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RESEARCH PAPER

Physiological response of wheat (*Triticum aestivum* L.) cultivars and inbred lines to salinity stress at the seedling stage

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Abstract

The lack of effective selection criteria for salt tolerance in the screening process is one of the reasons for limited success in conventional salt tolerance breeding. The objective of this study was to determine the effect of salinity stress of two concentration levels (0 and 150 mM NaCl) on 10 wheat cultivars and 319 F_7 inbred lines (derived from a cross between Roshan and Falat) and whether seedling traits could be used in breeding programs for salt tolerance. The study was conducted in a randomized completely block design with three replications in a supported hydroponic system. The results showed significant differences between control and salinity treatments for all measured traits. Differences among genotypes were significant for all traits. Shoot Na^+ content and K^+/Na^+ ratio increased and decreased for all genotypes in response to salinity, respectively. Arg and Sorkh tokhm had higher and lower shoot Na^+ contents, root to shoot Na^+ translocation and lower and higher K^+/Na^+ ratio in stress condition versus other genotypes and also had the maximum and minimum increases in shoot Na^+ content and minimum and maximum decreases in shoot K^+/Na^+ ratio in stress condition versus normal condition, respectively. It seems that Arg is a tissue tolerator and accumulating high levels of Na^+ in their shoots while maintaining relatively lower levels of leaf damage compared to sensitive genotypes. The results suggest that Na^+ exclusion, increased K^+/Na^+ ratio, chlorophyll content and root to shoot Na^+ translocation ratio could be valuable selection criteria for salt tolerance.

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Introduction

The world's most important limiting factor for crop growth can be considered water and soil salinity. More than 7 percent of total arable land in the world is affected by salinity (Flowers, 2004; Flowers *et al.*, 1997). Biological management practices, including identifying mechanisms of salt tolerance in crop plants and breeding of new varieties, are the most effective solution to reduced salinity problems. There are a number of mechanisms in cereals makes them able to tolerate salinity. Different physiological traits such as $Na^{+,}$ K^+ and Cl^- concentrations and K^+/Na^+ ratio have been related to the salt tolerance of cultivars of different species (Abel and MacKenzie, 1964; Ashraf and O'Leary, 1996; Flowers *et al.*, 1997; Greenway and Munns, 1980; Kingsbury and Epstein, 1984; Kingsbury and Epstein, 1986; Qureshi *et al.*, 1980; Rashid *et al.*, 1999; Shah *et al.*, 1987; Storey and Jones, 1978; Weimberg, 1987; Yeo and Flowers, 1982; Yeo *et al.*, 1990). For example in wheat, salt tolerance is associated with lower rates of sodium transport to the shoot, with high selectivity for K^+ over Na^+ (Chen *et al.*, 2007; Munns and James, 2003). Similarly in maize, salt-resistant genotypes show lower Na^+ uptake by roots and less translocation to the shoot (Sumer *et al.*, 2004), the latter possibly because of an efficient sodium uptake by the xylem parenchyma cells (Fortmeier and Schubert, 1995; Zörb *et al.*, 2005).

Grain yield obtained under saline field conditions is the last test for salt tolerance, but due to non-uniformity of the soil during the growing season because of temporal and spatial changes, field screening for tolerance to salinity is inefficient (Richards, 1983), so that such work must necessarily be carried out under controlled conditions. Researcher should attempt to establish some relationship between physiological traits and yield components for use as selection criteria for salt tolerance under controlled conditions (Salam *et al.*, 1999). The relation of various seedling growth parameters to seed yield and yield component under saline conditions are important for the development of salt tolerant cultivar for production under saline conditions (Rahman *et al.*, 2008). Valid selection criteria can be used in breeding programs.

To increase understanding of the mechanisms of salt tolerance in wheat, and to define the value of such putative selection criteria, a number of cultivars of hexaploid wheat and inbred lines were investigated in hydroponic culture. The objective of this study was to determine the effect of salinity stress of two concentration levels on some wheat cultivars and inbred lines and whether seedling traits could be used in breeding programs for salt tolerance.

Material and methods

Plant materials

We used an F_7 RIL population (consisting of 319 sister lines), their parents and 8 cultivars for this research. The RILs were derived from a cross between bread wheat cultivars Roshan and Falat (seri82). Roshan was a local salt tolerant cultivar and Falat (seri82) was salt-sensitive spring bread wheat from CIMMYT (Poustini and Siosemardeh, 2004). The cultivars included salt tolerance cultivar (Arg, Sorkh tokhm, Bam, Shole, Bulani and Mahuti) and salt sensitive cultivar (Moghan 3, Ghods).

Experimental design

We carried out this research in hydroponics culture under greenhouse conditions at the agricultural Biotechnology Research Institute of Iran (ABRII), in June and July 2012. We conducted this experiment in randomized completely block design with three replications under each of control and salinity stress. This research measured salt tolerance of 319 RILs, their parents and 8 cultivars at 0 and 150 mM NaCl concentrations (called N treatment and S treatment, respectively). We made sterile the surfaces of uniform-sized seeds of each line in 10% hypochlorite for 1 min, rinsed three times with distilled water. Then we allowed the seeds to germinate in two days on filter paper in Petri dishes containing distilled water. After that we transferred uniformly germinated seeds to holes made in sheet of 2 cm Styrofoam, which were floated on distilled water, with eight seedlings for each line of each repeat. Two days after transplanting, we applied half-strength Hoagland's nutrient solution (Hoagland and Arnon, 1950), and we increased it to full-strength after two days. Two days later, salt treatment started. To avoid salt shock, we added 50 mM NaCl daily to a final concentration of 150 mM for the S treatment, while in the N treatment, we added no NaCl. We aerated the solution without stopping and replaced it every seven days. The air temperature ranged from 15 to 30˚C. We checked the pH daily by pH meter (HI 991001, RoTH, Germany) and adjusted it to 5.5 to 6.0 using either HCL or NaOH.

Trait measurements

After treatment of 150 mM for four weeks, using a scale of 1 for green leaves to 9 for leaf death, we recorded salt injury index (SII) or leaf symptoms. Using an SPAD-502 chlorophyll meter (Minolta, Japan), we measured chlorophyll content (CHL) of base, middle and tip of the youngest fully expanded leaf for three seedlings. We harvested the roots and shoots separately and recorded maximum shoot height (SH) and the total shoots fresh weights (SFW), and then the roots and shoots rinse with distilled water. Meanwhile, we isolated the measuring leaves for chlorophyll content. We oven-dried the leaves, roots and shoots at 75˚C for 48h and measured shoot dry weights (SDW). For measuring Na^+ and K^+ in the leaves (shoots) and roots, 0.1 g of each line leave and roots weighed. We extracted the samples with 0.1 M acetic acid at 90˚C for 4 h and analyzed them for Na^+ and K^+ by the flame photometer (410, Corning M410, U.K). We found out the shoot Na^+ (SNC), shoot K^+ (SKC), root Na^+ (RNC), and root K^+ (RKC) concentrations. We calculated the Na^+ translocation from roots to shoots (Saqib *et al.*, 2005) as follows: RTSN = shoot Na^+ content (mmol) / root Na^+ content (mmol). Also, K^+ translocation from roots to shoots was calculated as follows: RTSK = shoot K^+ content (mmol) / root K^+ content (mmol).

Statistical analysis

Data were analyzed using SAS (version 9.1) statistical package. Mean comparisons were performed using least significant difference (LSD) test ($P<0.05$). Correlation coefficients were calculated for each trait under saline and control conditions using SPSS 15.

Results

Responses of cultivars and RILs under control and saline conditions

The combined analyses of variance showed that genotypes differed significantly at levels $P<0.01$ in all traits (Table 1). The interactions between genotypes and location were also significant for all traits, except for shoot dry weight and chlorophyll content indicating the different responses of the genotypes to increasing NaCl (Table 1). Other researcher indicated that dry weights compare to fresh weights o (Murillo-Amador *et al.*, 2002; Sayar *et al.*, 2010) and chlorophyll content (Ghaedrahmati *et al.*, 2013) were less affected by salinity. Thereby, it seems that the significant traits can be discriminated between salt tolerance and salt sensitive genotypes in wheat. Significant interaction between location and genotypes for sodium and potassium concentration and K^+/Na^+ in shoot and root explained that the genotypes reaction versus absorption of sodium and potassium are different under salt stress (Table 1).

The mean of genotypes traits are shown in Table 2. There was a range of responses to salinity among the genotypes for measured traits. Shoot height decreased for all genotypes in response to salinity. Bulani and Falat had higher and lower shoot heights in stress condition versus other genotypes, respectively. Sorkh tokhm and Ghods had the minimum and maximum decreases in shoot height in stress condition versus normal condition, respectively.

Shoot fresh and dry weights decreased for all genotypes in response to salinity. Sorkh tokhm and Moghan3 had higher and lower shoot fresh and dry weights in stress condition against other genotypes, respectively. Sorkh tokhm and Ghods had the minimum and maximum decreases in shoot fresh weight in stress condition against normal condition, respectively. Mahuti and Ghods had the minimum and maximum decreases in shoot dry weight in stress condition against normal condition, respectively.

Chlorophyll content increased for all genotypes in response to salinity. Sorkh tokhm had higher chlorophyll content in stress condition versus other genotypes. Bulani had the maximum increase in chlorophyll content in stress treatment versus normal treatment.

Salt injury index increased for all genotypes in response to salinity. Bam had higher salt injury index in stress condition against other genotypes and also had the maximum increase in salt injury index in stress condition versus normal condition.

Shoot Na^+ content increased for all genotypes in response to salinity. Arg and Sorkh tokhm had higher and lower shoot Na^+ contents in stress condition versus other genotypes and also had the maximum and minimum increases in shoot Na^+ content in stress condition versus normal condition, respectively. It seems that Arg is a tissue tolerator and accumulating high levels of Na^+ in their shoots while maintaining relatively lower levels of leaf damage compared to sensitive genotypes. Therefore, Arg must have the ability to reduce the amount of Na^+ accumulating in the cytoplasm of leaf cells, possibly through compartmentation of Na^+ in the vacuole, thereby reducing the toxic effect on cytosolic enzymes and processes (Rajendran *et al.*, 2009; Tester and Davenport, 2003).

Shoot K^+ content decreased for all genotypes in response to salinity. Sorkh tokhm and Falat had higher and lower shoot K^+ contents in stress condition versus other genotypes, respectively. Sorkh tokhm and Arg had the minimum and maximum decreases in shoot K^+ content in stress condition against normal condition, respectively.

Root Na^+ content increased for all genotypes in response to salinity. Bulani and Falat had higher and lower root Na^+ contents in stress condition versus other genotypes, respectively. Roshan and Sorkh tokhm had the maximum and minimum increases in root Na^+ content in stress condition versus normal condition, respectively.

Root K^+ content decreased for all genotypes in response to salinity. Ghods had higher root K^+ contents in stress condition against other genotypes. Mahuti and Falat had the maximum and minimum decreases in root K^+ content in stress condition against normal condition, respectively.

Shoot K^+/Na^+ ratio decreased for all genotypes in response to salinity. Sorkh tokhm and Arg had higher and lower shoot K^+/Na^+ ratio in stress condition versus other genotypes and also had the minimum and maximum decreases in shoot K^+/Na^+ ratio in stress condition versus normal condition, respectively.

Root K^+/Na^+ ratio decreased for all genotypes in response to salinity. Falat and Roshan had higher and lower root K^+/Na^+ ratio in stress condition versus other genotypes, respectively. Mahuti and Falat had the maximum and minimum decreases in root K^+/Na^+ ratio in stress condition versus normal condition, respectively.

Root to shoot Na^+ translocation decreased for most genotypes except Arg, Bam, Falat, Moghan3 and Shole in response to salinity. Arg and Sorkh tokhm had higher and lower root to shoot Na^+ translocation in stress condition against other genotypes respectively. Arg also had the maximum increases in root to shoot Na^+ translocation in stress condition versus normal condition. Sorkh tokhm also had the maximum decreases in root to shoot Na^+ translocation in stress condition against normal condition.

Root to shoot K^+ translocation increased for all genotypes in response to salinity. Ghods had lower root to shoot K^+ translocation in stress condition versus other genotypes. Mahuti and Falat had the maximum and minimum increases in root to shoot K^+ translocation in stress condition against normal condition, respectively.

Relationships between the traits

There were significant genetic correlations among some measured traits (Table 3). SII and SFW were negatively correlated in both treatments, but this correlation was low. The correlation between SII and SNC was not significant (r_g= 0.09) in S treatment, therefore some lines had a higher Na^+ concentration in shoot but showing few leaf symptoms. This result indicated that these genotypes had higher level of tissue tolerance (Genc *et al.*, 2010). Weak and negative correlations were observed between SNC and SFW (r_g= -0.48), SDW (r_g= -0.46) and CHL (r_g= -0.43) in S treatment, which explain the importance of this ion in salt tolerance. However, SKN was positively correlated with them and was negatively correlated with SII in S treatment. These findings suggested that higher-yielding genotypes might not be necessarily better Na^+ excluder ones (Genc *et al.*, 2010) and SKN may facilitate improvement of salt tolerance at seedlings. SNC and SKC had no significant correlation, but RNC and RKC had significant positive correlation, which explains that no competition was between K^+ and Na^+ in the root. Finally, SNC was negatively correlated with biomass traits and CHL in S treatment while SKC had no significant correlation with these traits. Even so, RNC had no significant correlation with biomass traits and CHL, while RKC was positively correlated with biomass traits and CHL (Table 3). These results suggest that the mechanisms controlling salinity in shoots and roots are different (Xu *et al.*, 2012).

The shoot Na^+ content in stress condition and salinity tolerance index (ST) for each genotype are plotted (Figure 1). ST was calculated as the ratio between the average values of shoot dry weight (SDW) for each genotype: SDW (salt treatment)/SDW (control) × 100% (Shavrukov *et al.*, 2011).Sorkh tokhm and some RILs like 52, 14 and 46 which had lower shoot Na^+ content and higher salinity tolerance index are salt tolerance genotypes. Arg and Shole are salt tolerance cultivars, but both had high shoot Na^+ content. Also, some RILs, for example numbers 181 and 168, had high shoot Na^+ content and salt tolerance index. Therefore, these genotypes may contain an effective mechanism for tissue tolerance to salinity and, therefore, can be a potential source of novel gene(s) for ST.

Discussion and conclusion

Different traits responsible for salt tolerance have been used for screening or selection by different workers (Cramer *et al.*, 1994; Greenway and Munns, 1980; Kuiper *et al.*, 1988; Matveev and Vakulenko, 1990; Sastry and Prakash, 1993; Weimberg and Shannon, 1988), but several points should be raised (Garcia *et al.*, 1997). First, no individual trait will necessarily correlate with overall plant performance. Secondly, tolerance could be improved by a favorable recombination of the trait. Finally, selection should be for the component trait and not for overall performance. The last point is especially important, because most traditional breeding is carried out based on plant vigor or yield.

Table 1. Analysis of variance for evaluated traits for cultivars and RILs.

Source of variation	D.F	Mean square											
		SH[1]	SFW[2]	SDW[3]	CHL[4]	SNC[5]	SKC[6]	RNC[7]	RKC[8]	SKN[9]	RKN[10]	RTSN[11]	RTSK[12]
Location	1	47027.3**	748.52**	3.27**	11862.3**	203.81**	124.06**	5245.63**	362.66**	138.45**	2923.83**	110.1**	1898.27**
Error	4	200.7**	48.35**	0.96**	336.9**	0.16**	3.52**	3.94**	0.0002*	0.0008*	0.004**	1.96**	12.15**
Genotypes	328	56.1**	0.94**	0.01**	40.9**	0.19**	0.12**	1.49**	0.06**	0.24**	1.38**	0.45**	19.42**
Location*Genotypes	328	13.9**	0.35**	0.00	19.30	0.21**	0.1**	1.95**	0.07**	0.21**	1.33**	0.5**	16.16**
Error	1312	10.70	0.27	0.00	17.20	0.02	0.02	0.33	0.00	0.00	0.00	0.04	0.18
CV%		7.80	34.36	30.20	13.30	17.68	9.31	18.07	1.24	2.78	2.45	16.65	10.89

** Indicates significance at the 0.01 probability level

[1] Shoot height; [2] Shoot fresh weight; [3]Shoot dry weight; [4]Chlorophyll content; [5]Shoot Na^+ concentration; [6] Shoot K^+ concentration; [7]Root Na^+ concentration; [8]root K^+ concentration; Shoot K^+/Na^+ ratio; [10]Root K^+/Na^+ ratio; [11]Root to shoot Na^+ translocation; [12] Root to shoot K^+ translocation.

Table 2. Responses of cultivars and RIL population evaluated under control and saline conditions in hydroponics in a greenhouse. Data are averages of three replications with eight sub-samples per replication.

Trait	treatment	Arg	Bam	Bulany	Falat	Ghods	Mahuty	Moghan3	Roshan	Sholeh	Sorkh tokhm	RILs	LSD 5%*
Soot height, SH (cm)	C	46.11	45.91	47.53	37.57	47.74	47.28	40.2	47.54	46.54	43.91	46.79	4.94
	S	34.89	35.69	39.99	29.63	33.09	38.67	30.36	37.37	38.97	38.33	36.97	2.58
Shoot fresh weight, SFW (g plant^{-1})	C	1.88	2.69	1.94	1.53	2.47	2.6	1.24	3.06	1.66	2.11	2.13	2.07
	S	0.88	0.94	0.81	0.8	0.69	1	0.52	1.19	0.65	1.27	0.91	0.31
Shoot dry weight, SDW (g plant^{-1})	C	0.17	0.22	0.18	0.18	0.3	0.21	0.15	0.34	0.18	0.26	0.24	0.13
	S	0.12	0.16	0.15	0.15	0.09	0.19	0.08	0.2	0.15	0.22	0.16	0.05
Chlorophyll content, CHL (SPAD value)	C	23.94	22.38	21.5	29.52	24.33	28.35	24.74	28.64	25.82	23.85	28.85	1.37
	S	38.48	33.37	35.9	34.8	34.15	36.7	29.42	37.51	29.18	39.47	33.66	2.17
Salt injury index, SII	C	2	2.43	2.33	2.38	3.33	2.67	3	1.77	3	2.59	2.32	1.64
	S	3.15	4.62	3.51	4.15	3.46	3.5	4.09	3.12	4.37	3.5	2.76	1.34
Shoot Na^+ concentration, SNC (m mol g^{-1} DW)	C	0.31	0.43	0.52	0.29	0.45	0.41	0.3	0.29	0.43	0.4	0.41	0.03
	S	1.67	1.24	1.39	1.34	1.12	1	1.45	0.74	1.5	0.56	1.07	0.33
Shoot K^+ concentration, SKC (m mol g^{-1} DW)	C	2.21	2.3	2.61	1.95	2.06	2	2.06	1.96	2.14	1.95	1.89	0.13
	S	1.44	1.53	1.74	1.32	1.39	1.64	1.55	1.45	1.7	1.83	1.39	0.12
Root Na^+ concentration, RNC (m mol g^{-1} DW)	C	0.33	0.46	0.48	0.31	0.47	0.41	0.32	0.34	0.42	0.6	0.31	0.04
	S	1.14	1.25	1.49	1.13	1.35	1.31	1.16	1.32	1.27	1.34	1.17	0.12
Root K^+ concentration, RKC (m mol g^{-1} DW)	C	0.9	1.66	1.61	0.88	1.61	1.56	1.06	0.88	1.51	1.27	0.85	0.20
	S	0.42	0.56	0.45	0.5	0.59	0.4	0.51	0.34	0.47	0.45	0.33	0.08
Shoot K^+/Na^+ concentration ratio, SKN	C	7.15	5.35	5.05	6.73	4.58	4.88	6.78	6.72	4.99	4.88	4.74	0.61
	S	0.86	1.23	1.25	1.14	1.24	1.64	1.07	2.32	1.13	3.29	1.44	0.35
Root K^+/Na^+ concentration ratio, RKN	C	2.74	3.58	3.37	2.54	3.47	3.82	3.3	2.51	3.59	2.11	2.71	0.50
	S	0.37	0.45	0.3	0.45	0.44	0.3	0.44	0.26	0.37	0.33	0.28	0.08
Root to shoot Na^+ translocation, RTSN	C	0.94	0.93	1.08	0.94	0.96	1.01	0.95	0.85	1.02	0.66	1.4	0.17
	S	1.47	1	0.93	1.22	0.83	0.77	1.25	0.55	1.18	0.41	0.93	0.30
Root to shoot K^+ translocation, RTSK	C	2.46	1.38	1.62	2.95	1.27	1.29	1.94	2.44	1.41	1.54	2.96	1.20
	S	3.44	2.72	3.89	3	2.36	4.14	3.04	4.4	3.58	4.08	4.96	0.57

In this study, the correlation between SII and other traits were low, especially in S treatment. Therefore, this study can not consider SII as a single selection criterion in breeding programs for salt tolerance in wheat seedling stage.

The results suggest that Na^+ exclusion and increased K^+/Na^+ ratio could be a valuable selection criterion for salt tolerance. This fact is in agreement with the findings of Xu *et al.* (2012) and Genc *et al.* (2010).

In this study it was found that CHL correlated with all the biomass traits and some of the physiological traits (SNC, RKC, SKN, RKN, RTSN and RTSK). CHL directly associate with light harvesting potential, and other researchers considered it as an important item of the photosynthetic capacity (Metwali *et al.*, 2011). Megdiche *et al.* (2008) also reported important roles for photosynthetic pigments content considering its direct association with salt tolerance. It needed for light harvesting and acts against salt-induced oxidative damages. This result shows that selection for CHL may improve salt tolerance in wheat (Ma *et al.*, 2007; Schreiner and Zozor, 1998).

Also, RTSN had a negative correlation with all the biomass traits, and this fact suggests that selection for decreasing the root to shoot Na^+ translocation may provide some progress in salt tolerance. Salt tolerance in the Triticeae is associated with better ability to discriminate between Na^+ and K^+ at the uptake sites of plasmalemma and to preferentially accumulate K^+ and exclude Na^+ (Ali *et al.*, 2004; Omielan and Epstein, 1991). Gorham (1990), Rashid *et al.* (1999) and Sarwar and Ashraf (2003) reported that in wheat, genetic variation in salt tolerance is associated with low rates of Na^+ transport to shoot and high selectivity for K^+ over Na^+. Such genotypes have the ability to manipulate root to shoot transport of Na^+ by: (1) reducing the net influx of Na^+ into the root; (2) increasing the net flux of Na^+ from the transpiration stream into the living root cells; (3) compartmentalizing shoot Na^+ into their sheaths and not leaf blades; or (4) a combination of all three mechanisms (Rajendran *et al.*, 2009).

Table 3. Correlation coefficients between different traits under N (above diagonal) and S (below diagonal) treatments.

	SH	SFW	SDW	CHL	SII	SNC	SKC	RNC	RKC	SKN	RKN	RTSN	RTSK
SH		0.28**	0.42**	0.12*	0.05	-0.12*	-0.12*	0.02	0.08	0.05	0.09	-0.09	-0.08
SFW	0.52**		0.86**	0.39**	-0.19**	0.40**	0.17**	0.09	-0.14*	-0.32**	-0.20**	0.27**	0.17**
SDW	0.51**	0.90**		0.46**	-0.15**	0.20**	0.06	0.06	-0.10	-0.17**	-0.13*	0.17**	0.11*
CHL	0.27**	0.63**	0.60**		-0.17**	0.19**	-0.16**	0.00	-0.12*	-0.29**	-0.08	0.21**	0.10
SII	0.03	-0.18**	-0.10	-0.05		-0.13*	-0.02	-0.14**	-0.04	0.12*	0.03	0.00	0.00
SNC	-0.14**	-0.48**	-0.46**	-0.43**	0.09		0.36**	0.02	-0.24**	-0.80**	-0.31**	0.67**	0.34**
SKC	0.09	-0.04	-0.09	-0.05	-0.05	-0.02		0.05	-0.04	0.25**	-0.12*	0.21**	0.26**
RNC	0.05	-0.01	0.03	0.00	0.01	0.07	0.10		0.33**	0.00	0.03	-0.49**	-0.29**
RKC	0.11**	0.22**	0.15**	0.30**	0.05	-0.19**	0.10	0.40**		0.22**	0.91**	-0.65**	-0.77**
SKN	0.11**	0.41**	0.37**	0.38**	-0.11*	-0.86**	0.30**	-0.05	0.16**		0.25**	-0.55**	-0.19**
RKN	0.09	0.23**	0.13*	0.32**	0.05	-0.23**	0.07	0.06	0.93**	0.19**		-0.48**	-0.75**
RTSN	-0.15**	-0.42**	-0.41**	-0.38**	0.08	0.87**	-0.06	-0.41**	-0.37**	-0.76**	-0.25**		0.71**
RTSK	-0.07	-0.17**	-0.13*	-0.24**	-0.06	0.18**	0.09	-0.42**	-0.77**	-0.10	-0.71**	0.40**	

*,** Indicates significance at the 0.05 and 0.01 probability level, respectively.

SH: Shoot height, SFW: Shoot fresh weight, SDW: Shoot dry weight, CHL: Chlorophyll content, SII: Salt injury index, SNC: Shoot Na^+ concentration, SKC: Shoot K^+ concentration, RNC: Root Na^+ concentration, RKC: root K^+ concentration, SKN: Shoot K^+/Na^+ ratio, RNC: Root K^+/Na^+ ratio, RTSN: Root to shoot Na^+ translocation, RTSK: Root to shoot K^+ translocation.

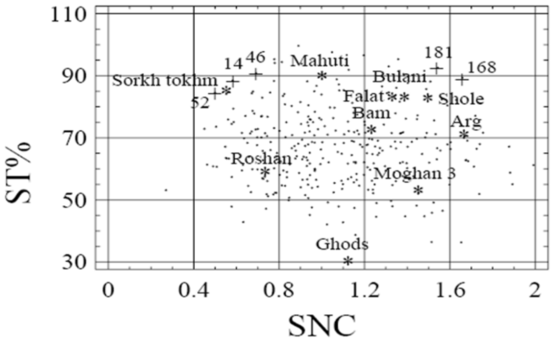

Fig. 1. Plot of Na+ accumulation (SNC) and salinity tolerance (ST) in 10 cultivars and RILS populations.

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