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Full Length Article

Evaluation of Wheat Cultivars Under Salinity Stress Based on Some Agronomic and Physiological Traits

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ABSTRACT

Fifteen Iranian wheat cultivars (*Triticum aestivum* L.) were compared for salt (NaCl & Na_2SO_4 in 1:1 ratio) tolerance using three treatments: 1.26 (control), 6.8 and 13.8 dSm^{-1} in a green house. During vegetable growth, shoot Na^+, K^+, K^+: Na^+ ratio and agronomic traits such as 1000-grain weight, grain yield, biological yield, number of tillers, number of fertile tillers, spike length, salinity susceptibility index (SSI) and salt tolerance index (STI) were measured. In general, tolerant cultivars (Kavir, Niknejad, Chamran & Falat) with better agronomic performance, contained low Na^+ and higher K^+ and K^+: Na^+ ratio compared to non-tolerant ones (Ghods, Bayat, Cross Adl & Zarin). Shoot Na^+ content was negatively correlated with grain yield ($r = -0.37$, $p < 0.05$). There was a negative correlation between shoot Na^+ content and STI ($r = -0.66$, $p < 0.01$) and a positive one with SSI ($r = 0.71$, $p < 0.01$). These two indexes may be useful for selection of tolerant cultivars under saline conditions.

Key Words: K^+: Na^+ ratio; Salinity susceptibility index; Wheat

INTRODUCTION

Soil salinity is one of the major environmental stresses affecting plant growth and productivity (Allakhverdiev *et al.*, 2000). Salinity induces water deficit even in well watered soils by decreasing the osmotic potential of soil solutes thus making it difficult for roots to extract water from their surrounding media (Sairam *et al.*, 2002). The effect of high salinity on plant can be observed at the whole plant level in terms of plant death and/or decrease in productivity (Parida *et al.*, 2004). Crop yield start declining when pH of the soil solution exceeds 8.5 or EC value goes above 4 dSm^{-1}. At higher EC values the crop yield are reduced so drastically that crop cultivation is not economical without soil amendments (Sairam & Srivastava, 2002). Growth resumes when the stress is relieved. Salinity stress biology and plant responses to high salinity have been discussed over two decades (Flowers *et al.*, 1977; Greenway & Munns, 1980; Ehret & Plant, 1999; Hasegawa *et al.*, 2000; Zhu, 2002).

The varietal differences in salinity tolerance that exist among crop plants can be utilized through screening programs by exploiting appropriate traits for salt tolerance (Kingsbury *et al.*, 1984). Grain yield is frequently used in crops such as wheat as the main criteria for salt tolerance (Jafari- Shabestari *et al.*, 1995). Other agronomic traits such as number of tiller, fertile tillers with other indices have been used for the assessment of salt tolerance. These parameters are the main criterions for selecting other complex traits such as resistance to salinity are not satisfying (Flowers & Yeo, 1995). Also the use of physiological markers such as content of Na^+, K^+ and the ratio of K^+: Na^+ are less feasible and in the view of some researchers are not promising (Shannon, 1984). However, it is believed that selection and breeding would be more successful in achieving maximum attainable tolerance, if it were based directly on the relevant agronomic and physiological mechanism(s) (Noble & Rogers, 1992).

Salt stress result in a considerable decrease in the fresh and dry weights of leaves, stems, tillers, fertile tillers and roots (Chartzoulakis & Klapaki, 2000). High ionic concentration competes with the uptake of other nutrients, especially K^+, leading to K^+ deficiency. Increased treatment of NaCl increases Na^+ and Cl^- and decrease in Ca^{2+}, Mg^{2+} and K^+ levels in number of plant (Khan *et al.*, 1999). There is a negative relationship between Na^+ and K^+ concentration in roots and leaves. The selective uptake of K^+ as opposed to Na^+ is considered to be one of the important physiological mechanisms contributing to salt tolerance in many plant species (Greenway & Munns, 1980; Gorham *et al.*, 1987; Chhipa & Lal, 1995; Ashraf & Khanum, 1997). It is well documented that a greater degree of salt tolerance in plant is associated with a more efficient system for selective uptake of K^+ over Na^+ (Wyn Jones *et al.*, 1984; Noble & Rogers, 1992). It has been reported that the salt tolerant barley varieties maintained lower Na^+ than non-tolerant ones (Schachtman *et al.*, 1991; Pakniyat *et al.*, 1997; Rivelli *et al.*, 2002).

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The use of plant ionic status along with agronomic traits has been shown to be applicable and their relationship with salt tolerance indices are considered strong enough to be exploited as a selection tool in the breeding of salt tolerance cultivars (Allakhverdiev *et al*., 2000). Genotype variation for agronomic and physiological traits has been reported for drought tolerance in wheat (Fischer & Maurer, 1978; Tavakol & Pakniyat, 2007) and safflower (Ashkani *et al.*, 2007). In this study, leaf Na^+ and K^+ concentration and some agronomic traits were measured to evaluate the salt tolerance in 15 wheat cultivars.

MATERIALS AND METHODS

Plant materials and sowing. Fifteen wheat cultivars (Table II) were compared at 3 salinity levels [1.26 (control), 6.80 and 13.80 dSm^{-1}] for their Na^+, K^+, K^+: Na^+, some agronomic traits (1000 grain weight, grain yield, biological yield, number of tillers, number of fertile tillers & spike length) and two salinity indices [salinity susceptibility index (SSI) and salt tolerance index (STI)], in a completely randomized design with 3 replications. The experiment was conducted in a glasshouse at Agricultural College, Shiraz University, in Badjgah, Iran, 2006. These cultivars were random regarding their salinity tolerance and some were known for their tolerance to salinity by local farmers in Iran. Cultivars "Kavir" and "Ghods" were known as salt-tolerant and Sensitive cultivars, respectively and they were used as check cultivars in this experiment. Ten seeds were planted in 5 kg pots filled with a clay loam soil (35% clay, 27% sand & 38% silt, bulk density 1.43 g cm^{-3} & EC 0.86).

The Plants were watered according to field capacity using tap water. After germination (15 days following sowing) three plants were retained in each pot.

Salt treatments application. The plants were subjected to three conditions: no salt (control) and two salinity levels [2.5 & 5 g salt (NaCl & Na_2SO_4 in 1:1 ratio) per kg of soil]. Salt stress treatments were applied 4 weeks after planting (at 2 leaf stage). Salt stock solution (25 g of both salts in 1:1 ratio dissolved per liter of deionized water) was applied to appropriate pots in split and in 4 stages within 4 weeks to final concentrations by irrigation based on soil field capacity.

Na^+, K^+ and K^+: Na^+ ratio measurements. Four weeks after applying salt treatments, leaf samples were collected, washed in distilled water to remove any external salt and dried at 60°C oven for 48 h. The dried samples were ground into a fine powder using a mortar and pestle. Samples (1 g) were ashed by putting them into crucibles and placed in 600°C electric furnace, for 4 h, 5 mL of 2 N HCl were added to cooled ash samples, dissolved in boiling deionized water, filtered and made final volume to 50 mL. Na^+ and K^+ were measured using standard flame photometer procedure (Vogel, 1955) and reported as mg g^{-1} dry weight.

Agronomic traits measurement. Observation for number of tillers, number of fertile tillers and spike length were measured 75 days after sowing. For the other agronomic traits (grain yield, plant dry matter & 1000 grain weight), observations were recorded at harvesting. The stress susceptibility index (SSI) was calculated for the grain yield for each cultivar using following formula (Fischer & Maurer, 1978):

$$SSI = \frac{1-\left(GYs/GYp\right)}{1-D}$$

Where GYs is the mean of cultivar under salt stress and, GYp the mean of cultivar under non-stress (control) conditions. D is the ratio of the overall mean of all cultivars under stress to the overall mean of all cultivars in control condition. Salt tolerance index (STI) was calculated for the grain yield of each cultivar as:

$$STI = \frac{Ys}{Yc}$$

Where Ys is the mean of the cultivar under salt stress and Yc the mean of cultivar under control condition.

Statistical analysis. Data were analyzed using MSTATC statistical package. Pearson correlation analysis was performed using SPSS13 statistical package. Mean comparisons were performed using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Analysis of variance and significance of Na^+, K^+, K^+: Na^+ and agronomic traits for salinity and cultivar factors are presented in Table I. Na^+, K^+ and K^+: Na^+ were highly significant ($p< 0.001$) for salinity and cultivars factors. Salinity had highly significant effect on grain yield ($p< 0.001$) and biological yield ($p<0.01$), while cultivars were significantly different for these traits ($p< 0.05$).

Na^+, K^+ and K^+: Na^+ contents. Salt treatments (1.26, 6.80 & 13.80 dSm^{-1}) had significant effects on Na^+, K^+ and K^+: Na^+ ratio of the wheat cultivars (Table I). Wheat cultivars were different in regard to Na^+, K^+ content and K^+: Na^+ ratio EC= 13.8 (Table II). This indicates the existence of genetic diversity of these traits among the wheat cultivars and it is in agreement with the results obtained by Hemati and Pakniyat (2006), who reported variation of these traits in bread and durum wheat cultivars in response to salt stress.

"Kavir" (a salt tolerant cultivar) had the lowest Na^+ content and the highest K^+: Na^+ ratio, whilst "Ghods" (a salt sensitive cultivar) had the highest Na^+ content and the lowest K^+: Na^+ ratio. Cultivars "Niknejad", "Chamran", "Falat" and "Morvdasht" having lower Na^+ and higher K^+: Na^+ ratios may be considered as salt tolerant cultivars and the cultivars "Bayat", "Cross Adl", "Zarin" and Darab-2 with higher Na^+ content and lower K^+: Na^+ ratios may be considered as non- tolerant cultivars (Table II). Considering the K^+: Na^+ ratios, our results are consistent with the finding of Chhipa and Lal (1995), who suggested that wheat

Table I. Analysis of variance for the traits investigated in 15 wheat cultivars in response to salinity stress.

Source	df	Na^+	K^+	K^+/Na^+	1000-grain weight	Grain yield	Biological yield	Tiller No.	Fertile tiller	Spike length
Salinity	2	***	***	***	*	***	**	***	***	**
Cultivar	14	***	***	***	**	*	*	*	*	*
Salinity*Cultivar	28	***	**	***	***	^{a} ns	ns	**	*	ns

^{a} Non- significant
* Significantly at $p < 0.05$.
** Significantly at $p < 0.01$.
*** Significantly at $p < 0.001$.

Table II. Average of evaluated criteria at EC = 13.80 dS m^{-1} in 15 wheat cultivars (Cultivars are ranked according to their shoot Na^+ contents)

No.	Cultivar	Shoot Na^+ (mg g^{-1})	Shoot K^+ (mg g^{-1})	K^+/Na^+ (mg g^{-1})	1000-grain weight (g)	Grain yield (g)	Biological yield (g)	Tiller	Fertile tiller	Spike length (cm)	SSI	STI
1	Kavir	41.3 h	64.2 a	1.55 a	35.9 cd	1.81 a	5.1 ab	2.5 a-d	1.7 bc	5.4 ab	0.4	0.9
2	Niknejad	60.2 g	57.7 a-d	0.96 b	32.1 fg	1.73 ab	5.1 abc	2.0 d	1.7 bc	5.4 ab	0.8	0.8
3	Chamran	66.5 g	58.8 bcd	0.88 b	36.0 cd	1.61 ab	4.3 abc	2.1 cd	1.8 abc	4.2 bc	0.9	0.8
4	Falat	79.0 f	56.8 bcd	0.72 bc	34.8 e	1.66 ab	4.7 abc	2.1 a-d	1.7 bc	5.1 ab	0.8	0.8
5	Marvdasht	79.0 f	63.1 ab	0.80 b	33.1 f	1.72 ab	5.8 a	2.2 a-d	1.8 abc	5.9 a	0.8	0.7
6	Azadi	87.4 ef	46.9 ef	0.54 cd	35.7 de	1.49 b	4.1 abc	2.6 a	1.8 abc	5.4 ab	1.1	0.7
7	Shiraz	89.5 de	59.2 abc	0.66 bc	36.9 abc	1.53 ab	4.2 abc	2.5 a-d	2.1 ab	4.2 bc	1.1	0.7
8	Pishtaz	93.7 cde	48.0 ef	0.51cd	38.1 a	1.71 ab	4.5 abc	2.2 a-d	1.7 bc	4.8 abc	1.2	0.7
9	Adl	97.9 cd	63.7 a	0.65 bc	36.5 bc	1.73 ab	4.2 abc	2.4 a-d	1.8 abc	4.3 bc	0.8	0.8
10	Star	97.9 bc	44.5 f	0.45 cd	37.3 abc	1.62 ab	4.7 abc	2.5 a-d	2.4 a	4.4 bc	1.4	0.7
11	Darab-2	100.0 c	52.9 cde	0.53 cd	36.5 bc	1.56 ab	4.8 abc	2.1 cd	2.0 abc	4.1 bc	0.9	0.8
12	Zarin	102.1 bc	52.5 cde	0.51 cd	35.6 de	1.72 ab	5.2 abc	2.4 a-d	1.5 c	5.4 ab	1.2	0.7
13	Cross Adl	110.5 ab	55.5 cd	0.50 cd	31.8 g	1.64 ab	5.2 ab	2.7 a	1.6 bc	5.6 a	0.8	0.8
14	Bayat	114.7 a	51.9 de	0.45 cd	32.4 f	1.59 ab	4.4 abc	2.5 a-d	1.8 abc	4.8 abc	1.6	0.6
15	Ghods	116.7 a	44.1 f	0.38 d	37.2 abc	1.51 b	3.9 c	2.2 a-d	1.8 abc	3.8 c	1.6	0.6
	Mean	89.1	54.6	0.67	35.3	1.64	4.7	2.3	1.8	4.8	1.0	0.7
	CV (%)	24.92	8.06	20.68	4.22	4.79	31.8	20.8	21.22	31.9	3.91	7.21

* Means followed by the same letter(s) in each column are not significantly different (DMRT, $p < 0.01$).

Table III. Correlation coefficients between Na^+, K^+, K^+/Na^+, agronomic traits and salinity indices of 15 wheat cultivars.

Traits	[11]	[10]	[9]	[8]	[7]	[6]	[5]	[4]	[3]	[2]
[1] K	0.801^{**}	-0.824^{**}	0.052	0.251	0.084	0.2	-0.459^{*}	-0.021	0.746^{**}	-0.589^{*}
[2] Na	-0.663^{**}	0.709^{**}	-0.045	-0.25	-0.369^{*}	-0.242	0.077	0.311	-0.441^{*}	
[3] K/Na	0.672^{**}	-0.544^{*}	0.32	-0.13	0.004	-0.189	-0.223	-0.13		
[4] Tiller	-0.69^{**}	0.142	-0.094	0.247	.061	-0.1	0.089			
[5] Fertile Tiller	0.352	-0.35	0.41^{*}	-0.521^{**}	-0.462^{*}	-0.397^{*}				
[6] Biological Yield	0.316	0.504^{*}	-0.543^{*}	0.769^{**}	0.251					
[7] Grain DM	-0.133	0.151	0.03	0.219						
[8] Spike Length	0.255	-0.401^{*}	-0.604^{**}							
[9] 1000 grain Weights	-0.114	0.211								
[10] SSI †	-0.936^{**}									

*,** significantly difference at $p<0.05$ and $p<0.01$ respectively.
† SSI and STI are "salinity susceptibility index" and "salt tolerance index" respectively.

cultivars with higher K^+: Na^+ ratios could be considered as salt tolerant ones grown under saline conditions.

Agronomic traits. Cultivars were different regarding their biological and grain yield at higher salt level (Table II). The highest biological and grain yield were given by "Kavir" and the lowest was belonged to "Ghods". The correlation between grain yield and Na^+ was negative ($r= -0.37$, $p< 0.05$) (Table III). Therefore, salt tolerant cultivars having lower Na^+ content, produced higher grain and biological yield under saline conditions. Akram *et al.* (2002) and Kamkar *et al.* (2004) showed that salinity reduces yield primarily by a sever reduction in grain number, 1000 grain weight and the grain yield. The same results were obtained for barley genotypes under saline conditions (Pakniyat *et al.*, 1997).

Salinity indices. There were variations between wheat cultivars in regard to SSI and STI under saline conditions (Table II). "Kavir" had the lowest SSI and the highest amount of STI. In contrast, "Ghods" had the highest SSI and the lowest of STI values. There was significantly positive correlation between Na^+ and SSI ($r= 0.71$, $p< 0.01$) showing that, non-tolerant cultivars having higher Na^+ contents, also have higher SSI index. Correlation between Na^+ and STI was negative ($r= -0.66$, $p< 0.01$) Positive correlation of SSI with Na^+ and negative one of STI with Na^+ revealed that by increasing Na^+, there would be an increase and a decrease in SSI and STI respectively (Table III).

The correlations between physiological traits, agronomic traits and salinity indices are presented in Table III. These results indicate that physiological traits (Na^+ & K^+: Na^+ ratio) and salinity indices (SSI & STI) were good indices for screening salt tolerant cultivars and these traits are correlated with grain yield and biological yield in wheat.

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