

Effects of Different Salt Concentrations on Germination and Seedling Development in Forage Turnip

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Abstract

Objective: This research was carried out to determine the effects of different salt concentrations on germination and seedling development in leaf type forage turnip (*Brassica rapa* L.).

Materials and Methods: In the study, seeds of the Lenox variety were germinated in 0, 50, 100, 150 and 200 mM NaCl solutions at 24±1 °C in darkness. The study was conducted in a randomized plot design with 4 replications. Germination percentage (%), potential germination (%), mean germination time (days), germination uniformity, germination rate, radicle and plumule lengths (cm), and seedling fresh weight (g) were determined. The data obtained from the study were analyzed by one-way ANOVA, Welch ANOVA, and Kruskal-Wallis statistical analysis methods. Tukey, Games-Hovel, and Bonferroni tests were used as multiple comparison tests.

Results: In this study, where different salt doses were applied to leaf-type forage turnip seeds, the differences among salt concentrations were found to be insignificant in terms of mean germination time and germination uniformity. However, the effect of salt concentrations on all other parameters examined in the study was found to be statistically significant. When 50 mM NaCl was present in the germination medium, germination percentage, germination rate, and potential germination increased compared to the control, but decreased with increasing doses. The first negative effect of salt on seedling development occurred at the 50 mM.

Conclusion: Although germination increased in the 50 mM NaCl solution compared to the control, seedling development was negatively affected, leading to the conclusion that the plant is sensitive to 50 mM salt concentrations in the early seedling stage.

Keywords: NaCl, Seed, Stress, Seedling development

Farklı Tuz Konsantrasyonlarının Yem Şalgamında Çimlenme ve Fide Gelişimine Etkisi

Öz

Amaç: Bu araştırma farklı tuz konsantrasyonlarının yaprak tipi yem şalgamında (*Brassica rapa* L.) çimlenme ve fide gelişimine etkisini belirlemek amacıyla yapılmıştır.

Materyal ve Yöntem: Araştırmada Lenox çeşidinin tohumları 0, 50, 100, 150 ve 200 mM NaCl çözeltisinde 24±1 °C'de karanlık ortamda çimlendirilmiştir. Araştırma 4 tekrarlamalı olarak tesadüf parselleri deneme deseninde yürütülmüştür. Çalışmada çimlenme oranı (%), potansiyel çimlenme (%), ortalama çimlenme süresi (gün), çimlenme üniformitesi, çimlenme hızı, radikula ve plumula uzunlukları (cm) ile fide yaş ağırlıkları (g) belirlenmiştir. Araştırmadan elde edilen veriler tek yönlü ANOVA, Welch ANOVA ve Kruskal-Wallis istatistik analiz yöntemleri ile analiz edilmiştir. Çoklu karşılaştırma testlerinden Tukey, Games-Hovel ve Bonferroni testi uygulanmıştır.

Araştırma Bulguları: Yaprak tipi yem şalgamı tohumlarına farklı tuz konsantrasyonlarının uygulandığı bu araştırmada, ortalama çimlenme süresi ve çimlenme üniformitesi bakımından tuz konsantrasyonları arasındaki farklılık önemsiz bulunurken, araştırmada incelenen diğer özelliklerin tamamında tuz konsantrasyonlarının etkisi istatistiki olarak önemli bulunmuştur. Çimlenme ortamında 50 mM NaCl bulunduğunda çimlenme oranı, hızı ve potansiyel çimlenme kontrole göre artmış, artan konsantrasyonlarda ise azalmıştır. Fide gelişiminde ise tuzun ilk olumsuz etkisi 50 mM konsantrasyonunda ortaya çıkmıştır.

Sonuç: Her ne kadar 50 mM NaCl çözeltisinde kontrole göre çimlenmede artış meydana gelse de fide gelişimi olumsuz etkilendiği için, bitkinin erken fide

döneminde 50 mM tuz konsantrasyonuna hassas olduğu sonucuna varılmıştır.

Anahtar kelimeler: NaCl, Tohum, Stres, Fide gelişimi

Introduction

An examination of forage crop cultivation in Türkiye, it can be seen that in 2023, forage crops were sown on approximately 2.72 million hectares of land, and there has been an increase in both the sowing area and cultivated plants species over the years, with the most widely cultivated species being alfalfa, sainfoin, maize, vetch, and cool-climate cereals (Anonymous, 2024). However, roughage production in Türkiye is still not at a sufficient level. Increasing roughage production requires increasing both the sowing area and the yield. In Türkiye, while there is a significant production deficit in many food plant species, increasing the sowing area of forage crops grown as the main crop in the cultivated area is quite difficult (Acar et al., 2025). Therefore, forage plants grown as double cropping are of particular importance for Türkiye.

Salinity is an important stress factor in plant production, and the germination stage is when plants are most sensitive to salt (Kuşvuran et al., 2015).

During dry periods, salts located in the lower layers of the soil are transported upwards, so seeds sown after prolonged summer droughts are exposed to greater salt stress during germination stage compared to other plant growth stagges. Therefore, salinity becomes a major problem for species sown in late summer or autumn.

The most common salt found in nature, NaCl, dissolves in the soil, releasing Na⁺ and Cl⁻ ions. They negatively affect seed germination through their osmotic and toxic effects.

Leaf-type fodder turnip (*Brassica rapa* L.) is a fast-growing and high-yielding species that can be grown as a winter forage crop without irrigation, rich in protein and vitamins, and resistant to frosts (Yavuz and Gülümser, 2022). This species, which has started to be cultivated in our country in recent years, has been included in statistics since 2012 and was sown on approximately 53,000 decares in 2023 (Anonymous, 2024). The increase in the cultivation of fodder turnip will contribute to the production of roughage. In this regard, it is important to conduct studies on the plant.

This study was conducted to determine the effects of different salt concentrations on seed germination and seedling development in leaf-type forage turnip.

Material and Methods

The research was conducted in the Laboratory of Faculty of Agriculture of Ordu University in 2024 and the leaf-type fodder turnip (*Brassica rapa* L.) cv. Lenox was used. In the experiment, seeds were germinated at NaCl concentrations of 0 (control), 50, 100, 150, and 200 mM. Twenty five seeds were placed between two sheets of filter paper in 10 cm petri dish, 15 ml of saline solution was added, and germination was achieved at 24±1 °C in a completely dark environment. Distilled water was used at the control. In this study, the petri dishes were stored in sealed bags to prevent evaporation. No solution was added to the petri dishes during the experiment. In the experiment conducted with 4 replications according to the randomized plot design, the germinated seeds were counted at 24-hour intervals from the beginning of the study. Seeds showing radicle emergence were considered germinated. The study was terminated when germination seed number did not change (after 8 days). In the study, germination percentage (%), germination potential (%) (Wang et al., 2016), mean germination time (days) (Matthews and Khajeh-Hosseini, 2007), germination uniformity (Bewely and Black, 1994), germination rate (Ranal and de Santana, 2006), radicle and plumule lengths (cm), and seedling fresh weight (g) were determined. The normality of the data was checked using the Shapiro-Wilk test, and the homogeneity was performed with Levene's test. The assumptions of the analysis of variance were not met by germination uniformity, radicle length, and plumule length. The data on germination uniformity were not normally distributed, and the variances were not equal. Therefore, the Kruskal-Wallis test was applied to it. While radicle length data did not follow a normal distribution, their variances were homogeneous. Therefore, the Kruskal-Wallis test was applied it, too. The plumule length data were normally distributed, their variances were not homogeneous. These data were analyzed using Welch ANOVA. Except for the parameters mentioned above, the data were analyzed using one-way ANOVA. To determine the differences among to the means, the Tukey's test was applied after one-way ANOVA, the Games-Howell test was done after Welch ANOVA, and the Bonferroni test was applied after Kruskal-Wallis. A 5% significance level was used in the calculations and interpretations. All

calculations were performed using the SPSS 20, and the graph was drawn using Excel.

Results and Discussion

Statistical analyses revealed that salt concentrations had a statistically significant effect on all characteristics except mean germination time and germination uniformity (Table 1 and 2). The highest germination percentage, germination potential, and germination rate were determined at 50 mM in the study; however, when the salt exceeded 50 mM, these characters were negatively affected by the salt and continued to decrease as the salt increased. Thus, the lowest values for these characters were determined at 200 mM. Furthermore, compared to the control, the first statistically significant decrease in germination percentage and germination potential occurred at

200 mM (Table 1). As is known, Na⁺ and Cl⁻ ions are nutrients for plants in small quantities (Kacar and Katkat, 2009). In the study, the increase in germination percentage at 50 mM compared to the control was likely due to the nutrient effect of Na and Cl. Similarly, it was determined that a 40 mM NaCl increased the germination percentage of the Sorghum X Sudan grass hybrid compared to the control (Şimşek Soysal et al., 2018). Salt stress reduces water uptake by seeds (Doğan and Budaklı Çarpıcı, 2016) and/or creates a toxic effects (Çulha and Çakırlar, 2011). The toxic effect of Na⁺ and Cl⁻ ions can adversely impact metabolic processes in seed during germination, such as respiration, hydrolysis of nutrients, and energy production, which are influenced by enzymatic activities (Alhammad et al., 2023).

Table 1. Germination characteristics of fodder turnip seeds germinated at different salt concentrations

NaCl concentrations (mM)	Germination percentage (%)	Germination potential (%)	Germination rate	Germination uniformity	Mean germination time (day)
	Mean ±St. Error	Mean ±St. Error	Mean ±St. Error	Mean ±St. Error	Mean ±St. Error
0	57.00±6.61ab	57.00±6.61a	7.92±0.94 bc	29.87±3.71	1.92±0.06
50	67.00±3.42a	64.00±5.16a	11.00±0.65a	37.16±3.64	1.83±0.11
100	57.00±3.42ab	51.00±5.97ab	8.96±0.79ab	29.93±3.34	1.95±0.16
150	48.00±2.83bc	46.00±1.15ab	9.21±0.34ab	30.54±0.27	1.57±0.08
200	36.00±1.63c	36.00±1.63b	6.00±0.35c	21.52±1.61	1.71±0.16
p/Asy. ^z	0.001*** (F=8.723)	0.008*** (F=5.168)	0.001*** (F=7.782)	0.066 ^{NS}	0.195 ^{NS} (F= 1.735)

^zAsy. : Significance value

In addition, it has been reported that Na⁺ ions inhibit many enzymes (Zhu, 2001), reduce the amount of gibberellic acid while increasing the amount of abscisic acid during germination processes, and cause toxic and oxidative stresses in cells (Shu et al., 2017). The decrease in germination that occur when the salt exceeded 50 mM was probably due to the reasons mentioned above.

For the yield, quality and accurate harvest time, it is desirable that the plant density is optimum and that the plants develop synchronously. Therefore, uniform germination with a high germination percentage and strong seedlings are desired. In the study, all seeds germinated within the first 3 days in control, while at

other treatments, germination continued only minimally after the 3rd day. In addition, as stated previously, the total number of germinated seeds also decreased, especially higher than 100 mM (Figure 1). Therefore, as salt stress increased, germination potential, germination uniformity, and germination rate decreased (Table 1).

Although previous studies have reported that salt stress significantly prolongs the mean germination time (Önal Aşçı and Üney, 2016; Şimşek Soysal et al., 2018; Şimşek Soysal et al., 2021), in this study the effect of salt concentrations on it was not statistically significant.

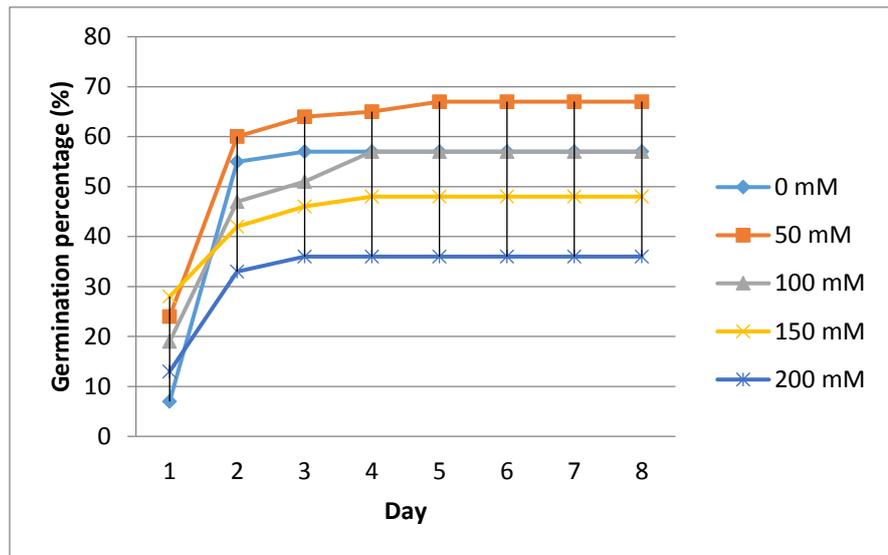


Figure 1. Cumulative germination percentage (%) of fodder turnip seeds germinated at different salt concentrations

Salt stress significantly negatively affected the growth of Lenox seedlings (root and shoot length, and seedling fresh weight) (Table 2). The first adverse effect of NaCl on plumule length and seedling fresh weight was determined at 50 mM, while this effect on radicle length occurred at of 100 mM. When radicle is exposed to salt stress, meristem cells expansion and division slow down due to osmotic stress and ionic toxicity caused by salt, ultimately leading to reduced root elongation (Rewald et al., 2013). The probable reason for the decrease in root length along with salt

stress in the study is also this situation. Root apical meristems are the primary sites where free cytokinins are synthesized in plant, and they are transported into shoot. Thus, cytokinins regulate cell division in both roots and shoots (translated from Taiz and Zeiger, 2002, by Türkan, 2008). Salt stress has been reported to inhibit cytokinin biosynthesis in plants, leading to reduced apical meristem growth and stunting of plant shoots (Kamran et al., 2021). In the research, the plumule length probably decreased because cytokinin synthesis and transport to plumule were reduced.

Table 2. The effect of different salt concentrations on seedling growth of fodder turnip.

NaCl concentrations (mM)	Radicula length (cm)	Plumula length (cm)	Seedling fresh weight (g)
	Mean ±St. Error	Mean ±St. Error	Mean ±St. Error
0	4.74±0.76a	6.29±0.37a	1.42±0.13a
50	3.00±0.22ab	2.56±0.14b	0.69±0.06b
100	1.64±0.22bc	2.17±0.05b	0.49±0.02bc
150	1.28±0.11bc	1.15±0.07c	0.39±0.05c
200	1.06±0.11c	1.05±0.10c	0.23±0.01c
p/Asy.	0.003***	0.000***	0.000***
		(Welch F= 71.578)	(F=45.000)

In addition, salt stress had a more negative impact on seedling development than on germination. Indeed,

the first negative effect of NaCl on germination percentage occurred at 150 mM, while plumule length

and seedling fresh weight were determined at 50 mM. This situation is likely due to the inhibitory/protective effects of the testa and other tissues surrounding the embryo on the salt reaching the embryo. When germination occurs, the radicle breaks through the seed coat and is thus directly exposed to the salt.

Conclusion

This study, which determined the effects of different salt concentrations on the germination and seedling development of Lenox, a leaf-type fodder turnip variety, showed that although 50 mM salt application increased the germination percentage, it significantly inhibited seedling development. Therefore, it was concluded that the cv. Lenox is sensitive to salt stress at 50 mM and higher during the early seedling phase.

Conflict of Interest

The authors have declared no conflict of interest.

Author Contribution Statement

The authors have equal contributions.

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