Anadolu Tarım Bilimleri Dergisi,
Anadolu Journal of Agricultural Sciences

e-ISSN: 1308-8769, ANAJAS Haziran 2023, 38 (2): 407-420

The Effect of Different Irrigation Water Salinity Levels on Rice Germination and Early Seedling Development

Farklı Sulama Suyu Tuzluluk Seviyelerinin Çeltikte Çimlenme ve Erken Fide Gelişimi Üzerine Etkisi

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Makale Bilgisi/Article Information

Makale Türü/Article Types: Araştırma Makalesi/Research Article
Geliş Tarihi/Received: 14 Mayıs/May 2023
Kabul Tarihi/Accepted: 5 Haziran/June 2023
Yıl/Year: 2023 | **Cilt-Volume:** 38 | **Sayı-Issue:** 2 | **Sayfa/Pages:** 407-420

Atıf/Cite as: Duman, H., Öztürk E., Akay, H. "The Effect of Different Irrigation Water Salinity Levels on Rice Germination and Early Seedling Development" Anadolu Journal of Agricultural Sciences, 38(2), Haziran 2023: 407-420.

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https://doi.org/10.7161/omuanajas.1115743

THE EFFECT OF DIFFERENT IRRIGATION WATER SALINITY LEVELS ON RICE GERMINATION AND EARLY SEEDLING DEVELOPMENT

ABSTRACT

Rice (*Oryza sativa* L.) is a vital cereal group that provides the basic food source for over half of the world's population and almost half of the daily calorie requirement. However, rice is susceptible to salt stress during germination and early seedling development. This study was conducted to determine the effect of different NaCl and CaCl concentrations on rice germination and early seedling development. The Efe variety, commonly grown in our country, was used in the study. Seeds were germinated and irrigated during the seedling and early growth stages using solutions prepared at 7 different NaCl and $CaCl_2$ concentration levels: 0.38 dS m^{-1} (T0), 1.5 dS m^{-1} (T1), 3 dS m^{-1} (T2), 5 dS m^{-1} (T3), 7 dS m^{-1} (T4), 9 dS m^{-1} (T5), and 11 dS m^{-1} (T6). The germination rate was examined 5 days after seed planting, while seedling growth parameters and leaf and root mineral contents were examined 15 days after planting. Salt tolerance and vigor index values were calculated. The study was conducted with 3 replications according to the randomized complete block design. Statistically significant differences were observed among the studied traits. The germination rate and early seedling growth traits decreased as the salt concentration increased. Regarding root mineral content, as salinity increased, Na, K, and Ca increased while the K/Na and Ca/Na ratios decreased. Similarly, regarding seedling mineral content, as salinity increased, Na, K, and Ca increased while the K/Na and Ca/Na ratios decreased. These findings indicate that rice plants are sensitive to salt stress during the germination and early seedling growth stages. The analysis showed that the maximum salt concentration for 80% germination was 7 dS m^{-1} (T3) for the Efe rice variety commonly grown in our country.

Keywords: Rice; Salinity Stress; Mineral Content, Seedling Establishment, Growth.

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ÖZ

FARKLI SULAMA SUYU TUZLULUK SEVİYELERİNİN ÇELTİKTE ÇİMLENME VE ERKEN FİDE GELİŞİMİ ÜZERİNE ETKİSİ

Çeltik (*Oryza sativa* L.), dünya nüfusunun yarısından fazlasının temel besin kaynağını ve günlük kalori ihtiyacının neredeyse yarısını sağlayan hayati bir tahıl grubudur. Bununla birlikte, çeltik, çimlenme ve erken fide gelişimi sırasında tuz stresine karşı hassastır. Bu çalışma, farklı NaCl ve CaCl konsantrasyonlarının çeltik

https://doi.org/10.7161/omuanajas.1296440

çimlenmesi ve erken fide gelişimi üzerindeki etkisini belirlemek amacıyla yapılmıştır. Araştırmada ülkemizde yaygın olarak yetiştirilen Efe çeşidi kullanılmıştır. Tohumlar, fide ve erken büyüme dönemlerinde 7 farklı NaCl ve CaCl konsantrasyon seviyesinde hazırlanan solüsyonlar kullanılarak çimlendirilmiş ve sulanmıştır. 0.38 dS m^{-1} (T0), 1.5 dS m^{-1} (T1), 3 dS m^{-1} (T2), 5 dS m^{-1} (T3), 7 dS m^{-1} (T4), 9 dS m^{-1} (T5) ve 11 dS m^{-1} (T6). Çimlenme oranı tohum ekiminden 5 gün sonra, fide büyüme parametreleri ile yaprak ve kök mineral içerikleri ise ekimden 15 gün sonra incelenmiştir. Tuz toleransı ve canlılık indeksi değerleri hesaplanmıştır. Çalışma tesadüf blokları deneme desenine göre 3 tekrarlamalı olarak yürütülmüştür. İncelenen özellikler arasında istatistiksel olarak önemli farklılıklar gözlenmiştir. Tuz konsantrasyonu arttıkça çimlenme oranı ve erken fide büyüme özellikleri azalmıştır. Kök mineral içeriğine bakıldığında, tuzluluk arttıkça Na, K ve Ca mineral içerikleri artarken, K/Na ve Ca/Na oranları azalmıştır. Benzer şekilde fide mineral içeriği bakımından tuzluluk arttıkça Na, K ve Ca artarken, K/Na ve Ca/Na oranları azalmıştır. Bu bulgular, çeltik bitkilerinin çimlenme ve erken fide büyüme aşamalarında tuz stresine duyarlı olduğunu göstermektedir. Yapılan analizler, ülkemizde yaygın olarak yetiştirilen Efe çeltik çeşidi için % 80 çimlenme için maksimum tuz konsantrasyonunun 7 dS m^{-1} (T3) olduğunu göstermiştir.

INTRODUCTION

Rice (*Oryza sativa* L.) constitutes the staple source of livelihood and basic food commodity for three billion people worldwide, primarily in Africa and Asia. The global average rice consumption exceeds 50 kg per capita per year, and it constitutes the basic food item for 90% of the population in the Asian continent (Heong et al., 2005; Vibhuti et al., 2015; Khush, 1997; Carrijo et al., 2017). The projected increase in the global population to 9.6 billion by 2050 indicates a continual rise in food demand. Despite the constant increase in rice production, it is not sufficient to meet the global demand (FAO, 2021; Steduto et al., 2012). Rice is a versatile crop that can grow in diverse climatic conditions, but different abiotic and biotic stress factors affect its yield. Among the abiotic stress factors, salinity is a major limitation to rice productivity worldwide (Riaz et al., 2019). Approximately 6% of the approximately 800 million hectares of land used for agricultural production worldwide suffer from soil salinity issues, which equates to 20 % of the total irrigated area (Gerona et al., 2019; FAO, 2008; Munns, 2002). In Turkey, the problem of salinity and alkalinity in agricultural soils has become increasingly prevalent in recent years due to the rapid development of irrigation practices and associated drainage issues. Of the total 2.7 million hectares of land affected by drainage problems, approximately 1.5 million hectares suffer from salinity and alkalinity issues (Dinç et al., 1993). Paddy is a plant that can grow continuously underwater and is therefore mainly cultivated in areas close to the sea, with a high demand for water. In rice cultivation in these regions, the use of groundwater leads to the entry of seawater, resulting in salinization of irrigation water (Mori and Kinoshita, 1987). Excessive accumulation of Na^+ in plants under salt stress inhibits the uptake of K (Siegel et al., 1980), and Cl^- can negatively affect NO_3^- uptake, leading to disruptions in ion balance in plants (Kirkby et al., 1977; Güneş et al., 1994; Inal et al., 1995; Lewitt, 1980). Although the salinity problem affects the growth and development of rice throughout its entire life cycle, the extent of the impact varies depending on the severity of salinity and the duration of exposure to salt. Additionally, rice is more sensitive to salt stress during germination and early seedling development (Kakar et al., 2019). Rice production is decreasing in many developing countries due to salinity and water scarcity, which raises concerns about global food security.

This research was carried out to determine the effect of different irrigation water salinity levels on germination and early seedling growth in rice.

MATERIALS AND METHODS

This study was conducted in 2021 at the Field Crops Department Laboratory of the Faculty of Agriculture at Ondokuz Mayıs University. The "Efe" rice variety was used as the experimental material. In the study, 7 different saline water concentrations were applied using $NaCl_2$ and $CaCl_2$ salts: 0.38 dS m^{-1} (T0), 1.5 dS m^{-1} (T1), 3 dS m^{-1} (T2), 5 dS m^{-1} (T3), 7 dS m^{-1} (T4), 9 dS m^{-1} (T5), and 11 dS m^{-1} (T6). The experiment was designed with a randomized complete block design with three replications. Prior to germination, seeds were subjected to surface sterilization for 10 minutes in a 5% sodium hypochlorite solution (Uyanık et al., 2014). Twenty seeds were placed in transparent plastic containers (10×10×4 cm) lined with double-layered drying paper, and 10 ml of NaCl and $CaCl_2$ solutions prepared at different salt concentrations were added to the containers using forceps (Akay et al., 2019; Öztürk et al., 2021). The germination containers were placed in a climate cabinet at a temperature of 25±1°C and 75% humidity, with a daily 12-hour light cycle of 12.000 lux. To prevent salt accumulation, filter papers were replaced every 2 days (Rehman et al., 1996). In the study, seeds that germinated during the first 7 days were counted, and seeds with a 2 mm radicle length were considered germinated (ISTA, 2003). On the 15th day of the study, measurements and calculations were carried out for root length, shoot length, root-to-shoot ratio, root dry matter content, shoot dry matter content, and germination rate (Akay et al., 2019; Öztürk et al., 2021), seedling vigor index (Butola and Badola, 2004), salt tolerance index (Matwijcuk et al., 2012), vigor index (Hu et al., 2005), ash content, and organic matter content. The seedling vigor index (SVI) was determined using the formula "SVI = (Root + Shoot Dry Weight) / (Days after Sowing)" (Butola and Badola, 2004) for rice seeds grown under different irrigation water salinities. The salt tolerance index (STI) was determined using the formula "STI = (Root + Shoot Dry Weight under Saline Treatment) / (Root + Shoot Dry Weight under Control Treatment)" (Matwijcuk et al., 2012; Akay et al., 2019). Root and shoot samples were dried at 70°C for 48 hours and ground for mineral content analysis. The Na, K, and Ca^2 mineral contents were measured using a flame photometer, and the K/Na and Ca^2/Na ratios were calculated (Sezer et al., 2021). The statistical analysis of the data was performed using the JMP statistical software. The significance of the differences between the means of the groups was determined using the Tukey test. Biplot, Pearson, and clustering analyses were conducted to investigate the relationships among the examined traits (JMP, 2019). Regression analysis was performed using Microsoft Excel.

RESULTS AND DISCUSSION

The average values of root length obtained in the study are presented in Table 1. When the results are analyzed according to different irrigation water salinity levels, the highest root length was determined as 5.09 cm at T0 (Control) level. The lowest root length was determined as 1.22 cm at T6 (11 dS m^{-1}) level (Table 1). As the salinity level in irrigation water increased, root length decreased, showing a 76% reduction compared to the control group. The average root length value was determined as 3.08 cm. Significant decreases in root length occurred as the salt concentration increased. Root development is an essential indicator of a plant's tolerance to salt. The roots show average growth if there is no salt barrier in water uptake during germination. Therefore, the setbacks in root development due to salt stress are caused by plant water uptake reductions (Yılmaz and Bayram, 2019). Direct exposure of the primary root system to NaCl suppresses cell expansion and cell cycle, directly inhibiting root growth. Alzahrani-Motos et al. (2018) demonstrated that abiotic stress factors, such as salinity, can significantly impact root anatomy and function.

When the results were analyzed regarding the salinity of the irrigation water, the highest stem length was determined to be 19.78 cm at level T1 (3 dS m^{-1}), while the lowest stem length was determined to be 14.00 cm at level T6 (11 dS m^{-1}) (Table 1). When the salinity levels in irrigation water of T1 and T2 were examined, they were found to be in the same statistical group regarding stem length. As the salinity levels of irrigation water increased (except for T0), the stem length decreased, showing a 70% decrease compared to the T1 level. The mean stem length value was determined to be 17.64 cm. The research data indicate that increasing salt concentrations hurt seedling height. A study conducted on sorghum found that low salt concentrations promoted germination, but at increasing levels, seedling heights decreased (Atış, 2011). Another survey of maize genotypes concluded that ion toxicity resulting from salt stress negatively affected plant growth and could cause a decrease in a root-shoot increase. The results obtained in light of this information are similar to those of the studies conducted.

When the stem dry matter ratio was examined according to different irrigation water salinity levels, the highest percentage was determined to be 21.93% at the T3 (7 dS m^{-1}) concentration, while the T4 and T5 concentrations (21.71% and 20.07%, respectively) were in the same statistical group. The lowest stem dry matter ratio was 15.88% at the control level T0 concentration. The mean stem dry matter ratio was determined to be 18.95%. Generally, as the salt concentration levels increased, the stem dry matter ratio also increased.

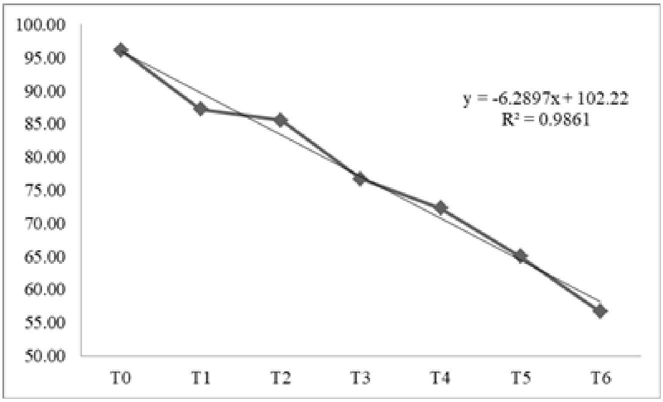
When Table 1 is examined, it is determined that the relationship between different salt concentrations and the mean root dry matter ratio is statistically indistinguishable. Root dry matter ratio ranged between 9.23% and 11.23%. The lowest root dry matter ratio was 9.23% at the T3 (7 dS m^{-1}) salinity level, while the highest root dry matter ratio was 11.2% at the T5 (9 dS m^{-1}) salinity level. The mean root dry matter ratio was 10.04% (Table 1).

Table 1. Parameters examined at different irrigation water salinity concentrations*

Salt Concentrations	Root Length (cm)	Stem Length (cm)	Stem Dry Matter Content (%)	Root Dry Matter Content (%)
T0	5.09 ± 0.46 a	19.06 ± 0.63 a	15.88 ± 3.23 b	10.45 ± 058
T1	4.17 ± 0.56 b	19.78 ± 0.53 a	15.90 ± 1.55 b	9.56 ± 0.73
T2	4.00 ± 0.33 b	18.72 ± 0.75 ab	18.06 ± 1.55 ab	9.34 ± 1.28
T3	3.83 ± 0.41 b	18.28 ± 0.86 abc	21.93 ± 1.78 a	9.23 ± 1.47
T4	1.94 ± 0.41 c	17.11 ± 0.77 bc	21.71 ± 2.21 a	9.88 ± 1.22
T5	1.28 ± 0.31 c	16.50 ± 0.78 c	20.07 ± 2.23 a	11.23 ± 1.02
T6	1.22 ± 0.36 c	14.00 ± 0.56 d	19.07 ± 1.84 ab	10.57 ± 1.64
Ort.	**3.08 ± 0.40**	**17.64 ± 0.70**	**18.95 ± 2.06**	**10.04** ± 1.13
KO	**7.31****	**11.49****	**18.62****	**1.63**
CV	**9.34**	**4.56**	**7.54**	**9.11**
	Germination Rate (%)	**Seedling Strength Index**	**Salt Tolerance Index**	**Vigor Index**
T0	98.33 ± 2.59 a	16.50 ± 0.92 a	100.00 ± 0.00 a	2374.17 ± 109.81 a
T1	86.67 ± 2.47 b	13.58 ± 0.76 b	96.22 ± 3.96 ab	2075.83 ± 95.19 b
T2	86.67 ± 2.96 b	12.89 ± 1.03 bc	88.83 ± 4.23 bc	1971.11 ± 127.41 bc
T3	80.00 ± 3.70 bc	11.06 ± 0.49 c	82.17 ± 2.74 cd	1768.89 ± 55.37 c
T4	75.00 ± 3.09 c	8.58 ± 0.58 d	78.69 ± 5.43 d	1429.17 ± 72.90 d
T5	66.67 ± 1.11 d	6.50 ± 0.34 e	70.09 ± 1.43 e	1183.33 ± 53.89 e
T6	56.67 ± 2.22 e	4.05 ± 0.32 f	58.06 ± 4.05 f	861.67 ± 45.06 f
Ort.	**78.57 ± 2.59**	**10.45** ± 0.63	**82.01 ± 2.94**	**1666.31 ± 79.95**
KO	**578.97****	**56.38****	**649.40****	**854575****
CV	**19.81**	**6.70**	**3.62**	**5.19**

Table 1 shows that rice seeds are significantly affected by increasing salinity conditions, and the germination rate varies between 56.67% and 98.33%. Results show that the highest germination rate among different irrigation water salinity concentrations, except for the control group, is 86.67% at the salinity levels of 1.5 dS m^{-1} (T1) and 3 dS m^{-1} (T2). The lowest germination rate is 56.67% at the salinity level of 11 dS m^{-1} (T6). As the irrigation water salinity levels increase, the germination rate decreases by 35%, except for the control (T0) group (Table 1, Figure 1).

Figure 1. Regression plot showing the effect of different irrigation water salinity levels on germination rate (%)



Based on the regression analysis conducted on the examined germination rate values, it was determined that there is a linear decrease in germination rate as the irrigation water salinity concentration increases (R2 = 0.9861). There is a highly significant relationship (Figure 1). Upon evaluation of the data obtained in this study, it shows similarities with many studies (Ravikovitch and Porath, 1967; Gates et al, 1966; Cooper and Dumbroff, 1973; Clarkson and Hanson, 1980; Epstein, 1981) indicating that germination rate decreases with increasing different irrigation water salt concentrations. It is thought that the increase in different irrigation water salinity concentrations may cause osmotic stress in the environment where germination takes place, reducing the available water ratio and negatively affecting germination, or may increase ion accumulation in the seed, causing toxic effects and reducing germination rate (Joshi, 1984).

When Table 1 is examined, it is determined that rice seeds are significantly affected by increasing salinity conditions, and the seedling strength index values vary between 4.05 and 16.5. When the findings are examined regarding different irrigation water salinity concentrations, the highest seedling strength index value, except for the control group, was determined to be 13.58 in 1.5 dS m^{-1} (T1). When evaluated for different irrigation water salinity concentrations, the highest seedling vigor index value, except for the control group (T0), was determined to be 13.58

at 1.5 dS m^{-1} (T1). The lowest seedling strength index value was 4.05 at the 11 dS m^{-1} (T6) level. The mean seedling strength index value was determined to be 10.45. As the irrigation water salinity levels increased, except for the control (T0) group, the seedling strength index decreased by 70% (Table 1). Compared with other studies, the germination and early seedling development periods are reported as the most sensitive periods for plants under salty conditions. Therefore, the resistance of plants to salinity during these periods is crucial (Ghoulam and Fares, 2001; Akay et al., 2019, Öztürk et al., 2021; Sezer et al., 2021).

In environments with high salt content levels, plants' ability to sustain their growth and development is defined as salt tolerance, and the values obtained through calculations are defined as salt tolerance indices (Maathuis and Altmann, 1999; Matwijcuk et al., 2012). Table 1 shows that rice seeds are significantly affected by increasing salinity conditions and the salt tolerance index values range between 58.06 and 99.22, except for the control group (T0). When examined in terms of different irrigation water salinity concentrations, the highest salt tolerance index value, except for the control group, was 96.22 at the salinity level of 1.5 dS m^{-1} (T1). The lowest salt tolerance index value is determined as 58.06 at the salinity level of 11 dS m^{-1} (T6). The average salt tolerance index value is defined as 82.01. The salt tolerance index value decreased by 42% except for the control (T0) group, as the irrigation water salinity levels increased (Table 1). Similar to many other studies, the salt tolerance index values decrease as the salt dose levels increase (Lacerda et al., 2003; Öztürk et al., 2021; Akay et al., 2019).

Upon examination of Table 1, it was determined that rice seeds were significantly affected by increasing salinity levels, and the vigor index values ranged from 2374.17 to 861.67. When analyzed concerning different irrigation water salinity concentrations, the highest vigor index value, except for the control (T0) group, was found to be 2075.83 at 1.5 dS m^{-1} (T1) salinity level. The lowest vigor index value was determined to be 861.67 at the 11 dS m^{-1} (T6) level. The mean vigor index value was found to be 1666.31. As irrigation water salinity levels increased, the vigor index decreased by 64% compared to the control (T0) group (Table 1). Similar results were found in the study conducted by Öztürk et al. (2021) when analyzed concerning vigor index values.

The results, presented in Figure 2, showed significant differences in ash and organic matter content between the different salt concentrations at a probability level of 0.01. The highest ash content was observed at a salinity level of 11 dS m^{-1} (T6) with 9.75%, while the lowest ash content, except for the control groupwas observed at a salinity level of 1.5 dS m^{-1} (T1) with 6.48%. Upon examining Figure 2, it was determined that the ash content increased linearly with increasing irrigation water salinity concentration. The average ash content in the roots was determined to be 9.75%. On the other hand, it can be observed from Figure 2 that there is an inverse relationship between the ash content and the organic matter content. As the irrigation water salinity level increases, the organic matter content in the roots decreases. The highest organic matter content was determined to be 95.04% in the control group, while the lowest organic matter content was determined to be 84.85% at a salinity level of 11 dS m^{-1} (T6). The average organic matter content in the roots was determined to be 89.88%.

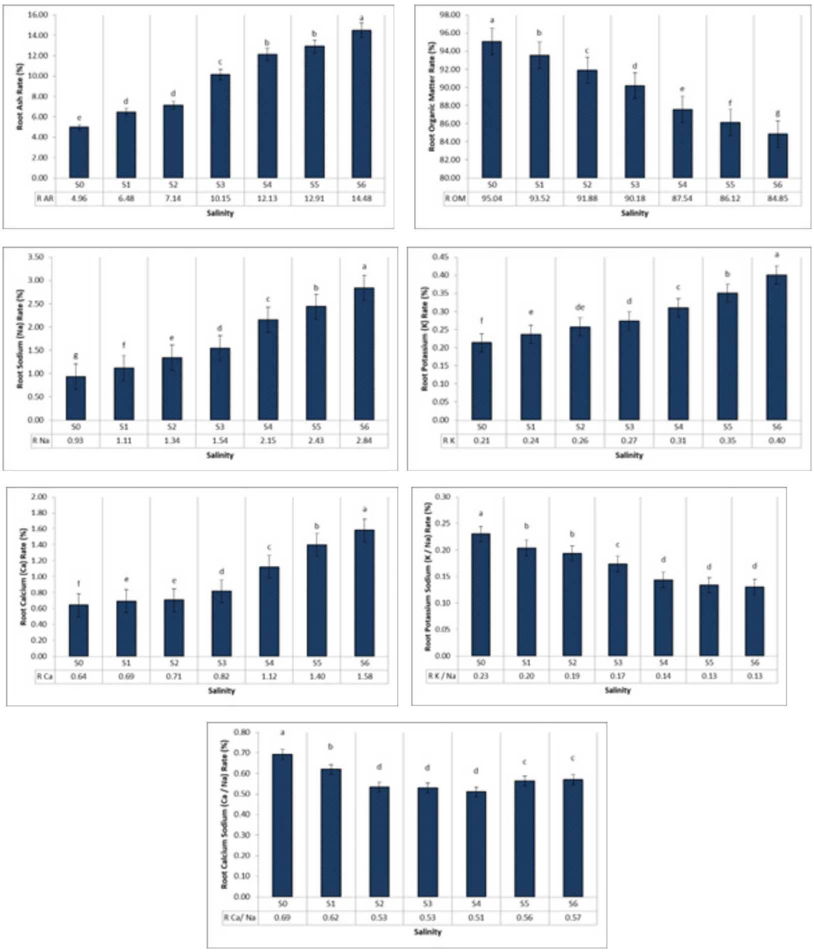


Figure 2. Values of organic matter, ash and mineral contents of rice plant roots grown at different irrigation water salinity levels.

It was determined that there were significant differences at the 0.01 probability level in terms of the Na, K, and Ca ratios examined in the roots. The highest Na ratio was 2.84% at a salinity level of 11 dS m^{-1} (T6), while the lowest ratio, except for the control group, was 1.11% at a salinity level of 1.5 dS m^{-1} (T1). The K ratio varied values between 0.21% and 0.40%. The highest K ratio was 0.40% at a salinity level of 11 dS m^{-1} (T6). Except for the control group, the lowest ratio was 0.24% at a salinity level of 1.5 dS m^{-1} (T1). In terms of the Ca ratio values, it was determined that they varied between 0.64% and 1.58%. The highest Ca^2 ratio was 1.58% at a salinity level of 11 dS m^{-1} (T6), while the lowest balance, except for the control group, was 0.69% at a salinity level of 1.5 dS m^{-1} (T1).

When analyzed in general, it was determined that as the irrigation water salinity levels increased, the Na, K, and Ca ratios also increased (Figure 2). The increase in calcium ratio plays an important role in the selective transport of potassium to make the plant resistant to salinity in the presence of excess sodium. Therefore, an increase in calcium uptake parallel to sodium uptake was reported by Clarkson, Hanson and Epstein (Clarkson and Hanson, 1980; Epstein, 1981).

The analysis found significant differences at the 0.01 probability level regarding K/Na and Ca/Na ratios. It was observed that the K/Na and Ca/Na ratios calculated for the roots generally decreased as the irrigation water salinity concentration increased. The highest K/Na ratio was determined to be 0.23 in the control group, while the lowest percentage was found to be 0.13 at the salinity level of 11 dS m^{-1} (T6). The highest Ca/Na ratio was 0.69 in the control group, while the lowest ratio was 0.57 at the salinity level of 11 dS m^{-1} (T6).

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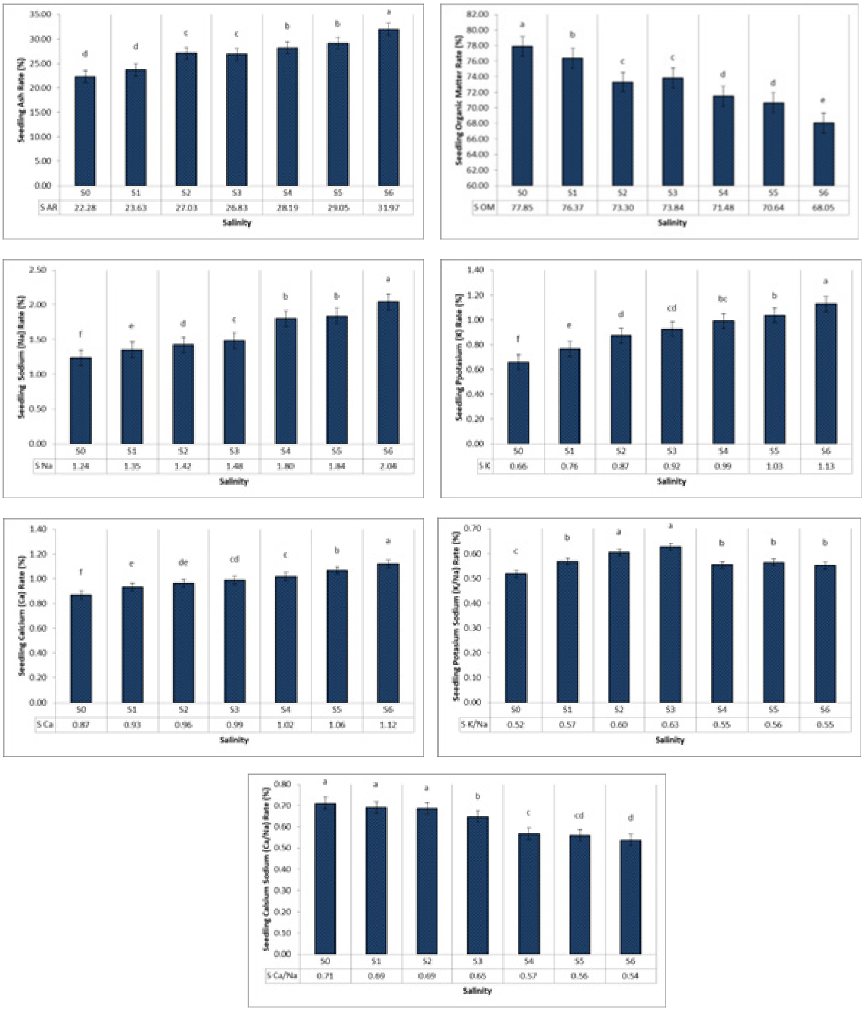

Figure 3. Values of organic matter, ash and mineral contents examined in rice plant seedlings grown at different irrigation water salinity levels.

When examined for ash content, it was found that as salt levels increased, the ash content increased, and the organic matter content decreased (Figure 2). The highest ash content was 31.97% at the 11 dS m^{-1} (T6) level, while the highest organic matter content was 77.85% at the control (T0) level. The lowest ash content was 22.28% and 23.63% at the control and 1.5 dS m^{-1} (T1) levels, respectively, while the lowest organic matter content was 68.05% at the 11 dS m^{-1} (T6) levels.

Significant differences were found at the 0.01 probability level regarding the Na, K, and Ca^2 ratios analyzed in rice seedlings. The highest Na ratio was 2.04% at the 11 dS m^{-1} (T6) salinity level, while the lowest percentage was 1.35% at the 1.5 dS m^{-1} (T1) salinity level except for the control group. The K ratio values ranged from 0.66% to 1.13%. The highest K ratio was determined to be 1.13% at the 11 dS m^{-1} (T6) salinity level, while the lowest ratio was 0.76% at the 1.5 dS m^{-1} (T1) salinity level except for the control group. In terms of Ca^2 ratio values, it was determined to vary between 0.87% and 1.12%. The highest Ca ratio was determined to be 1.12% at the 11 dS m^{-1} (T6) salinity level, while the lowest percentage was 0.93% at the 1.5 dS m^{-1} (T1) salinity level except for the control group.

The K/Na and Ca/Na ratios for the roots generally decreased as the salinity levels of the irrigation water increased. The highest K/Na ratio was determined to be 0.23% in the control group, while the lowest ratio was 0.13% at the salinity level of 11 dS m^{-1} (T6). The highest Ca/Na ratio was determined to be 0.69% in the control group, while the lowest ratio was 0.57% at the salinity level of 11 dS m^{-1} (T6).

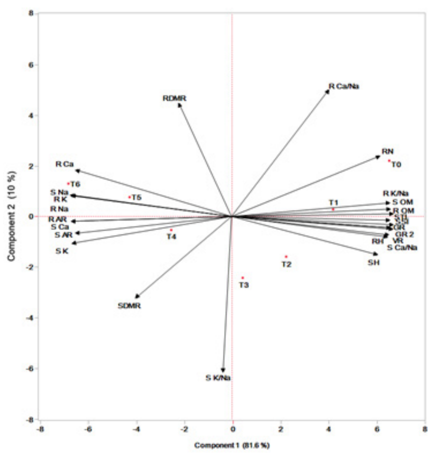

Figure 4. Biplot plot showing relationships between investigated traits and salt concentrations

The relationship between the studied features and different irrigation water salinity concentrations is presented in Figure 3 through a biplot graph. In this study, the first principal component was 81.6%, and the second principal component was 10%, resulting in a total variation of 91.6%. As the angle between the vectors narrows in the biplot graph, the relationship between the parameters the vectors represent strengthens, while it weakens as the angle widens (Öztürk et al., 2021).

In biplot analysis, the relationship between features and the relationship between salinity concentrations are explained. As the angle value between the vectors of two parts decreases (<90˚), it indicates a positive relationship, whereas as the angle value increases (90˚>), it shows a negative relationship. Furthermore, the positioning of salt applications also demonstrates which salt application has high values in terms of which features (Kendal, 2020).

Especially the T0, T1, and T2 applications indicate a positive relationship in terms of parameters such as root number, root K/Na ratio, seedling organic matter, root organic matter, salt tolerance index, vigor index, seedling strength index, germination rate, root length, and seedling length in the region. It has been found that the T3 application is positively related to seedling K/Na ratio, while the T6 application is closely related to root calcium content and seedling sodium content. The angle value between the vectors of germination rate and seedling length, root length, seedling and root organic matter content, salt tolerance index, vigor index, and seedling strength index is relatively narrow, indicating a high positive correlation between these features. On the other hand, there is a wide angle between the vectors of germination power and root and seedling Ca, Na, K, and ash content, showing a negative correlation between the two (Figure 2). The study found a positive relationship between agronomic features such as root length and seedling length of seedlings grown under salinity treatments and the germination rate.

CONCLUSION

This study examined the effect of different irrigation water salinity levels on rice germination and early seedling growth, and significant results were obtained in terms of the parameters investigated. As the level of salt concentration increased, it was determined that the germination rate and seedling growth characteristics decreased. It is possible to say that there are significant differences between rice plants under salty conditions in terms of their development and mineral content. Their growth may be limited by insufficient water use by the plants and disturbances in ion uptake and especially ion balance.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethic

This study was approved by the ethics committee.

Author Contribution Rates

Designing the Study: Author HD(%20), EÖ(%30), HA(%50)

Data Collection: HD(%40), EÖ(%30), HA(%30)

Data analysis: HD(%10), EÖ(%30), HA(%60)

Writing the Article: HD(%20), EÖ(%50), HA(%30)

Submission and Revision of the Article: HD(%5), EÖ(%65), HA(%30)

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