World Applied Sciences Journal 20 (7): 997-1007, 2012
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2012.20.07.157

Rice Growth and Yield Components Respond to Changes in Water Salinity Stress

[1]*Hassan Ebrahimi Rad,* [2]*Farshid Aref and* [3]*Mojtaba Rezaei*

[1]Department of Irrigation and Drainage, Firouzabad Branch, Islamic Azad University, Iran
[2]Department of Soil Science, Firouzabad Branch, Islamic Azad University, Iran
[3]Rice Research Institute, Rasht, Iran

Abstract: Salinity is one of the major environmental factors limiting growth and productivity of rice plants. This study was designed to analyze the effects of salinity on plant growth and yield components of rice at different growth stages. A greenhouse experiment was conducted in Rasht, North of Iran during 2010 growing season to determine the effect of different salinity levels on some yield components. Treatments were four levels of saline water with electrical conductivities at 2, 4, 6 and 8 dS m^{-1} and four growth stages: tillering, panicle initiation, panicle emergence and ripening. The experimental design was a complete block design with three replications. Results showed that increase in water salinity significantly decreased panicle length, number of filled grains per panicle and panicle weight but effect of different salinity levels on number of grains per panicle, number of empty grains per panicle, number of spikelets per panicle and panicle sterility was not significant. Control treatment irrigated by fresh water (at 1 dS m^{-1}) had the longest panicle length, most number of filled grains per panicle and most panicle weight and after that were salinities of 2, 4, 6 and 8 dS m^{-1}. In different growth stages of rice, all yield components were different; so that different growth stages had different sensitivity to salinity. Primary growth stages, it means tillering and panicle initiation showed more sensitivity to salinity than final growth stages (panicle emergence and ripening). Therefore, irrigation with saltwater at the final growth stages of rice, has less negative effect on the plant growth.

Key words: Salinity levels · Growth stages · Salt sensitive · Salt tolerance · Yield components

INTRODUCTION

In recent years, salinity concerns are increasing in rice (*Oryza sativa* L.) producing areas of Iran, where direct water-seeded system is dominant. Soil salinity is a major limitation to agricultural productivity in many parts of the world, especially in arid and semi-arid areas [1, 2]. Salinity inhibits plant growth by lowering soil water potential, causing ion toxicity and ionic imbalance within the tissues [1-3]. Ion concentration in leaves, an important parameter for assessing salt damage, depends on ion uptake, translocation and plant growth. Plant growth vigor, e.g. plant height or shoot biomass, was reported to have dilution effects on sodium accumulation in leaves of rice [4, 5]. Salinity appears to affect two plant processes: water relations and ionic relations. During initial exposure to salinity, plants experience water stress, which in turn reduces leaf expansion. During long-term exposure to salinity, plants experience ionic stress, which can lead to premature senescence of adult leaves and thus a reduction in the photosynthetic area available to support continued growth [6, 7]. Salinity also causes imbalance of the cellular ions, resulting in ion toxicity [8-11].

The negative response of plants to low water potential may prevail in saline soils, while single ion toxicity or nutritional unbalance maybe particularly severe in sodic soils [12]. A metabolic adaptation to low water potentials is increased cell osmotic pressure, which can be achieved through the accumulation in the cytoplasm of osmotic compatible solutes, such as sorbitol, mannitol and proline. Osmolytes in halophytes include uptake ions so that halophytes need to divert less energy to the production of osmotic compatible solutes [13, 14]. Most plants suffer salt injury at concentration equivalent of electrical conductivity of the soil saturation extract (EC_e) of 4 dS m^{-1} or higher. At such a level of salinity, plant growth is restricted even though enough water may be present in the root zone [15]. Plants under saline conditions show alterations in physiological processes. This involves diversion in photosynthesis, respiration

Corresponding Author: Farshid Aref, Department of Soil Science, Firouzabad Branch, Islamic Azad University, Iran.

and hormonal regulation, accumulation of solutes as well as various defense and adaptive mechanisms regulated at the molecular level including gene expression [16]. Crop yields start declining when pH of the soil solution exceeds 8.5 or ECe value goes above 4 dS m^{-1}. At higher ECe values the crop yields are reduced so drastically that crop cultivation is not economical without soil amendments [17]. In halophyte, or tolerant plants, there are several defense mechanisms, such as osmoregulation, ion homeostasis, antioxidant and hormonal systems, which help plants to stay alive and continue developing, prior to their reproductive stages [18-22]. Sugars are compatible solutes which accumulate in plant tissues that are exposed to abiotic stresses, such as, water deficit, extreme temperatures and salt stress. The accumulation of sugars may play an important role in the plant defensive mechanisms of osmoregulation and energy preservation [23-25]. Most of our crops are salt-sensitive. Consequently, salinity is an ever-present threat to agriculture, especially in areas where secondary salinisation has developed through irrigation or deforestation [26]. Different plant species under halophytic group through evolution have adapted to cope with salinity stress. Adaptive potential of the cereal crop to salt stress is very insignificant for their culture in the salt affected land [27].

To cope with the detrimental effects of salt stress, plants have evolved many biochemical and molecular mechanisms. Some of the biochemical strategies are (i) selective buildup or exclusion of salt ions, (ii) control of ion uptake by roots and transport into leaves, (iii) ion compartmentalization (iv) synthesis of compatible osmolytes, (v) alteration in photosynthetic pathway, (vi) changes in membrane structure, (vii) induction of antioxidative enzymes and (viii) stimulation of phytohormones [28, 29].

Rice fields often lack drainage facilities, or drain from one field to the other, thus building up salt levels during the season. Salt stress may, therefore, occur throughout the growing season and may coincide with susceptible growth stages of the rice crop [30, 31]. Rice has been identified as a salt susceptible and water deficit susceptible plant species, demonstrating negative effects, including, leaf necrosis, burning, stunting, flower sterility and yield loss [16, 19, 32, 33]. One important deleterious effect of elevated salinity is leaf senescence; young seedlings and plants at the flowering stage seem to be more sensitive than those at more mature growth stages [34]. Differential sensitivity during growth stages is one of the major issues in the management of saline water for irrigation [35]. Many reports of rice showed effects of salinity at early stage. Lutts *et al.* [34] reported that rice is more sensitive to salinity at the reproductive stage, but the reason is poorly known. Rice belongs to be very salt sensitive plant species during the early seedling stage, gains resistance during vegetative growth and again becomes sensitive during pollination and fertilization [16, 36].

Although rice is one of the most important food crops in the world, both economically and nutritionally, it ranks among the most sensitive to salinity [37, 38]. Salinity affects irrigated rice in various ways. Germination can fail or may be delayed, crop establishment, dry matter production and leaf area development may be decreased, seed set can decrease and sterility increase [31, 39]. It has been well documented that salinity affects rice seedling growth and decreases seedling establishment [32-34]. Salinity also affects rice grain yield and yield components such as spikelet number and tiller number [40]. A wide range of variation in stress responses due to salinity between and within rice varieties has been reported [5]. Asch and Wopereis [31] studied the effect of field-grown irrigated rice cultivars to varying levels of floodwater salinity and reported that floodwater electrical conductivity (EC) reduced germination rate for the most susceptible cultivar by as much as 50% and yield by 80% for the highest salinity level imposed. Also, Salinity strongly reduced spikelet number per panicle, 1000 grain weight and increased sterility, regardless of season and development stage. Ceuppens *et al.* [41] and Ceuppens and Wopereis [42] conducted thousands of soil salinity measurements in the delta to investigate the relation between cropping system and soil salinity. Their results illustrated that rice cropping reduced soil salinity, even when practised without drainage, due to the effect of the ponded water layer on the soil surface in irrigated paddy fields, blocking capillary rise of salts from the saline water table.

The objectives of this study were to determine the effects of salt levels and stress durations on some yield components of rice and reciprocal effectiveness of different level of salinity and growth stages on these factors.

MATERIALS AND METHODS

In order to study about the influence of irrigating water salinity in different growth stages of rice (*Oryza sativa* L.), Hashemi cultivar, a greenhouse experiment was conducted from May to July 2010 at the

Rice Research Institute, Rasht, Iran. The region altitude is 32 meter and its geographical coordinates is latitude 37° 12' N and longitude 49° 38' E. This study aimed to find the influence of salinity on rice growth and the best time to irrigate with saline water.

The experiments were laid out in a two factorial arrangement in a randomized complete block design and replicated three times. Treatments in this research had four levels of saline water: 2, 4, 6, 8 dS m^{-1} and it had four times to impel salinity: tillering stage (vegetative), panicle initiation (reproductive), from panicle emergence to the end of flowering stage (panicle emergence) and from the end of flowering stage to harvesting stage (ripening stage). In addition of the treatments of the project, a treatment with ordinary water (EC$\leq$1 dS m^{-1}) conducted in all growth stages.

Dates of rice cultivation stages in the considered 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, 3 transplants provided in normal condition were cultivated in pots with diameter and deepness of 25 cm. During 7 days after transplanting, all treatments were irrigated with ordinary water. Then, treatments of the project started by flooded irrigation in 5 cm height of water. After each growth stage, leaching with ordinary water was done and irrigation with ordinary water finished. All agricultural operations conducted commonly and equally in the region.

Considered salinities provided using pure NaCl and $CaSO_4$ in ratio of 2:1. To provide different salinities, basic water was provided firstly. 100 liters of ordinary water (EC$\leq$1 dS m^{-1}) was mixed with 425 g NaCl and 215 g $CaSO_4$ to provide basic water. To provide 2 dS m^{-1} salinity, 10 liters of basic water was mixed with 90 liters ordinary water. 4 dS m^{-1} salinity provided with 35 liters basic water and 65 liters ordinary water. 6 dS m^{-1} salinity provided with 60 liters basic water and 40 liters ordinary water. Finally, to provide 8 dS m□1 salinity, 86 liters basic water was mixed with 22 liters ordinary water.

Fertilizer was given to the treatments on the May 26 and June 24. Fertilizer was a mixed 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. There was a leaching stage with ordinary water to prevent accumulation of salt on the July 21. After crop is ripped, agricultural traits such as panicle length, number of grains per panicle, number of filled grains per panicle, number of empty grains per panicle, number of spikelets per panicle, panicle sterility and panicle weight were measured.

The obtained data of yield components were statistically analyzed using SAS computer software [43]. The Duncun's multiple range test was also performed to identify the homogenous sets of data.

RESULTS AND DISCUSSION

Panicle Length: Results in variance analysis (Table 1) showed that different growth stages had different sensitivity to salinity and effect of different growth stages and also effect of different salinities on panicle length was significant (P<0.01). High effectiveness of salinity on length of rice panicle has been reported by many researchers [44]. Soil salinity is a major environmental stress that adversely affects plant growth and metabolism. Salt salinity affects plant physiology through changes of the water and ionic status in the cells [7, 18, 45, 46].

With regard to the conclusions of panicle length comparison (Table 2), control treatment irrigated by fresh water (at 1 dS m^{-1}) had the longest panicle length, i.e. 24.95 cm; after which the longest panicle length belonged to treatments of 2, 4, 6 and 8 dS m^{-1}, respectively. These conclusions show that increase in water salinity decreases length of rice panicle. The least panicle length was 19.68 cm which obtained at 8 dS m^{-1} salinity which had 21% decrease in compare with control treatment. Panicle length, spikelet number per panicle and grain yield were significantly reduced after salt treatments [40, 47].

In different growth stages of rice, length of rice panicle was different; the longest panicle length belonged to ripening (23.54 cm) and the shortest length belonged to tillering stage (19.53 cm). Tillering and panicle initiation were the most sensitive stages to salinity, so that panicle length was 19.53 and 20.00 cm in tillering and panicle initiation respectively after which panicle emergence and ripening were placed with panicle length of 23.37 and 23.45 cm respectively. Considering effectiveness on panicle length, ripening stage showed the least sensitivity to salinity and after that were panicle emergence, panicle initiation and tillering stages, respectively. Generally, initial growth stages of rice, i.e. tillering and panicle initiation, had more sensitivity to salinity in compare with final growth stages, i.e. panicle emergence and ripening.

Asch and Wopereis [31] reported that among the particularly sensitive stages investigated here, the early reproductive stage, i.e. during 2 weeks around panicle initiation was more affected than flowering or seedling

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

Sources of variation	df	Panicle length	Number of grains per panicle	Number of filled grains per panicle	Number of empty grains per panicle	Number of spikelets per panicle	Panicle sterility	Panicle weight
	df				Mean squares			
Replication	2	2.19^{ns}	23.3^{ns}	154.99^{ns}	4.23^{ns}	0.63^{ns}	323.32^{ns}	0.15^{*}
Growth stages (GS)	3	54.93^{**}	610.82^{**}	1028.65^{**}	373.88^{**}	2.17^{*}	1211.83^{**}	0.98^{**}
Salinity levels (SL)	3	21.39^{**}	216.93^{ns}	350.90^{**}	17.46^{ns}	1.31^{ns}	154.77^{ns}	0.29^{**}
GS × SL	9	6.15^{ns}	73.65^{ns}	115.86^{ns}	38.95^{ns}	0.69^{ns}	416.94^{ns}	0.12^{*}
Error	3	2.80^{ns}	79.90^{ns}	74.53^{ns}	1456.00^{ns}	0.63^{ns}	253.46^{ns}	0.04^{ns}
CV%		7.74	19.25	25.01	50.11	14.72	82.10	21.93

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

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

	Panicle length	Number of grains per panicle	Number of filled grains per panicle	Number of empty grains per panicle	Number of spikelets per panicle	Panicle sterility	Panicle weight
Salinity levels (dS/m)							
2	22.65a	49.21a	37.77a	13.15a	5.61a	14.63a	0.96ab
4	22.34a	48.98a	39.73a	13.07a	5.62a	20.56a	1.10a
6	21.77a	47.39a	32.98ab	15.65a	5.44a	19.18a	1.03a
8	19.68a	40.17a	27.61b	13.74a	4.92a	23.47a	0.74b
Growth stages							
Tillering	19.53b	38.41c	29.34b	10.50b	4.98a	19.43a	0.74b
Panicle initiation	20.00b	42.64c	24.13b	21.91a	5.08a	33.59a	0.68b
Panicle emergence	23.37a	50.94ab	42.90a	9.70b	5.71a	10.99b	1.17a
Ripening	23.54a	53.76a	41.74a	13.49b	5.81a	13.84b	1.24a
Control	24.95	52.95	44.92	23.19	5.63	4.36	1.11

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

stage, particularly in the hot dry season. Vegetative growth in rice is less affected than grain production [16, 39].

In a comparison of reciprocal effectiveness of different level of salinity and growth stages, it was found that the highest panicle length was 24.95 cm in control treatment and the shortest panicle length was15.52 cm in tillering at 8 dS m^{-1} salinity.

Number of Grains per Panicle: With regard to the conclusion of variance analysis (Table 1), effect of different growth stages on number of grains per panicle was significant (P<0.01) but effect of different levels of salinity was not significant (p<0.05). High effectiveness of salinity on total grains of rice has been reported by many researchers [48]. Primary branches per panicle, panicle length, spikelets per panicle, number of filled spikelets and seed weight per panicle were significantly reduced by salinity [40].

Conclusions obtained by comparison of number of grains per panicle (Table 2) showed that control treatment by fresh water irrigation (at 1 dS m^{-1} salinity) had the most number of grains per panicle, i.e. 52.95 after which were treatments of 2, 4, 6 and 8 dS m^{-1} salinity; however there was not any significant difference between these treatments. The least number of grains per panicle was 40.17 in treatment at 8 dS m^{-1} salinity which has 24% decrease in compare with control treatment. Therefore, high salinity decreased total grains per panicle of rice. Number of grains per panicle was different in different growth stages of rice.

The most number of grains per panicle was 53.76 in ripening stage and the least average was 38.41 in tillering stage. Tillering stage was the most sensitive to salinity after which were panicle initiation (42.64), panicle emergence (50.94) and ripening (53.76). Therefore initial stages of plant growth had more sensitivity to salinity but the final stages were more resistant. Seedlings and the reproductive stages are very sensitive to salinity, while germination is relatively tolerant [11, 35, 49]. Zeng and Shannon [49] showed that salinity caused a significant reduction in seedling growth very soon after planting.

With regard to Fig. 1, which surveys reciprocal effect of different levels of salinity on growth stages, the most number of grains per panicle which was 56.42 belonged to ripening stage at 2 dS m^{-1} salinity and the least average which was 27.72 belonged to tillering stage at 8 dS m^{-1} salinity.

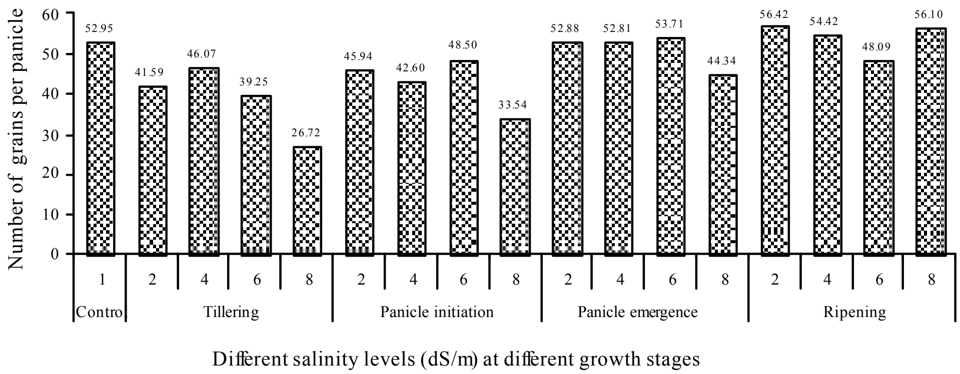

Fig. 1: Effect of salinity levels at different growing stages on the number of grains per panicle

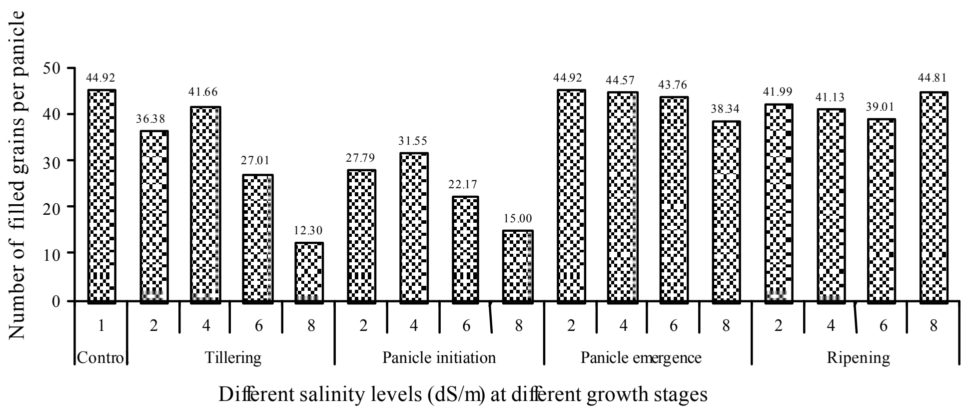

Fig. 2: Effect of salinity levels at different growing stages on the number of filled grains per panicle

Number of Filled Grains per Panicle: Conclusions of variance analysis of number of filled grains per panicle (Table 1) showed that different growth stages of rice showed different sensitivity to salinity. Effect of different growth stages and also different levels of salinity on number of filled grains per panicle was significant (P<0.01). Similar conclusions have been reported by other researchers [48]. Lots of regions in north of Iran are affected by salinity due to different reasons such as proximity to sea.

Conclusion of mean comparison of number of filled grains per panicle (Table 2) showed that control treatment irrigated by fresh water (1 dS m^{-1}) had the most number of filled grains per panicle (44.92) and then treatments of 2, 4 and 6 dS m^{-1} salinity placed in the same statistical class which respectively showed the following average amount of filled grains per panicle: 37.77, 39.73 and 32.98. The least number of filled grains per panicle amounted 27.61, was observed at 8 dS m^{-1} which showed 38% decrease in compare with control treatment. Therefore increased salinity resulted in decreased number of filled grains per panicle. In the other words, salinity decreases yield through decreasing amount of filled grains per panicle. Mahmood *et al.* [50] studied the effect of salinity levels on rice and stated that increased salinity significantly reduced the grain number per panicle. Over all mean grain number per panicle were 112.6, 61.7 and 52.0 in control, 5.2 dS m^{-1} and 10.5 dS m^{-1} salinity levels, respectively.

In different growth stages, number of filled grains per panicle was different. The most number of filled grains per panicle amounted 42.90, observed in panicle emergence and the least average amounted 24.13, was observed in panicle initiation. Tillering and panicle initiation were the most sensitive stages to salinity with number of filled grains per panicle of 29.34 and 24.13 respectively placing in class b. Panicle emergence and ripening stages with number of filled grains per panicle of 42.90 and 41.74 showed less sensitivity to salinity and placed in class a. Therefore, primary growth stages, i.e. tillering and panicle initiation showed more sensitivity to salinity in compare with final growth stages, i.e. panicle emergence and ripening. Most crop plants are salt tolerant at germination but salt sensitive during emergence and vegetative development [38]. The literature indicates that rice is sensitive to salinity, particularly during the seedling stage [51]. Of course, Khan *et al.* [44] reported that rice was more salt tolerant at germination than at other stages.

In survey on interaction effect of different levels of salinity and growth stages (Fig. 2), it was observed that the most number of filled grains per panicle amounted to 44.92 was belonged to control treatment and treatment of 2 dS m^{-1} salinity in panicle emergence stage and the least average was in tillering stage at 8 dS m^{-1} salinity amounted to 12.30.

Number of Empty Grains per Panicle: Effect of different growth stages on number of empty grains per panicle was significant ($P<0.01$) but effect of different levels of salinity was not significant ($P<0.05$) (Table 1). High effectiveness of salinity on number of grains has been reported by many researchers [48]. Salinity of water or soil increases emptiness in panicle [48].

With regard to the conclusions obtained through comparison of average mean of empty grains per panicle (Table 2), it was found that control treatment which irrigated by fresh water (at 1 dS m^{-1} salinity) had the most number of empty grains per panicle, i.e. 23.19, after which were treatments at 6, 8, 2 and 4 dS m^{-1} salinity, respectively. Therefore when salinity increased, number of empty grains per panicle deceased; however there was not any significant difference among different levels of salinities. So effectiveness of salinity on yield decrease is not included from increase in number of empty grains per panicle, because salinity decreased number of empty grains per panicle.

Different growth stages showed various sensitivities to salinity considering effectiveness of number of empty grains per panicle (Table 2). Panicle initiation stage showed the most emptiness, so located in class a so that its number of empty grains per panicle was 21.92. Ripening, tillering and panicle emergence stages all located in the next class (class b) so that their number of empty grains per panicle was as follow respectively: 13.49, 10.50 and 9.70. Therefore, considering effect on empty grains, the most sensitive stage on salinity was panicle initiation after which were ripening, tillering and panicle emergence stages, respectively. Reproductive development is considered less sensitive to salt stress than vegetative growth [38]. Salt stress in rice can reduce seedling emergence and when imposed at early vegetative stages, it reduces tillers and grain-bearing panicles leading to low yields [38].

Survey on reciprocal effect of different levels of salinities and growth stages (Fig. 3) has shown that the most number of empty grains per panicle was 27.77 occurred in panicle initiation at 6 dS m^{-1} salinity and the least amount was 6.76 occurred in tillering stage at 2 dS m^{-1} salinity.

Number of Spikelets per Panicle: Conclusions obtained through variance analysis (Table 1) showed that different growth stages had different sensitivity to salinity, considering effective on number of spikelets per panicle. Effective of different growth stages on number of spikelets per panicle was significant but effect of different levels of salinity was not significant ($P<0.05$). Yield sink capacity per plant was defined as the product of tiller number per plant, spikelet number per panicle, fertility and kernel weight [52]. High effectiveness of salinity on number of spikelets has been reported by many researchers [31]. In reproductive growth stage, salinity decreases filled spikelet. Regardless that which season it is, salinity decreases numbers of spikelet in any stages but the most sensitive stage is panicle initiation [31].

With regard to the conclusions of comparing number of spikelets per panicle (Table 2), control treatment had the most average (5.63) and after that were treatments of 4, 2, 6 and 8 dS m^{-1}, respectively. The least number of spikelets per panicle was 4.92 at 8 dS m^{-1} salinity; however there were not any significant differences between different levels of salinity. Zeng and Shannon [49] studied the effect of salinity on rice and reported that tiller number per plant and spikelet number per panicle were the most salinity-sensitive yield components, showing highly significant linear responses to salinity. These two yield components contributed the most variation to grain yield under salinity stress, based on stepwise analysis.

In different growth stages of rice, number of spikelets per panicle was different; the most number of spikelets per panicle was 5.81 in ripening stage and the least amount of it was 4.98 in tillering stage. Ripening stage showed the least sensitivity to salinity and after that were panicle emergence (5.71), panicle initiation (5.08) and tillering (4.98), respectively. Therefore primary growth stages were more sensitive to salinity considering effect on number of spikelets but final stages were more resistant. Seedling and reproductive stage tolerance are independent to each other [53]. Germination, active tillering and maturity are considered to be less sensitive to salinity than the seedling stage, early reproductive stage, pollination and seed formation [54].

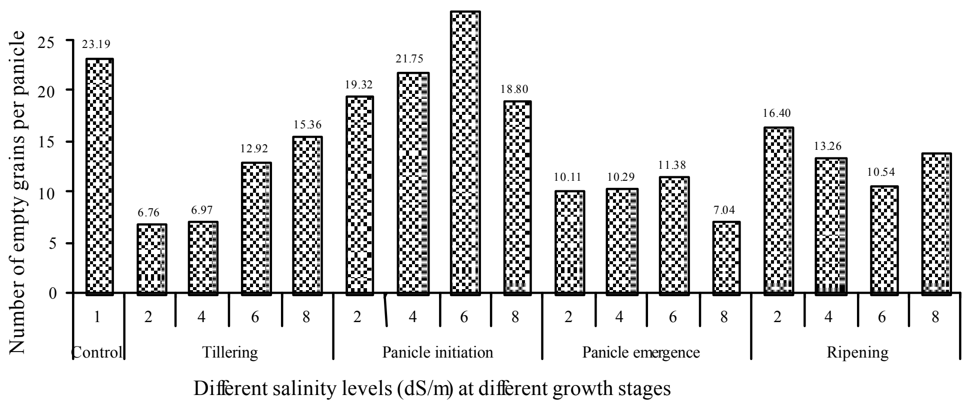

Fig. 3: Effect of salinity levels at different growing stages on the number of empty grains per panicle

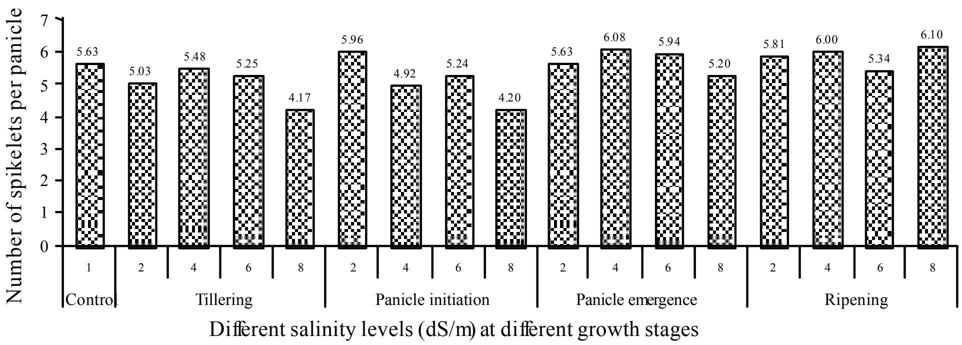

Fig. 4: Effect of salinity levels at different growing stages on the number of spikelets per panicle

In a survey on reciprocal effect of different salinity levels and growth stages (Fig. 4), the most number of spikelets per panicle was 6.10 in ripening stage at 8 dS m^{-1} salinity and the least average was 4.17 in tillering stage at 8 dS m^{-1} salinity.

Panicle Sterility: Conclusions of variance analysis (Table 1) showed that effective of different growth stages on sterility of panicle was significant ($P<0.01$) but effect of different levels of salinity was not significant ($P<0.05$). There is only one flower structure in each spikelet that will develop into a rice kernel after fertilization and filling [49]. High effectiveness of salinity on rice and sensitivity of rice to salinity has been reported by many researchers [31, 48]. Beatriz [48] reported that water or soil salinity increased panicle sterility. Salinity also delayed the emergence of panicle and flowering [40] and decreased seed set through reduced pollen viability [39, 40].

With regard to the conclusions of mean comparison of panicle sterility (Table 2), control treatment had the least panicle sterility (4.36). Increased salinity resulted in increased panicle sterility. Treatments of 8, 4, 6 and 2 dS m^{-1} salinity are ranged from the most to the least panicle sterility. Of course there was not any significant difference between salinity treatments. The most panicle sterility (23.47) was observed at 8 dS m^{-1} salinity which had 438% increase in compare with control treatment. Panicle sterility results in decreased yield; in the other words salinity decreases grain yield through increasing panicle sterility. The failure of seed set and the consequent decrease in yield may be due to a reduction in pollen viability [36]. Zeng and Shannon [49] showed a substantial reduction in filled grains at 6 dS/m and higher suggesting that high salinity was causing some sterility. Grain growth depends on current assimilation, remobilization of stored pre-anthesis assimilates and retranslocation of assimilates to grain after anthesis. During grain filling, leaf water potential plays an important role in assimilate production and partitioning [7, 55].

Survey on different rice growth stages showed that panicle sterility was different; the most amount of panicle sterility was 33.59 in panicle initiation and the least amount of it was 10.99 in panicle emergence. Therefore panicle initiation was the most sensitive stage to salinity and after that were tillering, ripening and panicle emergence stages, respectively. In fact primary stages, i.e. tillering and panicle initiation showed more sensitivity to salinity in compare with final growth stages. Salt tolerance

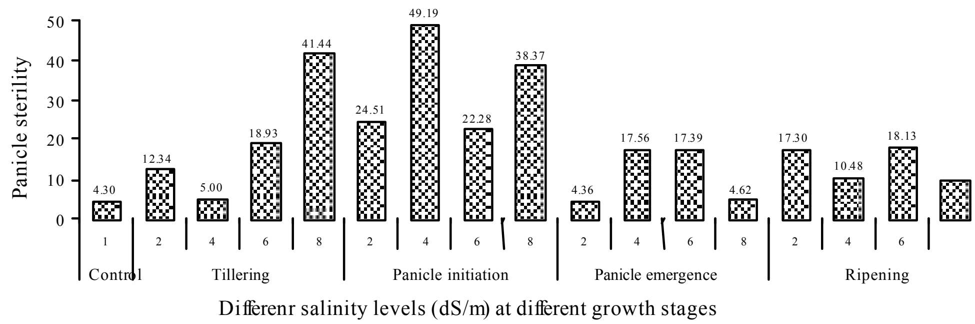

Fig. 5: Effect of salinity levels at different growing stages on the panicle sterility

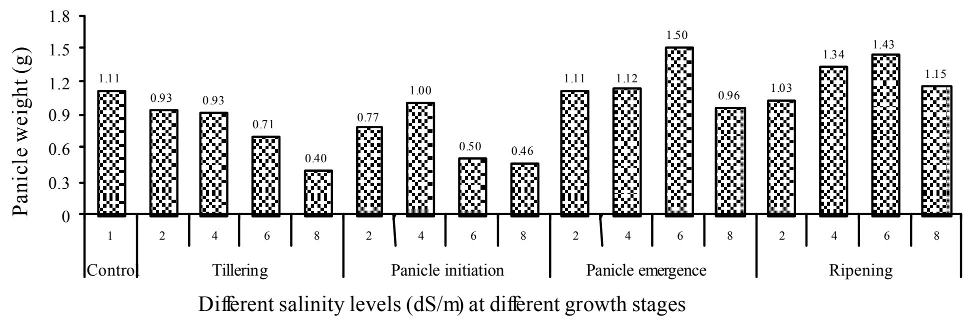

Fig. 6: Effect of salinity levels at different growing stages on the panicle weight

of crops may vary with their growth stage [56]. In general, cereal plants are the most sensitive to salinity during the vegetative and early reproductive stages and less sensitive during flowering and during the grain filling stage [57].

Survey on reciprocal effect of different levels of salinity and growth stages (Fig. 5) showed that the most panicle sterility was 49.19 in panicle initiation at 4 dS m^{-1} salinity and the least sterility was 4.30 in control treatment.

Panicle Weight: Conclusions of variance analysis (Table 1) showed that the effectiveness of different levels of salinity and also effectiveness of different growth stages on panicle weight was significant ($P<0.01$). Panicle weight, tiller numbers per plant and harvest index are important agronomic characters for the prediction of final yield in rice. These yield components are severely affected by salinity [40, 49]. High effectiveness of salinity on rice and sensitivity of rice to salinity of irrigation water have been reported by many researchers [33, 49]. While flowering, rice is very resistant to salinity but it is very sensitive at the beginning of seedling and reproductive stages; however it is less sensitive to salinity in tillering and seed filling [58].

With regard to the conclusions of mean comparison of panicle weight (Table 2), the most panicle weight was 1.11 g in control treatment. Salinity increase in water of irrigation decreased panicle weight so that the least panicle weight was 0.74 g at 8 dS m^{-1} salinity which had 33% decrease in compare with control treatment. Salinity decreases rice yield through decreasing panicle weight.

Effectiveness of different growth stages on panicle weight was different. The most panicle weight (1.24 g) was in ripening stage and the least amount (0.68 g) was in panicle initiation stage. Therefore panicle initiation showed the most sensitivity to salinity and after that were tillering, panicle emergence and ripening stages. In fact, the primary growth stages, it means tillering and panicle initiation showed more sensitivity to salinity than final growth stages (panicle emergence and ripening). The initial phase of growth reduction is due to an osmotic effect, is similar to the initial response to water stress and shows little genotypic differences. The second, slower effect is the result of salt toxicity in leaves [38].

In a survey on reciprocal effect of different levels of salinity and growth stages (Fig. 6), it was found that the most panicle weight was 1.50 g in panicle emergence at 6 dS m^{-1} salinity and the least amount was 0.40 g in tillering at 8 dS m^{-1} salinity.

CONCLUSION

Therefore, the use of saline water decreased panicle length, number of filled grains per panicle and panicle weight but had no effect on number of grains per panicle, number of empty grains per panicle, number of spikelets per panicle and panicle sterility. So saline water decreases yield components and thus grain yield decreases. Different growth stages of rice showed different sensitivity to salinity; so that irrigation with saline water at the early growth stages has more negative effect on yield and its components.

REFERENCES

1. Dubey, R.S., 1997. Photosynthesis in plants under stressful conditions, In Handbook of Photosynthesis, Ed. Pessarakli, M. Marcel Dekker, New York, pp: 859-875.
2. Kumar, R.G., K. Shah and R.S. Dubey, 2000. Salinity induced behavioural changes in malate dehydrogenase and glutamate dehydrogenase activities in rice seedlings of differing salt tolerance, Plant Sci., 156: 23-34.
3. Dubey, R.S., 1994. Protein synthesis by plants under stressful conditions, In Handbook of Plant and Crop Stress, Ed. Pessarakli, M. Marcel Dekker, New York, pp: 277-299.
4. Zeng, L., T.R. Kwon, X. Liu, C. Wilson, C.M. Grieve and G.B. Gregorio, 2004. Genetic diversity analyzed by microsatellite markers among rice (*Oryza sativa* L.) genotypes with different adaptations to saline soils, Plant Sci., 166: 1275-1285.
5. Yeo, A.R., M.E. Yeo, S.E. Flowers and T.J. Flowers, 1990. Screening of rice (*Oryza sativa* L.) genotypes for physiological characters contributing to salinity resistance and their relationship to overall performance, Theor. Appl. Genet. 79: 377-384.
6. Cramer, G.R. and R.S. Nowak, 1992. Supplemental manganese improves the relative growth, net assimilation and photosynthetic rates of salt-stressed barley, Physiol. Plant 84: 600-605.
7. Sultana, N., T. Ikeda and R. Itoh, 1999. Effect of NaCl salinity on photosynthesis and dry matter accumulation in developing rice grains, Environ. Exp. Bot., 42: 211-220.
8. Khan, M.H. and S.K. Panda, 2002. Induction of oxidative stress in roots of *Oryza sativa* L. in response to salt stress, Biol. Plant, 45: 625-627.
9. Demiral, T. and I. Turkan, 2005. Comparative lipid peroxidation, antioxidant defense systems and proline content in roots of two rice cultivars differing in salt tolerance, Environ. Exp. Bot., 53: 247-257.
10. Mandhania, S., S. Madan and V. Sawhney, 2006. Antioxidant defense mechanism under salt stress in wheat seedlings, Biol. Plant, 227: 227-231.
11. Darwish, E., C. Testerink, M. Khalil, O. El-Shihy and T. Munnik, 2009. Phospholipid signaling responses in salt-stressed rice leaves, Plant Cell Physiol., 50: 986-997.
12. Eynard, A., R. Lal and K. Wiebe, 2005. Crop response in salt-affected soils, J. Sustain. Agric., 27: 5-50.
13. Lambers, H., F. Stuart Chapin and T.L. Pons, 1998. Plant Physiological Ecology, Springer-Verlaz, New York, USA.
14. Lauchli, A. and E. Epstein, 1990. Plant responses to saline and sodic conditions, In Agricultural Salinity Assessment and Management, Ed. Tanji, K. K. ASCE Manuals and Reports No. 71, ASCE, New York, USA, pp: 1130-1137.
15. Mondal, M.K., S.I. Bhuiyan and D.T. Franco, 2001. Soil salinity reduction and prediction of salt dynamics in the coastal ricelands of Bangladesh, Agr. Water Manage., 47: 9-23.
16. Khan, M.A. and Z. Abdullah, 2003. Salinity-sodicity induced changes in reproductive physiology of rice (*Oryza sativa*) under dense soil conditions, Environ. Exp. Bot., 49: 145-157.
17. Sairam, R.K., K.V. Veerabhadra Rao and G.C. Srivastava, 2002. Differential response of wheat genotypes to long term salinity stress in relation to oxidative stress, antioxidant activity and osmolyte concentration, Plant Sci., 163: 1037-1046.
18. Hasegawa, P.M., R.A. Bressan, J.K. Zhu and H.J. Bohnert, 2000. Plant cellular and molecular responses to high salinity, Ann. Rev. Plant Physiol. Mol. Biol., 51: 463-499.
19. Nishimura, T., S. Cha-um, M. Takagaki and K. Ohyama, 2011. Survival percentage, photosynthetic abilities and growth characters of two indica rice (*Oryza sativa* L. spp. indica) cultivars in response to iso-osmotic stress, Span. J. Agric. Res., 9: 262-270.
20. Mahajan, S. and N. Tutejan, 2005. Cold, salinity and drought stresses: an overview, Arch. Biochem. Biophys. 444: 139-158.
21. Reddy, A.R., K.V. Chitanya, M. Vivekanandan, 2004. Drought-induced responses of photosynthesis and antioxidant metabolism in higher plants, J. Plant Physiol., 161: 1189-1202.

22. Wang, W., B. Vinocur and A. Altman, 2003. Plant responses to drought, salinity and extreme temperature: towards genetic engineering for stress tolerance, Planta, 218: 1-14.
23. Norwood, M., O. Toldi, A. Richter and P. Scott, 2003. Investigation into the ability of roots of the poikilohydric plant Craterostigma plantagenium to survive dehydration stress, J. Exp. Bot., 54: 2313-2321.
24. Morsy, M.R., L. Jouve, J.F. Hausman, L. Hoffmann and J.D. Stewart, 2007. Alteration of oxidative and carbohydrate metabolism under abiotic stress in two rice (*Oryza sativa* L.) genotypes contrasting in chilling tolerance, J. Plant Physiol., 164: 157-167.
25. Siringam, K., N. Juntawong, S. Cha-um and C. Kirdmanee, 2011. Salt stress induced ion accumulation, ion homeostasis, membrane injury and sugar contents in salt-sensitive rice (*Oryza sativa* L. spp. indica) roots under isoosmotic conditions, Afr. J. Biotech. 10: 1340-1346.
26. Flowers, T.J. and S.A. Flowers, 2005. Why does salinity pose such a difficult problem for plant breeders□, Agr. Water Manage., 78: 15-24.
27. Alamgir, A.N.M. and M. Yousuf Ali, 2006. Effects of NaCl salinity on leaf characters and physiological growth attributes of different genotypes of rice (*Oryza sativa* L.), Bangladesh J. Bot., 35: 99-107.
28. Parida, A.K. and A.B. Das, 2005. Salt tolerance and salinity effects on plants: a review, Ecotoxicol. Environ. Safe. 60: 324-349.
29. Turkan, I.T., 2009. Demiral, Recent developments in understanding salinity tolerance, Environ. Exp. Bot., 67: 2-9.
30. Joseph, B., D. Jini and S. Sujatha, 2010. Biological and physiological perspectives of specificity in abiotic salt stress response from various rice plants, Asian J. Agric. Sci., 2: 99-105.
31. Asch, F. and M.C.S. Wopereis, 2001. Responses of field-grown irrigated rice cultivars to varying levels of floodwater salinity in a semi-arid environment, Field Crop Res., 70: 127-137.
32. Shannon, M.C., J.D. Rhoades, J.H. Draper, S.C. Scardaci and M.D. Spyres, 1998. Assessment of salt tolerance in rice cultivars in response to salinity problems in California, Crop Sci., 38: 394-398.
33. Zeng, L., S.M. Lesch and C.M. Grieve, 2003. Rice growth and yield respond to changes in water depth and salinity stress, Agr. Water Manage., 59: 67-75.
34. Lutts, S., J.M. Kinet and J. Bouharmont, 1995. Changes in plant response to NaCl during development of rice (*Oryza sativa* L.) varieties differing in salinity resistance, J. Exp. Bot., 46: 1843-1852.
35. Zeng, L., M.C. Shannon and S.M. Lesch, 2001. Timing of salinity stress effects rice growth and yield components, Agr. Water Manage., 48: 191-206.
36. Abdullah, Z., M.A. Khan and T.J. Flowers, 2001. Causes of sterility in seed set in rice under salinity stress, J. Agron. Crop Sci., 187: 25-32.
37. Maas, E.V. and S.R. Grattan, 1999. Crop yields as affected by salinity, In Agricultural Drainage, Eds. Skaggs, R. W. and J. van Schilfgaarde, Agron Monogr 38, ASA, CSSA, SSA, Madison, WI, pp: 55-108.
38. Lauchli, A. and S.R. Grattan, 2007. Plant growth and development under salinity stress, In Advances in Molecular Breeding Toward Drought and Salt Tolerant Crops, Eds. Jenks, M. A. P. M. Hasegawa and S. M. Jain, Springer, Dordrecht, The Netherlands, pp: 1-32.
39. Khatun, S. and T.J. Flowers, 1995. Effects of salinity on seed set in rice, Plant Cell Environ. 18: 61-67.
40. Khatun, S., C.A. Rizzo and T.J. Flowers, 1995. Genotypic variation in the effect of salinity on fertility in rice, Plant Soil., 173: 239-250.
41. Ceuppens, J.M., C.S. Wopereis and K. Miezan, 1997. Soil salinization processes in rice irrigation schemes in the Senegal River Delta, Soil Sci. Soc. Am. J., 61: 1122-1130.
42. Ceuppens, J. and M.S.C. Wopereis, 1999. Impact of non-drained irrigated rice cropping on soil salinization in the Senegal River Delta, Geoderma, 92: 125-140.
43. SAS, 2001. SAS user's guide of release version 8. 2, SAS Inst. Cary, NC.
44. Khan, M.S.A., A. Hamid and M.A. Karim, 1997. Effect of sodium chloride on germination and seedling characters of different types of rice (*Oryza sativa* L.), J. Agron. Crop Sci., 179: 163-169.

45. Kashem, M.A., N. Sultana, T. Ikeda, H. Hori, T. Loboda and T. Mitsui, 2000. Alteration of starch-sucrose transition in germinating wheat seed under sodium chloride salinity, J. Plant Biol., 43: 121-127.
46. Sultana, N., T. Ikeda and M.A. Kashem, 2001. Effect of foliar spray of nutrient solutions on photosynthesis, dry matter accumulation and yield in seawater-stressed rice, Environ. Exp. Bot., 46: 129-140.
47. Cui, H., Y. Takeoka and T. Wada, 1995. Effect of sodium chloride on the panicle and spikelet morphogenesis in rice, Jpn. J. Crop Sci., 64: 593-600.
48. Beatriz, G., N. Piestun and N. Bernstein, 2001. Salinity-induced inhibition of leaf elongation in maize Is not mediated by changes in cell wall, Plant hysiol., 125: 1419-1428.
49. Zeng, L. and M.C. Shannon, 2000. Salinity effects on seedling growth and yield components of rice, Crop Sci., 40: 996-1003.
50. Mahmood, M., T. Latif and M.A. Khan, 2009. Effect of salinity on growth, yield and yield components in basmati rice germplasm, Pak. J. Bot., 41: 3033-3045.
51. Grattan, S.R., L. Zeng, M.C. Shannon and S.R. Roberts, 2002. Rice is more sensitive to salinity than previously thought, Calif. Agr., 56: 189-195.
52. Kato, T. and K. Takeda, 1996. Associations among characters related to yield sink capacity in spaced-planted rice, Crop Sci., 36: 1135-1139.
53. Moradi, F., A.M. Ismail, J. Egdane and G.B. Gregorio, 2003. Salinity tolerance of rice during reproductive development and association with tolerance at the seedling stage, Indian J. Plant Physiol., 8: 105-116.
54. Singh, R.K., K.N. Sing, B. Mishra, S.K. Sharma and N.K. Tyagi, 2004. Harnessing plant salt tolerance for overcoming sodicity constraints: An Indian Experience, Sustainable Management of Sodic Soils, Lucknow, India, pp: 81-120.
55. Bradford, K.J., 1994. Water stress and the water relations of seed development: a critical review, Crop Sci., 34: 1-11.
56. Mass, E.V. and C.M. Grieve, 1994. Tiller development in salt-stressed wheat, Crop Sci., 34: 1594-1603.
57. El-Hendawy, S.E., Y. Hu, G.M. Yakout, A.M. Awad, S.E. Hafiz and U. Schmidhalter, 2005. Evaluating salt tolerance of wheat genotypes using multiple parameters, Europ. J. Agron., 22: 243-253.
58. Lafitte, H., R.A. Ismail and J. Bennett, 2004. Abiotic stress tolerance in rice for asia progress and the future, International Rice Research Institute, DAPO 7777, Metro Manila, Philippines.