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Evaluation of salt tolerant bread wheat genotypes in Sudan

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Abstract

Salinity is the most important factor limiting wheat production in Sudan particularly in Northern States of the country. Identification of wheat genotypes tolerant to salinity is becoming one of the top priorities. In the present study, 13 wheat genotypes and three checks namely, Sakha 93, Kavir and Sistan were evaluated under non-saline and saline conditions. At both sites in the two seasons, differences among genotypes were significant for all the measured traits viz. days to 50% heading , days to 90% maturity , plant height, number of grains per spike , number of spikes m^{-2} , 1000-grain weight, grain yield kg ha^{-1} , biomass (kg ha^{-1}) and harvest index (%). Under saline conditions, the salinity stress affected all the parameters measured. Stressed plants had short stature with fewer numbers of spikes m^{-2}, number of grains per spike and reduced 1000-grain weight. Similarly, salinity stress hastened all the phenological characters studied and reduced grain yield, harvest index and biomass. The genotype Kauz was found to be the most suitable under salinity stress in Northern State. The genotype Kavir was moderately tolerant to salinity and suitable under non-saline conditions. Among the commercial cultivars, El-Neilain was moderately tolerant to salinity while Condor, Wadi El Neel and Sasareib were sensitive to salinity.

Keywords: Bread wheat, salinity, Sudan.

Introduction

Bread wheat (*Triticum aestivum* L.) is an important food crop in the world. The world wheat production is 557 million Mt, from an area of 208 million ha for 2003 season, (FAO, 2004). Bread wheat covers about 90% of the world wheat area, while durum wheat covers about 9% and minor species of wheat cover the remaining area. Wheat contributes more calories and more protein to the human diet worldwide than any other food crop (Haldore *et al*., 1982). The major production countries are USA, former USSR, Australia, China, Canada, India, France, Italy and Turkey. Wheat is grown as a winter season crop in the subtropics, despite the relatively high temperature that occurs during the growth cycle. Over seven million hectares of wheat is grown in approximately 50 countries under continual heat stress namely in environments with a mean daily temperature greater than 18 °C in the coolest month (Fischer and Byerlee, 1991).

Wheat in Sudan is grown as a winter crop. It suffers from a number of abiotic stresses such as heat, moisture, salinity, sodicity, poor fertility and water logging, and biotic stresses such as aphids, stem rust, leaf rust and weeds. Yet the short season (90-100 days) and relatively high temperature at early and late crop growth stages contribute greatly to its low productivity. The need for more food to satisfy the demands of the ever increasing population necessitated cultivation of high terrace soils away from the river. Proper management and reclamation of these salt-affected soils and availability of salt tolerant genotypes for direct use in these soils are essential for increasing their production. High salinity level drastically affects plant growth. Salinity affects plant growth through water deficit, nutritional imbalance and toxicity (Greenway and Munns, 1980). Wheat is a strategic crop in Sudan. The River Nile and Northern states are the most cool and suitable environments. Thus, wheat yields in these states are usually higher than those of central Sudan, i.e., Gezira. However, the wheat production under the fertile soils in these regions is restricted, because the areas are limited and the farmer prefers the cultivation of legumes and other crops. Due to these factors, the present research is justified by the need for horizontal expansion of agriculture in salt-affected upper terrace soils in the River Nile and Northern states.

The genetic background is responsible for the variation in wheat salt tolerance. Screening and selection for salt tolerance is important to help identifying parental breeding stocks. Generally, wheat is considered as moderately salinity tolerant (Francois *et al*., 1986) but tolerance rating can not provide accurate estimates of actual crop yield, which depend on many other growing conditions, including biotic and abiotic conditions (Mass, 1986). There is a large number of wheat germplasm adapted to Sudan environments but the response of these germplasm to salinity has not been fully investigated. The main objective of this study was to identify salt tolerant genotypes suitable for breeding purposes or direct use in salt-affected soils in Sudan.

Materials and Methods

Thirteen wheat genotypes (Table 1), plus three checks namely, Sakha 93 and two Iranian cultivars, namely, Kavir and Sistan were evaluated under saline and non-saline field conditions at Fetna, Merowe locality (Latitude: 18° 27' 0" N, Longitude: 31° 49' 59" E, Elevation: 258 meters. The design used was a Randomized Complete Block with three and five replications in the non - saline and saline sites, respectively. At the two sites, plot consisted of 4 rows, 4 m long spaced at 20 cm. Grain yield was assessed from a net area of 3.2 m². Planting dates were 13 December 2009 and 8 December 2010.

Experimental land at the saline site was ploughed by a chisel plough and leveled. In the non-saline field, the land was pre-irrigated, disk ploughed, harrowed and leveled. Planting was done by hand at a seed rate of 120 kg ha^{-1}. In the saline field, experiment received the recommended dose of 43 kg P_2O_5 ha^{-1} as triple super phosphate (TSP) during soil preparation, and the nitrogen fertilizer was added at a rate of 86 kg N ha^{-1} as urea in two split doses, at three weeks after sowing and at heading stage. Weeds were controlled manually and chemically using the herbicide 2, 4-D three weeks after sowing for the control of broadleaf weeds species in non-saline site. No weeds were observed in the saline soil site. The experiment at the non-saline site (Karu) was irrigated every 13 to 15 days throughout the growing season, while in the saline site, irrigation was done at 9 to 11 days intervals.

Data collected from the field experiment was subjected to analysis of variance (ANOVA) for the randomized complete block design. Mean separation was done using Duncan's Multiple Range Test (DMRT) for the different parameters collected from the field experiments.

In the two seasons soil samples were taken randomly from the saline site to determine the salinity level, exchangeable sodium percentage (ESP) and the soil pH (Table 2 and 3).

Results and Discussion

The results showed that the number of days to 50% heading decreased at the saline site (Table 4). A similar result was reported by Houshmand *et al*. (2004) who found that salinity stress shortened the life cycle of wheat in terms of heading and maturity dates by 8 and 11 days, respectively. The reduction in the number of days to physiological maturity (Table 5) was supported by the findings of Seetherma (1986) who stated that the physiological maturity was hastened by drought stress. The influence of salinity on plant height differed significantly among the various genotypes. The plant height of all cultivars was decreased under salinity (Table 6). This is in agreement with the finding reported by Ralanu (1975).

It was observed that during grain filling, the salinity stress substantially reduced the number of grains per head (Table 7). This might explain the significant difference in number of grains per head between the two sites. This result was similar to that reported by Mass *et al*. (1994) who found that the yield component most affected by soil salinity was the numbers of culms with ears. The entries no.7 and 4 were among the group that gave the highest number of grains per spike (Table 7). This might indicate that number of grains per spike could be used as a selection criterion for high grain yield under saline conditions. These results are in agreement with Francois *et al.* (1986) and Mass (1986).

In the second season, analysis of variance showed that the variation among genotypes was highly significant ($P \leq 0.01$) under the non-saline site. In the first season, mean grain yield at the non-saline site (karu soil) was two times greater than at the saline site (Table 8). In the first season, reduction in yield as affected by salinity varied among genotypes and ranged between 27% and 69%. Under saline conditions in the second season the check Sistan (no. 8) and the cultivar Sasareib (no. 16) gave the lowest grain yields. Also the entry no. 4 (Kauz //Trap # 1 / Bow) out - yielded all genotypes, in particular, the commercial cultivars (El Neilain condor, Wadi El Neel and Sasareib) by about 41.0%, 48.5%, 52.5% and 61.3%, respectively (Table 8). Results also showed that at the non-saline site in the first season, cultivar Condor (no.13) out yielded the commercial cultivars El Neilain (no.14), Sasareib (no.16) and Wadi El Neel (no.15), while at the saline site cultivar El Neilain (no.14) showed better performance than the other commercial cultivars. In the second season, based on grain yield under the salinity the entry no. 4 was relatively more adapted to salinity and exceeded cultivar El Neilain in grain yield (Table 8).The reduction in wheat grain yield as a result of salinity effect was mainly due to the lighter 1000-grain weight and lesser number of grains per spike as compared to that obtained from the non-saline site. Hanks *et al*. (1977) concluded from their findings that salinity stress reduced wheat grain yield per unit area. Murthy *et al*. (1979) reported that grain yield of wheat decreased with an increase in Na^+ and K^+ concentrations in the leaf. Similar results were also obtained by Mass and Hoffman (1977) who suggested that salinity negatively affected wheat grain yield.

The results obtained from this study clearly showed the existence of diverse genetic variability among wheat genotypes. This was well pronounced by the variation in the performance of the selected genotypes from the field experiment. The less yield of the early maturing genotype (entry no. 9) might be attributed to their phenology. On the other hand, high grain yield of the late maturing genotype (entry no. 4) was due to high number of grains per spike. The results obtained from this study also indicated that the genotypes that have high harvest indices gave higher grain yield as compared to those with low harvest indices (Table 9). Similar findings were obtained by Omanya *et al*. (1996) who found that there is a positive correlation between harvest index and wheat grain yield under drought conditions.

Table 1: Wheat genotypes used in the study.

Entry	Cultivar / line
1	UP 301 / Son 64 // P160 / 3 / Debeira
2	PC 930 / Giza155 // BOW
3	Giza 155 / Nai 60 -2
4	Kauz //Trap # 1 / Bow
5	Un known
6	Kauz / Pastor
7	Kavir (Iranian variety used as check)
8	Sistan (Iranian variety used as check)
9	Sakha 93 (Egyptian variety used as check)
10	Super Seri # 2
11	VEE/MJI//2*TUI
12	Un known
13	Condor (released commercial cultivar)
14	EL Neilain (released commercial cultivar)
15	Wadi EL Neel (released commercial cultivar)
16	Sasareib (released commercial cultivar)

Table 2: Analysis of twelve soil samples from the saline site at Fetna, Merowe locality in season 2009-10.

ESP	EC	PH	Depth (cm)	Sample no.
30	168.2	6.4	0-20	1
24	170.8	6.5	20-40	2
18	14.2	7.5	0-20	3
16	6.1	7.6	20-40	4
31	17.1	7.6	0-20	5
20	11.3	7.6	20-40	6
88	235.0	6.5	0-20	7
35	95.6	7.2	20-40	8
22	144.6	6.7	0-20	9
21	135.8	7.1	20-40	10

Table 3: Analysis of eight soil samples from the saline site at Fetna, Merowe locality in season 2010-11.

ESP	EC	PH	Depth (cm)	Sample no.
42	24.5	7.5	0 – 20	1
38	11.6	7.6	20 – 40	2
29	15.5	7.5	0 – 20	3
27	10.0	7.5	20 – 40	4
43	26.3	7.5	0 – 20	5
31	17.9	7.4	20 – 40	6
29	15.6	7.8	0 – 20	7
33	17.6	8.0	20 – 40	8

Table 4: Days to 50% heading of the bread wheat genotypes at saline and non-saline sites in different seasons.

Genotypes*	Days to 50% heading			
	2009-2010		2010-2011	
	Saline	Non-saline	Saline	Non-saline
1	58	64	63	71
2	51	62	62	66
3	53	60	59	63
4	58	66	65	73
5	56	63	64	71
6	57	64	63	71
7	55	66	62	67
8	69	75	73	80
9	47	55	55	59
10	53	64	50	69
11	51	62	58	65
12	52	60	59	63
13	50	60	60	64
14	54	64	59	66
15	57	64	60	66
16	59	64	64	68
Mean	55	63	61	68
S.E.±	0.485	0.489	2.399	0.438
C.V %	1.52	1.54	6.79	1.29

* Refer to Table 1 for the names of wheat genotypes.

Table 5: Days to 90% physiological maturity of the bread wheat genotypes at saline and non-saline sites in different seasons.

Genotypes*	Days to 90% physiological maturity			
	2009-2010		2010-2011	
	Saline	Non-saline	Saline	Non-saline
1	88	97	92	106
2	87	97	91	105
3	85	94	89	100
4	90	100	94	109
5	85	96	92	106
6	85	95	91	104
7	93	104	96	109
8	100	111	102	116
9	84	93	85	97
10	88	101	90	109
11	88	95	89	104
12	85	95	89	102
13	89	100	90	104
14	94	103	94	110
15	95	103	92	109
16	95	102	95	108
Mean	89	99	92	106
S.E.±	0.271	0.546	0.648	0.632
C.V %	1.21	1.10	1.22	1.19

* Refer to Table 1 for the names of wheat genotypes.

Table 6: Plant height of the bread wheat genotypes at saline and non-saline sites in different seasons.

Genotypes*	Site			
	Saline	Non-saline	Saline	Non-saline
	2009-2010		2010-2011	
1	55	75	48	84
2	53	72	53	79
3	57	76	49	88
4	60	75	57	83
5	56	71	48	82
6	52	71	44	78
7	62	77	55	86
8	73	86	56	87
9	46	66	46	71
10	58	73	53	84
11	57	73	51	80
12	58	78	50	85
13	50	74	49	80
14	64	84	48	104
15	63	82	55	93
16	60	82	51	87
Mean	58	76	51	84
S.E.±	1.727	2.185	2.365	1.245
C.V %	5.14	5.73	7.97	2.93

* Refer to Table 1 for the names of wheat genotypes.

Table 7: Number of grains per spike of the bread wheat genotypes at saline and non-saline sites in different seasons.

Genotypes*	Number of grains per spike			
	2009-2010		2010-2011	
	Saline	Non-saline	Saline	Non-saline
1	38	49	34	57
2	37	49	33	57
3	31	49	39	50
4	43	44	42	62
5	43	46	28	56
6	39	41	27	51
7	45	53	38	54
8	34	32	23	50
9	30	38	28	53
10	38	45	31	53
11	36	46	34	46
12	38	45	32	52
13	31	39	26	47
14	41	42	35	56
15	38	40	31	45
16	42	48	35	53
Mean	38	44	32	53
S.E.±	3.327	2.698	2.442	2.982
C.V %	15.11	12.11	12.93	11.24

* Refer to Table 1 for the names of wheat genotypes.

Table 8: Grain yield of the bread wheat genotypes at saline and non-saline sites in different seasons.

Genotypes*	Grain yield (kg ha^{-1})			
	Saline	**Non-saline**	**Saline**	**Non-saline**
	2009-2010		**2010-2011**	
1	2465	8046	1366	6792
2	3072	7786	1962	6054
3	4062	6926	1823	6944
4	4341	6015	2985	5667
5	3750	6562	1444	6553
6	3645	7421	1755	6258
7	4617	7968	1476	7529
8	3333	6640	1270	6267
9	2909	5702	1552	6301
10	3819	6874	1784	6292
11	3628	6812	1737	6336
12	3874	7812	1424	7161
13	3853	8983	1537	7243
14	5333	7588	1761	7716
15	3506	7030	1415	5503
16	3229	7395	1155	7091
Mean	3717	7222	1653	6607
S.E.±	471.52	495.67	236.95	419.99
C.V %	21.97	13.73	24.83	12.71

* Refer to Table 1 for the names of wheat genotypes.

Table 9: Harvest index of the bread wheat genotypes at saline and non-saline sites in different seasons.

Genotypes*	Harvest index (%)			
	Saline	**Non-saline**	**Saline**	**Non-saline**
	2009-2010		**2010-2011**	
1	33	37	30	34
2	40	40	32	29
3	38	38	28	33
4	38	33	34	30
5	38	35	26	31
6	40	37	33	32
7	37	37	26	33
8	26	29	21	27
9	41	39	31	36
10	37	35	32	29
11	33	40	31	34
12	39	36	27	33
13	38	39	24	31
14	39	37	27	31
15	37	34	24	27
16	29	33	23	31
Mean	36	36	28	31
S.E.±	2.381	1.196	2.151	1.35 2
C.V %	1.23	6.54	13.07	8.51

* Refer to Table 1 for the names of wheat genotypes.

Table 10: Biomass of bread wheat genotypes at saline and non-saline sites in different seasons.

*Genotypes	Wheat biomass (kg ha^{-1})			
	2009-2010		2010-2011	
	Saline	Non-saline	Saline	Non-saline
1	7083	21145	3595	19878
2	7513	19395	5023	20572
3	10346	17708	4952	20833
4	11180	17499	7293	18576
5	9860	18281	4546	20572
6	8819	19322	4859	19270
7	12291	21041	4658	22048
8	12291	19166	4795	23176
9	6916	14426	4346	17187
10	9999	19010	5028	21006
11	10520	16666	4885	18402
12	9791	21093	4499	21440
13	9930	22270	5097	23176
14	13472	20260	5056	24131
15	9374	20312	4346	19704
16	10416	21718	3766	22829
Mean	9987	19332	4796	20800
S.E.±	885.21	1136.57	579.157	786.831
C.V %	15.35	11.76	20.91	7.57

* Refer to Table 1 for the names of wheat genotypes.

Table 11: Thousand grain weight of the bread wheat genotypes at saline and non-saline sites in different seasons.

*Genotypes	1000-grain weight (g)			
	2009-2010		2010-2011	
	Saline	Non-saline	Saline	Non-saline
1	27	39	30	37
2	26	35	28	36
3	28	35	26	36
4	27	34	31	37
5	25	39	28	35
6	26	35	30	36
7	32	41	26	41
8	35	48	26	36
9	25	36	33	41
10	26	39	28	33
11	30	43	33	40
12	23	37	27	35
13	25	40	30	35
14	29	48	24	45
15	28	36	26	36
16	28	38	27	39
Mean	27	39	28	37
S.E.±	1.311	1.200	1.791	1.055
C.V %	8.17	6.11	10.80	5.58

* Refer to Table 1 for the names of wheat genotypes.

Table 12: Number of spikes m^{-2} of the bread wheat genotypes at saline and non-saline sites in different seasons.

*Genotypes	No. of spikes m^{-2}			
	2009-2010		2010-2011	
	Saline	Non-saline	Saline	Non-saline
1	364	487	248	424
2	525	550	332	448
3	514	485	317	487
4	430	425	463	323
5	520	480	335	466
6	525	578	293	444
7	468	473	369	451
8	642	550	375	405
9	449	486	327	468
10	486	503	320	410
11	490	461	316	455
12	448	540	282	486
13	688	736	360	706
14	589	507	310	450
15	435	535	285	531
16	510	561	239	491
Mean	505	522	323	465
S.E.±	50.987	32.653	54.905	34.182
C.V %	17.47	12.49	29.38	14.68

* Refer to Table 1 for the names of wheat genotypes.

Table 13: Number of spikelets per spike of the bread wheat genotypes at saline and non-saline sites in different seasons.

*Genotypes	No. of spikelets $spike^{-1}$			
	2009-2010		2010-2011	
	Saline	Non-saline	Saline	Non-saline
1	13	18	14	21
2	11	16	12	19
3	13	17	13	19
4	14	17	15	21
5	12	17	12	20
6	12	16	12	19
7	14	17	13	19
8	15	17	11	18
9	11	16	12	18
10	11	16	13	18
11	12	15	13	16
12	13	16	12	19
13	10	15	11	17
14	14	18	15	20
15	14	17	14	19
16	13	18	14	19
Mean	13	17	13	19
S.E.±	0.836	0.418	0.626	0.631
C.V %	11.13	4.88	8.07	6.51

* Refer to Table 1 for the names of wheat genotypes.

At the saline site, the genotypes significantly varied in most of the measured characters, except for grain and the biomass yield (Table 8 and 10). In this case, differences in biomass, thousand grain weight and harvest index among the genotypes were small (Table 11). The entries no. 4, 7 and 14 were relatively more adapted to salinity. This was evident by their high plant heights, number of spikes m^{-2}, biomass and number of grains per spike (Table 12). Therefore, such parameters could be used as an important selection criterion for salt-tolerance in the different wheat genotypes. The reduction in the different characters at the saline site could be attributed to salt stress. The findings of Mass and Grieve (1990), Grieve *et al*. (1994) and Francois et *al*. (1994) who reported that salinity alters wheat phonological development, delayed germination, decreased emergence percentage, hastens inflorescence and maturity, decrease primary and secondary tillers, number of spikelets per spike and number of leaves supported such findings.

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