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The Effect of Different Irrigation Water Quality on Germination Properties of Tomato (*Solanum lycopersicum* L.)

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Abstract

This study was conducted to investigate the effects of irrigation water with different salt (NaCl) concentrations (T0: pure water; T1: 1 dS m^{-1}; T2: 2 dS m^{-1}; T3: 3 dS m^{-1}) on the following: the germination rate, the germination time, the root length, and the plant growth of tomato (*Solanum lycopersicum* L.) seeds. In the present study, two tomato varieties, designated as SC21-21 and H-2274, were utilised for the experimental purposes. The process of seed germination was conducted within a laboratory setting, under controlled in vitro conditions, on a filter paper substrate maintained at a temperature of 25 °C. The findings of the study demonstrated that an increase in salt concentrations led to a decline in germination percentage, an extension in germination time, and a negative impact on root length and plant growth in both tomato varieties. The germination rate was found to be 97.33% in the control group (T0) of the SC21-21 variety, however this rate decreased to 60% at the highest salt concentration (T3). In the H-2274 variety, the germination rate was determined as 57.33% at T3, while it was 78.67% in the control group (T0). With regard to root length, the maximum value recorded was 19 cm in the control group; this value decreased to 9.167 cm as salt concentration increased. The findings of the study indicated that elevating the sodium chloride content had deleterious consequences on the germination and development of tomato seeds. The SC21-21 variety demonstrated a higher germination rate in comparison to the H-2274 variety when subjected to salt stress. In regions where salinity problems are pervasive, the selection of salt-resistant genotypes is paramount for the long-term viability of agricultural productivity.

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1. Introduction

Agriculture is a sector of paramount importance in terms of the nutrition of the global population, and as such, it is an industry that should not be overlooked. The primary source of human nutrition is agricultural production (Öztürk, 2021). Agricultural production of developed countries has also reduced due to climate change effects such as long droughts (Hemathilake and Gunathilake, 2022). In order to achieve successful agricultural production, it is imperative to cultivate robust plants that yield high-quality produce. Furthermore, it is essential to ensure optimal germination and seedling emergence rates for the specific variety (Heydecker and Gibbins, 1978). A healthy agro seed produces healthier, more viable, and vigorous seedlings, contributing to effective agricultural practices. In the current scenario, agriculture faces a wide range of challenges, including changing environmental conditions like salinity, drought, heavy metal accumulation in soil and climate changes etc., which can adversely affect seed germination, seedling development, and ultimately, crop production (Yadav et al., 2020; He et al., 2018). It is widely acknowledged that seed germination represents the most significant stage in the life cycle of plants (Khan et al., 2000; Bradford, 1995). In the context of divergent environmental conditions, the capacity for rapid and uniform seed germination is a favourable trait in tomato plants, as evidenced by numerous studies (Foolad et al., 2007). A considerable number of plant species demonstrate sensitivity to salt stress during the germination process. It has been established that the highest levels of germination tend to occur in the absence of salt, with a decline in germination observed in the presence of increasing salt concentrations (Khan et al., 2000). The process of germination in seeds is initiated by the absorption of water by the seeds. However, the presence of salt has been demonstrated to reduce water uptake (Othman, 2005). Reduced water uptake in seeds has been shown to prevent germination under saline conditions, both osmotically and by ion toxicity caused by high accumulation of Na and Cl ions around the seed (Murillo-Amador et al., 2002; Shokohifard et al., 1989). It has been demonstrated that increasing salt concentrations have a dual impact on seed germination: they not only prevent germination but also delay its onset and prolong the germination period (Rahman et al., 2000). The detrimental impact of salt stress on seed germination exhibits variation among different plant species (Torech and Thompson, 1993). Among these plant species, tomato is one of the most widely cultivated crops in the world and is resistant to moderately saline conditions (Maas, 1986). A considerable body of research has indicated significant variations among tomato varieties with regard to their salt tolerance (Foolad, 1996; Cuartero and Fernandez-Muñoz, 1999). In order to facilitate the sustained agricultural exploitation of regions afflicted by salinity, it is imperative to assess the tolerance levels of extant and newly developed varieties with regard to salinity. In this study, the responses of two tomato cultivars, SC21-21 and H-2274, which are of significance for tomato cultivation in Turkey and are extensively cultivated, to varying concentrations of salt stress during the germination period were investigated. The study evaluated the effects of varying salt concentrations on various parameters, including seed germination rate, germination time, root length, and plant growth. The study revealed the potential effects of salinity on tomato cultivation.

2. Material and Methods

The study was conducted in the Irrigation Water Quality and Drainage Laboratory of the Department of Agricultural Structures and Irrigation, Faculty of Agriculture, Ankara University. The experiment utilised seeds from two distinct tomato varieties, namely SC21-21 and H-2274, as the experimental material. The seeds were obtained from the Department of Horticulture, Faculty of Agriculture, Ankara University. In the preparation of irrigation water, the NaCl form was utilised as the salt source, given its prevalence in the soil and its propensity to accumulate within the soil structure. The irrigation water treatments were prepared as follows: Control (T0=pure water), T1=1 dS m^{-1}, T2=2 dS m^{-1} and T3=3 dS m^{-1}. The experiment was meticulously designed according to a randomised plot experimental design, incorporating three replicates and 25 seeds in each replicate. Germination tests were conducted within 11 cm diameter petri dishes, with filter paper positioned within and beneath the conditions of an air conditioning cabinet, which maintained a temperature of 25 ± 1 °C and constant humidity. The germination studies were based on the works of Anonymous (1985) and Şehirali (2002). Each germination medium was prepared by placing the seeds on a double layer of filter paper and moistening with different concentrations of water (5 ml). The prepared petri dishes were then labelled and placed in the climate cabinet with the lids closed. In order to detect germinated seeds, a method of seed counting was implemented, which was carried out at the same time each day from the day the seeds were soaked. The parameters under consideration were obtained by measuring and enumerating on specific days in accordance with ISTA regulations. The following parameters were measured: germination strength, germination percentage, root length, wet weight and dry weight. The measurement of dry weight was conducted by subjecting the fresh shoots to a drying process at a temperature of 70 °C for a duration of 72 hours. In addition, % mineral matter values have been calculated.

2.1. Mean germination time

The mean germination percentage calculated by formula (Formula 1). Mean germination time was noted every 24 h following ISTA (2003) with the help of formula (Formula 2). Where n is the number of total seeds germinated in 24 h and D is the number of days counting from the start of the germination experiment.

$$GP = \frac{Germinated\ seeds\ at\ final\ day}{Total\ seeds} \times 100 \qquad (1)$$

$$MGT = \sum(Dn)/\sum \mathrm{n} \qquad (2)$$

2.2. Root length

Root length (RL), seedling fresh weight (FW) and dry weight (DW) of 10 seedlings randomly selected from each replicate were measured on the 15th day.

2.3. Dry weight

Dry weight was measured after drying samples at 70 °C for 48 hours in an oven (Kaya et al., 2013).

2.4. Total mineral matter

The determination of mineral matter values was conducted in accordance with the Walkey-Black method as described by Anonymous (1954).

2.5. Statistical analysis

The analysis of variance for the obtained data was performed using the MINITAB package program, and the differences between the averages were evaluated according to the ANOVA test.

3. Results and Discussion

The parameters determined in this study, in which the effect of different irrigation water salt concentrations on the germination of different tomato (*Solanum lycopersicum*) seeds were examined, are presented in Table 1. These parameters include the germination percentage, mean germination time, root length, mineral matter (%) and organic matter (%).

Table 1. Results of the parameters examined in the study in relation to irrigation water quality

Variety	Irrigation water quality (dS m^{-1})	Germination percentage (%)	Mean germination time (Day)	Root length (cm)	Total mineral matter (%)
SC21-21	T0	97.33	8.71	21.17	3.50
	T1	82.67	9.52	14.33	7.76
	T2	74.67	9.95	14.50	19.64
	T3	60.00	10.75	10.50	21.90
H-2274	T0	78.67	9.18	16.83	6.50
	T1	74.67	10.47	14.67	11.93
	T2	70.67	10.82	9.00	14.64
	T3	57.33	11.10	7.83	19.47

3.1. Germination percentage

Germination percentage values were analysed separately for the relationships between cultivar and irrigation water quality. As illustrated in Figure 1, the values obtained for the germination percentage were subjected to analysis of variance. The interaction between cultivar and irrigation water quality was found to be significant at 5% level. The lowest germination percentage value (57.33%) was obtained for the H-2274 variety in the T3 subject with the highest salt content, while the highest value (97.33%) was obtained for the SC21-21 variety in the T0 subject. As the salinity value increased, the percentage of seeds that germinated decreased in both varieties. The findings indicate a correlation between the stress rates to which the subjects were exposed and the germination percentage values, which is consistent with other studies in this field (Benlioğlu and Özkan, 2015).

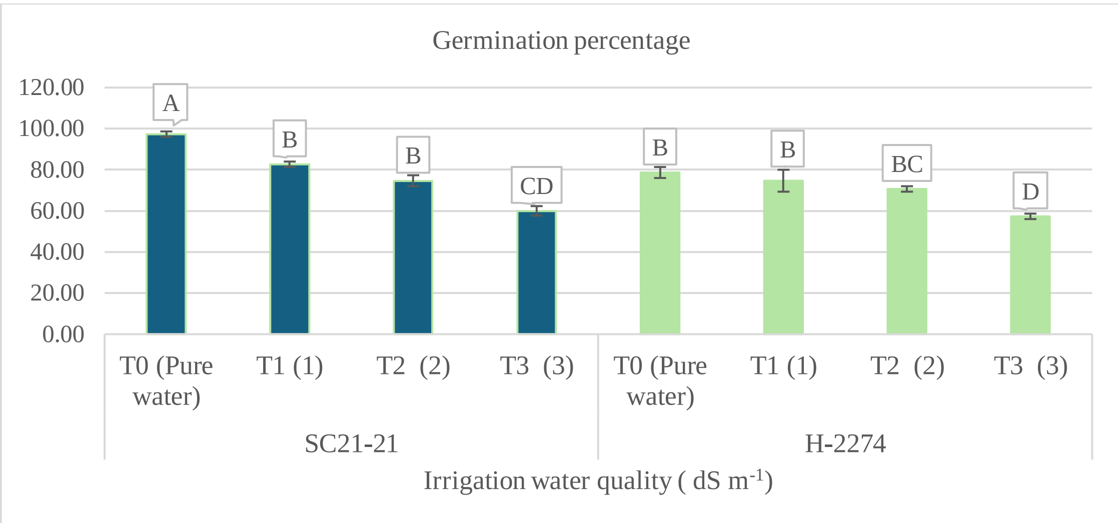
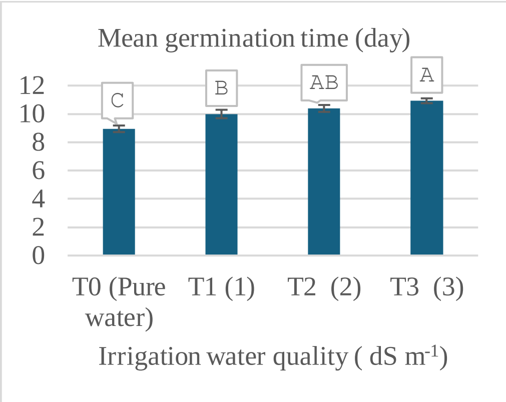


Figure 1. Germination percentage values for different irrigation water quality

3.2. Mean germination time

Mean germination time values were analysed separately in terms of the relationships between cultivar and irrigation water quality. Figure 2 shows the mean germination time values obtained from the analysis of variance. Mean germination time values were found to be significant at the 5% level for both cultivar and water quality subjects. As demonstrated in the T3 subject, which exhibited the highest salt content, germination occurred at 10.924 days. In contrast, the T0 subject demonstrated a significantly earlier germination time of 8.946 days. An analysis of the differences between tomato varieties revealed that the H-2274 variety was classified as being in class A, while the SC21-21 variety was classified as being in class B. It was observed that as the level of salinity increased, the time taken for seeds to germinate increased substantially. Kara et al. (2011) and Aybar Yalınkılıç et al. (2023) obtained similar results in their studies. Akçaman et al. (2017) reported that the germination rate and germination strength decreased with increasing salinity levels of irrigation water, as a result of a study conducted with different mastic bean lines.



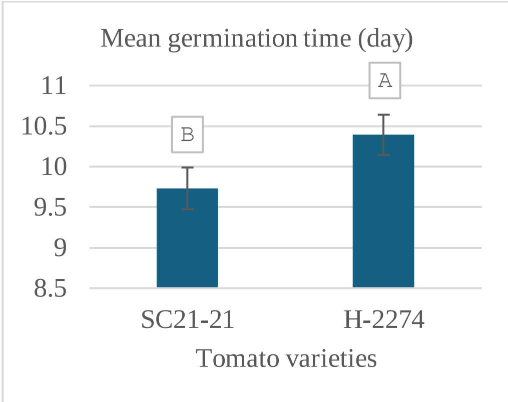


Figure 2. Average germination time values for different irrigation water quality

3.3. Root length

The analysis of variance table for the root length values examined in the study is shown in Figure 3. In terms of root length, the quality of the irrigation water was found to be significant at the 5% level. While the highest value was obtained in T0 with a root length of 19 cm, the lowest value was obtained in T3 with a value of 9.167 cm. It was observed that root length decreased in proportion to the increase in salinity. The results obtained in this study were consistent with those reported in the research conducted by Akçaman et al. (2017), Bagum et al. (2017), and Shokouhian and Omidi (2021).

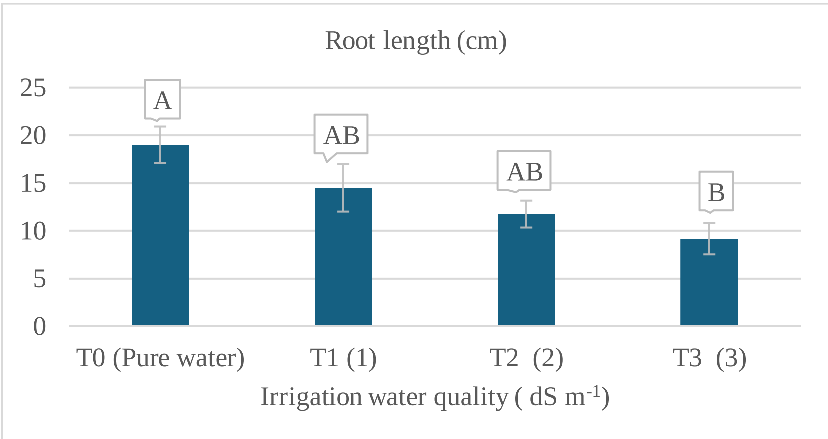


Figure 3. Root length values for different irrigation water quality

3.4. Total mineral matter

Total mineral matter values were examined in the study and displayed in Figure 4 according to variance analysis values. With regard to total mineral matter values, the quality of irrigation water was found to be significant at the 5% level. The subjects T3 and T0 exhibited the highest and lowest mineral matter values, respectively, at 20.685% and 5.002%. Following a comprehensive analysis of variance and a subsequent grouping of data based on Duncan's methodology, the following conclusion was reached: the irrigation water salinity exhibited a substantial impact on the total mineral matter content. In addition, a positive correlation was identified between the increase in salinity and the corresponding increase in total mineral matter content. These results are in parallel with the studies of Duan et al. (2004), Kara et al. (2011), Akçaman et al. (2017), Bagum et al. (2017).

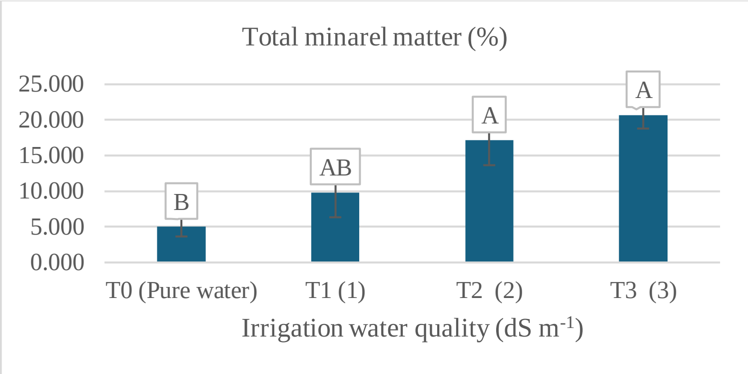


Figure 4. Total mineral matter values for diffirent irrigation water quality

4. Conclusion

This study revealed some negative effects of increasing salt concentration on the germination of tomato seeds. The variety designated as SC21-21 demonstrated a higher germination rate in comparison to H-2274. The findings of this study demonstrated that salt stress exerted a detrimental effect on plant growth, particularly with regard to the delayed emergence of seeds. Researchers have obtained similar results in studies on the subject. In areas where salinity levels are high, the utilisation of salt-tolerant genotypes is imperative for the long-term viability of agricultural productivity. However, when the conditions of soil and water are in question in the context of tomato cultivation, it has been revealed that germination should be carried out in special environments without salinity.

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