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Wheat Performance as influenced by Saline Irrigation Regimes and Cultivars

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ABSTRACT

To study the effect of different levels of saline irrigation water on wheat yield and its attributes of different wheat varieties,four irrigation water salinity levels namely, Control (ground water); EC: 4 dS/m; 8 dS/m; and 12 dS/mand 4 wheat varieties including 3 salt tolerant (*i.e.*KRL-210, KRL-1-4, KRL-19 and one salt non-tolerant variety HD-2894 were tested during *rabi* seasons of 2009-10 and 2010-11 at Water Technology Center, Indian Agricultural Research Institute (IARI), New Delhi, India**.**Maximum grain yield and biomass during 2009-10 were 5.03 t/ha and 12.45 t/harespectively, for non-tolerant variety HD-2894 irrigated with ground water. Highest wheat yield(5.25 t/ha)was recorded by HD-2894with ground water.Yield attributes were significantly affected by the saline irrigation water and wheat varieties. This study revealed that the salt tolerant variety can be recommended to achieve higher yields with increase in salinity of the irrigation water.

***Keywords*:** Saline irrigation, salt tolerant variety, wheat, grain yield, yield attributes

INTRODUCTION

Fresh water is becoming an increasingly scarce resource worldwide requiring enhancement of water productivity in agriculture (Pereira, 2006). Estimating attainable yield under water-limiting conditions will remain the focal point of investigation in arid and semi-arid regions. Irrigation water management for growing cereal crops assumes importance as majority of cultivated area in the world is under rice, wheat and maize crops (FAO, 2008). Due to the scarcity of fresh water, it has become necessary to investigate on the possible agricultural uses of marginal waters such as the drainage water, saline groundwater and treated wastewater.

Irrigation with saline water is affecting agricultural productivity, and causing hindrances in sustainable agricultural production. Experiments conducted in Hisar region of Haryana with by using irrigation water salinity of 2-4 dS/m, 4-6 dS/mand 6-8 dS/m, The yields of wheat obtainedwere 100 %, 89% and 60% respectively (FAO, 1992; Sharma and Minhas, 2005). Sharma and Rao (1998) found that by using pre-irrigation with non-saline canal water followed by saline drainage water of varying salinity 6 dS/m, 9 dS/m,12 dS/mand 18.8 dS/mthe yield reduction in wheat by 4.2%, 9.7%, 16.3% and 22.2%, respectively. Chauhan *et al.* (2008) reported wheat yield of 5.5 t/ hausing saline water having salinity of 8 dS/mwith pre-sowing irrigation of good quality water. The soil was of alluvial origin and groundwater salinity ranged from marginally saline (*i.e.* 2–6 dS/m) to saline (*i.e.* >6 dS/m). Chauhan *et al.* (2005) showed that at high salinity levels, appropriate conjunctive mode of water application could be adopted to grow wheat crop using low saline water (*i.e.*3.6 dS/m) and highly saline water (*i.e.*15 dS/m) during 2001-02 and 2002-03 at the experimental farm, Agra. It was found that the yield with low saline water could be obtained with cyclic mode (*i.e.* alternative low saline-high saline water cycle) or switching mode (*i.e.* first 2 or 3 irrigations with low saline followed by all irrigations with highly saline water) as high as 95% and the mixing modes attempted could also give more than 90 % of the yield obtained with low saline water. The yield in the case of cyclic mode was less than their counterparts as

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well as the mixing mode of application. Apparently, salt stress at germination and initial establishment stages affected the crop performance. They suggested that the yield under mixing mode could be improved provided mixing ratio is varied with growth stage of crop with constant total salt concentration. The grain yield and yield attributes of wheat were affected by the saline irrigation water (Nia *et al.,*2012). Research examinations on wheat yield under irrigated saline situation indicated that salinity level in the crop root zone played a significant role in deciding the crop yield besides other relevant factors (Sharma *et al.*, 1994; Khosla and Gupta, 1997; Ma *et al.*, 2008; Ghane*et al.*, 2009). However, experiment was undertaken to study the yield of salt tolerant wheat varieties under different irrigation water salinity levels.

MATERIALS AND METHODS

Experimental Site

Field experiment was conducted at the Water Technology Center (WTC) research farm of Indian Agricultural Research Institute, New Delhi during *rabi* seasons of 2009-10 and 2010-11. The WTC experimental farm is located between 28° 37' 22" to 28° 39' 00" N latitude and 77^0 8' 45'' to 77^0 10' 24'' E longitudes with an average elevation of 230 m above mean sea level. The experiment was split plot design with plot sizes of 5m × 1.6 m and total area including all the treatment combinations and replications were 1,029 m^2, having four irrigation water salinity levels (*viz.*Control S_1: (ground water); EC: 4 dS/m(S_2); 8 dS/m(S_3); and 12 dS/m(S_4)). Three salts (viz. NaCl, $MgSO_4$ and $CaCl_2$) were mixed in groundwater to prepare artificial saline water of desired salinity. The control plots were irrigated using ground water, which varied in salinity from 1.45 to 1.7 dS/ mduring the experiment period of two years. The experiment was conducted with four wheat varieties, including 3 salt tolerant (*i.e.* KRL-210 (V1), KRL-1-4 (V2), KRL-19 (V3)) and one non-salt-tolerant variety HD-2894 (V4). Wheat crop was sown on 10^{th} December during both the years of experimentation (Kumar*et al.*, 2013).

Crop Growth and Yield Data

Different growth stages of wheat crop for grain purposes are broadly divided into germination, tillering, vegetative and reproductive stages (Saikia*et al.*, 2009). The vegetative stages of the wheat cultivar used in the experiment can be further sub divided to a) crown root initiation (CRI) stage (*i.e.* 20 DAS); b) heading stage (*i.e.* 65 DAS). Subsequently, the reproductive stage can be further sub divided to a) anthesis or flowering stage (*i.e.* 75 days DAS); b) milking stage (*i.e.* 85 DAS); c) dough stage (*i.e.* 95 DAS) and d) physiological maturity stage (*i.e.* 125 DAS). The harvesting was done after the maturity stage with grain moisture content of about 12-15%.

The crop growth and physiological parameters (*i.e.* number of tillers per plant, plant height, number of spikes or effective tillers per sq. meter, spike length) were recorded during the experiment. Besides this the yield attributes (*i.e.* number of grain per spike, grain yield, thousand grain weight and harvest index) were estimated. The yield and its growth parameters were measured by harvesting plants of three middle rows of each plot at the physiological crop maturity stage. Grain yield was measured as weight of harvested grain with 12% grain moisture in each plot and converted to kg ha^{-1} unit for each treatment. Biomass yield was determined by taking the weight of above ground plant parts including the grain. Salinity generally slows the rate of crop growth, resulting in plants with smaller leaves, shorter height, and reduced economic yield (Shannon *et al.*, 1994). The degree to which growth is affected by salinity differs with crop species and variety. Due to higher salinity in top soil, the general tendency of root would be to grow deeper into soil in search of water.

Statistical Analysis

The generated data were analyzed statistically using MSTATC software for estimation of analysis of variance (ANOVA). The critical differences between the observed values under different treatment combinations were also estimated to understand the significant effect of different saline water treatments on yield of both salt and non-salt tolerant wheat varieties.

RESULTS AND DISCUSSION

Analysis of variance was carried out for the parameters acquired from the field experiment following the standard procedures applicable to split plot design (SPD). When the treatment effects were found significant, mean differences were tested using Duncan's Multiple Range Test (DMRT) at 5% level of significance. Measurements included the grain yield, biomass yield, harvest index and yield attributes (i.e. 1000 grain weight, grains per spike and spikes/m^2). The ANOVA presented in table 1 and 2, shows that during two years of the study, there were significant effects due to primary factors and their interactions.

The experiment showed that crop yield decreased with increasing salinity and the salt tolerant variety (V_2) resulted in better yield than other salt tolerant and non-salt tolerant varieties. The grain yield of wheat was higher during *rabi* 2010-11 than during *rabi* 2009-10 due to higher rainfall and favourable climatic condition. Maximum wheat grain yield was observed in treatment S_1V_4 (*i.e.* 5.25 t/ ha) during *rabi* 2010-11 and minimum yield (*i.e.* 1.72 t/ ha) was obtained in treatment S_4V_4 during *rabi* 2009-10. The average yield of salt tolerant variety (V_2) was higher by 26% and 41% during both years as compared to the non-salt tolerant variety (V_4) under irrigation water salinity of 8 and 12 dS/m, respectively. The interaction between salinity and variety is presented in Table 2 for both years. Analysis of variance of yield data indicated that the critical difference (CD) at 0.05 probability level of significance was 0.57 and 0.73 due to the interaction of salinity and variety for *rabi* 2009-10 and 2010-11, respectively (Table 2). Significant yield variation in both years of experiment with more yield during *rabi* 2010-11 might be attributable to the reduction in both the maximum and minimum temperature during entire growing period on an average by 2.2^{0}C and 1.1^{0}C, respectively and increase in average sun shine hours up to the crop heading stage by 1.6 hrs per day as compared to *rabi* 2009-10. This weather condition during *rabi* 2010-11 might have increased the photosynthesis and created a favourable environment for better crop growth and grain yield as compared to *rabi* 2009-10. This is corroborated by Saikia*et al.* (2009), which reported that such weather pattern favoured the growth and yield of wheat in Northern India. Besides this, the effective rainfall received during the crop growing season of *rabi* 2010-11 was 129% more than that received during *rabi* 2009-10. All these weather parameters during *rabi* 2010-11 might have created a favourable condition for better growth of wheat cultivars as obtained from the experiment under irrigated saline regimes.

The above ground biomass or straw yield of wheat was also higher during *rabi* 2010-11 than during *rabi* 2009-10 and above ground biomass yield decreased with increasing salinity. The biomass yield was observed to be maximum (13.48 t/ha) for treatment S_1V_4 during *rabi* 2010-11 and minimum yield (*i.e.* 5.46 t/ha) was obtained in treatment S_4V_4 during *rabi* 2009-10, which was of similar trend as that of grain yield. The experiment showed that the salt tolerant variety V_2 (KRL-1-4) resulted in better yield than other salt tolerant and non-salt tolerant varieties. The average yield of salt tolerant variety KRL-1-4 was higher by 22-25% and 25-30% during both years as compared to the non-salt tolerant variety HD2894 under irrigation water salinity levels of 8 and 12 dS/m, respectively (Table 1). The harvest Yield attributes

The yield attributes *viz* spikes per m^2 cropped area, grains per spike and 1000 grain weights were

Table 1: Yield, biomass and harvest index (HI) of different wheat varieties under different salinity levels for *rabi* 2009-10 and 2010-11.

Treatments	Grain yield (t/ha)		Straw yield (t/ha)		HI (%)	
	09-10	**10-11**	**09-10**	**10-11**	**09-10**	**10-11**
Salinity levels						
S1	4.22	4.91	7.8	17.4	38	39
S2	3.41	4.17	6.71	14.76	39	38
S3	3.05	3.79	6.18	13.42	40	38
S4	2.64	3.46	5.81	12.26	37	37
SEm±	0.1879	0.234	0.2587	0.8291	2.3754	1.6691
LSD (P= 0.05)	**0.4599**	**0.5727**	**0.6332**	**2.0293**	**NS**	**NS**
Varieties						
V1	3.27	4.1	6.55	14.53	39	38
V2	3.58	4.46	7.06	15.8	38	39
V3	3.43	4.26	6.82	15.11	39	38
V4	3.04	3.5	6.07	12.4	38	36
SEm±	0.1391	0.1769	0.2082	0.6271	1.4402	1.3794
LSD (P= 0.05)	**0.287**	**0.3651**	**0.4298**	**1.2943**	**NS**	**NS**

Table 2: Interaction between Salinity and Varieties on grain yield during *2009*-10 and 2010-11

Treatments	V1		V2		V3		V4	
	09-10	10-11	09-10	10-11	09-10	10-11	09-10	10-11
S1	3.81	4.5	4.09	5.13	3.94	4.75	5.03	5.25
S2	3.33	4.19	3.85	4.6	3.73	4.4	2.74	3.46
S3	3.12	4	3.27	4.2	3.15	4.1	2.68	2.85
S4	2.82	3.7	3.11	3.9	2.9	3.8	1.72	2.43
LSD (P= 0.05)	0.574 (*2009-10)*		0.730 (*2010-11)*					

significantly affected by the saline irrigation treatments and wheat varieties(Table 3). Spikes per m^2, which is the important yield component, ranged from 224 to 372 and 339 to 387 in the control (ground water) and for all wheat varieties during the year 2009-10 and 2010-11, respectively. From the experimental data, the reduction in spikes per m^2 for the salt tolerant variety, V_1, was observed to be 5%, 13% and 23% at salinity levels of 4, 8 and 12 dS/m, respectively. Similar trend was also observed for other salt tolerant varieties (V_2 andV_3) for same treatments. Moreover, the salt non-tolerant variety, V_4, was found to be more affected by the salinity and a reduction of 34%, 36% and 38% was observed for the salinity levels of 4, 8 and 12 dS/m, respectively (Table 3). It was observed that spikes per m^2 decreased with increasing values of salinity levels and the salt tolerant varieties, V_1, V_2& V_3, contains more spikes per m^2 as compared to salt non-tolerant variety, V_4. Furthermore, it was observed among the salt tolerant varieties that the value of spikes per m^2 for V_2 was highest as compared to V_1 and V_3. A Similar trend was observed for grains per spike as well as 1000 grain weight for different salinity levels and varieties (Table 3). In the control treatment, the values of grains per spike as well as 1000 grain weight were found to be relatively high for salt non-tolerant variety but an increase in salinity level showed reduction in the values of both parameters.

Table 3: Yield attributes of different wheat varieties under different salinity levels for *rabi* 2009-10 and 2010-11.

Treatments	1000 Grain Weight (g)		Grains per Spike		Spikes per m^2	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
S1V1	33	34	33	42	324	339
S1V2	35	37	35	48	367	382
S1V3	35	36	35	43	356	371
S1V4	36	38	36	48	372	387
S2V1	32	33	32	40	308	323
S2V2	34	35	34	46	348	363
S2V3	32	33	32	41	316	331
S2V4	27	28	27	38	248	260
S3V1	31	32	31	37	283	295
S3V2	31	33	31	43	298	310
S3V3	31	33	31	38	291	303
S3V4	27	28	27	35	241	253
S4V1	30	32	30	34	256	268
S4V2	31	32	31	40	275	287
S4V3	31	32	31	35	265	277
S4V4	26	27	26	33	232	244
LSD (P=0.05)						
salinity	1.71	1.78	1.83	3.7302	28.26	21.36
variety	1.04	1.09	1.06	3.1808	17.08	21.73
Salinity X variety	2.09	2.17	2.12	NS	34.16	43.45

Whereas, among the salt tolerant varieties there was no significant variation for grains per spike or 1000 grain weight (Table 3).

Correlation and regression analysis was carried out for assessing the degree of association among the yield components and the grain yield (Table 4 and Fig. 1). The correlation coefficients between the spikes per m^2 and grain yield were 0.79 and 0.72 for the year 2009-10 and 2010-11, respectively. The corresponding figures for the grains per spike, 1000 grain weight and biological yield with respect to grain yield were 0.77, 0.77 and 0.88 for *rabi*2009-10 and 0.71, 0.75 and 0.80 for *rabi* 2010-11, respectively. A significant and positive correlation was observed between the other yield attributes for both years.

Table 4: Correlation coefficients (*r*) of the association among the grain yield of wheat and its attributes for all treatments for *rabi* 2009-10 and 2010-11.

Yield attributes	Spikes per m²		Grains per Spike		1000 grain weight		Biological yield		Grain yield	
	09-10	10-11	09-10	10-11	09-10	10-11	09-10	10-11	09-10	10-11
Spikes per m²	1.00	1.00								
Grains per Spike	0.84	0.73	1.00	1.00						
1000 grain weight	0.84	0.80	1.00	0.63	1.00	1.00				
Biological yield	0.86	0.71	0.86	0.57	0.86	0.70	1.00	1.00		
Grain yield	0.79	0.72	0.77	0.71	0.77	0.75	0.88	0.80	1.00	1.00

Analysis revealed a positive and good correlation of grain yield with spikes per m^2, grains per spike, 1000 grain weight and biological yield (Fig 1). The respective coefficients of determination (R^2) values were 0.63, 0.6, 0.6 and 0.8 for the year 2009-10 and 0.51, 0.50, 0.57 and 0.64 for the year 2010-11. The R^2 for the 1000 grain weight and grain yield were non-significant for both the years.

Grading of wheat grain under different treatments

Grading of the grain was categorized into three fractions *viz* bold, light weight and under size (*i.e.* <1.8 mm), represented as Grade I, Grade II and Grade III, respectively. It was revealed that the proportion of the small grain size increased significantly by 3% to 27% and 4% to 29% for all

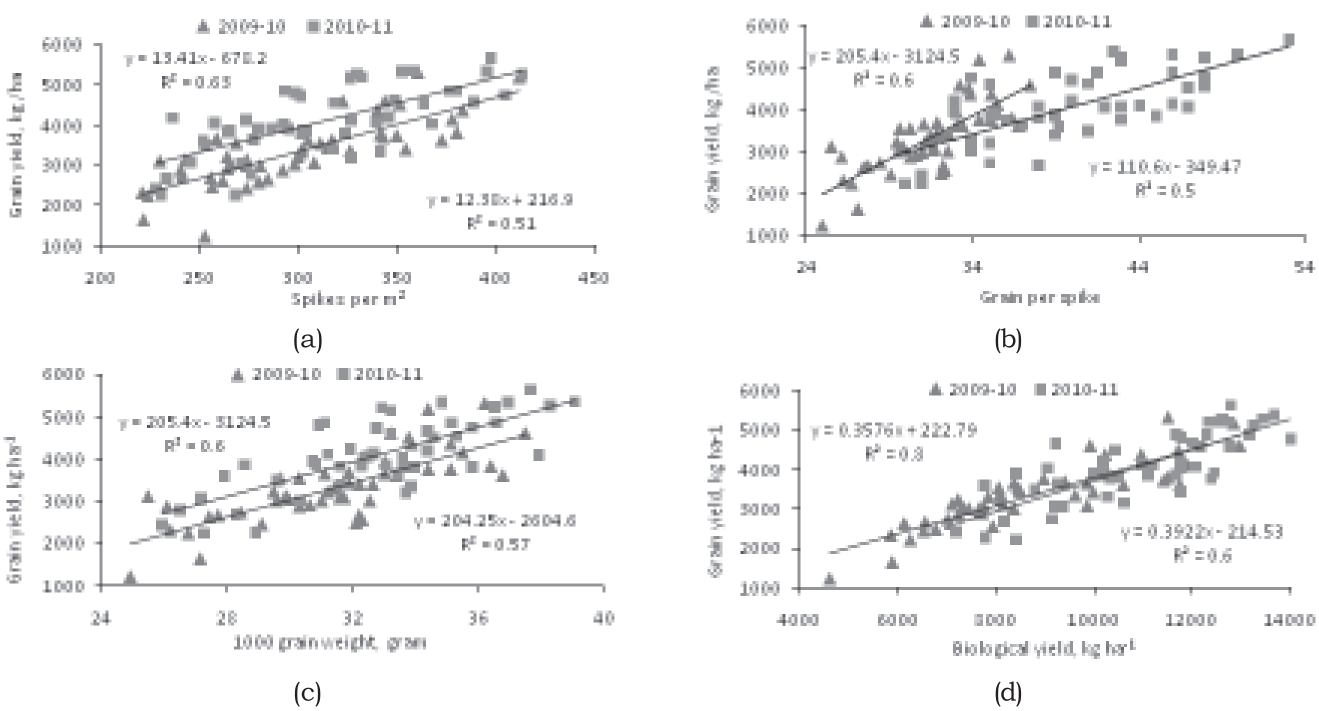

Fig. 1: Relationship between grain yield and its attributes for all treatments during *rabi* 2009-10 and 2010-11

treatments of the year 2009-10 and 2010-11, respectively. Interestingly, all varieties (*i.e.* salt tolerant and salt non-tolerant) increased the small grain fraction at higher salinity levels (*i.e.*12 dS/m), which in other words showed that yield of good quality bold grain decreased with the increase of salinity (Table 5). The proportion of bold grains ranged between 48 to 80% and 51 to 85% during the year 2009-10 and 2010-11, respectively and among all varieties this proportion was observed for V_4 variety, higher proportion of bold grain was observed in control (ground water) and lower proportion of bold grain was observed in S_4 salinity level.

The fraction with bold size but light in weight ranged between 5 to 19 % and 5 to 20 % for all treatments of the year 2009-10 and 2010-11, respectively. The small grain size fraction (S_3) varied significantly among the treatments and ranged from 3% to 27% during the year 2009-10 which further increased to 4% to 29% under various treatments.

It was observed that the wheat grain of grade I under different salinity levels decreased with increasing salinity levels. The fraction of grade II was observed to be non-significant between S_1, S_2 and S_4 salinity levels but significant difference was observed at S_3 salinity levels during both years Moreover, the fraction of grade III showed increasing with increase in salinity levels during both years. The fraction of different wheat varieties was observed to be significantly different for grade I during both years, whereas, the fraction of grade II and grade III was observed less in V_2 variety than other three varieties respectively.

Table 5 : Effect of salinity levels and varieties on grade of wheat grain

Treatments	Grain screening (%)					
	Grade I(Bold)		Grade II(Light Weight)		Grade III(Under Size)	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
S1V1	79	82	15	14	6	4
S1V2	76	81	11	11	8	8
S1V3	74	79	16	16	5	5
S1V4	80	85	9	9	6	6
S2V1	74	79	11	11	10	10
S2V2	79	84	9	9	7	7
S2V3	76	81	11	11	7	8
S2V4	68	72	14	15	12	13
S3V1	73	77	11	11	11	12
S3V2	77	82	11	11	7	7
S3V3	73	78	8	8	14	14
S3V4	75	80	5	5	14	15
S4V1	67	71	10	10	18	19
S4V2	73	78	8	8	14	14
S4V3	68	72	12	12	16	16
S4V4	48	51	19	20	27	29
LSD (P= 0.05)						
salinity	2.0327	2.2132	0.3724	0.4326	1.1627	1.21517
variety	3.4414	3.6310	0.3649	0.3218	0.3649	0.3781
Salinity X variety	6.88	7.26	0.72	0.64	0.72	0.76

CONCLUSION

It was concluded from two years study that the wheat grain yield, water use efficiency (WUE) and above ground biomass were significantly affected by both saline water regime and wheat varieties. Also irrigation water salinity levels were significantly affected at (P d” 0.05) on grain yield, biomass and yield attributes as well as grain fraction in 2009-10 and 2010-11, respectively. Moreover, wheat varieties were significantly affected at (P d" 0.05) in both experimental years. The salt tolerant wheat variety KRL-1-4 produced highest yield at irrigation water salinity levels of 8 and 12 dS/m. The average yield of KRL-1-4 was higher by 26% and 41% as compared to the non-salt tolerant variety HD2894 (V_4) under irrigation water salinity levels of 8 and 12 dSm^{-1}, respectively.The interaction effect of treatment on grain yield was significant (P d" 0.05) and CD was 0.57 and 0.73 for the year of 2009-10 and 2010-11, respectively. In both experimental years, the yield was highest (*i.e.* 5.25 t/ha) for V_4 variety at S_1 salinity level during 2010-11. Moreover, the yield due to combined effect of salt tolerant and salt non-tolerant wheat varieties was maximum (*i.e.* 3.9 t/ha) at higher salinity levels (S_4) for *rabi* 2010-11. The average above ground biomass yield of salt tolerant variety KRL-1-4 was higher by 22-25% and 25-30% during both years as compared to the non-salt tolerant variety HD-2894 under irrigation water salinity of 8 and 12 dS/m, respectively. The yield attributes were significantly affected by the saline irrigation treatments and wheat varieties. The important yield component, spikes per m^2 ranged from 224 to 372 and 339 to 387 in the control for both years of experiment. The correlation coefficient between the spikes per m^2 and grain yield was observed to be 0.79 and 0.72 and R^2 was 0.63 and 0.51 for *rabi* 2009-10 and 2010-11, respectively. The fractional analysis for grading of grain in salt tolerant and salt non-tolerant varieties showed an increase of the small grain fraction at higher salinity levels (12 dS/m) and also the proportion of good quality bold grain decreased with the increase of salinity levels. Nonetheless, it can be concluded that salt tolerant wheat varieties would increase the marketable grain yield and water use efficiency under irrigated saline environment.

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