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Effect of saline irrigation water on yield and yield components of rice (*Oryza sativa* L.)

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Salinity is an agricultural problem which decreases or restricts crop production worldwide. Saline water can be used in crop production if the yield reduction can be ameliorated. For this purpose, a greenhouse experiment was conducted in Rasht, North of Iran to assess the effects of water salinity levels at different growth stages of rice on yield and its components. Treatments included four levels of saline water (2, 4, 6 and 8 dS m^{-1}) and four growth stages (tillering, panicle initiation, panicle emergence and ripening) in a completely randomized block design. The results indicate that increased salinity significantly deceased grain yield, number of filled panicles, biomass and harvest index but effect of salinity on straw weight, 1000-grain weight, number of tillers and plant height was not significant. Increasing salinity decreased grain yield so that more increase in salinity showed more effect on yield decrease. The most grain yield, that is, 23.59 g/pot, was seen at control treatment irrigated by fresh water (at 1 dS m^{-1} salinity) and the least grain yield, that is, 12.59 g/pot, obtained at 8 dS m^{-1} salinity. Effect of different growth stages on all yield components except number of tillers was significant. Different growth stages showed different sensitivity to salinity. In fact, the primitive growth stages, that is, tillering and panicle initiation showed more sensitivity to salinity than final growth stages (panicle emergence and ripening). Therefore, irrigation with saline water at the early growth stages has more negative effect on yield and its components.

Key words: Yield, biomass, growth stages, saline soil, salt stress, water salinity.

INTRODUCTION

Salinity is an ever-present threat to crop yields, especially in countries where irrigation is an essential aid to agriculture (Flowers, 2004). In certain irrigation areas of northern Iran, inadequate rainfall and limited surface water supply have led to the use of saline groundwater for irrigation to sustain crop production and control the rising salinity in deep soils. Rice has been cultivated as a major crop for 11500 years, and it currently sustains nearly one-half of the world population. Rice is the principal source of food for more than one third of the world's population (Wu et al., 2004; Joseph et al., 2010). Use of saline water for irrigation requires careful planning and scheduling. Considering the annual variation in precipitation and evaporation, if saline water is used for irrigation, a moderate accumulation of salt in shallow soil is unavoidable (Yang-Ren et al., 2007). Drought and salinity are major factors limiting rice production in rainfed ecosystems, and they are increasing in importance in irrigated environments as a result of water shortages and poor maintenance of infrastructure (Salekdeh et al., 2002). Salt-affected soil is one of the most serious abiotic stress factors that reduce plant growth and development, therefore, leading to a decline in crop productivity, especially in glycophyte species (Hasegawa et al., 2000;

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Qadir et al., 2008; Cha-um and Kirdmanee, 2010). Salinity affects 19.5% of irrigated and 2.1% of dry land agriculture across the globe (FAO, 2000). In saline soil, there are many environmental factors which interact with salt contamination, such as soil pH (acidic or alkaline), water deficit and nutrient deficiency (James et al., 2005; Moradi and Ismail, 2007; Amirjani, 2011).

In the majority of plants, salt stress leads to changes in gene expression, leading to an increased synthesis of osmoprotectors and osmoregulators (Winicov, 1993; Teixeira and Pereira, 2007). Salinity imposes two constraints on plants: the hyperosmotic effect (especially short-term stress) due to lower soil water potential, and the hyperionic effect (especially long-term stress) due to direct toxicity of ions over metabolism and nutrition of plants (Verma and Mishra, 2005; Duan et al., 2008). Salt stress results from a number of detrimental processes including a toxic action of Na^+, the impairment of K^+ nutrition, a modification in the plant water status and secondary stresses such as oxidative stress linked to the production of reactive oxygen species (Zhu, 2002; Ndayiragije and Lutts, 2006). High concentrations of salts in soils impose both ionic and osmotic stresses on plants. The water deficit always has a negative effect, but many crop plants are primarily sensitive to Na^+ excess due to its adverse effects on cytosolic enzyme activities, photosynthesis and metabolism (Niu et al., 1995; Quintero et al., 2008). High concentrations of Na^+ disturb osmotic balance and results in "physiological drought", prevention (Turkan and Demiral, 2009).

Salt ion toxicity has numerous deleterious effects on plants such as denaturing cytosolic enzymes and facilitating the formation of reactive oxygen species that can damage membranes and proteins (Zhu, 2001; Munns, 2002; Maricle et al., 2007). The plant has to react physiologically at least to four major constraints for plant growth on saline substrates (Munns, 2002; Koyro, 2003; Rengasamy et al., 2003). Control mechanisms include: (a) growth rate and plant morphology, (b) resistance to water stress (reduction of the water potential), (c) regulation of CO_2 and H_2O-exchange by stomata and (d) avoidance of ion toxicity and nutrient imbalance (Koyro, 2006). Crop salt tolerance depends on numerous factors including soil drainage and on the method, frequency, quality and quantity of irrigation, which may favor or remove localized salt accumulations (Eynard et al., 2005). Reductions in growth rate occur because, in addition to toxicity by high salt concentration, the plants become unable to absorb enough water, because of the decrease in the osmotic component of soil water potential (Tester and Davenport, 2003). One of the key features of plant salt tolerance is the ability of plant cells to maintain optimal K^+/Na^+ ratio in the cytosol, when exposed to salt stress (Carden et al., 2003; Tester and Davenport, 2003; Haq et al., 2009). The earliest response of plant to salinity is a reduction in the rate of leaf surface expansion, followed by a cessation of expansion as the stress intensifies (Parida and Das, 2005). Rice has been classified as being salt-susceptible in both the vegetative and reproductive stages (Zeng et al., 2001; Moradi and Ismail, 2007), leading to a reduction in productivity of more than 50% when exposed to 6.65 dS m^{-1} electrical conductivity (EC) of salinity (Zeng and Shannon, 2000; Siringam et al., 2011).

Experimental evidence clearly indicates salinity as an important stressor for rice. Salt stress causes the reduction of rice yield, and sometimes-severe salt stress may even threaten survival (Joseph et al., 2010). Yield is a very complex character which comprise of many components and these yield components are related to final grain yield which are also severely affected by salinity (Shereen et al., 2005). Differences in yield response of rice to soil salinity can be related to climatic variations. In particular, a low relative humidity of the air during the growing season can enhance the yield losses per unit increase of salt concentration because the potential yield is higher in the dry season, as a consequence of longer and more intense solar radiation in the dry season than in the wet season (Asch et al., 2000; Eynard et al., 2005). Zeng and Shannon (2000) studied the effect of salinity on seedling growth and yield components of rice and stated that harvest indices were significantly reduced by salinity at 3.4 dS m^{-1} or higher. For better understanding, it is necessary that the salinity stress is started and stopped, to enable the quantification of damage and the differences in sensitivity over the cycle, by comparisons of salinity levels with the same duration of stress in different stages of rice growing (Zeng et al., 2001).

Symptoms of salt injury in rice are stunted growth, rolling of leaves, white leaf tips, white blotches in the laminae, drying of older leaves and poor root growth. The percentage of dead leaves is a good measure of salt injury (RRTC, 2002; El-Mouhamady et al., 2010). The objective of this study was to evaluate the grain yield of rice and its components as affected by different salinity levels during different growth stages.

MATERIALS AND METHODS

The experiment was carried out during 2010 growing season in greenhouse conditions at the Rice Research Institute, Rasht, Iran on the rice (*Oryza sativa* L.) to evaluate the effects of water salinity in different growth stages of rice on yield components. The experimental site is located at latitude 37° 12' N and longitude 49° 38' E and 32 m altitude. This experiment included three replications in the form of completely randomized block design and factorial that combinations of four levels of irrigation water salinity: 2, 4, 6 and 8 dS m^{-1}, and four growth stages: tillering, panicle initiation, panicle emergence and ripening stage. The cultivar used in this experiment was Hashemi. Dates of rice cultivation stages in the project were: date of transplanting, May 23, date of impelling salinity in tillering stage, June 6, date of impelling salinity in panicle initiation, June 17, date of impelling salinity in panicle emergence, June 27, date of impelling salinity in ripening stage, July 23. To conduct the experiment, three transplants provided in normal condition were cultivated in pots with diameter and deepness of 25 cm. Seven

Table 1. Analysis of variance for yield components as affected by salinity levels at different growth stages.

Sources of variation		Grain yield	Straw weight	1000-grain weight	Number of tillers	Number of filled panicles	Plant height	Biomass	Harvest index
	df	Mean square							
Replication	2	4.16^{ns}	11.88^{ns}	9.80^{ns}	66.06^{ns}	6.23^{ns}	177.25^{ns}	21.00^{ns}	26.46^{ns}
Growth stages (GS)	3	476.68**	272.70*	97.22**	35.24^{ns}	73.81**	917.39**	678.12**	1231.98**
Salinity levels (SL)	3	93.71**	62.16^{ns}	18.94^{ns}	17.08^{ns}	49.62**	172.17^{ns}	289.09*	220.06*
GS × SL	9	22.56^{ns}	31.67^{ns}	24.30^{ns}	24.4^{ns}	19.56^{ns}	61.89^{ns}	50.95^{ns}	131.30^{ns}
Error	3	15.81^{ns}	66.69^{ns}	12.6^{ns}	21.26^{ns}	9.55 ^{ns}	58.96^{ns}	75.26^{ns}	72.87^{ns}
CV%	-	24.86	27.08	15.72	19.26	18.80	5.90	18.80	25.11

* and ** respectively indicate significance at 5 and 1% levels; ns: nonsignificant.

days after cultivation; transplants were irrigated with usual water in all treatments. After that, performing treatments started by 5 cm height flooded irrigation. When each growth stage was finished, leaching was conducted with ordinary water and then irrigation with ordinary water was finished. Salinities for the considered treatments provided through mixing pure NaCl and $CaSO_4$ in ratio of 2:1. Basic water was required to provide salinities. 100 L of ordinary water (EC≤1 dS m^{-1}) was mixed with 425 g NaCl and 215 g $CaSO_4$ to provide basic water. 2 dS m^{-1} salinity was obtained through adding 10 L basic water in 90 L ordinary water. 4 dS m^{-1} salinity provided with 35 L basic water and 65 L ordinary water. For 6 dS m^{-1} salinity, 60 L basic water and 40 L ordinary water were mixed. Finally, to provide 8 dS m^{-1} salinity, 86 L basic water was mixed with 22 L ordinary water.

Fertilizing was conducted during 2 stages on the May 26 and June 24, in all pots. Fertilizer was a mixture of 6 kg urea (with 46% N), 8 kg potassium sulfate (with 50% K_2O) and 6 kg triple super phosphate (with 46% P_2O_5) which was added to treatments adequately. To prevent accumulation of salt, there was a leaching stage with ordinary water on the July 21. After ripeness, some agronomic characters such as grain yield, straw weight, 1000-grain weight, number of tillers, number of filled panicles, plant height, biomass and harvest index were measured based on 14% humidity. Standard analysis of variance techniques were used to assess the significance of treatment means. Each variable was subjected to analysis of variance (ANOVA) using the Statistical Analysis System (SAS) for each soil (SAS, 2001). Treatment (fraction) means were separated by Duncun's multiple range test.

RESULTS AND DISCUSSION

Grain yield

Data of variance analysis in Table 1 showed that effectiveness of different levels of salinity and also different stages of growth on grain yield was significant (P<0.01). Studies indicate that rice yields decrease with 12% for every unit (dS/m), increase in ECe (average root-zone EC of saturated soil extract) above 3.0 dS/m (Maas and Grattan, 1999; Grattan et al., 2002). Grattan et al. (2002) estimate a yield loss of 50% with an EC of around 7.4 dS m^{-1}. In some cases, however, the salinity of soil solution from 1.9 dS m^{-1} is already sufficient to significantly reduce the seedlings biomass and an EC of 3.4 dS m^{-1} compromises their survival (Zeng and Shannon, 2000; Fraga et al., 2010). Crop yield reductions in salt-affected soils result primarily from alteration of various metabolic processes in plants under salt stress (Eynard et al., 2005). With regard to the results of grain yield mean comparison (Table 2), control treatment irrigated by fresh water (at 1 dS m^{-1} salinity) had the most yields, that is, 23.59 g/pot. Increase in salinity decreased grain yield so that more increase in salinity showed more effect on yield decrease. Regarding grain yield, 2, 4, 6 and 8 dS m^{-1} salinities were placed after control treatment, respectively. The least grain yield, that is, 12.59 g/pot, belonged to treatment at 8 dS m^{-1} salinity. Results of yield mean comparison in different growth stages (Table 2) showed that the primitive growth stages, that is, tillering and panicle initiation were the most sensitive stages against salinity but final stages were more resistant.

Rice yields are often decreased with increasing salinity especially when experienced in the early development stages (Grattan et al., 2002; Menete et al., 2008). In germination level, rice is resistant against salinity but it is very sensitive at the beginning of seedling and reproductive growth and it is less sensitive in tillering and seed filling stages (Lafitte et al., 2004). The least grain yield (9.40 g/pot) was obtained in panicle initiation and after that tillering stage had grain yield of 11.81 g/pot; both stages placed in the same statistical class. Final growth stages, that is, panicle emergence and ripeness had the least sensitivity to salinity with grain yields of 21.77 and 20.98 g/pot respectively; therefore they were placed in the next statistical class. The use of non-saline water from the panicle initiation to the physiological maturity reduces salinity damage on rice yield (Fraga et al., 2010). Rice appears even more sensitive in

Table 2. Mean comparison of salinity levels at different growth stages affected on yield components of rice.

Parameter	Grain yield (g/pot)	Straw weight (g/pot)	1000-grain weight (g)	Number of tillers	Number of filled panicles	Plant height (cm)	Biomass (g/pot)	Harvest index
Salinity level (dS/m)								
2	18.71^{a}	32.18^{a}	21.85^{a}	25.67^{a}	19.08^{a}	132.50^{a}	50.88^{a}	37.27^{a}
4	17.79^{a}	32.02^{a}	22.87^{a}	23.75^{a}	16.88^{ab}	133.92^{a}	49.81^{a}	36.24^{a}
6	14.87^{ab}	27.77^{a}	24.34^{a}	23.00^{a}	14.42^{b}	129.17^{a}	42.64^{a}	34.66^{a}
8	12.59^{b}	28.64^{a}	21.55^{a}	23.33^{a}	15.37^{b}	125.42^{a}	41.23^{a}	27.77^{a}
Growth stage								
Tillering	11.81^{b}	24.28^{b}	21.32^{b}c	21.50^{a}	14.96^{b}c	122.67^{b}	36.09^{b}	31.13^{b}
Panicle initiation	9.40^{b}	35.48^{a}	19.35c	25.42^{a}	13.88c	122.75^{b}	44.88^{ab}	21.01c
Panicle emergence	21.77^{a}	28.80^{ab}	24.33^{ab}	24.75^{a}	19.33^{a}	136.83^{a}	50.57^{a}	43.68^{a}
Ripening	20.98^{a}	32.04^{ab}	25.62^{a}	24.08^{a}	17.58^{ab}	138.75^{a}	53.02^{a}	40.12^{ab}
Control	23.59	27.80	23.55	21.67	20.67	132.67	50.39	45.13

The same letters are not significantly different in each column ($p<0.05$) by Duncan's test.

the early developmental stages after germination. Rice is also sensitive at flowering, whereas at germination stage, it is considered exceptionally tolerant (Eynard et al., 2005). Survey in interaction of different levels of salinity and different growth stages (Figure 1) showed that the most grain yield (23.59 g/pot) belonged to control treatment and the least grain yield (3.84 g/pot) belonged to tillering stage at 8 dS m^{-1} salinity. Therefore, high salinity at the primitive growth stages had more effect on grain yield reduction, so that in comparison with control treatment, at 8 dS m^{-1} salinity in tillering stage, we had 83.7% reduction in grain yield. The yield level of rainfed lowland rice is, on average, around 2.3 t ha^{-1}, much lower than that of the irrigated systems of about 4.9 t ha^{-1}, which is due largely to many abiotic stresses such as drought, submergence, salinity, etc (Ali et al., 2006).

Higher salinity levels caused significant reduction in growth parameters like leaf area, leaf length and root and shoot dry weight (Ashrafuzzaman et al., 2002; Joseph et al., 2010).

Straw weight

With regard to the conclusions of variance analysis (Table 1), effectiveness of different growth stage on weight of straw was significant but different levels of salinity were not significant ($P<0.05$). In most of the cereals, seed production is less influenced by salinity than straw production. However, this is not true about rice, because this plant is sensitive against salinity in flowering and seeding stages. Reduction in shoot growth due to salinity is commonly expressed by a reduced leaf area and stunted shoots (Lauchli and Epstein, 1990).

Conclusions of straw weight mean comparison with salinity treatments (Table 2) showed that straw weight of control treatment was 27.80 g/pot. Different levels of salinity did not show any effectiveness on decrease of straw weight in comparison with control treatment; even straw weight was more at 2 and 4 dS m^{-1} salinities. However, there was not any significant difference between different levels of salinity. The results are in contradiction with Momayezi et al. (2009) who reported that dry matter weight of rice increased when salinity stress was raised to 7.5 dS m^{-1}, but above 7.5 dS m^{-1}, there was a decrease in dry matter weight. Also, Karami et al. (2010) showed that by increasing of salinity levels, mean weight of shoot dry matter, grain yield of paddy and stubble weight of rice decreased. A low level of Salinity with electrical conductivity (EC) of 5 to 6 dS m^{-1} can cause significant reduction in height, root growth and dry matter accumulation of susceptible rice lines (Ali et al., 2006). Different growth stages

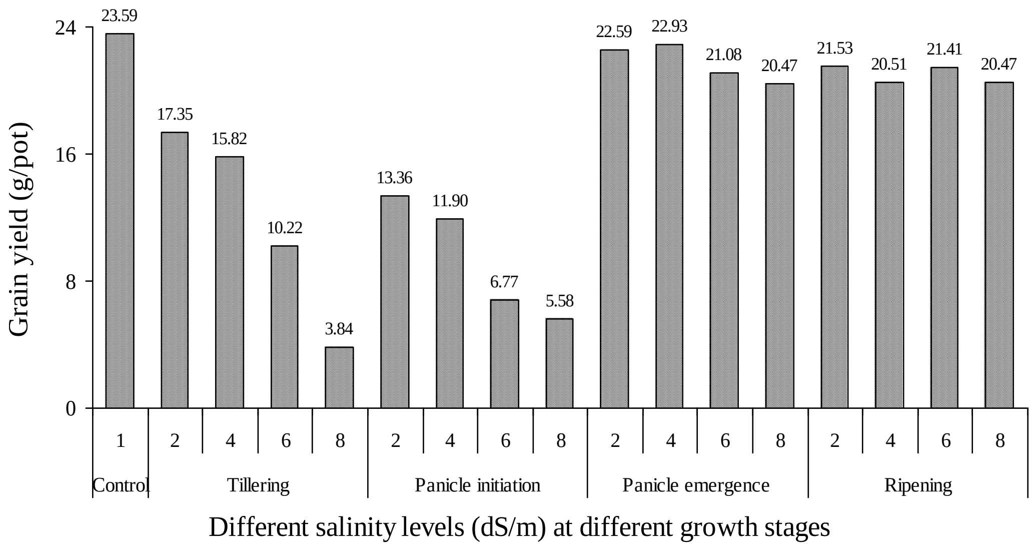

Figure 1. Effect of salinity levels at different growing stages on the grain yield.

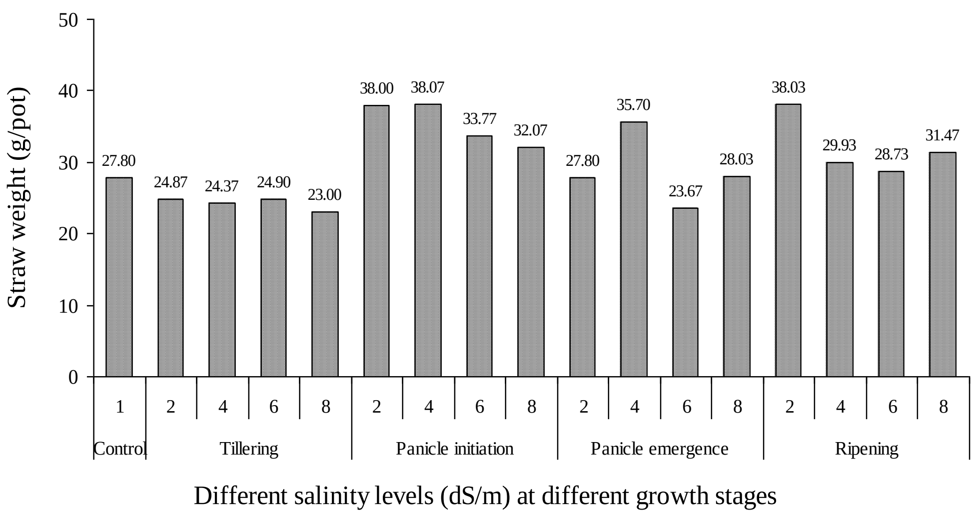

Figure 2. Effect of salinity levels at different growing stages on the straw weight.

showed different interactions against salinity. The least weight of straw (24.28 g/pot) was in tillering stage and most amount of it (35.48 g/pot) was in panicle initiation. Considering effect of salinity on straw weight, the most sensitive stage against salinity was tillering stage and after that were panicle emergence, ripeness and panicle initiation respectively. Therefore, considering effect of salinity on straw weight, reproductive stage of the plant, that is, panicle initiation is the most resistant stage against salinity but considering effect of salinity on grain yield, this stage is the most sensitive stage to salinity.

There have been numerous studies characterizing crop response to salinity at various developmental growth stages. During germination and emergence, tolerance is based on percent survival, while during the later developmental stages, tolerance is usually based on relative growth reductions (Lauchli and Grattan, 2007). Survey in reciprocal effect of different levels of salinity and growth stages (Figure 2) showed that the most straw weight (38.07 g/pot) was obtained in panicle initiation at 4 dS m^{-1} salinity and the least straw weight (23.00 g/pot) was obtained in tillering stage at 8 dS m^{-1} salinity.

1000-grain weight

Grain weight is an important yield component in cereal crops. Different growth stages showed different sensitivity to salinity (Table 1). Effect of different growth stages on 1000-grain weight was significant (P<0.01) but effect of

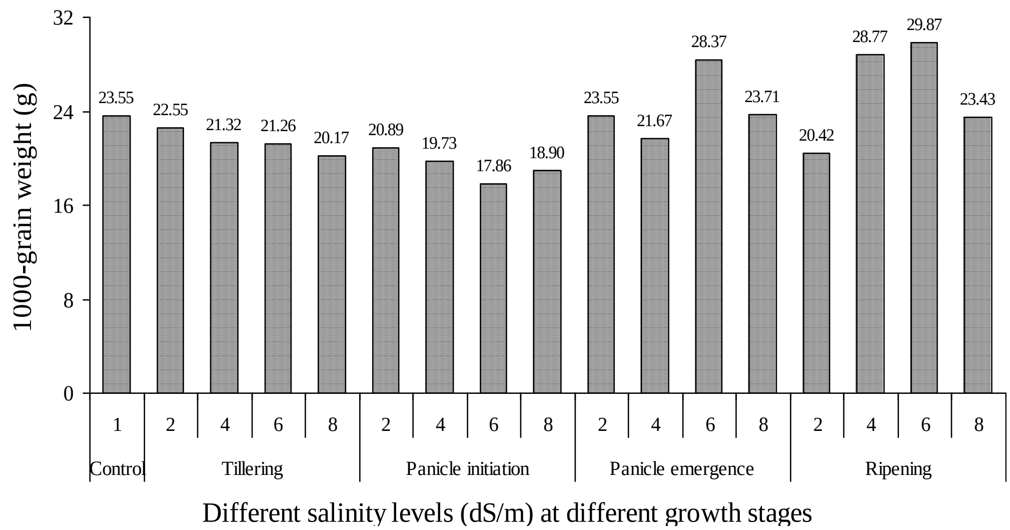

Figure 3. Effect of salinity levels at different growing stages on the 1000-grain weight.

different levels of salinity on 1000-grain weight was not significant (P<0.05). Similar results were reported by Mahmood et al. (2009) who studied the effect of salinity on rice and reported that grain weight of rice was least affected by salinity. Also, Karami et al. (2010) studied effect of salinity on rice and stated that by increasing of salinity levels, plant height, total number of tiller, number of fruitful tiller, number of full grain per cluster and kernel weight decreased. High influence of salinity on 1000-grain weight has been reported by many researchers (Asch and Wopereis, 2001; Beatriz et al., 2001). Asch and Wopereis (2001) reported that salinity in reproductive stage decrease 1000-grain weight. Results of mean comparison of 1000-grain weight with salinity treatments (Table 2) showed that 1000-grain weight was 23.55 g in control treatment. Irrigation at 2, 4 and 8 dS m^{-1} salinity decreased 1000-grain weight in comparison with control treatment but there was no significant difference between different levels of salinity and all of them placed in the same statistical class. Salinity decreases yield through decreasing 1000-grain weight. Salinity effects on grain weight were actually brought about by reduced hull size, as evidenced by its dimensions, and therefore took place already before flowering (Fabre et al., 2005). Results of mean comparison of 1000-grain weight in different growthstages (Table 2) showed that most weight of 1000 grains (25.62 g) was obtained in ripeness stage and it placed in class along with panicle emergence. 1000-grain weight was less in primitive growth stages, that is, tillering and panicle initiation than in final growth stages. Therefore, considering effect of salinity on 1000-grain weight, reproductive stages of the plant or primitive stages showed more sensitivity to salinity than final growth stages. After the salt-sensitive early-vegetative growth stage, the bulk of the research suggests that most crops become progressively more tolerant as the plants grow older (Lauchli and Epstein, 1990; Maas and Grattan, 1999; Lauchli and Grattan, 2007).

Survey in reciprocal effect of different salinities and different growth stages (Figure 3) showed that most 1000-grain weight (29.87 g) obtained in ripeness stage at6 dS m^{-1} and the least 1000-grain weight (17.86 g) obtained in panicle emergence at 6 dS m^{-1} salinity.

Biomass

Effect of different growth stages and also different levels of salinity was significant on biomass in levels of 1 and 5%, respectively (Table 1). With regard to the results of comparing biomass mean in salinity treatments (Table 2), it was showed that applying 4, 6 and 8 dS m^{-1} salinities decreased biomass in comparison with control treatment; in comparison with control treatment, reduction of biomass in these treatments was 1.1, 15.4, 18.2%, respectively. Most reduction in biomass showed at 4 to 6 dS m^{-1} salinities so that biomass reduction at 6 dS m^{-1} salinity was 14.4% in comparison with salinity of 4 dS m^{-1}. Yield components related to final grain yield were also severely affected by salinity (Zeng and Shannon, 2000). Different growth stages showed different sensi-tivity to salinity. The least and the most biomass were 36.09 and 53.02, which obtained in tillering and ripeness stages, respectively. In fact, the primitive growth stages showed more sensitivity to salinity than final growth stages. The most sensitive stage to salinity was tillering stage and after that were panicle initiation, panicle emergence and ripeness, respectively. Reduction in seedling growth and loss of stand due to salinity have been implicated as causative factors for yield losses in Iran rice production. The vegetative shoot biomass of rice, on the other hand, is often affected much less than reproductive growth (except for young

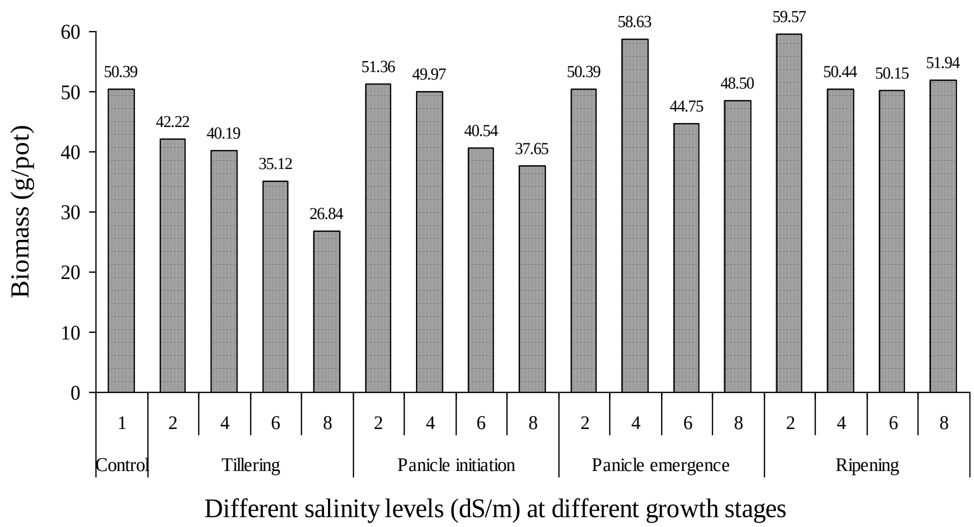

Figure 4. Effect of salinity levels at different growing stages on the biomass.

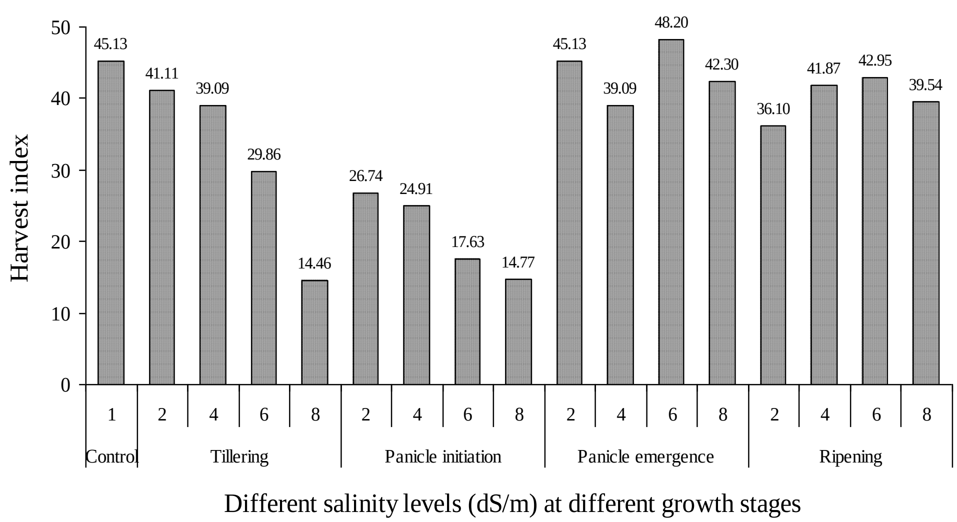

Figure 5. Effect of salinity levels at different growing stages on the harvest index.

seedlings) (Khatun and Flowers, 1995; Munns, 2002).

In a survey about reciprocal effect of different levels of salinity and growth stages (Figure 4), it was showed that the most biomass (59.57 g/pot) was obtained in ripeness stage at 2 dS m^{-1} salinity and the least biomass (26.84 g/pot) was obtained in tillering stage at 8 dS m^{-1} salinity.

Harvest index

With regard to the results of variance analysis (Table 1), effects of different levels of salinity and also growth stages on harvest index were significant at levels of 5 and 1%. High influence of salinity on harvest index and rice sensitivity to salinity of irrigating water was reported by many researches. Zeng and Shannon (2000) stated that harvest index was significantly decreased when salinity was at 3.40 dS m^{-1} and higher. The most harvest index (45.13) was shown in control treatment. Increase in salinity decreased harvest index so that harvest index at treatments of 2, 4, 6 and 8 dS m^{-1} salinity decreased 17.4, 19.7, 23.2 and 38.5%, respectively in comparison with control treatment. The most reduction in harvest index was shown at 8 dS m^{-1}. Different growth stages of rice had different reaction to salinity (Table 2). Harvest index in primitive stages of rice growth was less than final stages. The least harvest index (21.01) obtained in regeneration stage (panicle initiation) and the most harvest index (43.68) obtained in panicle emergence. Rice is reported as being salt-sensitive and displays the negative effects of salinity in its seedlings and reproductive stages (Zeng and Shannon, 2000; Zeng et al., 2003a; Cha-um et al., 2007).

In a survey on reciprocal effect of different levels of salinity and growth stages (Figure 5), it was shown that

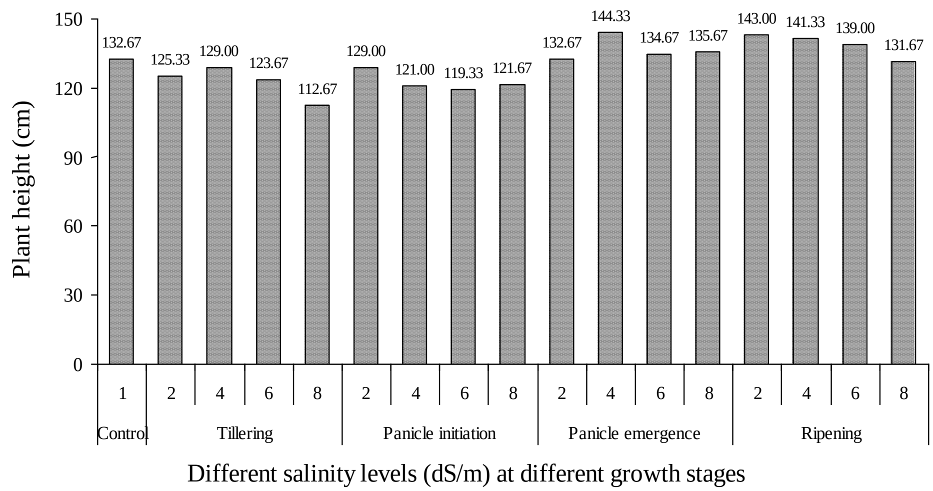

Figure 6. Effect of salinity levels at different growing stages on the plant height.

the most harvest index (48.20) was obtained in panicle emergence at 6 dS m^{-1} salinity and the least harvest index (14.46) was obtained in tillering stage at 8 dS m^{-1} salinity.

Plant height

With regard to the results of variance analysis (Table 1), effectiveness of different levels of salinity on plant height was not significant (P<0.05), but effectiveness of different growth stage on it was significant (P<0.01). Typical agronomic selection parameters for salinity tolerance are yield, survival, plant height, leaf area, leaf injury, relative growth rate and relative growth reduction (He and Cramer, 1992; Noble and Rogers, 1992; Franco et al., 1993; Munns, 1993; Ashraf and Harris, 2004). Plant height was 132.67 cm in control treatment. Applying 2 and 4 dS m^{-1} salinities did not have any effect on plant height in comparison with control treatment, but 6 and 8 dS m^{-1} salinities decreased plant height (Table 2). However, there were not any significant differences among different levels of salinity. The results are in contradiction with other researchers, so that Zeng and Shannon (2000) showed that all yield components investigated, except 1000-kernel weight, were significantly reduced at 6.1 dS m^{-1} and higher compared with the controls. None of the components was significantly reduced at 1.9 dS m^{-1}. Mahmood et al. (2009) reported that increasing salinity reduced the height of plant. The average height of 103.6, 91.9 and 82.7 cm was recorded from control, 5.2 and 10.5 dS m^{-1}, respectively. Effect of salinity on plant height was different in different rice growth stages; the highest plant appeared in ripeness stage and the shortest one appeared in tillering stage (Figure 6).

The primitive growth stages (tillering and panicle initiation) showed more sensitivity to salinity in comparison with the final stages. Therefore, the primitive growth stages and also high salinity in theses stages shortened the height of the plant.

Number of filled panicles

Effect of different levels of salinity and also growth stages on number of filled panicles was significant (P<0.01). Water and soil salinity decrease with number of panicles per square meter (Beatriz et al., 2001). With regard to the results of comparing means of number of filled panicles (Table 2), most number of filled panicles was 20.67 in control treatment. Increase in salinity decreased number of filled panicles so that 2, 4, 6 and 8 dS m^{-1} salinity is placed in the next ranks after control treatment, respectively. Salinity decreases yield through decreasing number of filled panicles. Different growth stages showed different sensitivity to salinity. Numbers of filled panicles in the primitive growth stages (tillering and panicle initiation) were less than filled panicles number in final growth stages (panicle emergence and ripeness). The least number of filled panicles, that is, 13.88, obtained in panicle initiation stage, so it is placed in the same statistical class with tillering stage. Therefore, regeneration stage, that is, panicle initiation, is the most sensitive stage to salinity and tillering, ripeness and panicle emergence placed respectively after that stage.

In a survey of reciprocal effect of different salinity levels and growth stages (Figure 7), it was showed that the least number of filled panicles (9.67) obtained in til-lering stage at 8 dS m^{-1} salinity and the most number of filled panicles (21.67) obtained in panicle emergence at 8 dS m^{-1} salinity.

Number of tillers

Effectiveness of different levels of salinity and also growth stages was not significant on number of tillers (P<0.05). The number of tillers per plant is an important yield parameter under salinity because it determines the

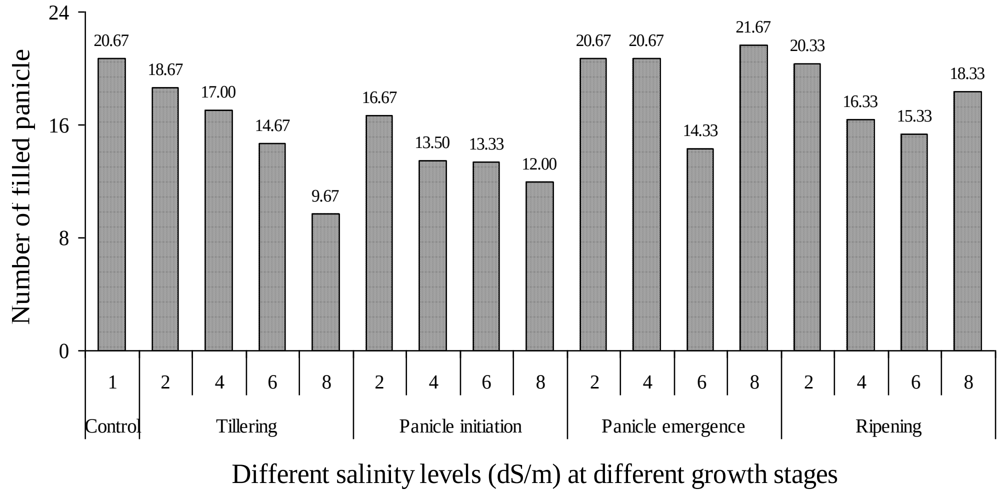

Figure 7. Effect of salinity levels at different growing stages on the number of filled panicles.

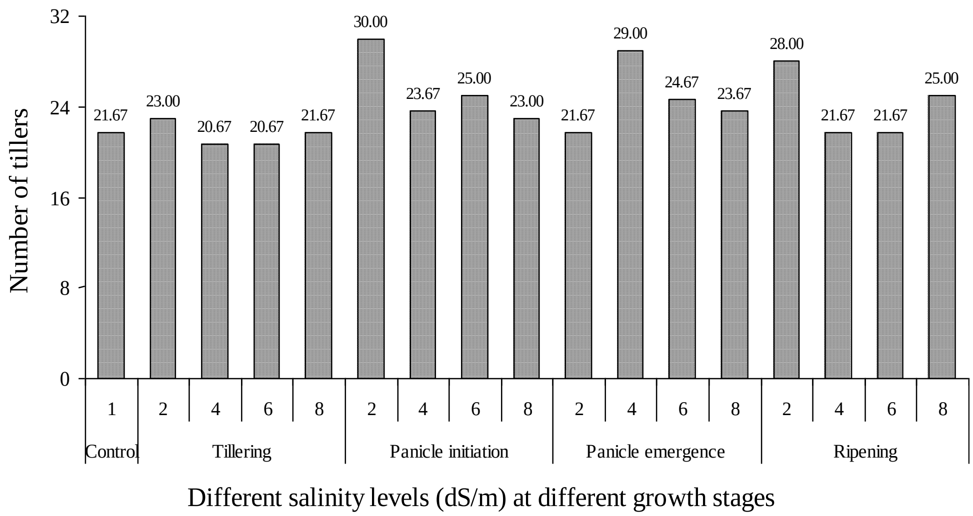

Figure 8. Effect of salinity levels at different growing stages on the number of tillers.

grain bearing panicles. Tiller number per plant depended on plant density, which was determined at vegetative stages (Wu et al., 1998; Zeng and Shannon, 2000). Zeng et al. (2003b) reported that salinity decreases number of tillers while imposing before panicle emergence. Therefore, salinity effectiveness on yield reduction is not due to reduction of tiller's decrease; increase in number of tillers increases yield. Yield of rice, in common with many other small-grain cereals is highly dependent upon the number of fertile tillers per plant. Generally, productive tillers emerge and develop early in the life cycle of the crop (Zeng et al., 2003a). Results of comparison in tiller's numbers' mean in salinity treatments (Table 2) showed that the least number of tillers (21.5) was obtained at 2 dS m^{-1} salinity. Different levels of salinity did not show any reduction on number of tillers so that all placed in the same statistical class. In addition, salinity has the same effect on number of tillers in different growth stages and all of them placed in the same statistical class. The results are in contradiction with other findings, so that Zeng and Shannon (2000) showed that tiller number per plant was significantly reduced at 4.5 dS m^{-1} and higher.

The ratio of spikelets per panicle/tillers per plant decreased with the increase of salinity. Haq et al. (2009) stated that salinity caused a significant reduction in number of tillers per plant compared to control treatment (non saline). El-Hendawy et al. (2005) stated that tiller number, leaf number and leaf area of wheat at vegetative stage decreased with increasing salinity. With regard to the interaction of different levels of salinity and growth stages (Figure 8), the most number of tillers (30) was obtained in panicle initiation at 2 dS m^{-1} salinity and the least number of tillers (20.67) was obtained in tillering stage at 4 and 6 dS m^{-1} salinities.

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