Asian Journal of Plant Sciences

ISSN 1682-3974

science alert

ANSInet
an open access publisher
http://ansinet.com

Asian Journal of Plant Sciences 5 (6): 1057-1060, 2006
ISSN 1682-3974
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Response of six Bread Wheat (*Triticum aestivum* L.) Cultivars to Saline Irrigation Water

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Abstract: In the present study the effect of 3 irrigation water (IW) salinities of 4, 8 and 12 dS m^{-1} were studied on grain yield and yield components of 6 wheat cultivars namely: Pishtaz, Shiraz, Mahdavi, Marvdasht, Kavir and Roshan during 2000 and 2002 growing seasons. The experiment was arranged in a split plot design, in four replicates, where irrigation water salinity and wheat cultivars were in the main plots and the sub-plots, respectively, in a silty clay loam soil. Increasing irrigation water salinity significantly decreased grain yield, number of spikes per square meter, plant height, grain filling duration and days to maturity. Based on mean productivity index (MP), geometric mean productivity index (GMP), stress tolerance index (STI) and stress susceptibility index (SSI); Roshan cultivar (a local grown cultivar, selected from local land races) was the most tolerant and stable cultivar in a wide range of irrigation water salinity levels. The Roshan mean grain yield was 4.237 Mg ha^{-1} in three IW salinity levels.

Key words: Wheat, cultivar, salinity, stress index, irrigation water

INTRODUCTION

Worldwide estimation of land under cultivation is about 13%, of which 30-50% of irrigated land is salt affected (Igbal, 2003). In Iran about 12% of the total land is under cultiuvation, about 50% of which is affected by salinity, sodicity and water-logged conditions to various degrees (Mirmohammady Maibody and Ghareyazie, 2002). Wheat is the staple food in many arid and semi-arid regions of Iran. These regions are also facing with soil and water resources salinity problem and falling ground water table. Selection of salt tolerant wheat cultivars are vital to yield enhancement. Ali *et al*. (2002) studied the response of 10 wheat genotypes to three irrigation water salinities (NaCl sources) of 0, 7.5 and 15 dS m^{-1}. Increasing IW salinity significantly decreased plant height, shoot wet and dry weight. It was concluded that enhancing wheat plant salt tolerance is possible due to genetic variability through conventional breeding techniques. Jafari Shabestari *et al*. (1993) studied the effect of saline IW on hexapliod and tetraploid wheat cultivars. For analyzing yield response, one of the selected characters was Fischer-Maurer stress index (SSI).

Shahsavand-Hasany and Abde-Mishani (1993) studied the effect of salt stress on native Iranian and foreign wheat cultivars. Increasing salinity decreased the number of days from planting to heading and days to physiological maturity, plant height, biomass, grain yield, weight of thousand seeds and number of spikes per unit area. Only, the number of grain per spikelet was not significantly affected by salinity. The salt tolerance index (the ratio of grain yield in stress environment to non-stress environment) was significantly correlated with grain yield in stress environment.

Afiuni *et al*. (2005) compared the response of 18 promising wheat lines with Kavir and Roshan cultivars, in saline conditions in which grain yields of the 8 promising lines were more than control. Houshmand *et al*. (2005) studied 8 durum wheat genotypes, in normal and salt-stress environments. The days to heading, days to maturity, plant height, number of seeds per spike, weight of grain per spike, weight of thousand seeds, number of spikes per unit area and harvest index decreased by salinity.

Various indices has been introduced for evaluating the response of different genotypes to environmental stresses. Fischer and Maurer (1978) introduced stress susceptibility index (SSI). The genotypes which are more stable across stress and non-stress environments, show lower SSI values.

Fernandez (1992) introduced the salt tolerance index (STI). More stable genotypes has higher STI values. Rosielle and Hamblin (1981) concluded that MP, GMP and STI are the most suitable indices for evaluation of plant response to environmental stress. High STI values has been employed for selection of salt tolerant barley genotypes (Noori-Niya *et al*., 2004; Jaradat *et al*., 2004). The objectives of this study were to evaluate the response of grain yield and yield components of 6 wheat cultivars to three levels of irrigation water salinity for selection of the most tolerant and stable cultivars.

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Table 1: The soil chemical properties for 0-30 cm

Year	SP%	EC(dS m^{-1})	pH	OC(%)	P	K	HCO_3^-	Na	Zn	Cu	Cl^-	SO_4^{2-}	Ca+Mg
					mg kg^{-1}						meq L^{-1}		
2000	49	6	7.6	0.60	12	295	2.4	92	1.30	1.08	138	40.6	90
2002	48	6	7.5	0.45	18	225	2.8	32	0.58	1.88	40	26.2	38

MATERIALS AND METHODS

The field study was conducted at Roudasht Agricultural Research Station of Isfahan Agricultural and Natural Resources Research Center in 60 km East of City of Isfahan (32° 29' N, 52° 10' E, 1560 m elevation) between 2000 and 2002 growing seasons. The soil is a silty clay loam (Typic, Haplosalid, fine mixed termic). A randomized complete block design with split plot arrangement in four replications was used for both years. The main plots were three levels of irrigation water salinity of 4, 8 and 12 dS m^{-1} and the sub-plots were six wheat cultivars namely: Pishtaz, Shiraz, Mahdavi, Marvdasht, Kavir and Roshan (a local grown cultivar, selected from local land races).

The seedbed was prepared using conventional moldboard plough and disking. Before fertilizer applications a composite sample was collected and macro- and micronutrients, organic matter, EC_e and pH were measured using standard laboratory methods (Table 1). Fertilizers application were according to the soil test recommendation (Iranian Soil and Water Research Institute), with N, P and K in the forms of Urea, Superphosphate triple and Potassium Sulfate, respectively.

Wheat was sown in 20 cm rows at the rate of 500 seeds per square meter considering the thousand seed weight, using an experimental field planter. The plots were 1.20 m (6 rows) wide by 4 m length. Planting dates were Nov. 22 and Nov. 25 for 2000 and 2002 growing season, respectively. None-saline irrigation water (EC =1 dS m^{-1}) was used for the planting and first post plant irrigation, for adequate seed germinations and plant establishment. The saline irrigation treatments were applied at the beginning of spring growing season. The grain yield were determined on 3 m^2, number of spikes per unit area on 0.6 m^2 and number of grains per spike on 20 spikes. The number of days to heading, number of days to maturity, plant height, grain yield, number of spikes per square meter and, weight of thousand seeds were measured for each treatment. The data was analyzed using analysis of variance and the means were compared using Duncan multiple range test.

Based on grain yields of 4 and 12 dS m^{-1} IW treatments, the susceptibility and tolerance indices were calculated by the following formulas:

- Tolerance index (Tol); Tol=Yp-Ys
- Mean productivity index (MP); MP = (Yp+Ys)/2
- Geometric mean productivity index (GMP); $GMP = \sqrt{Yp^* Ys}$
- Stress tolerance index (STI); $STI = \frac{Ys \times Yp}{\bar{Y}p\text{\^{}}2}$
- Stress susceptibility index (SSI); $SSI = \frac{1-\frac{Ys}{Yp}}{1-\frac{\bar{Y}s}{\bar{Y}p}}$

Where:

Yp = The mean yield of each cultivar in 4 dS m^{-1} IW salinity treatment

Ys = The mean yield of each cultivar in 12 dS m^{-1} IW salinity treatment

$\bar{Y}p$ = The mean yield of all cultivars in 4 dS m^{-1} IW salinity treatment

$\bar{Y}s$ = The mean yield of all cultivars in 12 dS m^{-1} IW salinity treatment

RESULTS AND DISCUSSION

Increasing IW salinity significantly ($p<0.05$) decreased grain yield. For 8 and 12 dS m^{-1} IW salinity treatments, grain yield decreased by 8.8 and 18% compared with the control (4 dS m^{-1}), respectively. The number of spikes per square meter decreased with increasing IW salinity, however, the effect of salinity on weight of 1000 seeds and numbers of grains per spike were not significant. Therefore, a large portion of yield decrease; is due to the decrease in numbers of spikes per unit area. The Roshan and the Shiraz cultivars, produced the highest and second highest grain yields of 4237 and 3972 kg ha^{-1}, respectively (Table 2). The reduction of the numbers of spikes due to increasing salinity is similar to the results reported by Francois *et al.* (1994) and Mass *et al.* (1996). Also, increasing IW salinity, reduced plant height, days to maturity and grain filling duration.

The genotypes having higher STI show higher yield stability across different environments (Fernandez, 1992). Therefore, Roshan cultivar with STI of 1.20 was the most stable cultivar in the wide range of IW salinities.

Table 2: The effects of irrigation water salinity and wheat cultivars on grain yield, spike per square meter, weight of thousand seeds, seed per spike, plant height, days to heading and days to maturity

Treatments	Grain yield (Mg ha^{-1})	Spike m^{-2}	Weight of thousand seeds (g)	Grain/spike	Plant Height (cm)	Days to heading	Days to maturity	Grain filling duration (day)
Salinity (dS m^{-1})								
4	3.870a	498a	36.1a	30.4a	74.6a	142a	177a	35a
8	3.535ab	470b	35.4a	30.7a	72.7a	142a	174ab	32ab
12	3.167b	427c	33.2a	28.8a	69.5b	143a	173b	30b
Cultivars								
Pishtaz	3.512b	428d	34.6b	26.6d	68.3cd	141c	174bc	33b
Shiraz	3.972a	507a	33.8b	28.1c	69.1c	145a	178a	33b
Mahdavi	3.105bc	458c	38.8a	28.9c	71.4b	141c	172c	31bc
Marvdasht	2.872c	451c	30.3c	32.9b	66.7d	141b	173c	29c
Kavir	3.449b	486b	34.3b	34.8a	67.9cd	138d	174bc	36a
Roshan	4.237a	460c	37.7a	28.4c	90.3a	143b	176ab	33b

Means within columns followed by the same lettet are not significantly different bases on Duncan multiple range test ($p<0.05$)

Table 3: The mean grain yield (Mg ha^{-1}) and stress index values of wheat cultivars during 2001 and 2002 growing seasons

Cultivars	Grain yield Ec_w= 4 dS m^{-1}	Grain yield EC_w Ec_w= 12 dS m^{-1}	Arithmetic mean index (MP)	Geometric mean index (GMP)	Tolerance index (Tol)	Stress tolerance index (STI)	Stress susceptibility index (SSI)
Pishtaz	3.927	3.096	3512	3487	831	0.81	1.17
Shiraz	4.240	3.607	3924	3911	633	1.02	0.82
Mahdavi	3.482	2.706	3094	3070	776	0.63	1.23
Marvdasht	3.303	2.565	2934	2911	738	0.57	1.23
Kavir	3.745	3.049	3397	3379	696	0.76	1.02
Roshan	4.526	3.987	4257	4248	539	1.20	0.66

Table 4: Correlation coefficient (R) of selected stress indices with grain yield, for 4 and 12 dS m^{-1} IW

	MP	GMP	Tol	STI	SSI
Grain yield, EC_w = 4 dS m^{-1}	0.99**	0.99**	-0.72ns	0.99**	-0.99**
Grain yield, EC_w =12 dS m^{-1}	0.99**	0.99**	-0.81*	0.99**	0.97**

** Significant at $p<0.01$, ns: not significant

Marvdasht cultivar with 0.57 STI value was the most sensitive cultivar (Table 3). Noory-Niya *et al.* (2005) and Jaradat *et al.* (2004) selected salt tolerant barley cultivars based on high values of STI indices.

The lower SSI value for a given cultivar the more stable is the cultivar in stress and non-stress environments (Fisher and Maurer, 1978). Roshan cultivar showed the lowest SSI value of 0.66, therefore was the most stable cultivar in stress environment. SSI value for both Marvdasht and Mahdavi cultivars were 1.23, which showed that they were the most salt sensitive cultivars. Rosielle and Hamblin (1981) reported that when considering both MP and Tol indices together, cultivars that show low Tol values and high MP values are more tolerant to salinity. Among studied cultivars, Roshan cultivar was ranked as the most tolerant cultivar, based on lowest Tol and highest MP indices of 539 and 4257, respectively.

The correlation coefficients between grain yields in 4 and 12 dS m^{-1} IW treatments with MP, GMP, Tol, STI and SSI indices showed that grain yield in 12 dS m^{-1} IW salinity treatment was positively correlated with MP, GMP and STI indices, however the grain yield was negatively correlated with Tol and SSI indices, in non-saline and saline environments (Table 4).

The results of correlation coefficient from this study also supported by Golparvar (2005) who reported that MP, GMP and STI values are highly and positively correlated with grain yield in stress and non-stress environments; therefore are good indicator of high yielding cultivar in saline and non-saline environments.

Due to Roshan high salt tolerance characteristic; participation of Roshan cultivar in future breeding programs for yield improvement in saline conditions is highly recommended.

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