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DETECTING DIFFERENCES IN SOME ELITE WHEAT LINES FOR SALT TOLERANCE THROUGH MULTI PARAMETERS EVALUATION I. MORPHOLOGICAL AND YIELD PARAMETERS

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Abstract

Salt tolerance potential of a newly developed wheat genotype (N-9760: V3) was assessed by comparing it with a known salt tolerant line (N-1073:V2) and a commercial cultivar (Inqlab: V1) using various growth parameters measured at the vegetative and maturity stages, The objectives were to know qualitative and quantitative tolerance status and possible utilization of the new genotype as well as to examine as to whether the parameters used to assess the tolerance at vegetative and maturity stages are affected differentially by various salinity levels. The experiment was conducted in pots using four salinity levels (EC 1.5, 5, 10 and 15 dS m^{-1}). Root and shoot length, root and shoot fresh and dry weight, number of leaves and leaf area were recorded at the vegetative stage, while plant height, number of tillers, spike length and grain yield $plant^{-1}$ were recorded at the maturity stage. Fresh weight of shoots, fresh and dry weights of roots, plant height, number of productive tillers and grain yield were least affected in V3 while shoot length, shoot fresh weight, number of leaves, leaf area and spike length were least affected in V2 by EC 15 dS m^{-1}. Both genotypes appeared tolerant but all the parameters studied at both stages were affected differentially by salinity levels and genotypes hence, testing of every new genotype appeared essential.

Introduction

Salinity is one of the major environmental constraints that limit plant growth through osmotic inhibition, specific ion effect or both (Ashraf, 1994; 2004) and limits yields by damaging the crop and the land beyond economic repair (Flower, 2004; Munns *et al.*, 2006). It has affected approximately 20% of agricultural land and 50% of cropland around the globe (Gassemi *et al*., 1995). Salinity stress generally hampers the rate of growth of most crops (Farooq, 1990), thereby causing poor economic yield (Shannon *et al.*, 1994). The concentrations at which these effects take place differ with the genetic capacity of the species, growth stage, and environmental interactions (Maas & Poss, 1989). Morphological symptoms reflect the detrimental effects of salinity stress. Salinity-induced decrease in shoot growth occurs due to suppression in growth in young growing parts and not in adult photosynthetic parts (Munns *et al*., 1982). This results in reduced size of leaves and stems of the salt-affected plants. In wheat, for example, salinity stress improves root-shoot ratio, suppresses leaf size, decreases number of tillers $plant^{-1}$, spikelets $spike^{-1}$, seeds $spike^{-1}$ and grain weight, which ultimately reduces dry matter as well as the grain yield (Khan & Abdullah, 2003). However, the degree to which all these parameters are affected by salinity differs with different crop species, varieties and interaction of each parameter with different salinity levels (Shannon & Grieve, 1999;

Noori & McNeilly, 2004). Here, we are presenting comparative differences in morphological and yield parameters observed at the vegetative and maturity stages in three different wheat genotypes subjected to different salinity regimes. The objectives were to know qualitative and quantitative tolerance status and possible utilization of the new genotype and to observe whether or not the parameters used to assess the tolerance at vegetative and maturity stages are affected differentially by various salinity levels and in different genotypes.

Materials and methods

Three genetically different wheat genotypes comprising Inqlab (Commercial cultivar: V1), N-1073 [salt tolerant wheat line produced through wide hybridization: V2 (Farooq *et al.*, 1995)] and N-9760 (salt tolerant breeding line: V3) were used in the present study. Uniform sized seeds of the test material were dusted with fungicide (Vitavax) and sown in plastic pots having 22 cm internal diameter and filled with 5 kg of soil to which 500 ml of 25 mg L^{-1} K_2HPO_4 were applied before sowing. Later, four salinity levels including control (Simple water with EC 1.5 dS m^{-1}), 5, 10 and 15 dS m^{-1} were applied as salinity treatments. These levels were prepared by dissolving appropriate amount of NaCl in water used for irrigation given with measured amount of water whenever it was necessary. Other agronomic practices were those recommended for general wheat cultivation. The experiment was conducted at the Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad in a net-house supplied with natural sun light. The mean day and night temperatures were 29±9°C and 15±7°C, respectively. The experiment was laid out in a completely randomized design with three replications. Different morphological and yield parameters comprising fresh and dry weights of root and shoot, root and shoot lengths, productive tillers $plant^{-1}$, number of leaves and leaf area, spike length and grain yield $plant^{-1}$ were recorded. Data for all parameters were analyzed statistically by analysis of variance according to Steel and Torrie (1980). Standard deviations were also calculated to compare mean values of treated and non-treated plants. Results are being presented as tables showing statistical status and figures showing actual values of parameters with and without salinity effects.

Results

Vegetative stage: Under non-saline conditions, the three genotypes differed significantly but only for shoot fresh weight however, differences induced by various salinity levels were highly significant (p<0.01) for both root and shoot fresh and dry weights. For these parameters, the interaction between genotypes and salt levels was not significant (Table 1).

Root fresh weight under control conditions was significantly higher in V2 which reduced highly significantly (p<0.01) under all salinity levels. However maximum and highly significant (p<0.01) reduction in root fresh weight was observed in V1 at EC15dS m^{-1} (Fig. 1a). Difference in dry weights of roots under control conditions was almost similar to that of fresh weight of root, but reduction in dry weights was highly significant in V2 and V3 especially at EC 15 (Fig. 1b). Contrary to this, there was no significant difference in shoot fresh and dry weights of the three genotypes under non-saline (control) conditions but, all salinity levels reduced both the parameters significantly with maximum reduction appeared in V1 (commercial cultivar) and minimum in V2 (salt tolerant wheat line) at EC 10 and 15 dS m^{-1} (Fig. 1c & d).

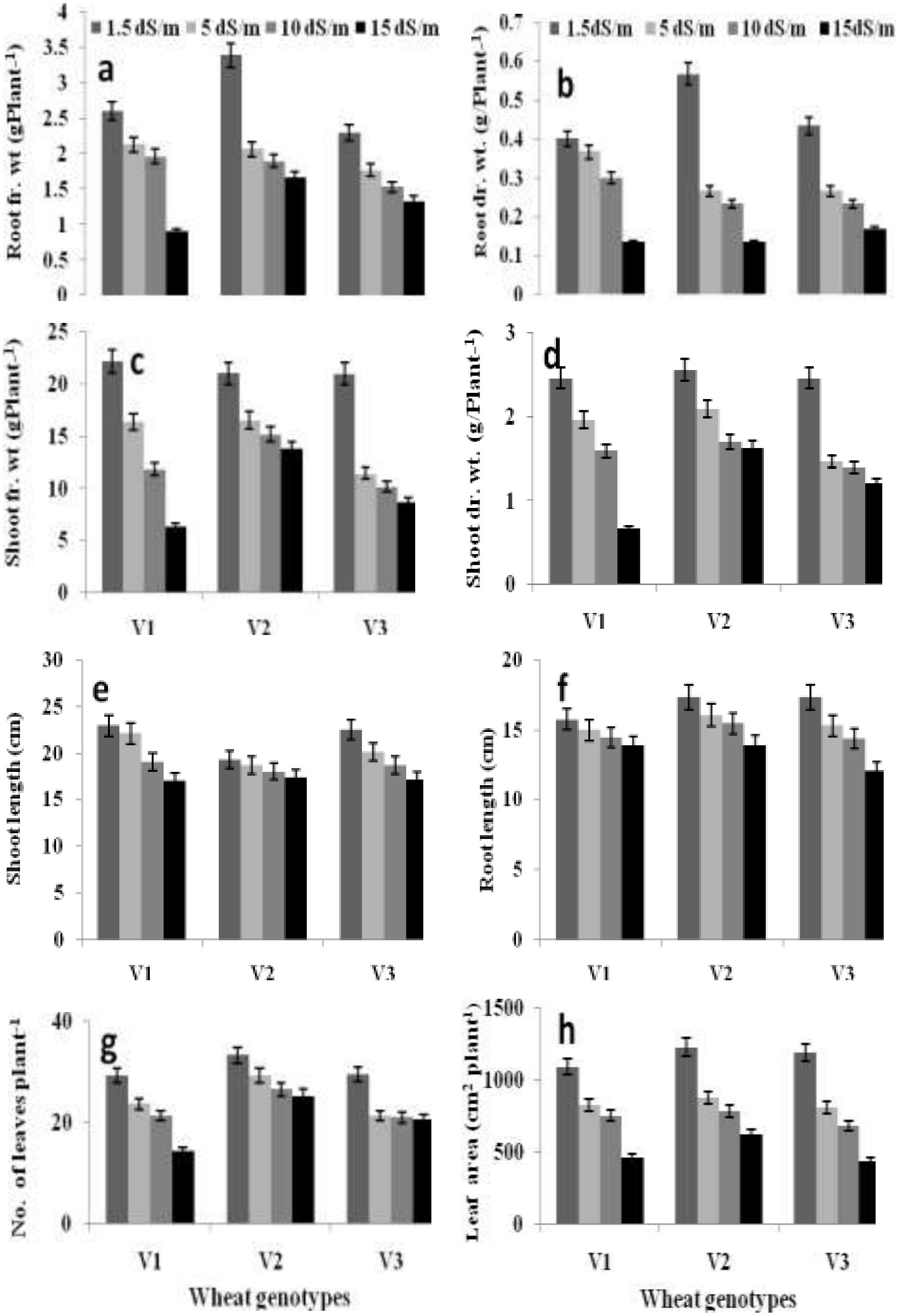

Fig. 1. Vegetative growth parameters including root fresh (a) and dry weights (b), shoot fresh (c) and dry weights (d), shoot (e) and root lengths (f), and number of leaves (g) and leaf area (h) of three wheat genotypes when subjected to salinity levels of EC 1.5 (control), 5, 10, and 15 dS m^{-1}

Table 1. Analyses of variance for fresh and dry weights of shoots (g plant^{-1}) and fresh and dry weights of roots (g plant^{-1}) of three wheat genotypes growing under varying levels of salinity (EC) in soil.

Source	Degree of freedom	Root fresh weight (g)	Root dry weight (g)	Shoot fresh weight (g)	Shoot dry weight (g)
Var	2	0.864 NS	0.002 NS	45.293 *	0.484 NS
Salt	3	3.338 ***	0.161 ***	228.755 ***	2.831 ***
Var x salt	6	0.276 NS	0.012 NS	15.035 NS	0.211 NS
Error	24	0.392	0.015	12.500	0.236
Total	**35**				

NS = Non significant, * = Significant at 0.05, ** = Significant at 0.01 and *** = Significant at 0.001 respectively.

Table 2. Analyses of variance for shoot and root length (cm), number of leaves and leaf area plant^{-1} of three wheat genotypes growing under varying levels of salinity (EC) in soil.

Source	Degree of freedom	Shoot length (cm)	Root length (cm)	Number of leaves plant^{-1}	Leaf area (cm^2) plant^{-1}
Var	2	11.636 **	3.331 NS	147 **	38540.485 NS
Salt	3	34.205 ***	19.172 **	182.667 ***	682821.357 ***
Var x salt	6	3.467 *	1.442 NS	13.444 NS	6633.122 NS
Error	24	1.349	2.708	18.472	34506.032
Total	**35**				

NS = Non significant, * = Significant at 0.05 ** = Significant at 0.01 and *** = Significant at 0.001 respectively

The three genotypes do not differ significantly with respect to root length and leaf area plant^{-1} but difference due to genotypes in shoot length and number of leaves plant^{-1} was highly significant under control conditions which further widens highly significantly due to various salinity levels. The interaction between variety and salinity level was only significant for shoot length (Table 2).

The shoot length in controlled plants of V2 was significantly less compared to V1 and V3 but salinity induced reduction in shoot length was not significant in V2, where as it was reduced significantly (p<0.5) in V1 and V3 at all salinity levels (Fig. 1e). Root length although was higher in V2 and V3 under normal conditions but the difference between the three genotypes was not significant. All salinity levels reduced root length but the difference was significant only in V2 and V3 and for EC 15 dS m^{-1} (Fig. 1f).

Like root length, number of leaves in V2 was also higher compared to V1 and V3 both under normal and saline conditions. Reduction in leaves was significantly higher in V1 and V3 at all salinity levels with the minimum leaves observed in V1 at EC 15dS m^{-1} (Fig. 1g). The difference in leaf area of the three genotypes was not significant under control conditions but, reduction in leaf area due to salinity was significant (p<0.5) especially in V1 and V3 at EC 15 dS m^{-1} (Fig. 1h).

Maturity stage: The difference in all the yield parameters of the three genotypes was highly significant (p<0.01) under control conditions, and various salinity levels have also affected them differentially and highly significantly. However, interaction between salt and genotypes is only significant for grain yield (Table 3). Among various yield parameters, plant height was significantly shorter in V3 compared to V1 and V2 and was further reduced significantly by EC 10 and 15 dS m^{-1}(Fig. 2a). Under normal conditions, numbers of productive tillers were significantly different in all the three genotypes with highest number observed in V2. Salinity induced reduction in tillers was also significant with maximum reduction observed in V1 and V3 and minimum in V2 at EC 15dS m^{-1} (Fig. 2b).

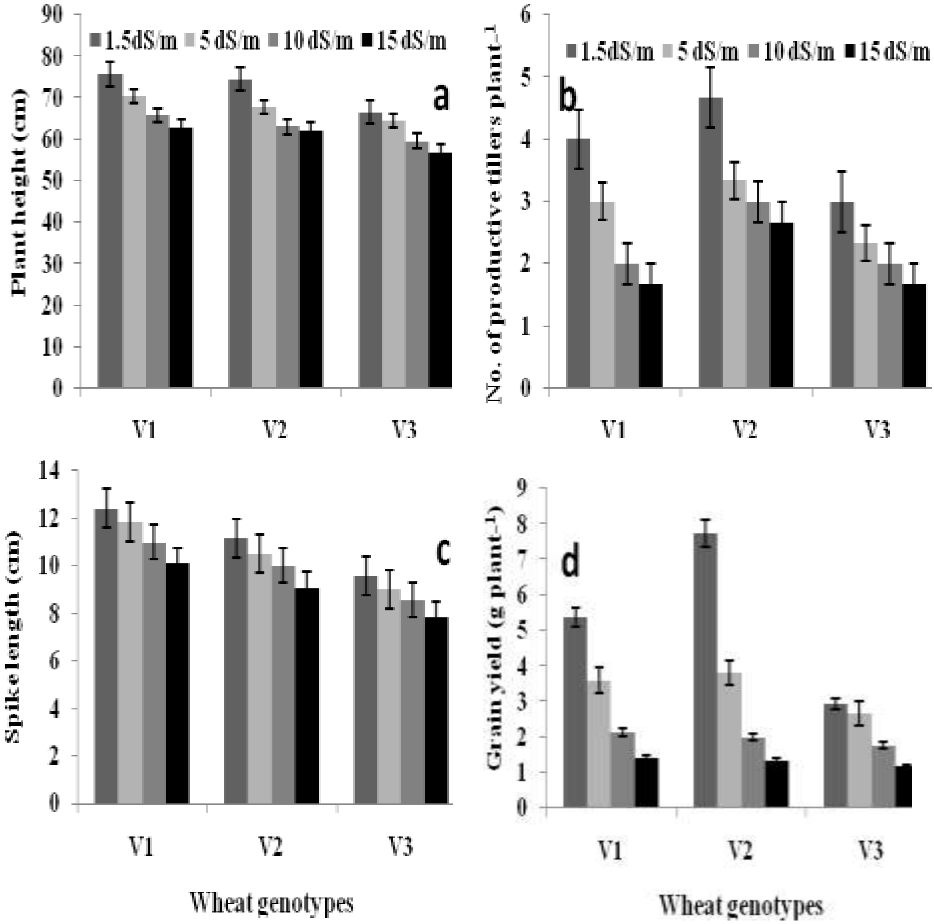

Fig. 2. Yield parameters including plant height (a), No. of productive tiller plant^{-1} (b) spike length (c) and grain yield plant^{-1} (d) of three wheat genotypes when subjected to salinity levels of EC 1.5 (control), 5, 10 and 15 dS m^{-1}.

Table 3. Analyses of variance for spike length (cm), number of productive tillers plant^{-1} and grain yield plant^{-1}of three wheat genotypes growing under varying levels of salinity (EC) in soil.

Source	**Degree of freedom**	**Plant height (cm)**	**Spike length (cm)**	**Number of productive tillers plant^{-1}**	**Yield (g) plant^{-1}**
Var	2	145.75 **	20.10 **	4.194 ***	7.68 **
Salt	3	241.30 **	6.903 **	6.148 ***	28.74 ***
Var x salt	6	4.334 NS	0.062 NS	0.231 NS	3.615 *
Error	24	17.584	0.707	0.333	1.311
Total	**35**				

NS = Non significant, ** = Significant at 0.01 and *** = Significant at 0.001, respectively.

Spike length was maximum in V1 and minimum in V3 under control conditions. Various salinity levels reduced spike length significantly but the magnitude of reduction in all the three genotypes was almost similar (Fig. 2c). The difference in grain yield was highly significant ($p<0.1$) under control conditions and was reduced highly significantly in V2 even with salinity of EC 5 dS m^{-1} (Fig. 2d). Grain yield was minimum in V3 and maximum in V2 under control. All salinity levels reduced grain yield significantly especially in V1. Interestingly, compared to V2 and V1, salinity induced reduction in grain yield was minimum in V3 and the pattern of reduction was similar at all salinity levels (Fig. 2d)

All the parameters in all the genotypes whether recorded at vegetative or maturity stages were affected differentially by salinity levels of EC 15 dS m^{-1}. Among them root length was least affected in V1 (commercial wheat cultivar Inqlab) by EC 15dS $m^{-1.}$ Shoot length, shoot fresh weight, number of leaves, leaf area and spike length were least affected in V2 (N-1073: breeding line developed through wide hybridization) while fresh weight of shoot, fresh and dry weights of roots, plant height, productive tillers and grain yield were least affected in V3 (N-9760: a breeding line) which thus appeared the most tolerant line after V2 (Table 4).

Discussion

The present study is based on evaluation of salt tolerance of commercial wheat cultivar (Inqlab: V1), a known salt tolerant wheat line (V2: N-1073) and a new wheat line (N9760) developed for salt tolerance using various parameters at the vegetative and maturity stages.

We observed and as has been reported earlier (Iqbal, 2003; Noori & McNiely, 2004) differential reduction in shoot length, root length, fresh and dry weights of shoot and roots, number of tillers, leaves and leaf area plant^{-1} and grain yield in all the three genotypes under the influence of various salinity levels. The newly evolved line V3 (N-9760) appeared the most salt tolerant because it exhibited minimum reduction in about 50% of the parameters studied under salinity level of EC 15 dS m^{-1}.

Vegetative growth of wheat plants is characterized by growth of tillers and leaf appearance and its area, therefore the three agronomic parameters were used to evaluate the test genotypes for salt tolerance. The highly significant ($p<0.01$) reduction due to salinity in number of tillers (one of the major contributors to grain yield) in V1 (commercial wheat cultivar) indicated that this genotype is salt sensitive and is not fit for cultivation on saline lands. Inhibition of leaf area by salinity has also been reported (Alberico & Cramer, 1993) in some of the salt sensitive crops. Since leaf area reduced more significantly in V3 than that in V1 (commercial cultivar), hence, V3 can also be termed as salt sensitive. Richardson & McCree (1985) however, believes that under water stress, some plants show greater ability to expand their leaves not because that leaf is not affected by stress but because of the slower development of water stress, which prolonged the osmotic adjustment. Therefore, comparatively more reduction of leaf area in V3 could possibly be its susceptibility to water stress and not necessarily to salt. This observation is further strengthened if coupled with comparatively and significantly less salinity induced reduction in number of productive tiller and grain in V3 (breeding line N-9760) compared to V1 and V2. This line (V3) can thus be termed as the most salt tolerant among the three genotypes tested.

Table 4. Comparative values of various growth parameters recorded at vegetative and maturity stages of three wheat genotypes growing under non saline conditions and % reduction in these values under the influence of various salinity levels.

Parameters	Values recorded under control		% Reduction at ECe 15dS m^{-1}	
	Maximum	Minimum	Maximum	Minimum
Vegetative stage				
Shoot length (cm)	V1 (23 cm)	All three (17 cm)	V1 & V3 (26.10)	V2 (11.76)
Root length (cm)	V2 &V3 (17.33)	V1 (15.8)	V3 (20.4)	V1 (12.50)
Shoot Fr. Wt. (g)	V1 (22.2 g)	V3 (21g)	V3 (72.0)	V2 (34.50)
Shoot dry Wt. (g)	V2 (2.56 g)	V1& V3 (2.47)	V1 (80.00)	V3 (51.2)
Root Fr. Wt. (g)	V2 (3.4 g)	V3 (2.3g)	V1 (65.40)	V3 (43.5)
Root dr. Wt. (g)	V2 (0.57 g)	V1 (0.4g)	V2 (77.00)	V3 (63.00)
No. leaves plant^{-1}	V2 (33.3 g)	V3 (29.6)	V1 (51.70)	V2 (24.00)
Leaf area (cm^2)	V2(1231.23cm^2)	V1 (1092.4cm^2)	V3(63.30)	V2 (49.22)
Maturity stage				
Pl. height (cm)	V1 &V2 (76.0 cm)	V3 (66.7cm)	V1 & V2 (17.3)	V3 (14.50)
Prod. tillers	V2 (4.67)	V3 (3.0)	V1 (60.0)	V3 (46.6)
Spike length (cm)	V1 (12.4 cm)	V3 (9.6cm)	V1 & V3 (18.55)	V2 (18.2)
Yield plant^{-1} (g)	V2 (7.7 g)	V3 (2.9cm)	V2 (83.12)	V3 (58.62)

58.3%, 16.7% and 25% of the parameters are most affected while 8.3%, 41.7% and 50% of the parameters are least affected by salinity level of 15 dS m^{-1} in V1, V2, and V3, respectively.

Like in other field crops (Write & Rajper, 2004; El-Hendawy *et al.*, 2005) soil salinity also affects grain yield of wheat may be due to less number of productive tillers which contributes towards the reduced grain yield. In the present study, number of productive tillers was significantly (p<0.1) higher in V2 compared to V1 and V3 but, salinity induce reduction was the minimum in V3. Similarly, grain yield was significantly (p<0.01) higher in V2 under control condition compared to V1 and V3 but it reduced highly significantly (p<0.01) under the influence of salinity. Contrary to this, grain yield under control was significantly (p<0.01) low in V3 but salinity-induced reduction was significantly less than that in V1 and V2. Even at 10 dS m^{-1}, it was not reduced to more than 50% of its original yield. All these observations indicated that V3 is actually the salt tolerant genotype while V2 produced more grain yield under saline conditions because it was originally a high yielding genotype. Even after reduction in 83% of its yield under EC 15 dS m^{-1} which rather indicated severe susceptibility to salt stress; V2 still maintained the highest yield under salinity of EC 15 dS m^{-1}. The actual yield potential of V3 is low but salinity induced reduction is 25% less compared to 83% observed in V2. This means as has long been advocated (Richards, 1992) that varieties developed for high yield potential may give more returns on saline lands compared to those developed particularly for salt tolerance.

Conclusion

We inferred that i) all the parameters used to evaluate salt tolerance affected differentially by different salinity levels. At maturity stage, tillers and grain yield was though, the maximum in V2 under control but salinity induced reduction in these parameters was significantly higher compared to V3 which inherently possessed low yield potential but reduction in yield due salinity was the minimum. Hence, both genotypes could be termed as salt tolerant but V2 is good if grain yield is to be obtained from salt affected lands and V3 could be used as potential donor of salt tolerance genes in breeding programs. ii) Since all the parameters studied at both the stages responded differently hence observation taken in one genotype at one stage of growth cannot be used to assess the potential of another genotype at same or different stage. Every genotype needed to be tested separately to ascertain its potential and accurate utilization.

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