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Selection Criteria for Salt Tolerance in Wheat Cultivars at Seedling Stage

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Abstract: Fourteen wheat cultivars were tested against various salinity levels to develop selection criteria for salt tolerance on the basis of different growth characteristics. It was concluded that assessment of tolerance to salinity based on different growth characteristics could not be considered worthwhile. In general, with the increase of salinity, shoot and root yield, shoot length, root length in some respect, number of total and green leaves and potassium contents decreased gradually where as sodium contents increased both in shoot and root of all the cultivars tested. Highly significant correlation was observed among, absolute shoot yield and absolute plant height, relative shoot yield and relative plant height, absolute and relative shoot root yield, absolute and relative plant height and absolute and relative green leaves.

Key words: Salinity, tolerance, absolute and relative yield, growth characteristics, selection criteria

Introduction

A considerable portion of irrigated land resources in arid and semi-arid regions of the world including Pakistan where, a large area has been rendered agriculturally unproductive due to high concentration of salts in the root zone. According to Khan (1998), 6.67 million hectares (mha) area of Pakistan is salt-affected. Wheat is the source of almost 20% of total necessary calories for the world's population. It is staple food of 43 countries including Pakistan, where it is grown on an area of 8.2 mha with total production of 16.6x 10^6 Mg and an average yield of 2048 kg ha^{-1} (Anonymous, 1995).
Salt-affected soils can be managed by reclamation, but due to less availability of good quality water, low soil permeability and high cost of management, this approach is not feasible on a large scale (Qureshi *et al.*, 1990). Saline agriculture technology is an alternative approach for effective utilization of salt-affected soils, which involves the cultivation of salt-tolerant species/crop. This technology gives economic returns from salt-affected soils and provide vegetative cover to soil which reduces evaporation and hence the rate of salinization (Qureshi and Barret-Lennard, 1998). Study of response of plants/crops to salinity under natural saline conditions is not feasible due to extreme variability in soil salinity both spatially and temporally (Richards, 1983). To avoid this problem, comparative differences for salt-tolerance among crops/varieties can be study under artificially salinized controlled conditions.
Different physiological traits such as selectivity for potassium, exclusion and/or compartmentation of Na^+ and Cl^- ions, osmotic adjustment by accumulation of organic solutes have also been related to salt-tolerance of crop plants (Wyn Jones and Storey, 1981). In this study an attempt has been made to develop selection criteria for salt-tolerance based on different growth characteristics and comparative performance of different wheat cultivars in artificial sodium chloride salinity in solution culture.

Material and Methods

The screening experiment was conducted in Greenhouse of the Department of Soil Science and Agricultural Chemistry, Zhejiang Agricultural University Hangzhou, P. R. China, during September and October 1990 with natural day light, day/night temperature of 28/15 ^{0}C. Seeds of seven cultivars (Yangmai No.5, Bao-119, Feng 86-4, Bao-22, cv.908, Bao-16 and cv.86-6) supplied by the Department of Soil Sciences and Agricultural Chemistry, Zejiang Agricultural University Hangzhou, P. R. China and seven (cv., 85276-2, cv. 86038, cv. 86299, cv. 86369, cv. 87094, FSD-85 and Pak-81) by the Ayub Agricultural Research Institute, Faisalabad, Pakistan were taken in a piece of muslin cloth separately and soaked in 0.2% fungicide solution for 18 hours, washed thrice with tap water and finally with distilled water. Then seeds were placed on filter paper in iron trays. The condition in trays kept moist with distilled water and trays remained covered until the sprout came out and waited for six days until the seedlings were transferred.
Six days old 20 seedlings of each cultivar were transferred on nylon mesh frames floating over half strength Hoagland nutrient solution in plastic containers having 50 liters capacity. Ten days old seedlings were subjected to incremental salt stress. Salt concentration was increased by 25mol m^{-3} after every 12 hours by adding NaCl to nutrient solution until the required salinity levels (75, 150, 225mol m^{-3}) were obtained in the respective containers. Solutions were renewed after every 7 days. The pH of 6.0-6.5 was maintained daily and any loss of water was made regularly. Solutions were aerated for 9 hours every day with air pump by splitting into 3 equal parts and intervals. The plants were harvested 17 days after salinization. The plants were washed for five minutes in running tap water followed by a quick rinse in distilled water and plant were blotted with tissue paper. The fresh weights of shoot and root, plant height and root length, number of total and green leaves of 20 plants together were recorded and results presented on the basis of average of 20 plants. The dry weight was recorded after plant dried at 70 ^{0}C. Then dried plant tissue were ground in mortar and pestle and stored in polyethylene bags and redried at the time of weighing for analysis. The ground plant materials were digested with 1N HCl for 24 hours at 40 ^{0}C, then the volume was shaked for one and half-hours and filtered. In the digest, sodium and potassium were determined by "ICP"(ICP model, Jarrel-Ash, ICAP-9000). Means and correlation among various growth characteristics was subjected according to Steel and Torrie (1980). The relative shoot dry yield obtained at high salinity level has tentively been considered to be the standard (most rational) criteria of relative salt tolerance of wheat cultivars while the results based on other growth characteristics were evaluated against it.

Results

Seedling growth data and ionic composition on the basis of average of 14 wheat cultivars are presented in Table 1, correlation between shoot yield and other growth characteristics in Table 2, where as comparative salt tolerance of all the cultivars tested based on different growth characteristics at the highest salinity level in Table 3. It is obvious in Table 1 that, with the gradual increase of salinity, shoot and root yield/ length and potassium contents decreased whereas sodium contents increased. However, in case of root length some cultivars showed little increase at highest salinity level.

Table 1: Effect of sodium chloride salinity on different growth characteristics of different wheat cultivars. (Average of 14 cultivars)

	Salt levels (mol m^{-3})			
Growth characteristics	0	75	150	225
Shoot fresh weight (mg $plant^{-1}$)	722(100)		425(55)	300(39)
221(29)				
Shoot dry weight (mg $plant^{-1}$)	73(100)	42(57)	34(46)	28(39)
Root fresh weight (mg $plant^{-1}$)	280(100)		172(61)	136(49)
76(27)				
Root dry weight (mg $plant^{-1}$)	22(100)	15(68)	13(58)	9(43)
Shoot length (Cm)	24(100)	17(71)	15(65)	14(58)
Root length (Cm)	15(100)	12(80)	9(63)	10(66)
Total number of leaves	-	-	-	3(63)
Number of green leaves	-	-	-	2(40)
Shoot sodium (m mol kg^{-1} d. wt)	35	1424	1622	1780
Root sodium (m mol kg^{-1} d. wt)	55	640	747	878
Shoot potassium(m mol kg^{-1} d. wt)	1725	939	868	682
Root potassium(m mol kg^{-1} d.wt)	975	421	300	203

Figures in parenthesis are percentage of their respective control.

Table 2: Relationship between shoot yield and other growth characteristics of wheat cultivars grown at 225 mol m^{-3} sodium chloride salinity.

Variables			Correlation coefficient
Absolute shoot yield	vs.	Absolute root yield	0.9779*
Absolute shoot yield	vs.	Absolute plant height	0.9995**
Absolute shoot yield	vs.	Absolute green leaves	0.9886*
Relative shoot yield	vs.	Relative root yield	0.9829*
Relative shoot yield	vs.	Relative plant height	0.9992**
Relative shoot yield	vs.	Relative green leaves	0.9866*
Absolute shoot yield	vs.	Relative shoot yield	0.9998**
Absolute root yield	vs.	Relative root yield	0.9962**
Absolute plant height	vs.	Relative plant height	0.9988**
Absolute green leaves	vs.	Relative green leaves	0.9999**

* Significant ** Highly significant

Table 3: Comparative salt tolerance of wheat cultivars based on different growth characteristics at 225-mol m^{-3} sodium chloride salinity.

	Fresh shoot yield		Dry shoot yield		Fresh root yield		Dry root yield		Shoot length	
Merit position	AY	RY	AY	RY	AY	RY	AY	RY	AY	RY
1	C4	C11	C8	C5	C5	C5	C2	C2	C4	C10
2	C12	C1	C12	C2	C2	C2	C9	C9	C1	C2
3	C5	C6	C4	C6	C13	C13	C4	C5	C8	C8
4	C3	C5	C5	C1	C4	C12	C13	C13	C3	C14
5	C8	C9	C1	C9	C12	C14	C8	C6	C10	C6
6	C6	C2	C3	C8	C6	C11	C10	C4	C2	C1
7	C1	C10	C10	C11	C14	C6	C3	C8	C14	C3
8	C2	C13	C7	C10	C7	C4	C12	C14	C6	C11
9	C10	C12	C2	C3	C3	C3	C5	C10	C9	C4
10	C7	C14	C6	C13	C9	C7	C6	C3	C7	C13
11	C14	C2	C9	C12	C10	C9	C14	C1	C13	C9
12	C9	C8	C13	C4	C11	C8	C1	C11	C5	C7
13	C13	C4	C14	C14	C8	C10	C7	C12	C12	C12
14	C11	C7	C11	C7	C1	C1	C11	C7	C11	C5
	Root length		**Total leaves**		**Green leaves**		**Sodium contents**		**Potassium contents**	
	AY	RY	AY	RY	AY	RY	Shoot	Root	Shoot	Root
1	C3	C2	C5	C8	C3	C3	C7	C9	C1	C12
2	C2	C3	C4	C9	C6	C6	C13	C14	C12	C13
3	C5	C6	C8	C4	C5	C8	C14	C4	C5	C4
4	C1	C5	C9	C6	C2	C2	C12	C12	C8	C8
5	C4	C1	C6	C3	C8	C1	C10	C1	C10	C2
6	C6	C4	C14	C1	C4	C4	C1	C3	C4	C1
7	C 14	C14	C3	C10	C1	C10	C6	C8	C2	C6
8	C13	C13	C1	C12	C10	C9	C11	C13	C3	C5
9	C7	C7	C2	C5	C12	C5	C9	C7	C13	C14
10	C11	C10	C7	C2	C9	C12	C2	C5	C6	C3
11	C10	C11	C12	C14	C7	C13	C8	C10	C7	C9
12	C9	C8	C11	C13	C13	C7	C3	C6	C14	C10
13	C8	C9	C10	C7	C11	C11	C5	C2	C11	C7
14	C12	C12	C13	C11	C14	C14	C4	C11	C9	C11

1. AY= Absolute yield. 2. RY= Relative yield. Cultivars are abbreviated as C1 (Yangmai-5), C2 (Bao-119), C3 (Feng. 86-4), C4 (Bao-22), C5 (908), C6 (Bao-16), C7 (86-6), C8 (85276-2), C9 (86038), C10 (86299), C11 (86369) C12 (87094), C13 (FSD-85), C14 (Pak-81).

The comparative salt tolerance of cultivars in Table 3 indicates that cv. 86369 and cv. 86-6 produced maximum and minimum relative fresh shoot yield where as cv. 908 and cv. 86-6 gave maximum and minimum relative dry shoot yield respectively. In case of root relative fresh and dry yield, cv.908 and cv. Bao-119 produced highest yield respectively, where as cv. Yangmai- 5 and cv.86-6 gave lowest relative fresh and dry yield, respectively. As regard shoot and root length, cv. 86299 and cv.908 produced maximum and minimum relative shoot length where as cv. Bao-119 and cv.87094 gave highest and lowest relative root length, respectively. Although salinity reduced the shoot and root length, but some cultivars showed little increase in root length at the highest salinity level as compared to lower salinity levels. From total number of leaves point of view, it was found that cv. 85276-2 and cv.86369 gave maximum and minimum relative leaves respectively, where as maximum and minimum green leaves were found in Feng 86-4 and Pak-81 respectively.

As regard sodium contents, cv.86-6 and Bao-22 accumulated maximum and minimum contents in their shoots, where as cv.86038 and cv.86369 in their roots respectively. From potassium contents point of view, Yangmai-5 and cv. 86038 accumulated maximum and minimum in their shoots where as cv. 87094 and cv. 86369 in their root respectively. In general all the cultivars accumulated different amount of sodium and potassium contents in their shoots and roots at all the salinity levels. There is no any apparent relationship between sodium and potassium contents and salt tolerance of cultivars tested was observed. Due to difference in growth habit of different cultivars, it was concluded that assessment of tolerance to salinity based on growth characteristics can not considered worthwhile. Relationship between shoot yield and other growth parameters in Table 2 indicated, that highly significant correlation exist among, absolute shoot yield and absolute plant height, relative shoot yield and relative plant height, absolute and relative shoot root yield, absolute and relative plant height and absolute and relative green leaves.

Discussion

In saline environment where salts are present in higher concentrations, plant growth is affected negatively in various ways such as osmotic effects, specific ion effect and nutritional imbalance; probably all occurring simultaneously (Flowers *et al.*, 1991). Initial growth inhibition in saline environment is induced by the decreased water potential of rooting medium due to higher salt concentration (Munns *et al.*, 1995). A secondary effect of high concentrations of Na^{+} and Cl^{+} in the root medium is the suppression of uptake of essential nutrients such as K^{+}, Ca^{++}, NO_3 etc. (Gorham and Wyn Jones, 1993). The gradual increase of NaCl salinity decreased the shoot and root yield, shoot length and potassium contents where as sodium contents increased. However in case of root length some cultivars showed little increase at highest salinity level. Aslam and Muhammad, 1972; Chaudhri *et al.*, 1978; Cornish, 1984; Brugnoli and Lauter, 1991 and Akhtar *et al.*, 2001, have reported similar adverse affect of salinity. The decrease in shoot and root yield of all cultivars with the addition of salt could be due to the reduction of physiology availability of water with the increase in solute suction from saline media or accumulation of toxic ions in plants. This data is in agreement with those of Aslam and Muhammad, 1972; Roth, 1989; Sharma, 1989; Ehret *et al.*, 1990. Gradual reduced in shoot and root length is due to the toxic effect of added salts as well as delay in germination. Increase in root length of some cultivars at the higher salinity level, might be due to the varietal characters differences among the cultivars tested. Inconsistent pattern between number of total and green leaves and salt tolerance of cultivars was observed and this is might be due to the different genetic character of cultivars.

As regard the mineral contents, salinity increased the sodium and decreased the potassium contents gradually, in general all the cultivars accumulated different amount of sodium and potassium contents in their shoot and root at all the salinity levels which were might be due to difference in dry matter yield as well as their individual genetic characteristics. Further root accumulated lower amount of sodium than shoot. It appears that most of the sodium was translocated to the shoot which caused more reduction in case of shoots as compared to roots. Table 1 also indicates that root potassium contents were about four times lower than root sodium contents at the highest salinity level. This indicates the inhibition effect of sodium on potassium uptake. Epstein (1977) reported that the basic cause of potassium deficiency in case of salinization was a competitive interrelationship between sodium and potassium. There is no any apparent relationship between sodium and potassium contents and salt-tolerance of cultivars tested was found. Although there is evidence that species having high potassium levels could tolerate the presence oh high sodium (Fink, 1977) but in case of this study it is difficult to establish relationship.

The relative shoot dry yield obtained at high salinity level has tentively been considered to be the standard (most rational) criteria of relative salt tolerance of wheat cultivars while the results based on other growth characteristics were evaluated against it (Table 3). Inconsistent pattern among the growth characteristics and salt tolerance of cultivars tested was found. Thus the assessment of tolerance to salinity based on growth characteristics cannot be considered worthwhile. In rating plant to salinity tolerance, both the absolute and relative shoot yield at high salinity level have been used by various workers. It is felt that the consideration of relative growth value is necessary when comparing cultivars that differ widely in growth habit or, are grown under different environment conditions (Mass and Hoffman, 1977). Further more research is needed to establish such correlation among cultivars to exploit their differences in salt tolerance.

For the purpose of developing a suitable screening strategies / selection criteria for wheat, answer to the following questions "among" other are necessary. What should be the salt composition of the growth medium? At what stage should salinity be applied? What level and duration of salinization should be used?

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