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Original scientific article

THE EFFECTS OF IRRIGATION WATER SALINITY ON THE SEED GERMINATION AND SEEDLING GROWTH OF RICE

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To determine the effects of irrigation water salinity on seed germination and seedling development of two rice cultivars, irrigation waters with low SAR (below 3) were prepared in different salinity levels (control [0.5], 2, 4, 8, 12, 16, and 20 dS m^{-1}) from different salinity sources (NaCl, $MgS0_4$, and $CaCl_2$ salts). The average germination rate was decreased for the cv. Baldo 20.19%, while for cv. Osmancık - 97 it was 26.73%. The average of the single seedling dry weight of cv. Baldo was 0.2666 g, while for cv. Osmancık-97 it was 0.2569 g. The average single seedling dry weight was 0.2940 g in the control application. In parallel to the increased irrigation water salinity level, the single seedling dry weight decreased. The irrigation water salinity had not affected up to 4 dS m^{-1} in terms of the germination rate decrease and the single seedling dry weight of rice, but it started to be affected when increased salinity level to 8 dS m^{-1} and it was more effective at higher doses. Also, cv. Osmancık-97 was more sensitive to irrigation water salinity than cv. Baldo. In conclusion, it turns out that the irrigation water to be used in rice farming should not have salinity since the tolerance of the rice plant against irrigation water salinity is low.

Keywords: rice, germination rate, seedling development, irrigation water salinity, SAR

INTRODUCTION

The origin of the rice is probably India. Rice is a typical cultivated plant in the Asian mainland. It is stated that rice cultivation started to be made in 3000 BC in the world. Rice farming is known to have 2300 years of history in Europe. Rice farming started approximately 500 years ago in Turkey. It is the main nutrient for more than half of the world's people. Rice production areas in Asia mainland correspond to 90% of world rice production and cultivation

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areas. The top three countries that produce the most paddy in the world are China, India, and Indonesia (ŞAHIN, 2002). The mentioned countries are those in the temperate-humid climate zone. Looking at the daily diets of these countries, it is seen that rice is the main food source.

Salinity is one of the primary agricultural problems, especially in semi-arid and arid regions. The salinity of the water used in irrigation affects plant development directly or indirectly. The high density of salt in water negatively affects plant growth by increasing the osmotic pressure and limiting the uptake of water from the soil. Osmotic stress, which augments due to the increase in salt density in the plant root zone, is the main factor causing a decrease in growth in the early stages of plant growth (MUNNS and TESTER, 2008).

Another negative effect of salinity on plant development is the ionic effect which prevents plants to take basic nutrients regularly (EKMEKÇI, 2005). The reduced level of CO_2 assimilation, stomatal closure, transpiration rate, exclusion of Na^+ ion, and K^+ absorption and increased level of antioxidant enzymes serve as a potential indicator in the identification of tolerant genotypes at the early seedling stage (SENGUTTUVEL *et al.*, 2013). Salt stress significantly damages plant productivity by differentiating the biochemical, physiological, and molecular processes of the plant (MICKELBART *et al.*, 2015). Irrigation water salinity, which is the main component of the sustainability of agricultural production, is important for both soil and plants. Water demand, a limited and finite resource, is constantly increasing. Therefore, the use of irrigation water, which is called low quality in agricultural production, becomes compulsory (AKÇAMAN *et al.*, 2017). Irrigation water quality is one of the main issues to be emphasized in semi-arid and arid regions where irrigated agriculture is carried out. The most important reason for salinity in irrigated areas is the quality and quantity of irrigation water and fertilizers used unconsciously. The increase of salt density in the cultivated plants has a great effect on the amount of product obtained and the resistance of the plant to salinity (TAŞ *et al.,* 2018a). Depending on the characteristics of the water used as a source, the problems of alkalinity and salinity occur in the irrigated areas over time, and if no precautions are taken, they can reach dimensions that will limit or even prevent agricultural production (TAŞ *et al.*, 2018b). Although salt stress occurs in plants at a level of 4.0 dS m^{-1} electrical conductivity (EC) in saturated soil extract, it is known that these values differ greatly according to the plant species (ONAGA and WYDRA, 2016). This value is determined as 3.0 dS m^{-1} in rice (VOLKOV and AMTMANN, 2006). It is stated that there is a 12% decrease in efficiency for each unit dS m^{-1} on these limit values. When plants gradually accumulate salt, they face nutrient imbalance with osmotic and oxidative stress (ONAGA and WYDRA, 2016). Morphological, physiological, and biochemical changes to be detected in plants against salt stress are not a cause but a result of a different number of gene expressions (TIRYAKI, 2018). MUNNS (1993) proposed that cell mortality occurs as salt concentrations exceed the vacuole capacity. Rice is considered to be one of the main food items that are essential for more than half of the world's human existence and greatly reduce productivity with abiotic tensions. SINGH *et al.* (1973) reported that in a field trial carried out by growing wheat with irrigation waters with different EC and SAR (Sodium absorption ratio) values, as the EC and SAR values increased, the grain and stalk yield decreased. HORUZ and KORKMAZ (2014), in their study to investigate the effect of feeding with silicon in lowering the salt tension in the rice, found that salt causes a decrease in grain yield. The tolerance of plants to salinity varies according to their genetic differences (COŞKUN *et al.,* 2016).

Although rice is not salinity tolerant, it can be grown better in saline environments than other plants due to the environmental conditions in which it is grown, because in the saline soils, the area must be left underwater to wash the salts. Thus, the salinity of the soil can be reduced by washing the salts in the environment. Therefore, rice can be considered an important plant in the rehabilitation of saline areas. As a result of literature reviews, it is seen that most of the studies on the determination of the effect of salt in plants are on sodium salinity and SAR value is not taken into consideration. At high SAR values, plants are exposed to chlorine poisoning rather than salt. For this reason, SAR values must be taken into consideration in salinity studies. In this study, the effects of irrigation water prepared at different EC levels with low SAR values (below 3) on germination of seed and seedling development of rice were investigated.

MATERIAL AND METHODS

Experimental seeds of rice cultivars (cv. Osmancık-97 and cv. Baldo) obtained from Çanakkale Onsekiz Mart University Faculty of Agriculture were used as plant material in the trials. NaCl, $MgS0_4$, $CaCl_2$ salts were used as salinity sources for the preparation of the application solutions. Trials were carried out in 2019 at the laboratory of Çanakkale Onsekiz Mart University Faculty of Agriculture. Irrigation water salinity levels (control [0.5], 2, 4, 8, 12, 16, and 20 dS m^{-1}) were prepared from different salinity sources (NaCl, $MgS0_4$, and $CaCl_2$) with SAR values below 3. The rice seeds were kept in 2.5% sodium hypochlorite solution in a 1000 ml beaker for 5 minutes for disinfection. After disinfection, the seeds were washed 2 times with sterile distilled water. Then, the seeds are swelled and activated in sterile distilled water for 24 hours. The experiment was created according to the experimental design of "random blocks factorial" with 3 replications. In the two-factor experiment, 10 seeds were added to the glass Petri dishes (6 cm in diameter), in which filter paper was placed. 10 ml of saline water solution with different salinity levels per application was added to each Petri dish. Petri dishes were wrapped with paraffin film to prevent water loss through evaporation that may occur from Petri dishes. After these processes, seed-planted Petri dishes were placed in a plant growth cabinet that was suitably conditioned for germination (plant growth cabinet environment was adjusted to 70% humidity and 22-24°C temperature) and left for germination. To determine the germination rate, the seeds germinated on the 7^{th} day were counted, the values obtained were subtracted from 100 and the results were evaluated as the germination rate decreased. Arc Sinus (Square Root) transformation [AS (SR) t] was performed to zoom the data into a normal distribution. This type of transformation was needed because the percentage of data does not fit into the normal distribution. As a result of the transformation made in this way, the significance sensitivity of small values also changes and allows for more accurate comparison. Germination seedlings were dried at 60° C for 72 hours to determine the seedling dry weight. The data obtained from the experiments were analyzed using JMP 13 statistical software.

RESULTS AND DISCUSSION

The single seedling dry weight

As a result of the analysis of variance made to the data from the experiment, the effect of cultivars and 'Cultivar x EC' interaction on the single seedling dry weight was statistically significant ($p<0.05$), and the effect of EC was statistically significant ($p< 0.01$).

Table 1. Means of single seedling dry weight of rice cultivars and student's t multiple comparison tests

Cultivar	The single seedling dry weight (g)
Baldo	0.2666 a*
Osmancık-97	0.2569 b

LSD: 0.003289

*: Means indicated by the different letters on the same column it is not statistically similar ($p<0.05$)

The average single seedling dry weight was 0.2666 g in cv. Baldo and 0.2257 g in cv. Osmancık-97 (Table 1 and Figure 1). In terms of single seedling dry weight, it took place in two different groups. This situation can be interpreted as the varieties that may be affected to different degrees from salinity stress conditions due to differences in their genetic structure. While the single seedling dry weight average was 0.2294 g in control application according to EC levels, 0.2287 g and 0.2818 g in the 2 and 4 dS m^{-1} applications, respectively, were in the same group with the control. Levels of 8, 12, 16, and 20 dS m^{-1} were in different groups than the control group. The lowest values were 0.2332 and 0.2188 g at the levels of 16 dS m^{-1} and 20 dS m^{-1}, respectively. In parallel with the increase in irrigation water salinity level, the single seedling dry weight has also decreased (Table 2 and Figure 2). The average of single seedling dry weight according to the 'cultivar x EC' interactions, the highest values (0.2922, 0.2988, 0.2862, 0.2932, and 0.2296 g) were obtained in 'Baldo x 0', 'Baldo x 2', 'Baldo x 4', 'Baldo x 8', and 'Osmancık-97 x 0' interactions respectively. The lowest values (0.2405, 0.2268, 0.2285, 0.2434, 0.2398, and 0.2091 g) were obtained in 'Baldo x 12', 'Baldo x 16', and 'Baldo x 20', 'Osmancık-97 x 12', 'Osmancık-97 x 16', and 'Osmancık-97 x 20' interactions as shown in the Table 3.

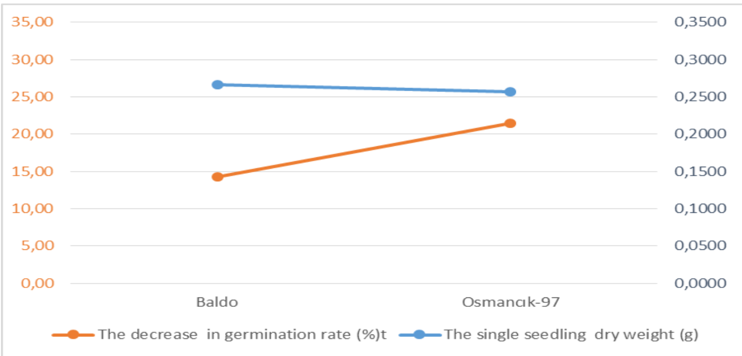

Figure 1. Effects of the irrigation water salinity on the single seedling dry weight and the decrease in germination rate according to rice cultivars

Table 2. Means of the single seedling dry weight according to EC levels and student's t multiple comparison tests

EC (dS m^{-1})	The single seedling dry weight (g)
0	0.2940 a*
2	0.2872 ab
4	0.2818 ab
8	0.2753 b
12	0.2420 c
16	0.2333 cd
20	0.2188 d

LSD: 0.01529

*: Means indicated by the different letters on the same column it is not statistically similar ($p<0.05$)

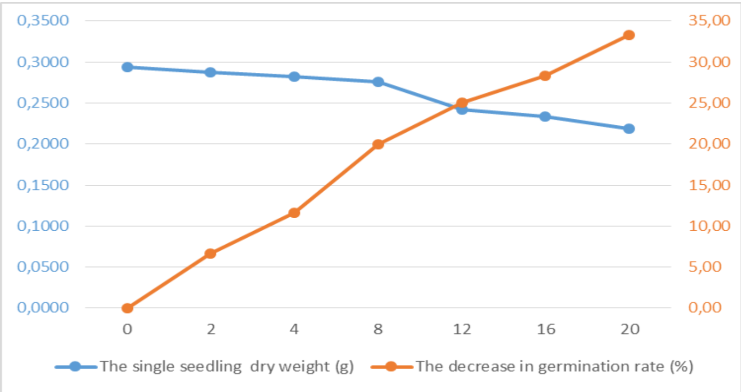

Figure 2. Effects of the irrigation water salinity levels on the single seedling dry weight and the decrease in germination rate of rice

Some researchers (SINCLAIR and HOFFMANN, 2003; MUNNS *et al.*, 2006; TEKIN *et al.*, 2014) reported that irrigation water salinity causes a decrease in development and yield in some cereals, as well as losses increase in parallel with increasing salinity level and tolerance varies according to cultivars. There are differences among the rice genotypes of response to salinity stress (KUCHANURI and SPATTAR, 2006; SENGUTTUVEL *et al.*, 2013; KAMYAB-TALESH *et al.*, 214). Different researchers (DRAFT *et al.*, 2007; KAYDAN *et al.*, 2007; KUMAR *et al.*, 2007; KARA *et al.*, 2011; AYDINŞAKIR *et al.*, 2013; COŞKUN and TAŞ, 2017) reported that the irrigation water salinity affects the germination rate and seedling development of cereals such as wheat, corn, barley, rice, and triticale. Also, this effect increases with increasing of the salinity level. Rice is very sensitive to salt tension, especially during the young seedling and flowering stages (REDDY *et al.*, 2017).

Table 3. Means of the single seedling dry weight according to 'cultivar x EC' interactions and student's t multiple comparison tests

Cultivar x EC	The single seedling dry weight (g)
Baldo x 2	0.29880 a*
Osmancık-97 x 0	0.29572 ab
Baldo x 8	0.29315 ab
Baldo x 0	0.29220 ab
Baldo x 4	0.28621 ab
Osmancık-97 x 4	0.27734 bc
Osmancık-97 x 2	0.27561 bc
Osmancık-97 x 8	0.25744 cd
Osmancık-97 x 12	0.24344 de
Baldo x 12	0.24052 de
Osmancık-97 x 16	0.23981 de
Baldo x 20	0.22848 ef
Baldo x 16	0.22683 ef
Osmancık-97 x 20	0.20907 f

LSD: 0.02138

*: Means indicated by the different letters on the same column it is not statistically similar ($p<0.05$)

The decrease in germination rate

As a result of the analysis of variance performed after applying AS (SR) transformation to the data from the experiment, the effect of 'cultivar x EC' interaction on the decrease in germination rate was statistically significant ($p<0.05$), while the effect of cultivars and EC was statistically significant ($p<0.01$).

Table 4. Means of the decrease in germination rate of rice cultivars and student's t multiple comparison tests

Cultivar	The decrease in germination rate (%)^t	The decrease in germination rate (%)^o
Osmancık-97	26.73 a*	21.43
Baldo	20.19 b	14.29

LSD: 2.8159

*: Means indicated by the different letters on the same column it is not statistically similar ($p<0.05$)

^{t}: Arc Sinus (Square Root) transformed values.

^{o}: None transformed values.

The average decrease in the germination rate was 14.29% in cv. Baldo, while it was 21.43% in cv. Osmancık-97 (Table 4 and Figure 1). In terms of the decrease in germination rate, it took place in two different groups. This situation can be interpreted that varieties may be affected to different degrees by stress conditions due to differences in their genetic structure. The decrease in the germination rate was 0.00% in the control application. All applications were in different groups than the control group. In 2 and 4 dS m^{-1} applications, 6.67% and 11.67%, respectively, were in the same group. The highest values were 28.33% and 33.33% in 16 dS m^{-1} and 20 dS m^{-1} applications, respectively. The decrease in germination rate increased parallel to the increase of salinity level (Table 5 and Figure 2). The lowest decrease in germination rate values (0.00, 0.00, 3.33, and 0.00%) were obtained in 'Baldo x 0', 'Baldo x 2', 'Baldo x 4', and 'Osmancık-97 x 0' interactions respectively, while the highest values (26.67, 30.00, 26.67, 30.00, and 36.67%) were obtained in 'Baldo x 16', 'Baldo x 20', 'Osmancık-97 x 12', 'Osmancık-97 x 16' and 'Osmancık-97 x 20' interactions respectively (Table 6). The irrigation water salinity causes a decrease in that germination rate, seedling development, crop development, and grain yield in the different grains such as wheat, triticale, barley, rice, and corn, as well as losses increase in parallel with increasing salinity level, and tolerance varies according to cultivars (KONAK *et al.*, 1999; TASLAK *et al.*, 2007; KAYDAN *et al.*, 2007; KUMAR *et al.*, 2007; KARA *et al.*, 2011; AYDINŞAKIR *et al.*, 2013; KAMYAB-TALESH *et al.*, 2014; COŞKUN and TAŞ, 2017). It has been reported that the increase in irrigation water salinity causes a decrease in the germination rate of durum and bread wheat, primitive varieties are more tolerant to irrigation water salinity than current cultivars (TAŞ *et al.*, 2018 a b).

Table 5. Means of the decrease in germination rate according to EC levels and student's t multiple comparison tests

EC (dS m^{-1})	The decrease in germination rate (%)^t	The decrease in germination rate (%)^o
20	35.83 a*	33.333
16	32.64 ab	28.333
12	30.55 bc	25.000
8	27.05 c	20.000
4	18.55 d	11.667
2	13.87 d	6.667
0	5.74 e	0.000

LSD: 5.2681

*: Means indicated by the different letters on the same column it is not statistically similar ($p<0.05$)

^{t}: Arc Sinus (Square Root) transformed values.

It may be interpreted that the cultivars emerged differently in terms of the single seedling dry weight and the decrease in germination rate and that they may have reacted to stress conditions at different degrees due to the differences in the genetic structure of the cultivars. Parallel to the increase in the irrigation water salinity level, the decrease in the single seedling dry weight and the increase in the decrease in germination rate can be interpreted that the rice plant is tolerant to low levels of irrigation water salinity but sensitive to high levels. When the 'Cultivar x EC' interactions are examined, it can be interpreted that the cv. Baldo is more tolerant than the cv. Osmancık-97 and the tolerance decrease with the increase of salinity in both varieties. If it is necessary to add low-quality water to irrigation water used in rice farming, it is possible to mix low-quality waters into high-quality irrigation waters in early development periods, considering that the tolerance of salinity of the rice plant is higher than in later periods. It will be beneficial to avoid such practices as it will cause a loss of efficiency in future development periods. With this study, to reach high yields in rice farming, high-quality irrigation water is required, it has been confirmed once again and it can be evaluated that the use of salty water in rice farming is also objectionable for the sustainability of agricultural soils.

In conclusion, it turns out that the irrigation water to be used in rice farming should not have salinity, since the tolerance of the rice plant against irrigation water salinity is low also irrigation water with high salinity will cause salt to accumulate in the soil.

Table 6. Means of the decrease in germination rate according to 'cultivar x EC' interactions and student's t multiple comparison tests

Cultivar x EC	The decrease in germination rate (%)^t	The decrease in germination rate (%)^o
Osmancık-97 x 20	37.82 a*	36.67
Baldo x 20	33.83 ab	30.00
Osmancık-97 x 16	33.64 ab	30.00
Osmancık-97 x 12	31.65 abc	26.67
Baldo x 16	31.65 abc	26.67
Baldo x 12	29.46 bc	23.33
Osmancık-97 x 8	29.46 bc	23.33
Osmancık-97 x 4	26.83 bcd	20.00
Baldo x 8	24.64 cd	16.67
Osmancık-97 x 2	22.01 d	13.33
Baldo x 4	10.28 e	3.33
Osmancık-97 x 0	5.74 e	0.00
Baldo x 0	5.74 e	0.00
Baldo x 2	5.74 e	0.00

LSD: 7.4502

*: Means indicated by the different letters on the same column it is not statistically similar ($p<0.05$)

^{t}: Arc Sinus (Square Root) transformed values.

^{o}: None transformed values.

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EFEKTI SLANOSTI VODE ZA NAVODNJAVANJE NA KLIJANJE SEMENA I RAST KLIJANACA PIRINČA

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Izvod

Za utvrđivanje uticaja saliniteta vode za navodnjavanje na klijanje semena i razvoj rasada dve sorte pirinča, pripremljene su vode za navodnjavanje sa niskim SAR (ispod 3) sa različitim nivoima saliniteta (kontrola [0,5], 2, 4, 8, 12, 16, i 20 dS m-1) iz različitih izvora slanosti (NaCl, MgS04 i CaCl2 soli). Prosečna klijavost je smanjena za cv. Baldo 20,19%, dok je za cv. Osmandžik - 97 bilo je 26,73%. Prosečna suva masa pojedinačnih sadnica cv. Baldo bilo je 0,2666 g, dok je za cv. Osmandžik-97 iznosila je 0,2569 g. Prosečna suva težina pojedinačne sadnice bila je 0,2940 g u kontroli. Paralelno sa povećanim nivoom saliniteta vode za navodnjavanje, smanjila se suva težina pojedinačnih sadnica. Salinitet vode za navodnjavanje nije uticao do 4 dS m-1 u smislu smanjenja klijavosti i suve težine pojedinačne sadnice pirinča, ali je počeo da utiče kada je nivo saliniteta povećan na 8 dS m-1 i bio je efikasniji u većim dozama. Takođe, cv. Osmancık-97 je bio osetljiviji na salinitet vode za navodnjavanje od cv. Baldo. U zaključku, ispostavlja se da voda za navodnjavanje koja se koristi pri gajenju pirinča ne bi trebalo da ima soli, jer je tolerancija biljke pirinča na slanost vode za navodnjavanje niska.

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