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Physiological characterization of rice under salinity stress during vegetative and reproductive stages

Farshid Aref[2]* and Hassan Ebrahimi Rad[1]

[1]Department of Soil Science, Firouzabad Branch, Islamic Azad University, Iran
[2*]Department of Irrigation and Drainage, Firouzabad Branch, Islamic Azad University, Iran
*farshidaref@yahoo.com; farshidaref@iauf.ac.ir

Abstract

Salinity is one of the major environmental factors limiting crop productivity. For this reason, a greenhouse experiment was conducted in Rasht, North of Iran during 2010 growing season to evaluate the salinity levels of irrigation water at different growth stages on the some physiological characterization of rice. Treatments were arranged in a randomized complete block design with two factors and three replications. Factor one included four levels of saline water (2, 4, 6, and 8 dS m^{-1}); factor two consisted of four growth stages (tillering, panicle initiation, panicle emergence and ripening). The results of this work showed that effect of different salinity levels on the all yield components except percentage of filled grains per panicle was not significant. Increase in salinity levels decreased this component. Effect of different growth stages on total number of empty grains per panicles, percentage of filled grains per panicle, number of unfilled panicles and percentage of ratio of number of unfilled panicles to tillers was significant but effect of different saline water on length of unfilled panicle and number of spikelets per unfilled panicle was insignificant. Resistance of final growth stages, i.e. panicle emergence and ripening stages against salinity was more than primary growth stages, i.e. tillering and panicle initiation. Therefore, in irrigation with saline water the final growth stages were important and irrigation with saline water should be applied at final growth stages.

Keywords: Saline water, Salt tolerance, Growth stages, Yield components, Panicle.

Introduction

The most important cereal crop in the world is rice, yielding one-third of the total carbohydrate source. Three billion people consider rice as their stable food, accounting for 50-80% of their daily calorie intake. Rice is a salt-sensitive monocot (Darwish *et al.,* 2009;Maas & Hoffman, 1997; Shereen *et al.,* 2005). Salinity is a limiting environmental factor for plant production, and is becoming more prevalent as the intensity of agriculture increases. Around the world, 100 million ha, or 5% of arable land, is adversely affected by high salt concentrations, which reduce crop growth and yield (Ghassemi *et al.,* 1995; Gunes *et al.,* 2007).

Salt and drought stresses have toxic effects on plants and lead to metabolic changes, like loss of chloroplast activity, decreased photosynthetic rate and increased photorespiration rate which then lead to an increased reactive oxygen species production (Winicov, 1993; Hoshida *et al.,* 2000; Teixeira & Pereira 2007). Soil salinity is considered as one of the major factors that reduce plant growth in many regions in the world. Soils in the arid and semiarid regions have excessive concentrations of soluble salts, which adversely affect plant growth. Two important limitations for crop production in arid and semi-arid regions are water shortage and poor quality. Different methods of water management are used to cope with water shortage (Sepaskhah & Yousofi-Falakdehi 2010). In salt-affected soil, there are many salt contaminants, especially NaCl which readily dissolves in water to yield the toxic ions, sodium ion (Na^+) and chloride ion (Cl^-). Also, the water available in the salt-contaminated soil is restricted, inducing osmotic stress (Castillo *et al.,* 2007; Pagter *et al.,* 2009; Siringam *et al.,* 2011). Salinity and sodicity can reduce plant growth and alter ionic relations by ionic and osmotic effects and oxidative stress (Borsani *et al.,* 2001; Eraslan *et al.,* 2007; Tarakcioglu & Inal 2002). Salinity inhibits plant growth in three principle ways: by ion toxicity (mainly of Na^+ and Cl^-), osmotic stress, and nutritional disruption (Caines & Shennan, 1999). Accumulation of toxic levels of NaCl in the cytoplasm must therefore be avoided. Plant adaptations to salinity include sequestration of salt ions in vacuoles and accumulation of 'compatible compounds', such as sugars, proline and glycinebetaine in the cytoplasm to balance the osmotic pressure (Hopkins, 1999; Jampeetong & Brix 2009). Dhanapackiam & Muhammad Ilyas (2010b) showed that NaCl had a greater effect on osmotic pressure.

Salt stress is one of the most important abiotic stresses that adversely affect natural productivity and causes significant crop loss worldwide. Almost every aspect of the plant's physiology and biochemistry is affected (Darwish *et al.,* 2009). The deleterious effects of salinity on plant growth are associated with (i) low osmotic potential of soil solution (water stress), (ii) nutritional imbalance, (iii) specific ion effect (salt stress), or (iv) a combination of these factors (Ashraf & Harris 2004; Marschner, 1995). All of these cause adverse pleiotropic effects on plant growth and development at physiological and biochemical levels and at the molecular level (Munns, 2002; Tester & Davenport 2003; Winicov, 1998). Many enzymatic activities of plants are adversely affected by high Na^+ concentration (Maathuis & Amtmann 1999). Salt tolerance is related to exclusion of Na^+ ion and distribution of almost uniform concentration of this ion in all leaves (Ashraf & O'Leary 1995; Haq *et al.,* 2009).

The phytotoxicity of NaCl is likely due to its ability to generate reactive oxygen species (ROS) represented predominantly by superoxide anion (O_2^-), hydrogen peroxide (H_2O_2), and hydroxyl radicals (OH) (Huang *et al.,* 2005; Tanou *et al.,* 2009; Tuteja, 2007; Verma & Mishra 2005).

In salt-susceptible (glycophytes) plant species, biochemical, physiological and morphological characteristics are negatively affected, leading to abnormal growth and development, and eventual plant death (Hasegawa *et al.,* 2000; Nishimura *et al.,* 2011; Parida & Das 2005). Most cultivated plants are glycophytes with limited compartmentation of NaCl. Glycophytes are not as effective as halophytes in ionic partitioning at the cellular level, but more effective at the plant and tissue level (Lauchli & Epstein 1990). The energy requirement for salt exclusion in glycophytes explains in part the stimulation of root respiration by soil salinity (salt respiration) and the loss of net synthesis of organic C (Eynard *et al.,* 2005; Lambers *et al.,* 1998). Concerning halophytic plants that are tolerant of sodium toxicity, osmotic stress might be the main reason of growth inhibition (Turkan & Demiral 2009). Upon prolonged exposure of a plant to NaCl, Na^+ is translocated from the roots to the transpiring leaves, where it can reach toxic levels. Many of the mechanisms that enable plants to tolerate high soil salinity are related to the maintenance of low Na^+ in shoots (Quintero *et al.,* 2008; Tester & Davenport 2003). There are several defense mechanisms against salt in salt-tolerant, or halophyte, species, such as osmoregulation (glycinebetaine and proline), antioxidants (enzymatic and nonenzymatic agents), ion homeostasis, and hormonal systems (Cha-um & Kirdmanee 2010; Hasegawa *et al.,* 2000; Singh *et al.,* 2008; Vaidynathan *et al.,* 2003). When salt is first encountered by a plant, there are two phases to its response. The first phase is a response to the changed water relations brought about by the lowering of the external water potential by the salt. These initial effects of salinity (phase 1, due to a change in water potential) are likely to be the same for cultivars of differing salt tolerance. Only as ions are accumulated over time (phase 2) do true difference in salt tolerance appear (Flowers & Flowers 2005; Munns, 1993). Sensitive cultivars accumulate ions more quickly than tolerant cultivars and this ion accumulation leads to leaf death and, progressively, death of the plant (Flowers & Flowers 2005; Munns, 2002). The reduced water potential at saline habitats creates in the plant a two-edged problem: a corresponding water and ion stress. The uptake and accumulation of Na^+ and Cl^- into the different plant organs is highly controlled (Hasegawa *et al.,* 2000; Marschner, 1995), salt-resistant species often possess special features to remove NaCl from the cytoplasm, e.g. by compartmentation in the vacuole (Koyro, 2006; Muhling & Lauchli 2002).

Crop yield response to soil salinity depends on soil water regime, which is modified by irrigation amounts, frequency and salinity of irrigation water (Eynard *et al.,* 2005). The use of saline water for irrigation requires study of long-term changes in soil salinity because under conditions of drought, soil may be in the state of salt accumulation, with soil salinity exceeding the tolerant limit for crops (Yang-Ren *et al.,* 2007). The high levels of salts in irrigation water can restrict or even scupper the rice cultivation, also by the presence of some elements in toxic concentrations (Fraga *et al.*, 2010; Silva, 2004). Rice is considered as moderately salt sensitive crop fort the newly reclaimed saline areas. Therefore, developing salinity tolerance rice varieties is a very important approach not only for increasing yields, but also for conquering saline soils (El-Mouhamady *et al.,* 2010). Dhanapackiam & Muhammad Ilyas (2010a) studied effect of salinity on chlorophyll and carbohydrate contents of sesbania grandiflora seedlings and showed significant positive influence of higher salinity concentrations on the parameters. Zeng & Shannon (2000) found that seedling growth was adversely affected at salinity levels as low as 1.9 dS m^{-1}, but this effect did not translate into a reduction in grain yield. Asch & Wopereis (2001) studied the effect of field-grown irrigated rice cultivars to varying levels of floodwater salinity and concluded that use of salinity tolerant cultivars, drainage if floodwater EC >2 dS m^{-1} at critical growth stages, and early sowing in the WS to avoid periods of low air humidity during the crop cycle, are ways to increase rice productivity.

Therefore, the objective of this work aims to investigate the effect of different salinity levels on some physiological characterization of rice.

Materials and methods

To determine salt sensitivity for rice (*Oryza sativa* L.) at various growth stages, a factorial experiment arranged as randomized complete block design with three replications was performed at the Rice Research Institute in Rasht, North of Iran during May to July 2010. The site is situated at latitude 37°12' N and longitude 49°38' E and 32m altitude. Hashemi, as a widely cultivated variety in Guilan province, was used. Two factors tested in this experiment. The first factor was different levels of salinity in irrigation water (including four levels of salinity: 2, 4, 6 and 8 dSm^{-1}) and the second factor was the time of impelling salinity in different levels of rice growth stages (including tillering, panicle initiation, panicle emergence and ripening stages).

The experiment conducted in greenhouse condition (pot under shelter) in order to prevent from effecting unwanted factors and to have a better control on condition. 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. 3 transplants which were grown

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

Sources of variation		Length of unfilled panicle	Number of spikelets per unfilled panicle	Total number of empty grains per panicles	Percentage of filled grains per panicle	Number of unfilled panicles	Percentage of ratio of number of unfilled panicles to tillers
	df	Mean squares					
Replication (R)	2	11.79 ns	5.61 ns	19659.77 ns	238.19 ns	25.33 ns	313.01 ns
Growth stages (GS)	3	17.79 ns	2.07 ns	148278.58**	1669.81**	45.47*	618.64*
Salinity levels (SL)	3	15.19 ns	3.41 ns	4879.19 ns	557.72**	2.47 ns	110.95 ns
GS × SL	9	11.40 ns	7.09 ns	21106.81 ns	375.20**	17.27 ns	270.31 ns
Error	3	6.83 ns	5.41 ns	27329.19 ns	122.19 ns	12.33 ns	168.15 ns
CV%		16.28	57.79	57.24	15.78	86.89	79.67

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

	Length of unfilled panicle	Number of spikelets per unfilled panicle	Total number of empty grains per panicles	Percentage of filled grains per panicle	Number of unfilled panicles	Percentage of ratio of number of unfilled panicles to tillers
Salinity levels (dS/m)						
2	15.94a	4.72a	313.58a	74.22ab	3.50a	12.35a
4	16.23a	3.74a	270.75a	77.15a	4.42a	16.33a
6	17.40a	4.14a	296.75a	66.47ab	3.83a	16.70a
8	14.66a	3.49a	274.08a	62.36b	4.42a	19.95a
Growth stages						
Tillering	14.77a	3.60a	201.33b	69.57a	3.50ab	16.06ab
Panicle initiation	15.27a	4.59a	443.58a	53.82b	6.92a	26.53a
Panicle emergence	17.19a	3.89a	215.17b	81.09a	2.67b	10.58b
Ripening	17.01a	4.01a	295.08ab	75.72a	3.08ab	12.16ab
Control	20.13	4.75	229.00	80.87	1.00	5.40

in ordinary condition cultivated in pots with diameter and deepness of 25cm filled with agricultural soil. 7 days later, plants were irrigated with ordinary water. Flooded irrigation with 5cm height was the first stage to perform treatments. After each growth stage, leaching with ordinary water was done and irrigation with ordinary water finished. All agricultural stages conducted in a normal way and in the same way based on what was usual in the region.

Required salinities in irrigation water obtained by pure NaCl and $CaSO_4$ with a ratio of 2:1 and pots irrigated with them. Basic water requires to provide different levels of salinity, therefore 425 gr NaCl and 215 gr $CaSO_4$ was added to 100 liters ordinary water (EC≤1 dS m^{-1}). 2 dS m^{-1} salinity obtained through adding 10 liters basic water in 90 liters ordinary water. 4 dS m^{-1} salinity obtained by adding 35 liters basic water in 65 liters ordinary water. For 6 dS m^{-1} salinity 60 liters basic water and 40 liters ordinary water were mixed. Also 8 dS m^{-1} salinity concluded from 86 liters basic water and 22 liters ordinary water.

All treatments fertilized for 2 times: first on the May 26, and second time on the June 24. 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) were mixed and added to the treatments adequately. Leaching conducted to prevent accumulation of salt on the July 21. After ripeness, some physiological characterization such as length of unfilled panicle, number of spikelets per unfilled panicle, total number of empty grains per panicles, percentage of filled grains per panicle, number of unfilled panicles and percentage of ratio of number of unfilled panicles to tillers were measured.

Analysis of variance (ANOVA) was performed on all experimental data and means were compared using the Duncan's multiple range test with SAS software (SAS, 2001). All data were checked for normality before being analysed. The significance level was P<0.05.

Results and discussion

Length of unfilled panicle

Effect of different growth stages and also different levels of salinity on length of unfilled panicle (Table 1) was not significant (P<0.05). High effectiveness of salinity on length of unfilled panicles of rice has been reported by many researchers (Khan *et al.,* 1997).

Conclusions of mean comparison of length of unfilled panicle (Table 2) showed that control treatment with fresh water irrigation (1 dSm^{-1}) had the longest length of unfilled panicle (20.13 cm). Increasing salinity resulted in shorter length of unfilled panicle in compare with control treatment but there were not any significant differences between different levels of salinity. The shortest length of unfilled panicle (14.66 cm) was at 8 dSm^{-1}; this treatment showed 27% decrease in compare with control treatment.

Effect of different growth stages of rice on length of unfilled panicle was different. The most length of unfilled panicle (17.19) observed in panicle emergence and the least amount (14.77) observed in tillering stage. Of course there were not any significant differences between different growth stages. Momayezi *et al.* (2009) stated that salt composition can affect rice growth at germination and early seedling stages.

In a survey of interaction effect of different levels of salinity and different growth stages it was found that the most length of unfilled panicle (21.72 cm) was in ripening at 6 dSm^{-1} salinity and its least amount (13.17) was in tillering stage at 2 dSm^{-1} salinity.

Number of spikelets per unfilled panicle

Conclusions of variance analysis (Table 1) showed that effect of different growth stages and also different levels of salinity on number of spikelets per unfilled panicle was not significant (P<0.05). The loss of potential spikelets are due to the degeneration of primary and secondary branches and flower primordial (Zeng & Shannon 2000). High effectiveness of salinity on number of spikelets has been reported by many researchers (Zeng *et al.,* 2003). Number of spikelets affects by salinity (Zeng *et al.,* 2003).

With regard to the conclusions of mean comparison of number of spikelets per unfilled panicle (Table 2), the most number of spikelets per unfilled panicle (4.75) observed in control treatment. Increasing salinity decreased number of spikelets per unfilled panicle, so that at 8 dSm^{-1} salinity spikelets per unfilled panicle reduced up to 26% in compare with control treatment. Also the least number of spikelets per unfilled panicle was 3.49 at 8 dSm^{-1}. Although different levels of salinity decreased spikelets per unfilled panicle, but there were not any significant differences between these levels and all levels placed in the same statistical class.

In different growth stages of rice, number of spikelets per unfilled panicle was different. The most number of spikelets per unfilled panicle (4.59) was in panicle initiation and the least average number (3.60) was in tillering stage. Increasing unfilled panicle decreases rice yield; with regard to this matter that there were not any significant differences between different levels of salinity and growth stages, therefore, effect of salinity on yield reduction is less affected by number of spikelets per unfilled panicle.

Survey on interaction effect of different salinity and growth stages showed that the most number of spikelets per unfilled panicle (8.33) observed in panicle initiation at 2 dSm^{-1} and the least average number (2.83) observed in panicle initiation at 4 dSm^{-1} salinity.

Total number of empty grains per panicles

With regard to the conclusions of variance analysis (Table 1), different growth stage of rice had different sensitivity to salinity. Effect of different growth stages on total number of empty grains per panicles was significant (P<0.01) but effect of different levels of salinity on it was not significant (P<0.05). High effectiveness of salinity on number of empty grains has been reported by many researchers. Increased number of incompletely filled grains might be a result of assimilate shortage during grain filling, brought about by early leaf senescence caused in this case by salinity (Fabre *et al.*, 2005; Murchie *et al.,* 2002; Sheehy *et al.,* 2001; Zaibunnisa *et al.,* 2002; Zeng & Shannon 2000). Frequently, many spikelets on the lower primary branches do not produce a mature grain, and this loss of potential grains may adversely affect the grain number and yield. This failure in spikelet development has been attributed to a limitation in carbohydrate supply to the developing panicle (Abdullah *et al.,* 2001).

Conclusions of mean comparison of total number of empty grains per panicles (Table 2) showed that control treatment (1 dSm^{-1}) had the least total number of empty grains per panicles (229.00). Treatments of 2, 4, 6 and 8 dSm^{-1} had total number of empty grains per panicles respectively as follow: 313.58, 270.75, 296.75, and 274.08 which all placed in the same statistical class. These salinity level increased total number of empty grains per panicles in compare with control treatment (37, 18, 29 and 20% increase, respectively). Increasing empty grain decreases rice yield. Therefore increased salinity resulted in increased total number of empty grains per panicles and finally it decreases yield. Sterility and reduction in seed set were primarily due to reduced translocation of soluble carbohydrates to primary and secondary spikelets, accumulation of more sodium and less potassium in all floral parts and inhibition of the specific activity of starch synthetase in developing rice grains, thus reducing seed set (Abdullah *et al.,* 2001).

Different growth stage showed different reaction to total number of empty grains per panicles. The most total number of empty grains per panicles (443.58) observed in panicle initiation and its least amount (201.33) observed in tillering stage. Panicle initiation is the most sensitive stage to salinity and after that were ripening, panicle emergence and tillering stages. An increased empty grain is an important factor to decrease yield. So in panicle initiation which numbers of empty grain increased, yield increased too. At germination and during maturation rice exhibits its highest tolerance. However, salt stress in all developmental stages of rice can contribute to yield losses (El-Saidi, 1997). Rice has previously been reported to be salt-sensitive at the seedling and reproductive stages, leading to a reduction in crop productivity (Moradi & Ismail, 2007; Zeng & Shannon, 2000; Zeng *et al.,* 2001).

In survey on reciprocal effect of different levels of salinity and growth stages (Fig.1) the most total number of empty grains per panicles (533.67) observed in panicle initiation at 6 dS m^{-1} and the least amount (131) observed in tillering stage at 4 dSm^{-1}.

Percentage of filled grains per panicle

Conclusions of variance analysis showed that different growth stages have different sensitivity to salinity (Table 1). Effect of different growth stages, different levels of salinity and also their interaction effect on percentage of filled grains was significant (P<0.01). Salinity is one of the major environmental factors limiting plant growth and yield (Parida and Das, 2005). High effectiveness of salinity on grains has been reported by many researchers (Beatriz *et al.,* 2001). Beatriz (2001) reported that salinity of soil or water decreases number of grain per panicle and harvest index. Pollen viability, a very important trait that is greatly influenced by the ionic toxicity under salinity, was found to be a governing trait for the ultimate grain yield (Mohammadi Nejada *et al.,* 2010).

Conclusions of mean comparison of percentage of filled grains per panicle (Table 2) showed that control treatment had the most percentage of filled grains per panicle (80.87). Increasing different levels of salinity resulted in decreased percentage of filled grains per panicle, so that treatments of 2, 4, 6 and 8 dSm^{-1} decreased percentage of filled grains per panicle (8, 4, 18, 23%, respectively) in compare with control. The least percentage of filled grains per panicle (62.36) observed at 8 dS m^{-1}. In general, crops are less sensitive to salinity in glasshouse conditions than outdoors, where wind, low relative humidity and extreme temperatures may increase evapotranspiration (Eynard *et al.,* 2005).

Percentage of filled grains per panicle in different growth stages was different. The most percentage of filled grains per panicle (81.09) observed in panicle emergence and the least amount (53.82) observed in panicle initiation. The most sensitive stage to salinity was panicle initiation and after that were tillering, ripening and panicle emergence. Crops were most sensitive during vegetative and early reproductive stages, less sensitive during flowering and least sensitive during the seed filling stage (Lauchli & Grattan 2007). There are other reports where grain yield is much more depressed by salt than the vegetative growth (other than that of very young seedlings) (Cui *et al.,* 1995; Khatun & Flowers, 1995; Khatun *et al.,* 1995; Shereen *et al.,* 2005). As plants mature, they become progressively more tolerant to salinity, particularly at later stages of development (Lauchli & Grattan 2007).

Therefore resistance of final growth stages, i.e. panicle emergence and ripening stages against salinity was more than primary growth stages, i.e. tillering and panicle initiation.

With regard to Fig.2, survey on reciprocal effect of different level of salinity and growth stages showed that the most percentage of filled grains per panicle amounted 86.25, observed in tillering at 4 dSm^{-1} and the least amount (41.64), observed in panicle initiation at 6 dSm^{-1}.

Number of unfilled panicles

Effect of different growth stages on number of unfilled panicles was significant (Table 1) but effect of different levels of salinity on it was not significant (P<0.05). High effect of salinity on rice and rice sensitivity to salinity of irrigation water has been reported by many researchers (Asch & Wopereis 2001; Beatriz *et al.,* 2001). Beatriz (2001) reported that salinity of water or soil decreases number of panicles in rice.

With regard to the conclusions of mean comparison of number of unfilled panicles (Table 2), control treatment (1 dSm^{-1}) had the least number of unfilled panicles (1.00). Increased level of salinity resulted in increased unfilled panicles. Of course, there were not any significant differences between different levels of salinity. Whatever number of unfilled panicles is more, amount of yield decreases. Therefore, the salinity decreases yield through increasing unfilled panicles. Khatun and Flowers (1995) studied the effect of NaCl salinity on sterility and seed set in rice. Salinity increased the number of sterile florets and viability of pollen, becoming more pronounced with increased salinity. Drought during grain filling is also known to cause incomplete filling associated with reduced specific weight of kernels (Tsuda, 1993).

Different growth stages showed different effectiveness on number of unfilled panicles. The most unfilled panicles (6.92) observed in panicle initiation and the least amount of it (2.67) observed in panicle emergence. Considering effectiveness of salinity on unfilled panicles, different growth stages showed different sensitivity to salinity; panicle initiation was the most sensitive stage to salinity and after that were tillering, ripening and panicle emergence stages. In general, primary growth stages showed more sensitivity to salinity than final growth stages.

In survey of reciprocal effect of different levels of salinity and different growth stages (Fig. 3), it was observed that the most number of unfilled panicles (10.00) was in panicle initiation at 4 dSm^{-1} and the least amount was 0.8 in control treatment.

Percentage of ratio of number of unfilled panicles to tillers

Conclusions of variance analysis (Table 1) showed that the effect of different growth stages on percentage of ratio of number of unfilled panicles to tillers was significant but effect of different levels of salinity was not significant (P<0.05). High effectiveness of salinity on rice and sensitivity of rice to salinity of irrigation water has been reported by many researchers (Beatriz *et al.,* 2001; Zeng *et al.,* 2003). Salinity of water or soil decreases numbers of panicle and increases numbers of tillers (Beatriz *et al.,* 2001). Razzaque *et al.,* (2009) showed that salinity above 3 dSm^{-1} sharply reduced all growth characters.

Fig. 1. Effect of salinity levels at different growing stages on the total number of empty grains per panicles

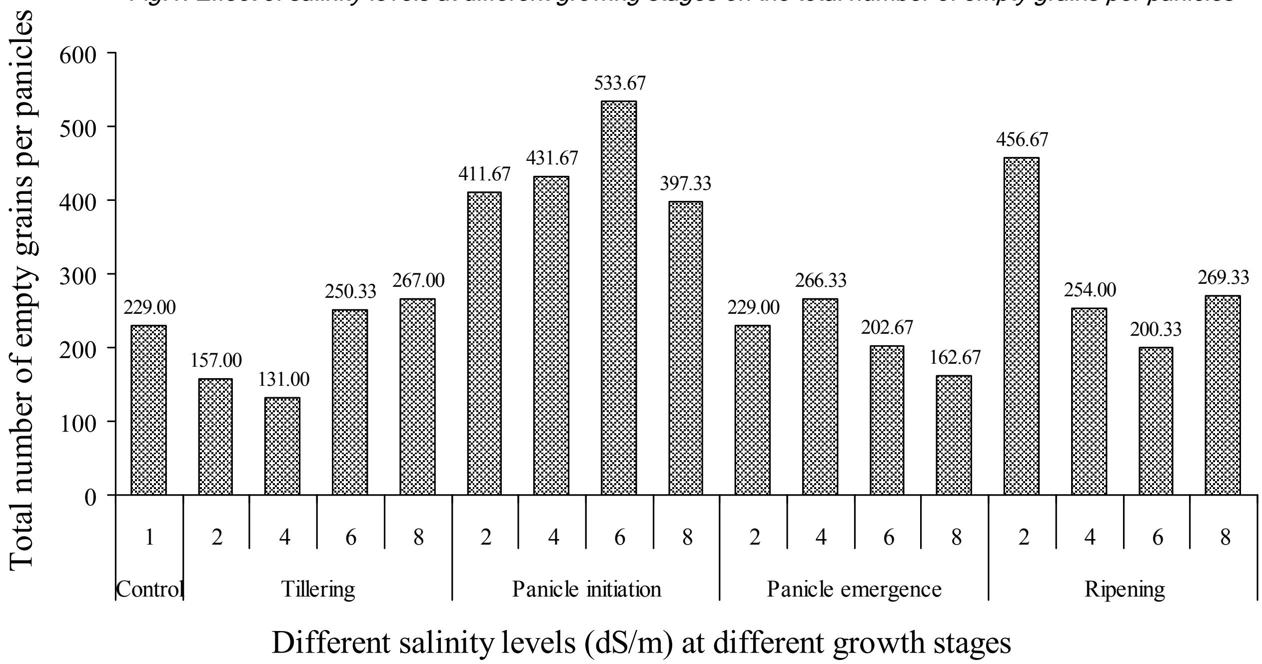
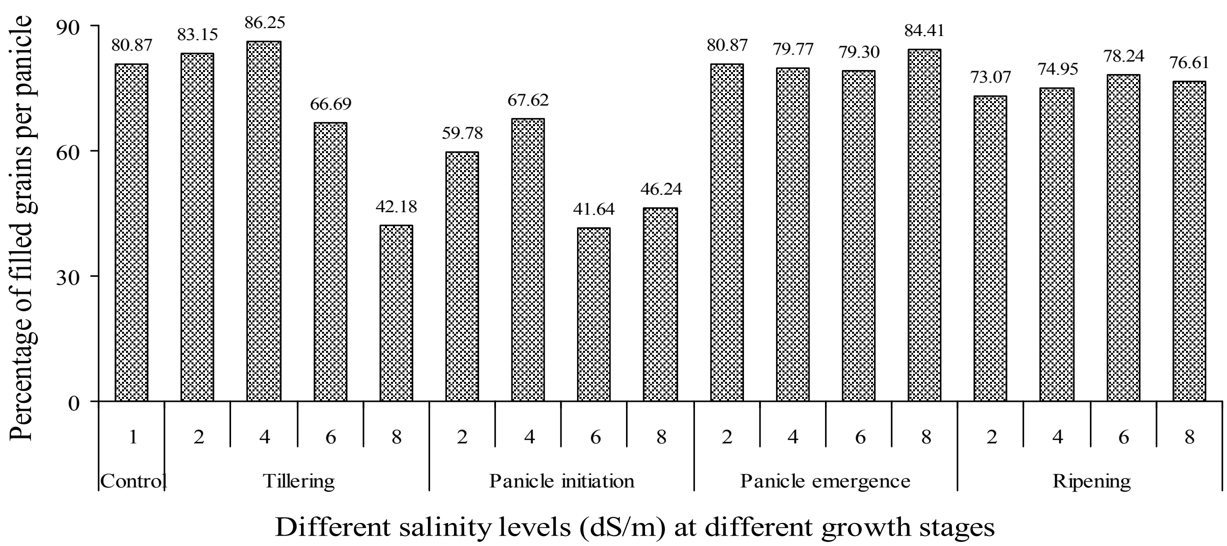


Fig. 2. Effect of salinity levels at different growing stages on the percentage of filled grains per panicle



With regard to the conclusions of mean comparison of percentage of ratio of number of unfilled panicles to tillers (Table 2), control treatment (1 dSm^{-1}) had the least percentage of ratio of number of unfilled panicles to tillers (5.40). Increased salinity increased percentage of ratio of number of unfilled panicles to tillers so that it increased from 2 to 8 dSm^{-1} and the most amount of it (19.95) observed at 8 dSm^{-1}. Percentage of ratio of number of unfilled panicles to tillers is one of the determining factors of yield so that whatever this ratio increases, yield decreases too.

In different growth stages of rice, percentage of ratio of number of unfilled panicles to tillers was different. The most percentage of ratios of number of unfilled panicles to tillers (26.53) observed in panicle initiation and the least of it (10.58) observed in panicle emergence. Panicle initiation was the most sensitive stage to salinity and after that were tillering, ripening and panicle emergence stages.

Survey in reciprocal effect of different levels of salinity in growth stages (Fig. 4) showed that the most percentage of ratios of number of unfilled panicles to tillers (37.26) observed in panicle initiation at 4 dS m^{-1} and the least amount of it (4.55) observed in tillering at 4 dS m^{1}.

Fig.3. Effect of salinity levels at different growing stages on the number of unfilled panicles

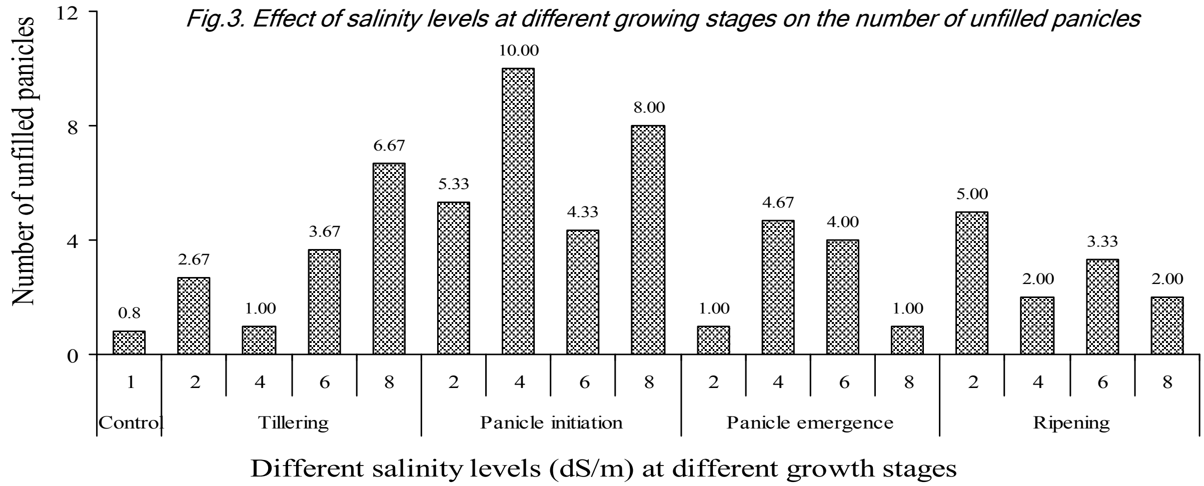
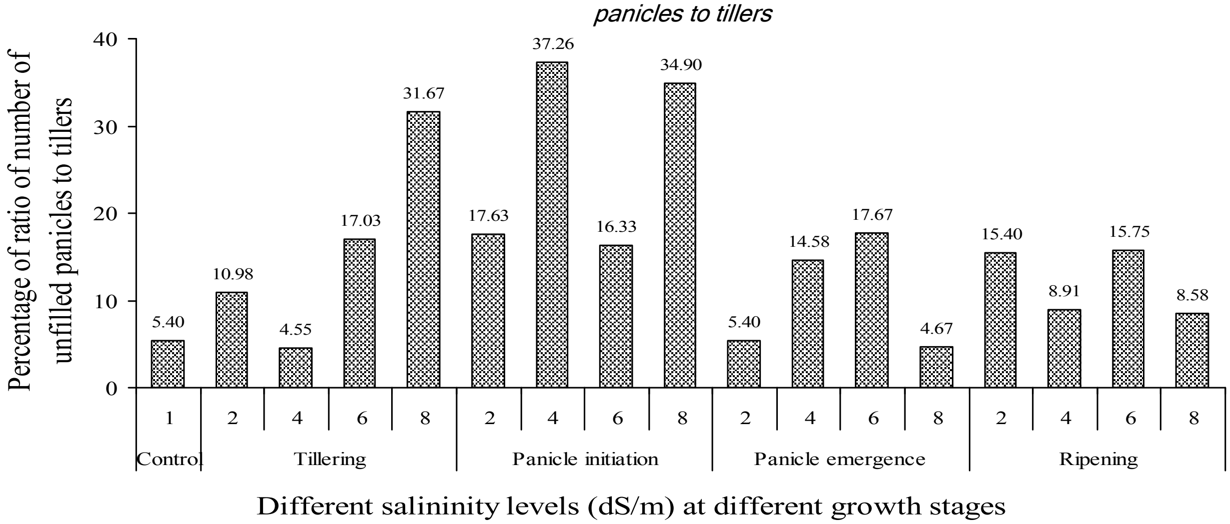


Fig.4. Effect of salinity levels at different growing stages on the percentage of ratio of number of unfilled panicles to tillers



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