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STUDIES ON PHYSIOLOGICAL AND BIOCHEMICAL PARAMETERS OF SALT TOLERANCE IN WHEAT

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ABSTRACT

Ten wheat cultivars were screened for salt tolerance at seedling stages under glasshouse conditions. Four levels of salinity i.e., 0.25 (control) 10, 15 and 20 dS m^{-1} were induced in soil. As the growth of wheat cultivars raised in saline soil substrates indicated that Na^+ and Cl^- ions in plants increased with the increase in salinity levels, while K^+ decreased accordingly. The salt tolerant cultivars (LU-26S, Blue Silver and Pirsabak-85) have low Na^+ and Cl^- ions and high K^+ contents. Overall correlation studies between shoot yield of cultivars and Na^+, Cl^-, K^+ and K^+/Na^+ ratio showed the Na^+ and Cl^- exclusion and K^+ inclusion mechanisms are operating in salt tolerance in wheat crop.

Key-words: Salt tolerance, wheat, cultivars, K^+/Na^+ ratio

INTRODUCTION

Salt tolerance of the crop not only varies from crop to crop but the varietal differences of salt tolerance in the same crop have also been reported by many researchers (Dhawan *et al*, 1987). As more and more land is becoming salinized by poor irrigation practices, the impact of salinity is becoming more important thus creating the need for salt tolerant plants (Winicov, 1998).

Tolerance to salinity and sodicity problems is certainly complex and it is mainly associated with the ability to limit the accumulation of Na^+ and Cl^- with the maintenance of high K^+/Na^+ ratios in the shoot (Greenway and Munns, 1980; Gorham *et al*., 1985 and Weimberg, 1987). It has also been concluded that various cultivars of wheat may adopt different mechanisms for tolerating high external salinity, out of which exclusion of Na^+ and Cl^- especially from the expanding tissues (Young leaves) was the most outstanding one and could possibly be used as the physiological criteria for the selection and breeding of salt tolerant wheat genotypes. (Rashid *et al*., 1991). This study was therefore undertaken to study the physiological and biochemical parameters of salt tolerance in wheat genotypes under controlled saline conditions.

MATERIALS AND METHODS

Studies on physiological and biochemical parameters of salt tolerance in wheat cultivars at seedling stage was carried out in glass-house of NWFP Agricultural University, Peshawar. Ten wheat cultivars were tested at four levels of induced salinity i.e. 2(control), 10, 15 and 20 dS m^{-1} in soil. The seed of the above cultivars were obtained from Department of Plant Breeding and Genetics, NWFP Agricultural University, Peshawar and wheat Section, Agriculture Research Institute, Tarnab. Seedling performance of the cultivars was tested in soil placed in plastic pots (10 cm diameter and 20 cm deep), each filled with four kilogram of sandy loam soil. The experiment design was complete randomized with 2-factors. A basal dose of P and half recommended N (120 and 90 kg ha^{-1}) as DAP and urea was added to soil at the time of sowing whereas, remaining half was applied with second irrigation. Salinity levels in soil were created by the addition of NaCl and $CaCl_2$. In each pot predetermined amount of salts was added and the soil was kept moist for one week for equilibrium. For sowing, the soil was brought to saturation level and allowed to dry to field capacity. Six seeds of each cultivar were sown in one pot. The pots were covered to avoid evaporation. After seven days of sowing, the moisture was replenished with equal water additions. Plastic pots were irrigated as and when required with normal water. The experiment ended after four week and fresh and dry shoot weights were recorded and correlated with Na^+ and Cl^- contents.

RESULTS AND DISCUSSION

Plant height: The plant height (Table 3) decreased with increase in salt concentration with soil. There was nearly 50% reduction in plant height when grown at the highest salinity level as compared to the lowest one. Blue Sliver, Chahwal-86 and Abasin – 81 cultivars grew taller at all salinity levels, while Pirsabak – 85, Pak – 81 and Sarsabz showed poor performance at 20 dS m^{-1} salinity level. Neumann (1995) indicated that salinity can rapidly inhibit root growth and hence capacity of water uptake and essential mineral nutrients from soil due to which plant can not grew taller. Salt stress inhibited the growth of shoot more than root in all Brassica species. Similar observations have been reported in barley (*Hordeum vulgare* L.) by Huang and Redmann 1991, in Pigeon pea (*Cajanus cajan*) by Subbarao *et al*, 1991.

Table 1. Plant height of wheat cultivars grown under saline conditions.

Cultivars	**Salinity levels dS.m^{-1}**				
	2 (Control)	**10**	**15**	**20**	**Mean**
	-------------------------cm-----------------------				
Khyber -87	30.3 abcd	21.7 jklm	17.3 pqrs	15.0 tuv	21.08 d
LU- 26s	29.0 cde	23.3 hij	17.3 pqrs	15.3 stuv	21.23 cd
Pak - 81	29.0 cde	23.3 hij	18.0 opq	13.3 v	20.90 d
Chakwal - 86	30.0 bcd	22.0 jkl	18.3 nop	16.0 qrst	21.58 cd
Barani - 83	28.3 de	22.3 ijkl	17.7 opqr	15.7 rstv	21.00 d
Shalimar - 88	27.7 e	22.3 ijkl	17.0 pqrst	15.0 tuv	20.50 d
Blue Sliver	31.3 ab	25.6 fg	21.0 klm	17.20 pqrs	23.78 a
Abasin - 81	32.3 a	24.3 ghi	20.3 lmn	16.7 pqrst	23.40 ab
Sarsabz	31.0 abl	24.7 gh	19.7 mno	13.7 uv	22.28 bc
Pirsabak - 85	27.0 ef	23.0 hijk	18.7 nop	13.0 v	20.43 d
Mean	29.6 a	23.3 b	18.5 c	15.1d	-

Means followed by different letters in same column are significantly different from each other at 5% level of significance
Lsd at 0.5 = 0.6782 (Salinity means), 1.175 (variety means), 2.035 (treatment means)

Fresh shoot yield: The shoot yield (Table 1) distinctly decreased with increase of salt addition in soil substrate and there was nearly 50% reduction in fresh shoot yield grown at the highest salinity level as compared to the lowest one. The cultivars, which gave better means yield over salinity levels were Blue Silver, Pak-81 and Pirsabak-85 while Khyber-87, Sarsabz and Shalimar-88 showed poor performance at low salinity. But in salinity level of 20 dS m^{-1} gave better yield Blue Silver, LU-26s and Chakwal- 86, while Pak-81, Barani-83 and Shalimar -88 gave poor shoot yield. It is now well evident that salt tolerance in many crop species varies with the change in their growth stage (Kingsbury & Epstein, 1984) at low salinity, the comparatively less reduction in their fresh weights were observed even at the exposure to salinity for four weeks. This indicated that plants affected by salts at lower concentration could tolerate salt stress for longer duration before significant reduction in seedling growth occurs (Zeng and Shannon, 2000).

Table 2. Fresh shoot yield of wheat cultivars grown under saline conditions.

Cultivars	**Salinity levels dS.m^{-1}**				
	2 (Control)	**10**	**15**	**20**	**Mean**
	-------------g / 6 Plant-------------				
Khyber -87	3.87 d	2.06 ijk	1.72 i-n	1.40 l-o	2.26 e
LU- 26s	4.83 c	2.75 fg	1.91 ij	1.60 j-o	2.77 cd
Pak - 81	4.66 c	3.55 de	1.60 j-o	0.80 p	2.65 cd
Chakwal - 86	5.51 b	2.88 f	1.63 j-o	1.50 k-o	2.88 c
Barani - 83	4.72 c	2.84 f	1.70 i-h	1.08 op	2.59 cde
Shalimar - 88	4.60 c	2.76 fg	1.73 i-n	1.11 op	2.55 cde
Blue Sliver	7.07 a	3.85 d	2.68 fgh	1.98 i-l	3.90 a
Abasin - 81	6.75 a	3.13 ef	1.87 i-m	1.45 l-o	3.30 b
Sarsabz	5.11 bc	2.70 fgh	2.13 hij	1.27 nop	2.80 cd
Pirsabak - 85	3.26 ef	3.08 ef	2.25 ghi	1.33 m-p	2.48 de
Mean	5.04 a	2.96 b	1.92 c	1.35 d	-

Means followed by different letters in same column are significantly different from each other at 5% level of significance
Lsd at 0.5 = 0.1953 (Salinity means), 0.3382 (variety means), 0.5859 (treatment means)

Dry shoot yield: The shoot weight (Table 2) also declined with increase in salts concentration in soil substrate and there was nearly 50% reduction in dry shoot yield grown at the highest salinity level as compared to the lowest one. The cultivars which gave better yield at high salinity levels included Blue Silver, Chakwal–86 and LU- 26S whereas

Pak – 81, Khyber-87 and Barani-83 showed poor performance at 20 dS m^{-1} salinity level. Similar kinds of observations have been reported by Jamil and Rha (2004) in sugar beet and cabbage.

Table 3. Dry shoot yield of wheat cultivars grown under saline conditions.

Cultivars	Salinity levels dS.m^{-1}				
	2 (Control)	10	15	20	Mean
	-------------g / 6 Plant-------------				
Khyber -87	0.64 b-g	0.29 l-o	0.25 no	0.21 no	0.35 d
LU- 26s	0.69 b-e	0.49 f-k	0.36 g-n	0.29 l-o	0.46 bc
Pak - 81	0.71 bcd	0.58 c-h	0.29 l-o	0.14 o	0.43 bcd
Chakwal - 86	0.81 b	0.47 g-l	0.35 j-n	0.30 l-o	0.48 bc
Barani - 83	0.72 bcd	0.45 h-m	0.28 mno	0.22 no	0.42 cd
Shalimar - 88	0.80 b	0.53 d-j	0.31 k-o	0.28 mno	0.48 bc
Blue Sliver	1.09 a	0.66 b-f	0.50 f-j	0.35 j-n	0.65 a
Abasin - 81	1.07 a	0.49 f-j	0.29 l-o	0.26 no	0.53 b
Sarsabz	0.75 bc	0.50 f-j	0.35 j-n	0.21 no	0.45 bcd
Pirsabak - 85	0.55 d-i	0.52 e-j	0.38 i-n	0.23 no	0.42 cd
Mean	0.78 a	0.50 b	0.34 c	0.25d	-

Means followed by different letters in same column are significantly different from each other at 5% level of significance

Lsd at 0.5 = 0.6175 (Salinity means), 0.107 (variety means), 0.1853 (treatment means)

IONIC CONTENTS OF SHOOT:

Sodium Content of Shoots: The sodium contents in shoot were (Table 2) increased progressively with salt addition in soil substrate with mean value of 840 and 1568 m mol kg^{-1} in plants grown at 10 and 20 Ds. m^{-1} salinity levels, respectively. LU-26S, Blue Silver and Pirsabak-85 have comparatively low Na^+ contents whereas some cultivars such as Barani-83, Pak-81 and Khyber-87 have higher. The results for ion uptake showed that the high biomass producing cultivars e.g. Blue Silver, LU-26S and Pirsabak-85 contained significantly lower Na^+ contents in shoots compared with the other cultivar. The results for tolerant cultivars can be explained in the light of early findings of many scientists that the salt tolerant mesophytes generally excluded either Na^+ and /or Cl^- from their shoots (Lauchli *et al*., 1994; Asharaf, 2004; Saqib *et al*., 2005). Therefore, exclusion of Na^+ at root level is vital for the plants growth under saline conditions (Munns *et al*., 2000; Tester and Davenport 2003).

Table 4. Shoot Sodium contents of wheat cultivars grown under saline conditions.

Cultivars	Salinity levels dS.m^{-1}			Mean
	10	15	20	
	-----------------m mol kg^{-1}--------------			
Khyber -87	1033 ghi	1294 e	1391 d	1239 bc
LU- 26s	713 no	967 hij	1113 fg	931 g
Pak - 81	971 hij	1358 de	1535 c	1288 ab
Chakwal - 86	742 mno	1141 f	1717 b	1200 cd
Barani - 83	953 ij	1056 gh	1867 a	1292 a
Shalimar - 88	766 lmn	1014 hi	1668 b	1149 e
Blue Sliver	666 o	885 jk	1158 f	903 g
Abasin - 81	845 kl	1011 hi	1676 b	1177 de
Sarsabz	782 lmn	1006 hi	1843 a	1210 cd
Pirsabak - 85	712 no	825 klm	1696 b	1077 f
Mean	818 c	1056 b	1566 a	-

Means followed by different letters in same column are significantly different from each other at 5% level of significance

Lsd at 0.5 = 29.67(Salinity means), 51.39 (variety means), 89.01 (treatment means)

Shoot Potassium Contents: Data regarding shoot potassium contents have been given in Table-3. The shoot potassium contents have decreased rapidly in all cultivars with salt addition, with maximum mean value of 756 m mol Kg^{-1} noted in plants grown at 10 dS m^{-1} and minimum of 499 mmol kg^{-1} in plants grown at 20 dS m^{-1}. High K^+ absorbing cultivars in decreasing order were Blue Silver, LU-26S and Pirsabak-85. However, comparatively low K^+ contents were found in a shoot of Barani-83, Pak-81 and Khyber -87 while others cultivars have intermediate values.

Therefore, maintenance of high K^+ at shoot level is vital for the plants growth under saline conditions (Munns *et al*., 2000).

Table 5. Shoot Potassium contents of wheat cultivars grown under saline conditions.

Cultivars	**Salinity levels dS.m^{-1}**			**Mean**
	10	**15**	**20**	
	-----------------m mol kg^{-1}--------------			
Khyber -87	745 de	578 l	500 n	608 c
LU- 26s	856 ab	696 e-h	569 lm	707 a
Pak - 81	677 f-i	719 efg	437 p	611 c
Chakwal - 86	726 efg	642 h-k	444 op	604 c
Barani - 83	712 efg	618 jkl	489 nop	606 c
Shalimar - 88	730 ef	615 kl	497 no	614 bc
Blue Sliver	861 a	728 efg	575 l	721 a
Abasin - 81	715 efg	640 uk	494 no	616 bc
Sarsabz	747 de	674 g-j	472 mop	631 b
Pirsabak - 85	804 bc	800 cd	517 mn	707 a
Mean	757 a	671 b	499 c	-

Means followed by different letters in same column are significantly different from each other at 5% level of significance
Lsd at 0.5 =18.57 (Salinity means), 18.57 (variety means), 55.71 (treatment means)

Shoot Chloride Contents: Chloride contents in shoot (Table 4) also increased progressively (1451 to 2625 m mole kg^{-1}) when root salinity increase from 10 dS m^{-1} to 20 dS.m^{-1}. Some cultivars such as Blue Silver, LU-26S and Pirsabak-85 accumulated less Cl^- in shoot, while Sarsabz, Shalimar-88 and Barrani-83 had more chloride than others cultivars. At 20 Ds. m^{-1} Abasin-81, Sarsabz and Shalimar-88 had highest contents while Blue Silver, LU-26s and Pirsabak-85 have accumulated least contents in shoots.

Table 6. Shoot Chloride contents of wheat cultivars grown under saline conditions.

Cultivars	**Salinity levels dS.m^{-1}**			**Mean**
	10	**15**	**20**	
	-----------------m mol kg^{-1}--------------			
Khyber -87	1377 o	1927 j	2187 f	1830 e
LU- 26s	1007 t	1787 l	2057 h	1617 h
Pak - 81	1280 q	2020 i	2520 c	1940 d
Chakwal - 86	1090 s	1950 j	2260 e	1767 f
Barani - 83	1380 o	2200 f	2400 d	1993 bc
Shalimar - 88	1330 p	2020 i	2670 b	2006 b
Blue Sliver	1293 q	1463 n	2077 h	1611 h
Abasin - 81	1240 r	1830 k	2870 a	1980 c
Sarsabz	1460 n	2120 g	2840 a	2140 a
Pirsabak - 85	1447 n	1647 m	1947 j	1680 g
Mean	1290 c	1896 b	2383 a	-

Means followed by different letters in same column are significantly different from each other at 5% level of significance
Lsd at 0.5 = 11.86 (Salinity means) 20.54(variety means, 35.57 (treatment means)

Shoot K^+/Na^+ Ratios: K^+/Na^+ ratios shoot in have been depicted in Table-5. The data revealed that salt addition from 10 dS m^{-1} and 20 dS m^{-1}, decreased the mean K^+/Na^+ ratios from 0.920 and 0.332 m mol kg^{-1} in the plants. Blue Silvar, LU-26S and Pirsabak-85 have high shoot K^+/Na^+ ratios, while minimum values were noted in Shalimar-88, Pak-81 and Khyber-87. High salinity 20 dS m^{-1} Sarsabz, Chakwal-86 and Abasin -81 have low K^+/ Na^+ ratios while LU- 26s, Blue Silver and Pirsabak-85 have higher ratios. The K^+/ Na^+ ratio of the leaf tissue and K^+ concentrations in the soil solution strongly correlated with the yield response of the ten genotypes grown at the different salinity. Aslam *et al*. (2001) attributed increase in rice yield to the enhanced K^+/ Na^+ ratio by the addition of Ca^{++} in solution culture and also in salt affected soil. Salt tolerant crop varities are believed to maintain higher K^+/ Na^+ ratio (Cao *et al*, 1991; Levy and Torrento, 1995; and Glenn *et al*, 1997). The distribution of Na^+ between solution and solid (exchange) phase depends strongly on potassium adsorption capacity of the soil (Richards, 1954; Levy and Feigenbaun (1996).

Table 7. Shoot K^+/Na^+ ratios of wheat cultivars grown under saline conditions.

Cultivars	Salinity levels dS.m^{-1}			Mean
	10	15	20	
Khyber -87	0.722 fg	0.446 no	0.359 op	0.509 d
LU- 26s	1.207 ab	0.722 fg	0.512 lmn	0.813 b
Pak - 81	0.698 fgh	0.532 k-n	0.285 pq	0.505 d
Chakwal - 86	0.985 c	0.562 j-m	0.259 q	0.602 c
Barani - 83	0.752 ef	0.586 i-m	0.262 q	0.533 d
Shalimar - 88	0.958 c	0.609 h-k	0.298 pq	0.622 c
Blue Sliver	1.294 a	0.823 de	0.495 mn	0.871 a
Abasin - 81	0.849 d	0.634 ghw	0.295 pq	0.592 c
Sarsabz	0.963 c	0.674 f-i	0.257 q	0.631 c
Pirsabak - 85	1.132 b	0.974 c	0.305 pq	0.804 b
Mean	0.956 a	0.656 b	0.333 c	-

Means followed by different letters in same column are significantly different from each other at 5% level of significance
Lsd at 0.5 =0.02982 (Salinity means), 0.05165 (variety means), 0.08946 (treatment means)

CORRELATION

Relationships between fresh shoot yields and shoot Na^+, K^+, K^+/Na^+ ratio and Cl^- contents shown in Table 8 indicated that there was positive correlation between shoot yields and K^+ and K^+/Na^+ ratios while negative relation with shoot Na^+ and Cl^- contents. Positive relation shows that K^+ is one of the compatible solutes, which plays important roles in osmoregulation of cells and for activation of enzymes, promotes plant growth. Negative relationship between shoot yields and toxic Na^+ and Cl^- ions indicated the exclusion mechanism of these ions by the cultivars having higher yields. However, shoot Na^+ contents have highly negative correlation with shoot yields, while the shoot Cl^- has similar negative trend but to lesser extent. It is clear from ionic contents, that salt tolerant cultivars accumulated more K^+ and excluded toxic Na^+ and Cl^- ions and salt sensitive cultivars behaved reverse thus confirming the Na^+ and Cl^- exclusion mechanism for salt tolerance in crops. (Schachtman and Liu, 1999).

Table 8. Linear relationship between fresh shoot yield and Shoot ion contents of wheat cultivars grown under saline conditions.

Character	Salinity levels dS. m^{-1}	Regression Constant (a)	Regression Co-efficient (b)	Correlation (r)
Na^+	10	1.28	- 0.159	- 0.512 **
	15	1.63	- 0.279	- 0.567 **
	20	2.15	- 0.45	- 0.489 **
K^+	10	0.61	0.054	0.447 *
	15	0.50	0.077	0.545 **
	20	0.43	0.060	0.334 NS
Cl^-	10	1.61	- 0.067	- 0.210 NS
	15	2.55	- 0.289	- 0.391 NS
	20	3.61	- 0.748	- 0.440 *
K^+ / Na^+	10	0.13	0.288	0.561 **
	15	0.10	0.265	0.631 **
	20	0.11	0.179	0.507 **

NS = Non Significant; * = Significant at 5% probability level; ** = Significant at 1% probability level

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