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Effect of NaCl on Root Growth and Ionic Relations of Wheat

ZULFIQAR ALI, ABDUS SALAM KHAN, IFTIKHAR AHMAD KHAN AND FAQIR MUHAMMAD AZHAR
Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad–38040, Pakistan
Corresponding e-mail: zulfiqarpbg@hotmail.com

ABSTRACT

Root growth and ionic relations of wheat seedlings were compared when grown in 0, 10 and 15 dS m^{-1} NaCl solutions. Based upon absolute root length data, 4WLRG/1-8 and 8965 found to be more tolerant than LU-26S, whereas 4WLRG/1-12 and 2WLRG/1-12 with greatest decrease in root lengths in salt stress may be regarded as the most salt sensitive accessions. The differing responses of these accessions to salinity were substantiated by the data on ion uptake. The data suggest that the rooting technique has been effective in distinguishing salt tolerant and salt sensitive accessions at early plant developmental stage.

Key Words: *Triticum aestivum;* Wheat; salinity tolerance; Na^+; K^{++}

INTRODUCTION

Despite utilizing the genetic information for screening salt tolerant plants using morphological plant characters the work may be speeded up, if selection is also based on the physiological mechanisms controlling salinity tolerance in a crop species under investigation. Several authors had emphasized on the importance of availability of physiological information on salt tolerance (Greenway & Munns, 1980; Flowers & Yeo, 1986; Laüchli & Epstein, 1990). Mechanisms of salt tolerance may differ between closely related species (Rush & Epstein, 1981a, 1981b; Salim, 1991) and even varieties (Yeo & Flowers, 1983; Azhar & McNeilly, 1989; Salim, 1989).

Plant responses to salinity are in general extremely complex, and an array of physiological mechanisms are involved in enabling them to cope with stressful conditions (Wyn Jones, 1981). However, variation in salinity tolerance amongst those plant species showing glycophytic adaptation is related to the efficiency with which they exclude excess of Na^+ from their leaves (Greenway & Munns, 1980; Azhar & McNeilly, 2001). Salim (1991) identified a barley variety which accumulated high Na^+ content in shoots and exhibited increased salt tolerance, and by contrast in emmer wheat enhanced salinity tolerance was due to low Na^+ uptake (Nevo *et al*., 1992). These studies were planned to know the role of morpho-physiological characters in wheat to cope with salinity stress.

MATERIALS AND METHODS

Five wheat accessions namely, 4WLRG/1-8, 8965, 4WLRG/1-12, 2WLRG/1-12 and LU-26S {described previously salt tolerant (Farooq *et al*., 1995)} were used in this experiment. The seeds of these accessions were grown in iron trays filled with acid washed gravel. These trays were placed in a glasshouse with natural temperature (10-15 ^{0}C) and photoperiod (10 h) during November 2000. The young seedlings at the two-leaf stage were transferred to aerated half strength Hoagland solution (Hoagland & Arnon, 1950). Each of the five accessions was planted in quadruplicate in the two NaCl treatments i.e. 10 and 15 dSm^{-1}, and one without salt (control). The appropriate salinity levels in the two containers were developed after two days of transplanting the seedlings, and completed in four equal NaCl doses in four days. The pH of the solutions ranged from 6.0 to 6.5 and was maintained daily using 1*N* HCl and/or NaOH solutions. The NaCl solutions in the containers were changed after two weeks. After four weeks growth, longest root lengths, were measured. The seedling leaves of each accession grown in control, 10 and 15 dS m^{-1} were stored separately at 5^{o}C in micro-tubes for one week in a refrigerator. The cell sap was extracted using the standard technique of centrifugation (Gorham *et al*., 1984). The cell sap was diluted by adding de-ionized water. The concentrations of Na^+ and K^+ ions in the samples were measured with the help of a flame photometer (model PFP-7, make Buck Scientific, USA). Uptake of potassium in relation to sodium (K^+/Na^+) was also computed using data of Na^+ and K^+ ions. The data on seedling growth, and uptake of ions in each accession were analysed using ordinary analysis of variance technique (Steel & Torrie, 1980).

RESULTS

This experiment was designed to substantiate salt tolerance of 4WLRG/1-8, 8965, 4WLRG/1-12 and 2WLRG/1-12. In this experiment in addition to measuring root lengths during early plant development, the plant material was analysed for concentrations of Na^+, K^+, and K^+/Na^+, and compared with that of LU-26S. Concentrations of Na^+ and K^+ in the seedlings were determined and compared in order to see the effectiveness of the rooting technique as selection criterion.

The results of analyses of variance of absolute root lengths, Na^+, K^+, and K^+/Na^+ ratio for the five wheat accessions are given in Table I, which reveal significant differences ($p \leq 0.01$) in root lengths, Na^+, K^+, and K^+/Na^+ ratio measured between the accessions. Differences between the three NaCl levels were also significant ($p \leq 0.01$). Significant interaction term (acc. x conc., $p \leq 0.01$) suggests that root lengths were affected under low and high NaCl salinities. However, non-significant ($p \geq 0.05$) interaction reveals that accessions did not differ for uptake of Na^+, K^+, and K^+/Na^+ ratio across salinities. The data on absolute root length, Na^+, K^+, and K^+/Na^+ ratio of the 5 accessions in control and two NaCl salinity are given in Table II.

It is obvious that 4WLRG/1-8 and 8965 having produced longer root lengths 20 and 15 cm, respectively than those of 2WLRG/1-12 and 4WLRG/1-12, which produced 8 and 7 cm, respectively displayed their superior salt tolerance. By contrast, root length of LU-26S was measured 10 cm. Although accessions did not differ for the uptake of Na^+ and K^+ ions during 4-weeks of growth, yet these differed considerably from each other for the Na^+ and K^+ concentration. The comparison of accessions based upon Na^+ ion uptake shows that accessions 4WLRG/1-8 and 8965 had the least concentration of Na^+ ions i.e. 90 m $molL^{-1}$ and 78 m $molL^{-1}$ respectively, whilst 4WLRG/1-12 and 2WLRG/1-12, accumulated more Na^+ 184 and 110 m $molL^{-1}$, respectively. The cultivar LU-26S contained 85 m $molL^{-1}$. Uptake of potassium in the accessions provides further estimates of the responses of accessions to salinity. Thus 4WLRG/1-8 had the maximum K^+ uptake (101 $molL^{-1}$), followed by 2WLRG/1-12 (97 m $molL^{-1}$). By contrast, LU-26S and 4WLRG/1-12 contained 82 m $molL^{-1}$ and 71 m $molL^{-1}$ respectively. The adverse effect of NaCl is also shown by estimate based upon K^+/Na^+ ratio, and again differences among the five accessions are apparent. Though all the entries differed in K^+/Na^+ ratio, accession 8965 and 4WLRG/1-8 accumulated more K^+ than Na^+, the ratio in these accessions being 1.87 and 1.67, respectively. In contrast, K^+/Na^+ ratio in 4WLRG/1-12, 2WLRG/1-12 and LU-26S are 0.94, 1.45 and 1.34, respectively.

The comparison based upon absolute root length data, 4WLRG/1-8 and 8965 seemed to be more tolerant than LU-26S, whereas 4WLRG/1-12 and 2WLRG/1-12 with greatest decrease in root lengths in salt levels may be regarded as the most salt sensitive accessions. The differing responses of these accessions to salinity were substantiated by the data on uptake of Na^+, K^+ and K^+ in relation to Na^+. Accessions 4WLRG/1-8 and 8965 with more K^+/Na^+ ratio were more tolerant than the others.

DISCUSSION

Although the sample of genotypes was very small, these five accessions differed significantly for their root lengths, and also for accumulation of Na^+, K^+, and K^+/Na^+ ratio (Table I). High salt tolerance of 4WLRG/1-8 and 8965, and poor response of 4WLRG/1-12 and 2WLRG/1-12, in comparison with LU-26S, was evident by the data given in Tables II. Root lengths of five accessions revealed high salt tolerance of 4WLRG/1-8 and 8965, and poor salt tolerance of 4WLRG/1-12 and 2WLRG/1-12 (Table II), and the differing abilities of the four accessions to grow under salinized solution were found to be correlated with accumulation of K^+, and K^+/Na^+ ratio. These data suggest that the rooting technique has been effective to distinguish salt tolerant and salt sensitive accessions. The rooting technique has been used extensively as a selection criterion in order to identify salt tolerant and sensitive genotypes in a number of grass species (Hannon & Bradshaw, 1968; Ashraf *et al*., 1986a, 1986b), sorghum (Azhar & McNeilly, 1987; Azhar *et al*., 1998), maize (Rao & McNeilly, 1999; Khan & McNeilly, 2000; Khan *et al*., 2003), lucerne (Al-Khatib *et al*., 1993), and cotton (Akhtar & Azhar, 2001).

Table I. Mean squares for various traits of 5 wheat accessions grown in control and 2 NaCl concentrations

Source of variation	DF	Root length	Na^+	K^+	K^+/Na^+ ratio
Accessions (Acc.)	4	50.99**	4871.78**	1748.27**	0.003 **
Concentrations (Conc.)	2	2702.93**	271824.09**	235170.31**	0.0786**
Acc. x Conc.	8	16.92**	1539.61 NS	257.58 NS	0.0003 NS
Within + Residual	45	5.56	2313.26	825.75	0.0002

* = $p \leq 0.05$; ** = $p \leq 0.01$; NS = $p > 0.05$

Table II. Absolute root length, Na^+, K^+ and K^+/Na^+ ratio of 5 wheat accessions grown in control and 2 NaCl concentrations

Accessions	Root length (cm)		Na^+ (m $molL^{-1}$)		K^+ (m $molL^{-1}$)		K^+/Na^+ ratio	
	Control	Mean of 2 salinities	Control	Mean of 2 salinities	Control	Mean of 2 salinities	Control	Mean of 2 salinities
4WLRG/1-8	27.25	19.67	5.17	90.30	297.62	101.31	57.57	1.67
8965	22.00	14.86	4.00	77.70	258.54	87.76	64.64	1.87
2WLRG/1-12	25.63	7.51	4.16	109.74	266.17	97.30	63.98	1.45
4WLRG/1-12	22.63	6.76	5.28	183.82	271.89	71.48	51.49	0.94
LU-26S	19.38	9.87	4.64	84.97	252.82	81.91	54.49	1.34
LSD 5% (Acc. x Conc.)		6.71		63.99		26.17		0.029

Low uptake of Na^+ by 4WLRG/1-8 and 8965, and increased uptake by 2WLRG/1-12 and 4WLRG/1-12 reveal that the former two accessions excluded Na^+, and the later did not. There is ample evidence to show that salt tolerant plants exclude more Na^+ than sensitive ones, a characteristic of glycophytic species. In emmer wheat enhanced salinity tolerance had been reported due to low Na^+ uptake (Nevo *et al*., 1992). Similarly growth performance of wheat was found to be correlated with exclusion of Na^+ under low and high salinity (Rashid *et al*., 1999; Salam *et al*., 1999). High levels of K^+ in young expanding tissue is associated with salt tolerance in many plant species (Gorham, 1993; Storey *et al*., 1993; Khatun & Flowers, 1995). Thus 4WLRG/1-8 and 8965 with greater K^+/Na^+ ratio may be regarded as high salt tolerant as compared with 2WLRG/1-12 and 4WLRG/1-12 with low K^+/Na^+ ratio. By contrast LU-26S appeared to be moderately tolerant to salinity. However, Gorham (1993) advocated that all plants discriminate to some extent between Na^+ and K^+, Na^+ can be substituted for K^+ uptake, and mechanisms similar to this may be operative for both ions (Schroeder *et al*., 1994).

CONCLUSION

The rooting technique may be used as selection criterion to select salt tolerant genotypes from segregating populations in hydroponic culture under salt stress. In saline fields, root length could not be measured, therefore, K^+/Na^+ ratio could be used to select salt tolerant genotypes from segregating populations.

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