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Full Length Research Paper

Effects of salt stress on germination and early seedling growth of rice (*Oryza sativa*) cultivars in Iran

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An experiment was carried out in 2009, in order to investigate the effects of salt stress (S_1= 0.0, S_2 = 2.0, S_3 = 4.0, S_4= 6.0 and S_5= 8.0 ds.m^{-2} Nacl) on germination and seedling properties of three rice cultivars (Anbar, LD and Hamar). Experiment was arranged as split-plot based on randomized complete block design in three replications, with the salinity levels in main plots and rice cultivars in subplots. The results indicate that all traits were significantly ($P \leq 0.05$) affected by salt stress, where germination, plumule and radicle length and weight were decreased with increasing in salt concentration. The extent of these reductions was related with the variations in rice cultivar under different salt stress condition. By increasing NaCl concentration, seed germination delayed and decreased in all cultivars. Regarding the relationship between speed of germination and seed vigor, salt stress decreased seed vigor of rice cultivars LD a superior cultivar under all salt stress which can be suggested for cultivation under salinity condition.

Key words: Salinity, seed germination, seedling property, seed vigor.

INTRODUCTION

Crop plants usually exposed to multitude of natural biotic and abiotic stresses limit their growth and productivity. Salinity is one of the major abiotic constraints on crop production and food security and adversely impact the social-economic fabric in many developing countries, affecting about 95 million hectares worldwide (Ghassemi-Golezani et al., 2010). The UNEP (United Nations Environment Program) estimates that 20% of the agricultural land and 50% of the cropland in the world is salt-stressed (Yan, 2008).

Salt and osmotic stresses are responsible for both inhibition or delayed seed germination and seedling establishment (Almansouri et al., 2001). Germination failures on saline soils are often the results of high salt concentrations in the seed planting zone because of upward movement of soil solution and subsequent evaporation at the soil surface (Baybordi and Tabatabaei, 2009). These salts interfere with seed germination and seedling growth. The detrimental effect of salinity occurs because of osmotic stress (Bliss et al., 1986) and specific ion toxicity (Hampson and Simpson, 1990). The interaction of specific ion and osmotic effects induce a reduction in the number of seed germinated and retardation in the rate of germination. Thus, germination and seedling characteristics are the most viable criteria used for selecting salt tolerance in plants. Germination percentage and seedling growth are also most criteria for cultivar selection (Boubaker, 1996). It has been reported that under saline conditions, germination ability of seeds differ from one crop to another and even a significant variation is observed among the different varieties of the same crop (Maas and Hoffman, 1977; Hakim et al., 2010).

Germination and seedling development is very important for early establishment of plants under stress condition. Selecting cultivars for rapid and uniform germination under saline conditions can contribute towards early seedling establishment. Therefore, this study was aimed to evaluate the rice genotypes for salt stress by assessing germination speed and percentage, plumule and radicle length and weight.

MATERIALS AND METHODS

Seeds of three rice cultivars (*Oryza satica*) including Anbar, LD and

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Table 1. Effect of salinity (ds.m^{-2}) on germination percentage of different rice cultivars.

Cultivar	0.0	2.0	4.0	6.0	8.0
Anbar	100 a	94.0 a	90.0 a	37.0 b	24.5 a
LD	98.0 a	88.0 a	78.0 b	60.0 a	25.0 a
Hamar	98.0 a	86.0 a	76.0 b	18.0 b	4.0 b

Different letters in each column indicates significance at P ≤0.01.

Table 2. Effect of salinity (ds.m^{-2}) on germination speed of different rice cultivars.

Cultivar	0.0	2.0	4.0	6.0	8.0
Anbar	8.7 a	6.3 a	3.4 a	1.9 a	0.66 a
LD	7.1 b	5.9 a	2.9 ab	2.5 a	0.79 a
Hamar	7.0 b	4.6 b	2.2 b	0.83 b	0.15 b

Different letters in each column indicates significance at P ≤0.01.

Hamar were used in the study and were obtained from the Agricultural Research Center of Ahwaz. Before cultivation, seeds were sterilized in 1% sodium hypochlorite solution for three minutes, and then were rinsed with sterilized water and were air-dried.

The salt solutions were prepared based on the methods by (Rhoades et al., 1992) with electrical conductivity (EC) of 0 (as control), 2.0, 4.0, 6.0 and 8.0 ds.m^{-2}. These salt solutions were selected because the salt stress limiting crop growth in south west Iran was derived from saline water with maximum EC of 8 ds.m^{-2}.

To observe the influence of different NaCl concentration on seed germination and seedling growth of rice cultivars, a split plot experiment based on randomized complete block design (RCBD) with three replications was employed. The main plots were allocated to salinity levels, while the sub-plots were assigned for rice cultivars.

Twenty five seeds of each variety in four replications were placed in Petri dishes in four replications. In each Petri dish, 2 layers of filter paper were moistened with 10 ml of salinity treatments. The plates were placed into an incubator at 25 ± 2°C in darkness for 7 days. The papers were altered once after every 2 days to prevent salt accumulation (Rehman et al., 1996). The germinability was recorded on the seventh day after placing. The number of seeds germinated was expressed as percentage under each treatment.

Twenty five seeds each in four replications were sown in substratum for germination. The substratum was kept in a germinator maintained at 25 ± 2°C temperature for 7 days. Numbers of seedlings emerging daily were counted from the beginning of the experiment till germination was completed. Thereafter, germination speed was computed by using the following formula (ISTA, 2005):

$$G.S = n / d$$

Where, n is the number of seedlings emerging on day 'd' and d is the day after planting.

The data for the shoot and root length (mm), fresh weigh (mg) of plumule and radicle and dry weight (mg) of plumule and radicle were measured eighth days after germination (ISTA, 2005). Dry weights were measured after drying at 70°C for 48 h into an oven (ISTA, 2005).

The analysis of variance of the data and the comparison of the means on the base of the least significant difference (LSD) were carried out, using MSTATC software.

RESULTS

Percentage of germination

Percentage of germination was significantly affected by salt stress and cultivars (P≤0.01), where increasing in severity of salinity stress reduced percentage of germination (Table 1). While no significant difference was observed under control and lower salt condition (salinity level of 0.0 and 2.0 ds.m^{-2}), increasing in salinity to higher salt concentration had different effect on germination percentage of rice cultivars. The highest germination percentage under lower levels of salinity (from 0.0 to 4.0 ds.m^{-2}) was observed for Anbar, while LD cultivar had the highest germination under sever (6.0 and 8.0 ds.m^{-2}) salt stress (Table 1).

Speed of germination

A direct relationship was observed between speed of germination and increase of NaCl concentration up to 8.0 ds.m^{-2} (P≤0.01) (Table 2). When NaCl concentration increased to 8.0 ds.m^{-2}, speed of germination decreased in comparison to the control condition. It decreased to 92.5, 89.0 and 98% (from 0.0 to 8.0 ds.m^{-2} of salinity level) in Anbar, LD and Ahmar cultivars, respectively (Table 2). Maximum germination speed was recorded in LD cultivar. Based on speed of germination, the cultivars can be arranged in the following order: LD> Anbar> Hamar.

Seedling properties

Fresh weight of plumule and radical

Salinity had significant effect on plumule and radicle fresh

Table 3. Effect of salinity (ds.m^{-2}) on fresh weight (mg) of plumule and radicle of different rice cultivars.

Cultivar	Plumule					Radicle				
	0.0	2.0	4.0	6.0	8.0	0.0	2.0	4.0	6.0	8.0
Anbar	252 a	203 a	162 a	51 b	11 b	280 a	194 a	88 a	11 b	1.5 b
LD	250 a	188 a	144 a	88 a	48 a	199 b	140 a	79 a	28 a	11 a
Hamar	150 b	78 b	39 b	65 b	15 b	135 b	73 b	43 b	8 b	0.5 b

Different letters in each column indicates significance at P ≤0.01.

Table 4. Effect of salinity (ds.m^{-2}) on dry weight (mg) of plumule and radicle of different rice cultivars.

Cultivar	Plumule					Radicle				
	0.0	2.0	4.0	6.0	8.0	0.0	2.0	4.0	6.0	8.0
Anbar	40.0 a	28.0 a	17.0 a	1.0 b	0.2 b	19.0 b	16.0 b	12.0 a	0.5 b	0.2 b
LD	37.0 a	24.0 a	18.0 a	4.0 a	1.0 a	35.0 a	33.0 a	10.0 a	3.0 a	1.0 a
Hamar	12.0 b	4.0 b	1.5 b	0.4 b	0.2 b	22.0 b	11.0 b	1.5 b	0.4 b	0.2 b

Different letters in each column indicates significance at P ≤0.01.

Table 5. Effect of salinity (ds.m^{-2}) on length (mm) of plumule and radicle of different rice cultivars.

Cultivar	Plumule					Radicle				
	0.0	2.0	4.0	6.0	8.0	0.0	2.0	4.0	6.0	8.0
Anbar	15.0 a	10.0 a	5.0 b	4.0 b	2.6 b	15.0 b	13.0 b	6.0 b	3.0 b	4.0 a
LD	10.0 b	8.0 b	7.0 a	6.0 a	4.0 a	35.0 a	17.0 a	9.0 a	5.0 a	4.0 a
Hamar	14.0 a	10.0 a	5.0 b	4.0 b	2.8 b	34.0 a	17.0 a	4.0 b	3.0 b	3.2 a

Different letters in each column indicates significance at P ≤0.01.

weight (P ≤0.01), where increase in salt concentration reduced these traits (Table 3). Differences in fresh weight of plumule and radicle were significant in different cultivars under different salinity level (P ≤0.01). Anbar and LD cultivars had the highest value of fresh weight of plumule and radicle under control (0.0 ds.m^{-2}) treatment. However, LD was superior cultivar under sever salinity stress in terms of these traits (Table 3).

Dry weight of plumule and radicle

These traits decreased with increase in salinity level (Table 4). There were significant differences among wheat cultivars (P ≤0.01) at NaCl levels for dry weight of plumule and radicle. The highest dry weight of plumule and radicle was observed for LD cultivar. While Anbar cultivar showed the highest reduction (99.5%) of plumule dry weight (from 0.0 to 8.0 dsm^{-2} of salinity level), Hamar cultivar had the highest reduction (99.1%) of radicle dry weight (Table 4).

Length of plumule and radical

Increase in NaCl concentration resulted in reduction of plumule and radicle length (Table 5). Inspite of its lower length of plumule under lower salt concentration, LD cultivar had longer plumule under sever salt stress.

Regarding radicle growth, decreasing of this trait was observed under salt stress (Table 5). As was expected, the control and the highest concentration of NaCl had the longest and shortest radicle length, respectively. LD was the most susceptible cultivar to salt stress in terms of radicle length (Table 5).

DISCUSSION

Little researches have been performed regarding seed germination responses of Iranian rice cultivars to salinity stress. This research was carried out to observe the effects of salinity on germination and seedling growth of three rice cultivars. The maximum germination percentage under all salinity levels took place in LD cultivar. The results show that by increasing NaCl concentrations, germination in the cultivars delayed and decreased. Salt stress declined the germination in rice cultivars. It is also assumed that in addition to toxic effects of certain ions, higher concentration of salt reduces the water potential in the medium which hinders water absorption by germinating seeds and thus reduces germination (Jamil et al., 2006). Ayaz et al. (2000) also reported that decrease of germination percentage is related to reduction in water absorption into the seeds at imbibitions and seed turgescence stages. Ahmad and Gupta (1991) reported the susceptibility of seed germination to salt stress. Duan et al. (2007) worked on seed germination of *Suaeda salsa* under salt stress reported that the seeds germinated best in none-saline condition and germination percentage decreased as level of salinity increased which ranged from 68 to 91% depending on salt concentration. According to Abogadallah and Quick (2009), salinity may affect seed germination by decreasing the ease with which the seeds take up water because the activity and events normally associated with germination get either delayed and/ or proceed at a reduced rate.

The plumule and radicle growth are the most important parameters for salt stress because roots are in direct contact with soil and absorb water from soil and shoot supply it to the rest of the plant.

For this reason, plumule and radicle length provides an important clue to the response plants to salt stress (Jamil, 2004). The plumule and radicle length of seedlings grown in salt solutions also showed decline, indicating that the salt stress not only affected germination but also the growth of seedlings, which indicates that synthetic ability of seed, and thus, dry matter production of the seedlings, was affected. This is in conformity with the findings of Djanaguiraman et al. (2003) and Hakim et al. (2010) who reported that plumule and radicle length was conspicuously affected by salt.

The reduction in plumule and radicle development (their length and weight) may be due to toxic effects of the Nacl used as well as unbalanced nutrient uptake by the seedling. Demir and Arif (2003) reported that salinity may inhibit root and shoot elongation due to slowing down the water uptake by plant which supports the findings of the current study. Reduced seedling growth has also been reported by Huang and Reddman (1995) on barley, Foolad and Jones (1993) on tomato, Maghsoudi and Maghsoudi (2008) on wheat and Jennette et al. (2002) on phaseolus under salt stress condition.

Conclusion

In general, it can be concluded that under control condition (no salt stress), all three cultivars of rice had good growth. But they showed different response to higher levels of salinity. However, salinity reduced all germination properties of rice cultivars, especially seed vigor. These results indicate that genetic variation exists among rice cultivars in terms of early seedling growth rate under salt stress condition, where under sever salt stress, LD cultivar was the most tolerant cultivar which can be suggested for cultivation under salt stress condition.

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