Zhang, X. Luo, H. Jiang and L. Liu. 2017. Unraveling the root proteome changes and its relationship to molecular mechanism underlying salt stress response in radish (*Raphanus sativus* L.). Frontiers in Plant Science 8: 1192.

Şentürk, B., ve H. Sivritepe. 2015. Bezelye (*Pisum sativum* L.) tohumlarında NaCl ile yapılan priming uygulamaları için en uygun protokolün belirlenmesi. Uludağ Üniversitesi Ziraat Fakültesi Dergisi 29 (2): 95-105.

Tatar, N., Y. Öztürk, ve E. B. Çarpıcı. 2018. NaCl ön uygulamalarının farklı tuz seviyelerinde çok yıllık çim (*Lolium perenne* L.)'in çimlenme özellikleri üzerine etkileri. Türk Tarım ve Doğa Bilimleri Dergisi 5 (1): 28-33.

Tripathy, B., S. Rout, U. N. Mishra, G. Sahoo, K. Pradhan, A. K. Prusty, and L. Dash. 2021. Vegetables: a potential source of nutraceuticals. Annals of the Romanian Society for Cell Biology 25 (4):17921-17941.

Turhan, A., ve V. Şeniz. 2010. Farklı tuz konsantrasyonlarının Türkiye'de yetiştirilen bazı domates genotiplerinin çimlenmesi üzerine etkileri. Uludağ Üniversitesi Ziraat Fakültesi Dergisi 24 (2): 11-22.

Vitali, V., M. Sutka, L. Ojeda, R. Aroca, and G. Amodeo. 2021. Root hydraulics adjustment is governed by a dominant cell-to-cell pathway in *Beta vulgaris* seedlings exposed to salt stress. Plant Science 306: 110873-.110884.

Yamaguchi, T., and E. Blumwald. 2005. Developing salt-tolerant crop plants: challenges and opportunities. Trends in Plant Science 10(12): 615-620.

Yıldırım, E., ve İ. Güvenç. 2005. Deniz yosunu özü uygulamalarının tuzlu koşullarda pırasada tohum çimlenmesi üzerine etkisi. Bahçe 34 (1): 83-90.

Yolcu, S., H. Alavilli, P. Ganesh, M. Panigrahy, and K. Song, 2021. Salt and drought stress responses in cultivated beets (*Beta vulgaris* L.) and wild beet (*Beta maritima* L.). Plants 10 (9): 1843-1870.

Yuan, G., X. Wang, R. Guo. and Q. Wang. 2010. Effect of salt stress on phenolic compounds, glucosinolates, myrosinase and antioxidant activity in radish sprouts. Food Chemistry 121 (4): 1014-1019.