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Effect of Different Substrate K^+ / Na^+ Ratios on Yield and Potassium Sodium Selectivity of Selected Wheat Cultivars

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Abstract: The results of this study indicate, that salt tolerance of wheat cultivars under consideration is related to high potassium sodium selectivity (S_{K^+, Na^+}) and lower concentration of $K^+ + Na^+$ in the plant tissue. It is found that higher the S_{K^+, Na^+} the higher the absolute dry matter yield and higher the salt tolerance of cultivars. Cultivars Bao-119, FSD-85 and c.v., 86-6 showed tolerant, medium and sensitive behavior respectively under saline condition. It is also evident that a decrease K^+/Na^+ ratio in media resulted in increased uptake of Na^+ and decreased that of K^+. At the same time $S_{K^+ Na^+}$ increased while total concentration of $K^+ + Na^+$ decreased. Further more the lower K^+/Na^+ ratio of 1/50 decreased the uptake of Na^+ and increased the K^+. It can therefore, be deducted that S_{K^+, Na^+} should be considered seriously when breeding salt tolerant wheat cultivars to be grown economically in saline soils. Much more research is still needed in this area.

Key word: Salinity, tolerance, K^+/N^+a ratio, S_{K^+, Na^+}, wheat cultivars

Introduction

Salinity and sodicity has affected about 10% of the total world land (Szabolcs, 1991). Approximately 20 m ha land deteriorates to zero production each year (Malcolm, 1993) mainly due to salinization. The salt affected area in Pakistan is estimated about 6.67 m ha (Khan, 1998) of which 60% is saline sodic where as in Punjab saline sodic area is about 80% (Muhammad, 1983). Salt affected soils can be managed by reclamation, but due to less availability of good quality of water, low soil permeability and high cost of amendments, 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 cultivars. This technology gives economic returns from salt affected soils and provide vegetative covers to soil which reduces evaporation and hence the rate of salinization (Qureshi and Barrett-Lennard, 1998).

Study of response of plants/crops to salinity under naturally saline condition 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 studied under artificially salinized control conditions. Different physiological traits such as selectivity for potassium, exclusion and/or compartmentation of sodium and chloride ions, osmotic adjustments by accumulation of organic solutes have all been related to salt tolerance of crops plants (Wyn Jones and Storey, 1981).

A good supply of potassium increases the plants tolerance and resistance to environmental stress due to its functions in osmoregulation, energy status and in the synthesis of high molecular compounds (Beringer and Trolldenier, 1978). Plants usually have high selectivity for potassium uptake over sodium, particularly under low saline conditions and at low external potassium concentration (Epstein, 1972). However, there is extensive evidence that high sodium levels in the growth medium depress potassium uptake in many plants (Bernstein, 1975 and Wyn Jones, 1981). Saline-sodic soils widely differ in K^+/Na^+ ratios (Richards, 1954). Plant growth under such conditions is confronted with potassium sodium interaction, which may result in reduced yield due to ion imbalance stress (Bernstein, 1975; Devitt *et al.*, 1981). A study of the impact of varying external K^+/Na^+ ratios at one constant $K^+ + Na^+$ concentration was made on growth, K^+ and Na^+ contents in plants tissue and S_{K^+, Na^+} of three selected wheat cultivars, to assess as to what extent this physiological parameter confers salt tolerance in wheat.

Material and Methods

Experiment was conducted in wire house of the department of Soil Science and Agricultural Chemistry, Zhejiang Agricultural University, Hangzhou, P. R. China during 1991 with natural daylight and day/night temperature of 16/8 ^{0}C, respectively. Sufficient healthy seeds of three wheat cultivars {2 Chinese (Ba0-119, cv.86-6) and 1 Pakistani (FSD-85)} selected from screening experiment, as tolerant, moderate and sensitive were soaked in 0.2% fungicide solution for 18 hours. After draining fungicide solution, the seed were washed thrice with water. Then seeds were sown in quartz sand in iron trays. The condition in trays kept moist with water and trays remained covered until the sprout came out and waited for nine days. Nine days old 24 seedlings of each cultivars were transferred to 1 cm plugged holes in wooden covers over 32 liters of ½ strength Hoagland nutrient solution in plastic containers. Twelve holes were used for each cultivars and each hole having 2 seedlings. Twelve days old seedlings were subjected to salt stress. Total potassium plus sodium concentrations were achieved in two days by dividing salt in three equal parts. The solutions were aerated with air compressor for 9 hours every day by splitting in 3 equal parts (early morning, noon and early night).

Nutrient solution used having final potassium concentration 3-mol m^{-3} that was subtracted during calculation of higher potassium concentrations. Potassium sodium ratios used were 3:0, 1:1, 1:10, 1:20 and 1:50 where as total salinity was 150 mol m^{-3} ($K^+ + Na^+$). Potassium sodium concentrations, ratio and total salinity maintained was as in Table 1.

Table 1: Potassium sodium concentrations, ratios and total salinity used in solution culture.

Concentrations K^+ (mol m^{-3})	Na^+ (mol m^{-3})	Ratios K^+ / Na^+	Total salinity $K^+ + Na^+$(mol m^{-3})
3.00	0.00	3:0	Nutrient solution
75.00	75.00	1:1	150
13.60	136.40	1:10	150
7.10	142.90	1:20	150
3.0	147.00	1:50	150

After 23 days of salt stress the fresh and dry weight of shoots and roots was recorded. For the estimation of K^+ and Na^+ contents, the pooled samples were ground and material was digested with 1N HCl for 24 hours at 40 ^{0}C. Then required volume was shaked for 1.5 hours and filtered. In the digest K^+ and Na^+ were determined by " ICP" model, Jarrel-Ash, ICAP-9000. Potassium sodium selectivity was calculated in shoot and root as stated by Pitman (1976).

S_{K^+, Na^+} = K^+ / Na^+ in plant tissue / K^+/ Na^+ in external solution

Results

The gradual increase of sodium, dry weight of shoot and root decreased. Maximum and minimum shoot dry weight was observed at ratio 1/10 and 1/50, respectively (Table 2), whereas in case of root, ratio 1/10

Table 2. Effect of external K^+/Na^+ ratios at 150-mol m^{-3} salinity level on yield and potassium sodium selectivity of wheat cultivars (Average of three cultivars).

Characters	Control (K^++Na^+)	150 mol m^{-3} (K^+ + Na^+)			
	3:0	1:1	1:10	1:20	1:50
Shoot					
D. Wt mg/plant	159.56	57.05	62.64	59.00	6.14
F.Wt/D.Wt	9.21	7.58	7.95	7.14	7.61
Na+ m mol/gm D.Wt	0.01	0.36	0.68	0.78	0.71
K^+ m mol/gm D.Wt	1.60	1.59	1.02	0.89	0.94
Na^+ + K^+ m mol/gm D. Wt	1.61	1.95	1.70	1.67	1.65
S_{K^+, Na^+}		7.42	25.50	38.80	112.50
Root					
D. Wt mg/plant	60.33	24.78	26.17	24.42	24.58
F.Wt / D.Wt	15.99	14.42	14.39	13.64	13.08
Na^+ m mol/gm D. Wt	0.01	0.50	0.90	1.01	0.91
K^+ m mol/gm D. Wt	1.50	1.24	0.73	0.66	0.58
Na^+ + K^+ m mol/gm D. Wt	1.51	1.74	1.63	1.67	1.49
S_{K^+, Na^+}		4.24	13.90	22.20	54.50

D.Wt = Dry weight F.Wt = Fresh weight

Table 3. Yield and potassium sodium selectivity of shoot and root of three wheat cultivars at varying external K^+/Na^+ ratios at 150-mol m^{-3} salinity (Average of K^+ / Na^+ ratios in 150 mol m^{-3} Na^++K^+ concentration).

Characters	K^++Na^+ mol m^{-3}	Cultivars		
		Bao-119	c.v.86-6	FSD-85
Shoot				
D. Wt mg/Plant	3.00	183.25	153.92	141.50
	150.00	65.57	55.64	58.82
F. Wt /D.Wt	3.00	9.33	9.22	9.06
	150.00	7.80	7.95	6.96
Na^+ m mol/gm D.Wt	3.00	9.00^{-03}	9.04^{-03}	8.41^{-03}
	150.00	0.47	0.73	0.70
K^+ m mol/gm D.Wt	3.00	1.58	1.65	1.58
	150.00	1.06	1.16	1.11
Na^+ + K^+ m mol/gm D.Wt	3.00	1.59	1.66	1.59
	150.00	1.53	1.89	1.81
S_{K^+, Na^+}	150.00	12.99	9.22	9.25
Root				
D. Wt mg/Plant	3.00	70.79	51.13	59.08
	150.00	31.60	22.89	20.47
F. Wt / D. Wt	3.00	16.10	15.83	16.01
	150.00	14.57	14.86	11.79
Na^+ m mol/gm D.Wt	3.00	0.014	0.015	0.012
	150.00	0.74	0.97	0.76
K^+ m mol/gm D.Wt	3.00	1.47	1.52	1.52
	150.00	0.94	0.74	0.74
Na^+ + K^+ m mol/gm D.Wt	3.00	1.48	1.54	1.53
	150.00	1.68	1.71	1.50
S_{K^+, Na^+}	150.00	7.31	4.44	5.59

D.Wt = Dry weight F.Wt = Fresh weight

produced maximum and 1/20 gave minimum dry weight. As regard the behavior of individual cultivars (Table 3), Bao-119 gave maximum absolute dry weight of shoot followed by FSD-85 and c.v. 86-6. It is evident (Table 2) that shoots Na^+ contents increased progressively up to 1/20 ratio and then decreased at 1/50 ratio. Potassium decreased up to ratio 1/20 and then increased at ratio 1/50 in case of shoot whereas K^+ gradual decreases at all ratio was found in root. As concerned potassium sodium selectivity (S_{K^+, Na^+}), data in Table 2 &3 indicate that there was rapid increase in S_{K^+, Na^+} with progressive increase of Na^+. The highest and lowest S_{K^+, Na^+} were noted at K^+/Na^+ ratio of 1/50 and 1/1 both in shoot and root respectively. As regard the cultivars individual behavior, Bao-119 had the highest and c.v. 86-6 had the lowest S_{K^+, Na^+} both in shoot and root, which indicated a good agreement between S_{K^+, Na^+} and salt tolerance of cultivars.

Discussion

The shoot and root dry matter yield seemed to be affected by complex interaction between the substrate K^+/ Na^+ ratios, nature of tissue involved and the variety itself. It is obvious (Table 3) that at 150 mol m^{-3} concentration (K^++Na^+), c.v. 86-6 gave maximum fresh and dry weight ratio and was followed by Bao-119 and FSD-85.High fresh and dry weight ratio in case of c v. 86-6 is due to high uptake of sodium both in shoot and root, because high amount of Na^+ in plant increase plant succulence. This high growth ratio in case of c.v. 86-6 in the presence of high Na^+ both in shoot and root is in agreement with those of Flowers *et al.* (1977) and Flowers (1985). Production of higher weight in Bao-119 and lower in c v 86-6 is due to minimum and maximum accumulation of Na^+ in their shoot and root respectively. It indicates that lower yield is due to the toxic effect of sodium. There was no any apparent relationship between the K^+ status of cultivars and tolerance to salinity was observed. Increase in shoot Na^+ contents up to ratio 1/20 and then decreased at 1/50 ratio and reverse is true in case of K^+, supported the hypothesis of Epstein (1972), who claimed that plant usually have high selectivity of potassium over sodium particularly under low saline condition and at low external potassium concentration. The adverse effect of salinity on wheat was similar as have been reported for general crops (Bernstein, 1975; Wyn Jones, 1981). Comparative poor growth in high K^+/Na^+ ratio might be due to greater chloride accumulation in shoot in the presence of high potassium chloride. Toxic effect of potassium chloride over sodium chloride in *Vigna radiata* L. (Salim and Pitman, 1983) has been reported. Salt tolerance behavior on absolute shoot yield basis is in agreement with those of Nieman and Shannon (1976) who reported that salt tolerance can be apprised by at least three different criteria, plant survival, absolute plant growth and relative growth in saline condition as compared to non-saline condition. It is evident from ($K^+ + Na^+$) contents of shoots and roots, that at low K^+/Na^+ ratio, K^+ restricted Na^+ uptake. General effect of salinity on plant is to reduce (K^+/Na^+) level in the shoot but salt tolerant plants keep the high S_{K^+, Na^+} due to preferential uptake of K^+ over Na^+ under saline condition (Greenway and Munns, 1980; Wyn Jones, 1981; Gorham *et al.*, 1985 b) which confers salt tolerance in many crops. It is concluded from this study that, salt tolerance of wheat cultivars is related to higher S_{K^+, Na^+} and lower concentration of $K^+ + Na^+$ in plant tissue. Salt tolerance of cultivars is in order of Ba0-119>FSD-85> cv. 86-6. Potassium sodium selectivity should be considered seriously when breeding salt tolerant wheat cultivars to be grown economically in saline soils.

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