THE EFFECTS OF SALINITY AT DIFFERENT GROWTH STAGE ON RICE YIELD

EFFETS DE LA SALINITE DE L'EAU SUR LE RENDEMENT DU RIZ AUX DIFFERENTS STADES DE CROISSANCE

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ABSTRACT

Demand for fresh water due to population growth reduces water availability for agriculture, compelling us to find ways to utilize poor quality water in agriculture. In order to assess the possibility of brackish water use in rice production and the effects of saline water at different growth stages of rice (Hashemi variety, as a popular local variety), a pot experiment was conducted in Rice Research Institute at Rasht at the North of Iran during 2010 crop season. Four levels of water salinity: 2, 4, 6, and 8 dSm^{-1} were applied at 4 different growth stages: tillering, panicle forming, heading and ripening stages. Another treatment, irrigated with fresh water during the whole growth stages was applied as control for comparison of means. Saline water was made by using NaCl + $CaSO_4$ (2:1). After 7 days as a period of recovery, salinity treatments were imposed up to 5cm of standing water. In order to prevent salt concentration at the end of each growing stage, pots' soils were washed and irrigation was continued with fresh water. All agricultural practices were done based on usual farmers' practices. After harvesting, plant height, biomass, harvest index, yield and yield components were measured and analyzed, mean comparison was done based on DMRT. Results showed a considerable sensitivity of the chosen rice variety to salinity. Salinity had significant effects on yield, number of filled panicle ($p<0.01$), biomass and harvest index ($p<0.05$). Effects of timing of salinity introduction in different rice growth stages on yield, number of filled panicle, biomass and harvest index ($p<0.01$) and dry weight of straw were statistically significant ($p<0.05$). The highest yield was obtained from fresh water (no salinity) with 21.5 g/pot while salinity treatments of 2, 4, 6 and 8 dSm^{-1} yielded 18.71, 17.79, 14.87 and 12.59 g/pot, respectively, representing 21, 25, 37, 47%

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yield losses. The panicle formation and tillering stages with 9.40 and 11.81 g/pot of yield were the most sensitive stages to salinity. The other growth stages including heading and ripening with 20.98 and 21.77 g/pot, respectively, were the least sensitive stages to salinity. The best time of using saline water during the crop season of the chosen rice variety seems to be after panicle initiation to the end of ripening. Application of saline water of any EC in early growth stage will cause a high yield loss.

Key words: *salinity, stages of growth, yield, rice.*

RESUME ET CONCLUSIONS

La croissance démographique et aussi l'augmentation de la consommation d'eau ont réduit la disponibilité de l'eau douce. Cette situation aboutit à une pression croissante sur les ressources en eau et par conséquent une baisse de la portion d'eau du secteur agricole. Ces nouvelles conditions nous ont amenés à trouver de nouvelles solutions pour l'utilisation de l'eau de mauvaise qualité dans l'agriculture. La province de Guilan, une grande zone de production du riz au nord de l'Iran, a aussi rencontré ce genre de problèmes. Une tendance à utiliser l'eau salée dans la production de riz est en augmentation ces dernières années, mais la gestion optimale des eaux salées est toujours discutable. Afin d'évaluer la possibilité d'utiliser les eaux saumâtres dans la production du riz et aussi ces effets sur les stades différents de croissance (variété Hashemi, une variété locale populaire), une expérimentation en vase a été menée à la centre de recherche sur le riz à Rasht au Nord d'Iran, sous un abri pendant la saison du riz en 2010. Quatre niveaux de salinité de l'eau soit 2, 4, 6 et 8 dS.m^{-1} ont été appliqués aux quatre stades différents de croissance de cette variété de riz local, c'est-à-dire: tallage (stade de végétation), formant des panicules (stade de la reproduction), l'épiaison et la phase de maturation. Un autre traitement à l'eau fraîche pendant tous les phases de croissance a été préparée à faire de comparaison moyenne, considéré comme le traitement témoin. L'eau salée a été faite à l'aide de NaCl + CaSO4 (2:1). Après 7 jours, comme une période de récupération, les vases ont été submergées sous 5 cm des eaux salées selon les traitements considérés. Afin d'éviter l'accumulation de sel, à la fin de chaque stade de la croissance, les sols des vases ont été lavés et l'irrigation a été continuée en appliquent l'eau douce. Toutes les pratiques agricoles ont été effectuées sur la base habituelle des agriculteurs. Après la récolte, la hauteur du plant, la biomasse, l'indice de récolte, le rendement et les composantes du rendement ont été mesurés et analysés. La comparaison statistique a été faite sur la base de test de Duncan nouvelle gamme multiples (DTRM). Les résultats montrent une grande sensibilité à la salinité. Taux de salinité de l'eau avaient des effets significatifs sur le rendement, le nombre de panicules remplies (p <0,01), la biomasse et l'indice de récolte (p <0,05). Les effets de la date de l'introduction de la salinité dans les stades différents de croissance du riz sur le rendement, le nombre de panicules remplies, la biomasse et l'indice de récolte (p <0,01) et le poids de paille sèche ont été statistiquement significative (p <0,05). Le rendement le plus élevé a été obtenu à partir de l'eau douce (pas de salinité) avec 21,5 gr par vase, alors que les traitements de la salinité de 2, 4, 6 et 8 dS.m-1 ont donnés 18,71, 17,79, 14,87 et 12,59 gr par vase, respectivement, soit 21, 25, 37 et 47% des pertes de rendement. On peut affirmer que la formation des panicules et le tallage avec un rendement de 9,40 et 11,81 gr par vase, respectivement ont été les stades les plus sensibles à la salinité. D'autres stades de croissance comme l'épiaison et la maturation avec un rendement de grain de 20,98 et 21,77 gr par vase, respectivement, ont été les stades les moins sensibles à la salinité. En *générale, les stades de riz les plus sensibles ont été la reproduction et la végétation. Le meilleur moment de l'utilisation de l'eau salée pendant la saison de cette variété locale de riz iranien est après la panicule jusqu'à la fin de la maturation. Application de l'eau salée (de différentes EC) en début de croissance provoque une perte de rendement élevé.*

Mots clés: *Salinité, stades de croissance, rendement, riz.*

(Traduction française telle que fournie par les auteurs)

1. INTRODUCTION

High population growth increases fresh water requirement for the communities and reduces both available land and fresh water for agriculture. These conditions made paddy cultivators to go for rice cultivation in marginal land using marginal quality of water for irrigation (Gregorio et al. 2002). Shortage of fresh water and continuous drought created lots of problems in rice production. Therefore using low quality water is inevitable (Zeng and Shannon, 2000). Large This agricultural lands in the world suffer from problems of salinity (Kijne, 2006). Rezaei et al. (2010) showed that a vast area of Guilan province, though suitable for rice cultivation, is suffering from groundwater salinity. Guilan Province Regional Water Company has declared increase in Electrical conductivity (EC) in Sefidrood. As studies showed rice sensitivity to any kinds of soil and water salinity, it is necessary to find methods to tackle this problem (Kavosi, 1995).

Several researches showed influences of photosynthesis reduction during flowering stage on the yield and yield components. In this stage, salinity decreases photosynthesis thus, unfilled spikelet increases and consequently the creation of filled grain in the panicle decreases (Munns and Termaat, 1986). Salinity before heading influences the number of tiller, which influences the number of panicle and weight of each panicle during the period of 3 leaf stage until booting (Zeng and Shannon, 2003), but it does not affect percentage of fertility, weight of shoot and weight of kernels. The influence of osmotic pressure is more on the percentage of panicle fertility, weight of 100 grains and thus on the yield of reproductive stage in comparison with vegetative stage. In saline lands usually symptoms similar to stress of drought conditions are seen due to decrease in water absorption which resulted from plants' osmosis potential. Salinity causes delay in flowering and ripening and decreases the number of tillers, biomass and leaf area (Castillo et al 2007; Kavosi, 1995). Some reports showed that during germination, rice was very tolerant to salinity but it was very sensitive in seedling and reproductive stages. However it is less sensitive during tillering and grains filling (Lafitte et al 2004). At the same time some others reported that, during germination rice had the most sensitivity to salinity in comparison with other stages.

Rice is affected by salinity during transplanting, after transplanting and flowering, however it logarithmically endure salinity stress until ripening (Falah, 2010). In reproductive stage, salinity decreases the number of filled panicles, fertile panicle, weight of 100 grains and percentage of fertile grains and increases fertile tillers. Influences of this pressure increase in warm weather and high evaporation (Asch et al 2000). Without any regard to the seasons of year, salinity decreases yield, the number of panicle, weight of 100 grains and increases sterility in all rice cultivars and in any growth stages but the most sensitive stage is panicle initiation (Asch et al 2000). Increasing salinity tolerance in rice could develop its production in regions where influenced by salinity and they are not usable at present (Suriya-aruroj et al 2004). No researches have been done in Guilan province to study the response of rice to salinity of irrigating water in different growth stages. In order to study the effects of using saline water at different stages on a popular variety, Hashemi, this study was conducted.

2. MATERIALS AND METHODS

In order to assess the possibility of using brackish water in rice production and the effects of saline waters on different growth stages of rice (Hashemi variety, a popular local variety), a pot experiment was performed in Rice Research Institute in Rasht in the North of Iran, under a shelter during 2010 crop season. 4 levels of water salinity i.e. 2, 4, 6, and 8 dSm^{-1} were applied at 4 different growth stages i.e. tillering (vegetation stage), panicle forming (reproductive stage), heading and ripening stages of this local rice variety. A supplementary treatment irrigated with fresh water (control: EC≤1 dSm^{-1}) during the whole growth stages was applied to do mean comparison.

Saline water was made by using NaCl+ $CaSO_4$ (2:1) in fresh water. After 7 days as a period of recovery, salinity treatments were exerted up to 5cm water standing. In order to prevent salt concentration, at the end of each growing stages, pot soils were washed and irrigation was continued with fresh water. All agricultural practices were done based on usual farmers practice. Rice was transplanted in May (Table 1) and harvested in August. After harvesting rice yield, 1000 kernels weight, number of filled panicle, number of tillers, plant height, weight of straw, biomass, harvest index, and the average weight of rice panicle were measured and analyzed. The Duncan Multiple Rang Test (DMRT) was used to do mean comparison of the data.

3. RESULTS AND DISCUSSION

3.1 Yield

Analysis of variance (Table 1) showed that the influences of different salinities on the yield of rice was statistically significant (P<0.01). High influence of salinity on rice yield and rice sensitivity to the salinity of irrigating water was reported by several researches (Kadda et al 1973; Munns and Termaat, 1986; Shahdy, 1994). Rice is a very sensitive plant to salinity of water and soil; this sensitivity is so that if we use high quality and not saline water in saline soils, yield and water of stem would decrease (Casanova, et al 1999). Different growth stages had different sensitivity to salinity. Sensitivity of different rice growth stages or time of salinity introduction on the yield was statistically significant (P<0.01). Similar results were reported by other researchers (Zeng and Shannon, 2003). During germination, rice is very tolerant against salinity but it is very sensitive in seedling and reproductive stages. However it is less sensitive during tillering and grains filling (Lafitte et al, 2004).

Results of mean comparison of yields with salinity treatments (Table 2 and Figure 1), showed that control treatment with fresh water yielded the most amount with 21.59 g/pot. Salinity treatment of S1, S2, S3, S4 which are equal to salinity of irrigating water of 2, 4, 6 and 8 dSm^{-1}, yielded 18.71, 17.79, 14.87, 12.59 g/pot, respectively. Losses of yield in these treatments comparing with application of fresh water were 13, 17, 31 and 41 percent respectively. These results showed a high sensitivity of Hashemi rice variety to salinity. Some repots suggested that the best approach to increase yield in the lands influenced by salinity is using varieties which are tolerant against salinity of soil and water (Kadda et al, 1973). But the others reported that due to decreasing in mineralization and low accessibility of nitrogen for roots, salinity causes low absorption of nitrogen by the plant. Therefore to mitigate the low absorption of this vital element, nutrition elements such as nitrogen and zinc should be applied to compensate the yield loss of salinity (Verma and Neue, 1984).

The results of Table 1 also showed that panicle initiation, yielding 9.40 g/pot was the most sensitive stage to salinity. Tillering stage yielding 11.81 was the second stage which was sensitive to salinity. Of course there were not significant differences between these two stages statistically. The two last growth stages including heading and ripening with yield of 20.98 and 21.77 had then the least sensitivity to salinity and placed in the next class. The responses of rice to salinity are different in different growth stages.

Table 1. Analysis of variance of different treatments (Analyse de variance des traitements différents)

MS										
the average weight of rice panicle (g)	harvest index	Biomass	weight of straw (g)	Plant height (cm)	the number of tillers	the number of filled panicle	1000 seeds weight (g)	yield (g)	D.F	S.O.V
0.29**	220.06*	289.09*	62.16	172.167	17.08	49.62**	18.94	93.706**	3	Salinity
0.98 **	1231.98**	678.12**	272.7*	917.39**	35.24	73.81**	97.22**	476.683**	3	Timing (growth stages)
0.120 *	131.3	50.95	31.67	61.899	24.43	19.56 ns	24.3 ns	22.562 ns	9	Salinity × Timing
0.04	72.87	75.26	66.69	58.961	21.26	9.55	12.69	15.805	30	Error
21.93	25.11	18.8	27.08	5.9	19.26	18.8	15.72	24.86	-	CV%

*,**: significant at 5% and 1%
ns: Not significant

Table 2. Mean comparison of the treatments (Comparaison de la moyenne des traitements)

weight of rice panicle (g)	harvest index	biomass	Weight of straw (g)	the height of plant (cm)	number of tillers	number of filled panicle	1000 seeds weight (g)	Yield (g)	s.o.v
									salinity
0.96ab	37.27a	50.88a	32.18a	132.50a	25.67a	19.08 a	21.85 a	18.71a	2
1.10a	36.24a	49.81a	32.02a	133.92a	23.75a	16.88ab	22.87 a	17.79a	4
1.03a	34.66a	42.64a	27.77a	129.17a	23.00a	14.42b	24.34 a	14.87ab	6
0.74b	27.77a	41.23a	28.64a	125.42a	23.33a	15.42b	21.55 a	12.59b	8
									Growth stages
0.74b	31.13b	36.09b	24.28b	122.67b	21.50a	14.96bc	21.32 bc	11.81b	tillering
0.68b	21.01c	44.88ab	35.48a	122.75b	25.42a	13.88c	19.35 c	9.40b	panicle forming
1.17a	43.68a	50.57a	28.80ab	136.83a	24.75a	19.33a	24.33 ab	21.77a	ripening stage
1.24a	40.12ab	53.02a	32.04ab	138.75a	24.08a	17.58ab	25.62 a	20.98a	heading stage
1.11	45.13	50.39	27.80	132.67	21.67	20.67	23.55	21.59	control

Means followed by the same letters are not different at 5%

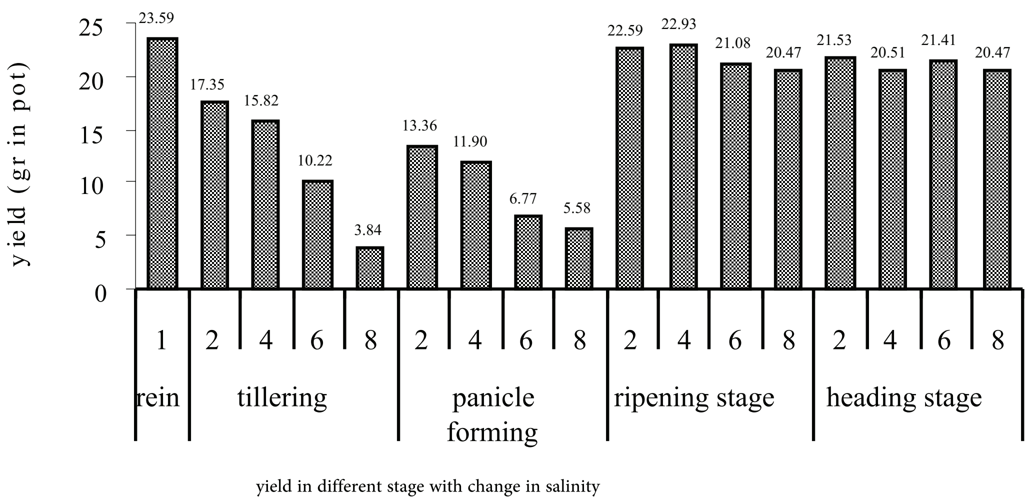

Fig. 1. yield of rice irrigated with different levels of salinity introduced in different growth stages (le rendement du riz irrigué avec différents niveaux de salinité introduit dans différents stades de croissance)

Young seedlings are very sensitive to salinity in the first stage of growth. With regard to Figure 1, salinity of 2, 4, 6, 8 dSm^{-1} in different growth stages of rice had different yields; the most yield was observed in heading stage and the least yield in panicle initiation.

3.2 1000 Kernels weight

Analysis of variance (Table 1) showed that the influence of applying salinity in different stages on weight of 1000 kernels was significant ($P<0.01$). High influence of salinity on the weight of 1000 kernels was reported by several researchers (Asch et al, 2000; Beatriz et al, 2001; Gridhar, 1988; Homaee, 2001; Saadat et al, 2005; and Yeo, 1986). Salinity of irrigation in reproductive growth stage decreases weight of 100 grains (Homaee, 2001). It delays ripening of rice about one week; weight of 1000 kernels significantly decreases with salinity increase (Gridhar, 1988).

Results of mean comparison of 1000 kernels weight treated by salinity (Table 2) showed that 1000 kernels weight in control treatment was 23.55 g. Treatment S3 with 24.34 gr, treatment S2 with 22.87 g, treatment S1 with 21.85 gr and treatment S4 with 21.55 g were placed in the same class.

Ripening with 1000 kernels weight of 25.63 gr along with heading placed in class A. Heading stage with 1000 kernels weight of 24.33 g along with ripening stage placed in class A and also along with tillering stage placed in class B. Tillering stage with 1000 kernels weight of 21.32 g placed in class B along with panicle initiation stage and from other side placed in C class along with treatment in panicle initiation. Panicle initiation with 1000 kernels weight of 19.35 g along with tillering placed in class C.

3.3 Number of filled panicle

The results (Table 1) showed that different salinity and timing of the salinity introduction influences on the number of filled panicle were significant ($P<0.01$). High influences of salinity on the number of filled panicle were reported by several researchers (Aschl and Marco 2001; Beatriz et al 200).

The results of mean comparison of the number of filled panicle (Table 2) showed that the control treatment with fresh water having 20.67 filled panicles produced the most number. Salinity treatment S1 with 19.08 filled panicles along with treatment S2 placed in class A. Treatment S2 with 16.88 filled panicles along with treatment S1 placed in class A in one side, and in the other side with treatment S3 and S4 placed in class B. Treatment S4 with 15.42 filled panicles and treatment S3 with 14.42 filled panicles along with treatment S2 placed in class B. In salinity timing treatments, heading stage with 19.33 filled panicles along with ripening stage placed in class A. Treatment ripening stage with 17.58 filled panicles along with heading stage placed in class A, but in the other side along with treatment tillering stage placed in class B too. Treatment tillering stage with 14.96 filled panicles with treatment ripening stage were in class B and in the other side with treatment panicle initiation placed in class C. Treatment panicle initiation with 13.88 filled panicles along with treatment in tillering stage placed in class C.

3.4 Number of tillers

Results (Table 1) showed that the influence of different salinities on the number of tillers was not significant. The influence of applying salinity in different stages on the number of tillers was not significant too ($P<0.01$). Effects of salinity on the number of tillers were reported by researchers (Asch et al, 2000; Beatriz et al, 2001; Gridhar, 1988; Saadat et al, 2005; and Zeng and Shannon, 2003). The number of tillers in different levels of salinity (3.6 to 8.3 dSm^{-1}) decreased, but it was not statistically significant (Gridhar, 1988). The result of mean comparison between the numbers of tillers (Table 2) showed that treatment with fresh water had 21.67 tillers. Salinity treatment S1 with 19.08 tillers and treatment S2 with 23.75 tillers and treatment S4 with 23.00 tillers and salinity treatment S3 with 23.33 tillers are placed in class A. Treatment panicle initiation with 25.42 tillers and treatment heading stage with 24.75 tillers and treatment of ripening stage with 24.08 tillers and treatment in tillering stage with 21.50 tillers placed in stage A.

3.5 Plant height

The results (Table 1) showed that the influence of different salinity levels on the height of plant was significant. The influence of salinity on the height has been reported by many researchers (Falah, 2010 and Gridhar, 1988). The results showed that the height of rice in different levels of salinity (3.6 to 8.3 dSm^{-1}) decreased but not statistically significant (Gridhar, 1988). The result of mean comparison of rice height (Table 2) showed that in treatment with fresh water, the plant height was 132.67cm. Salinity treatment S2 with height of 133.92, salinity treatment S1 with height of 132.50, salinity treatment S3 with height of 129.17 and salinity treatment S4 with height of 125.42cm placed in class A. Treatment ripening stage with height of 138.75 and treatment heading stage with height of 136.83cm placed in class A. Treatment heading stage with height of 122.75 and treatment tillering stage with height of 122.67cm placed in class B.

3.6 Weight of straw

The effects of salinity on the weight of straw was significant ($P<0.01$). The influence of salinity on the dry weight of straw was reported by many researchers (Kavosi, 1995; and Zeng and Shannon, 2003); whereas some research showed that salinity does not affect on the weight of straw before heading stage (Zeng and Shannon, 2003). The result of mean comparison of the weight of straw treated with salinity (Table 2) showed that in treatment irrigated with fresh water the weight of straw was 27.80 g/pot. Salinity treatment S1 with straw weight of 32.18 g/pot, salinity treatment S2 with straw weight of 32.02 g/pot, salinity treatment S3 with straw weight of 28.64 g and salinity treatment S4 with straw weight of 27.77 g/pot placed in class A. Treatment panicle initiation with straw weight of 35.48 gr per pot along with treatment heading stage and ripening stage placed in class A. Treatment ripening and heading stages with straw weight of 32.04 and 28.80 g/pot, respectively, along with treatment panicle initiation placed in class A and in the other side along with treatment tillering stage placed in class B. Treatment tillering stage with straw weight of 24.28 g/pot along with treatment heading and ripening stages placed in class B.

3.7 Biomass

Analysis of variance (Table 1) showed that the influence of different salinities on biomass was very significant (P<0.01). The influence of salinity on biomass has been reported by many researchers (Kavosi, 1995; Yeo and Flowerse, 1986; Zeng and Shannon, 2003). The influence of different stages on amount of biomass in the probability level of 1% has been significant.

The result of mean comparison of biomass which is salinity treated (Table 2) showed that in the treatment of control with fresh water, amount of biomass is 27.80 gr per pot. Salinity treatment S1 with biomass amount of 50.88, salinity treatment S2 with biomass amount of 49.81, salinity treatment S3 with biomass amount of 42.64 and salinity treatment S4 with biomass amount of 41.23 g/pot are placed in class A. Treatment in ripening and heading stages with biomass amount of 53.02 and 50. 57 g/pot respectively along with treatment in panicle initiation are placed in class A. Treatment in panicle initiation with biomass amount of 44.88 g/pot in one side along with treatment in heading and ripening stages is placed in class A and in other side along with treatment in tillering stage is placed in class B. Treatment in tillering stage with biomass amount of 36.09 g/pot along with treatment in panicle initiation is placed in class B.

3.8 Harvest index

Analysis of variance (Table 1) showed that the effects of different salinities on harvest index was significant (P<0.01). The influence of salinity on the harvest index was reported by many researchers (Kavosi, 1995; Yeo and Flowerse, 1986; Zeng and Shannon, 2003). The results of mean comparison of harvest index with salinity treatments (Table 2) showed that in treatment with fresh water, the harvest index was 45.13 percent. Salinity treatment S1 with harvest index of 37.27, salinity treatment of S2 with harvest index of 36.24, salinity treatment S3 with harvest index of 34.66 and salinity treatment S4 with harvest index of 27.77 percent placed in class A. Treatment heading stage with harvest index of 43.68 percent along with treatment ripening stage placed in class A. Treatment ripening stage with harvest index of 40.12 percent in one side along with treatment in heading stage placed in class A and in other side along with treatment tillering stage placed in class B. Treatment tillernig stage with harvest index of 31.13 percent along with treatment ripening stage placed in class B. Treatment panicle initiation with harvest index of 21.01 percent placed in class C.

3.9 The average panicle weight of rice

Analysis of variance (Table 1) showed that the effects of different salinities on the average panicle weight of rice was significant (P<0.01). Salinity has a very significant influence on grain yield (Yeo and Flowerse, 1986). The result of mean comparison of the average panicle weight (Table 2) showed that in treatment with fresh water, the average panicle weight was 1.11 g/pot. Treatment S2 with average panicle weight of 1.10 and salinity treatment S3 with average panicle weight of 1.03 gr per pot along with salinity treatment S1 placed in class A. Salinity treatment S1 with average weight panicle of 0.96 gr per pot in one side along with treatments S2 and S3 is placed in class A and in other side along with salinity treatment S4 is place in class A. Salinity treatment S4 with average panicle weight of 0.74 g/pot along with salinity treatment S1 placed in class B. Treatment ripening and heading stages, respectively with average panicle weight of 1.24 and 1.17 g/pot placed in class A. Treatment tillering and panicle initiation stages with average panicle weight of 0.68 and 0.74 g/pot, respectively placed in class B.

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