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MORPHO-PHYSIOLOGICAL ADAPTATIONS OF WHEAT GENOTYPES TO SALINITY STRESS

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Abstract

To explore morpho-physiological alteration in wheat for salinity tolerance, a glass house experiment was laid out in randomized complete block design (RCBD) with three replications at Nuclear Institute of Agriculture, (NIA) Tando Jam, Pakistan. Studies were conducted with two levels of salinity (Control, and 12 dS m^{-1} NaCl) and five wheat genotypes. Due to salinity stress morphological and yield attributes like plant height, total tillers, productive tillers, spike length, number of spikelets per spike, number of grain per spike, 1000 grain weight, grain weight per plant were decreased in all wheat genotypes, however, wheat ESW-9525 showed significantly less reduction in all these parameters than other wheat genotypes. Biochemical attributes like proline glycine betaine and total soluble sugars were increased in all the genotypes due to salinity. Wheat geotype Bakhtawar maintained the highest Na while the minimum Na contents were found in ESW-9525 that had the highest correlation with grain yield. The tolerant and stable cultivars were ESW-9525 and Sarsabz which had highest yield at 12 dS m-^{1} salinity than other cultivars.

Key words: Salinity, Wheat, Proline, Salt tolerance, Na^+/K^+ Ratio

Introduction

Wheat (*Triticum aestivum* L.) is a main cereal crop of Pakistan and a staple diet of its people. Pakistan is one of the top ten wheat producing countries of the world with contribution of 10.1 percent to the value added in agriculture and 2.2 percent to GDP. The wheat production remained at 24.2 million tones during 2012-13 (Anon., 2013).

Salinity is the most significant environmental stress which reduces the crop growth and yield, especially in arid and semi arid region of the world (Khan *et al*., 2009, 2010). Salinity damages the soil which is beyond economic repair (Munns *et al.,* 2006; Ashraf, 2009; Saleem *et al*., 2011). It causes imbalance in nutrients uptake in plants like $K^{+,}$ Na^+ , Ca^{2+} and Cl^- which alters the plant metabolism by affecting osmotic potential, enzymatic activities, membrane permeability and electrochemical potential (Grattan & Grieve, 1999; Khan *et al*., 2010). Seed germination is effected either by induction of osmotic stress which causes disturbance in imbibitions of germinating seed or through ionic toxicity (Hosseini *et al*., 2003). Salinity impaired the plant acquisition and utilization of necessary nutrients particularly K^+ and Ca^{2+} which are responsible for reduced crop productivity under saline conditions (Viegas *et al.,* 2001; Ashraf, 2004; Hu & Schmidhalter 2005; Munns *et al.,* 2006).

It is reported that plants vary in salinity tolerance due to vriation in their ability to accumulate different ions (Ashraf & McNeilly 1988; Glenn *et al.,* 1996), that determine their capability and adaptive ability of the photosynthetic apparatus of crops growing under stressed environment (Shahbaz *et al*., 2011).

Proline and sugars are well-known osmoprotectants solute and accumulate in various organisms under salt stress. High concentration of these osmoprotectants can be advantageous to stressed plants (Hyun *et al*., 2003). The factors determining salt tolerance in wheat are improved K^+/Na^+ ratio of leaves, enhanced uptake of K^+ and less of Na^+ contents (Mahar *et al*., 2003, Munns, 2007). New genotypes of wheat having diverse salt tolerance are being developed continuously to cope with the salinity and improving crop productivity. So, it is necessary to evaluate the newly developed salt tolerant genotype necessary to have understandings about their mechanism of nutrient absorption, adaptive ability, resulting their successfully growth with high crop productivity.

The current study was undertaken to study the adaptability of five newly developed wheat cultivars to saline environments by determining morphological and physiological alterations and yield stability under salinity stress.

Material and Methods

Study was carried out to examine the salt tolerance of five wheat genotypes using physiochemical activities like Na, K, K/Na ratio, proline, betaine and total sugar. Seeds were obtained from Plant Breeding Division, Nuclear Institute of Agriculture, Tandojam Pakistan. Experiment was conducted in a glass house with salinity treatment (12 dS/m NaCl) along with control. Physiochemical attributes i.e., Na, K, K/Na ratio, proline, betaine and total sugar were estimated at the time of flowering and agronomical parameters at harvesting.

Determinations of ionic contents: Sodium and Potassium contents were measured according to Ansari & Flowers, 1986. In order to study the inorganic salts (Na^+ and K^+), fully expanded leaves (flag leaf) of each accession grown under stressed and non-stressed conditions were selected. The leaf samples were dried for 72 hours in hot air oven at 72°C. For the determination of Na^+ and K^+ in dried grinded leaf, the plant material was reacted with 0.2 m*M* acetic acid (CH_3COOH) in water bath for 1 h pre-heated at 95°C, the extracted solution was filtered and suitable dilution was made. Na^+ and K^+ concentrations were determined by flame photometer (Jenway, Model PFP7).

Determinations of osmoprotectants: Total soluble sugar was determined in fresh leaves according to Riazi *et al*., (1985). Proline was estimated according to Bates *et al*., (1973) and glycine betaine as described by Grieve & Gartan (1983).

Statistical analysis: The collected data was analyzed by implying Fisher analysis of variance technique and significant treatments means were analyzed using least significance difference (LSD) test at 0.05 probability levels (Steel *et al.,* 1997).

Results

Salt treatment significantly reduced total number of tillers plant^{-1}, number of fertile tillers plant^{-1}, spike length, number of spikelets per spike, number of grains per spike, grain weight per plant and1000-grain weight. Wheat genotypes did not differ significant for plant height; however the most elevated plant height among the genotypes under control was recorded for cultivar Bakhtawar while in case of salinity cultivar Sarsabz showed most increase in plant height (Table 2). Maximum total tillers per plant were observed in LU-26s followed by Sarsabz while minimum were in Bakhtawar closely followed by V-7012. Similarly, maximum number of fertile tillers per plant, spike length, number of spikelets per spike, number of grains per spike were observed in Sarsabz and Bakhtawar and Sarsabz had minimum values for all these parameters. Wheat geotypes LU-26s and V-7012 maintained the lowest number of spikelets per spike, number of grains per spike (Table 2). In case of grain weight per plant and 1000-grain weight genotypes V-7012 had minimum values, while, Sarsabz and ESW-9525 had the highest values for these parameters. The highest 1000 grain weight under controlled and salinity was noted for LU-26s followed by Sarsabz (Table 2). Interaction between salinity and genotypes was significant. Wheat genotypes categorized on the basis of 50% relative reduction in above mentioned parameters at 12 dS/m and the genotypes Sarsabz and ESW-9525 maintained the highest values for all these attributes by maintaining <50% reduction, followed by V-7012 (Table 1).

Salinity treatments significantly affected the Na+, K+ contents and K^+/ Na^+ ratio in leaves of all wheat genotypes (Table 3). Among the genotypes, non of the genotype significantly differ in Na^+ contents under control while in case of salinity Bakhtawar accumulated maximum Na^+ contents and ESW-9525 showed minimum increase in Na^+ contents along with lowest reduction in K^+ contents. Whereas LU-26 revealed maximum decline in K^+ contents. In case of interaction the highest K^+ contents were maintained by Sarsabz in control and ESW-9525 under salinity stress. Similarly greater K/Na ratio with minimum reduction was observed in the leaves of wheat genotype V-7012, followed by Sarsabz. The K^+ contents and K^+/Na^+ ratio had the highest correlation with grain yield. The grain yield increased with increase in K^+ contents (Fig. 1b) and with greater K^+/Na^+ ratio (Fig. 1c) but the correlation between grain yield and Na^+ is negative means grater the Na contents flower is yield (Fig. 1a).

Table 1. Some growth parameters of five wheat genotypes grown under increased salinity.

S.#	Genotypes	Plant height	Total tillers	Prod. Tillers	Spike length	No. spikelets/ spike	No. of grains plant^{-1}	Grain wt. /spike	1000 grain wt.	No. of variables having (<50% red.)
1.	V-7012	+	+	+	+	+	-	-	-	5
2.	Lu-26s	+	+	+	+	+	+	+	+	8
3.	Bakhtawar	+	-	+	+	+	-	-	-	4
4.	ESW-9525	+	+	+	+	+	+	+	+	8
5.	Sarsabz	+	+	+	+	+	+	+	+	8

Table 2. Effect of salinity on growth, yield and yield related traits of wheat genotypes.

Treatments	Plant height (cm)	Total tillers	Productive tillers	Spike length (cm)	No. of spikelets/spike	No. of grains/ spike	Grain weight/ plant (g)	1000 grain weight (g)
Control								
V-7012	64.67b	3.67a	2.67b	8.07b	10.27b	68.67b	2.54b	41.23b
Lu-26s	77.33a	4.33a	4.33a	9.00a	13.33a	86.67a	3.75a	51.60a
Bakhtawar	85.33a	3.33b	3.33b	7.50b	11.73a	74.67b	2.56b	35.07b
ESW-9525	57.33a	4.00a	3.67a	8.00b	12.67a	83.33a	3.24a	44.27a
Sarsabz	78.00b	4.00a	4.00a	9.45a	13.33a	87.67a	3.26a	44.37a
Saline								
V-7012	43.67b	2.00b	2.00b	5.67a	6.83a	22.00b	0.89b	17.67b
Lu-26s	45.33a	3.00a	3.00a	6.75a	8.67a	47.67a	2.36a	33.23a
Bakhtawar	45.33a	1.67b	1.67b	5.42b	8.33a	31.67b	0.98b	15.60b
ESW-9525	31.00b	2.67a	2.67a	5.67a	8.50a	52.33a	2.31a	28.27a
Sarsabz	54.67a	3.00a	3.00a	6.63a	8.83a	57.33a	2.14a	32.73a
LSD ≤ 0.05	9.36	0.7539	0.7792	1.256	2.372	11.97	0.6197	9.250

Means in a column not sharing a common letter differ significantly by Fisher's protected Least Significant Difference (LSD) at 5% probability level

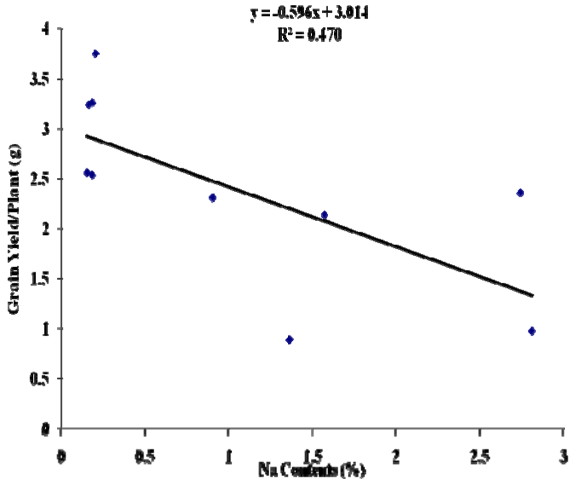

Fig. 1a. Relationship between Na^+ contents and grain yield for wheat genotypes treated with 12 dS m^{-1} NaCl in green house.

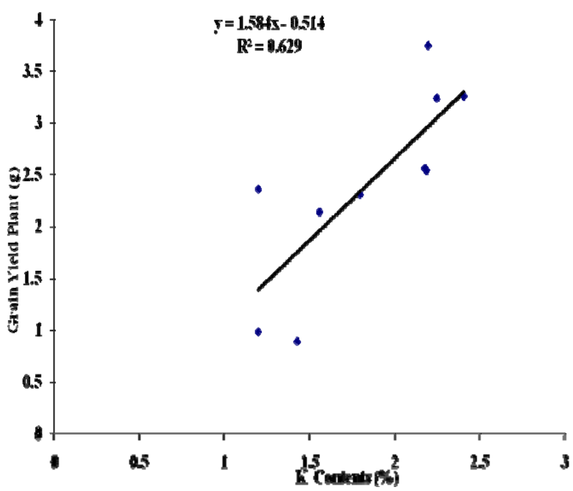

Fig. 1b. Relationship between k^+ contents and grain yield for wheat genotypes treated with 12 dS m^{-1} NaCl in green house.

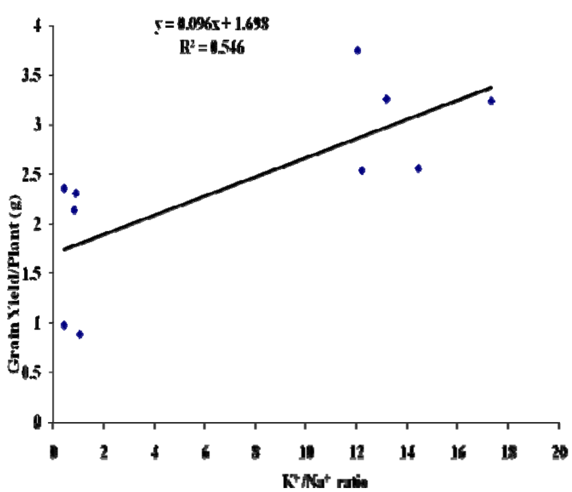

Fig. 1c. Relationship between Na^+/k^+ ratio and grain yield for wheat genotypes treated with 12 dS m^{-1} NaCl in green house.

Salinity stress affected proline, glycine betaine and total sugars significantly (Table 3). Maximum increase in proline, glycinebetaine and total sugars were estimated in wheat genotype Sarsabz followed by LU-26s and minimum were in Bakhtawar.. Under normal conditions the highest proline and glycine-betaine contents were noted in ESW-9525 while in saline environments Sarsabz showed the greater proline and glycine-betaine contents followed by V-7012. In case of treatments salinity performed better than control in physiological traits (Proline, glycine betaine and total sugars) also show the positive correlations with grain yield (Fig. 1d, e, f).

Discussion

This study revealed that among the tasted cultivars Bakhtawar is most sensitive because it maintained >50% reduction in most of studied attributes (Table 1). Reduction in plant growth (plant height) due to salinity is commonly reported by many worker (Shirazi *et al.,* 2005; Saboora & Kiarostami, 2006; Khan *et al.,* 2006) and most recently supported by Mirzaei *et al*., (2012) who also reported that presence of salinity in the growth medium significantly decreased dry weight and plant height. The decrease in plant height in wheat genotypes may be due to presence of excessive salts in root zone (Singla & Garg, 2005) which reduced the water and essential nutrets uptake. The salinity stress adversely affected the number of grain per spike, grain weight per plant and 1000 grain weight in all wheat genotypes (Table 2) it seems that the growth and yield processes are very sensitive to salinity and similar findings are also noted by Akram *et al*., (2002), Kamkar *et al*., (2004) and Khan *et al*., (2009) all reported that salinity stress reduces growth, yield and yield components. The decrease in number of grains is the major cause of grain yield reduction under salt stress that may be due to ionic toxicity and osmotic stress created by the excessive salts present in the growth medium (Mass & Grieve, 1990).

Salinity stress induced significant changes in Na^+, K^+ contents and K^+/Na^+ ratio in all wheat genotypes. In present study K^+/Na^+ was greater in wheat genotype ESW-9525, followed by Bakhtawar than others (Table 3). Reduced Na^+ uptake and improved K^+ uptake are the key indicators of salinity tolerance in higher plants (Marschner, 1995, Hu & Schmidhalter, 1997). The ability of plants to limit Na^+ transport into shoot is important for the maintenance of growth rates and protection of the metabolic process in elongating cells from the toxic effect of Na^+ (Razmjoo *et al*., 2008). The results of this study strengthen by outcome of Poustini & Siosemardeh (2004) and Hussain & Munns (2005) who suggested that uptake and transport of low Na^+ and maintenance of high K^+/Na^+ in shoots or the leaves is related with salt resistance in wheat and in some other plant species.

Table 3. Effect of salinity on ionic contents and some biochemical parameters of wheat genotypes.

Treatments	Na+ contents (mg g-1 dry wt.)	K contents (mg g-1 dry wt.)	K+ /Na+ ratio	Proline contents (mmol g-1 fresh wt.)	Glycine betaine (mmol g-1 dry wt.)	Total sugars (mg g-1 dry wt.)
Control						
V-7012	0.18a	2.19b	12.20b	5.02a	5.88b	8.30a
Lu-26s	0.20a	2.20b	12.03b	5.07a	5.23b	8.14a
Bakhtawar	0.15a	2.18b	14.43b	5.03a	7.15a	8.52a
ESW-9525	0.16a	2.25b	17.31a	5.25a	5.52b	8.18a
Sarsabz	0.18a	2.41a	13.17b	4.93a	5.37b	8.08a
Saline						
V-7012	1.36a	1.43b	1.05b	19.37b	26.00b	22.32a
Lu-26s	2.74a	1.20b	0.43b	10.21b	18.78b	15.92b
Bakhtawar	2.81a	1.20b	0.43b	10.60b	19.20b	15.27b
ESW-9525	0.90b	1.80a	0.90b	18.34b	23.00b	20.14b
Sarsabz	1.57b	1.56b	0.83b	22.77a	28.75a	22.05a
LSD ≤ 0.05	0.0919	0.1404	1.084	0.9929	1.053	0.9619

Means in a column not sharing a common letter differ significantly by Fisher's protected Least Significant Difference (LSD) at 5 % probability level

Salinity stress significantly enhanced the concentration of proline, glycinebetaine and total sugars in all wheat genotypes, however, wheat genotypes Sarsabz and LU-26s had maintained the highest proline content under saline conditions (Table 3). The consequences of this study are related to findings of Wang *et al*., (2007) who reported that during osmotic adjustment, plants accumulate proline and other organic solutes in response of salt stress, usually believed to function as a protector against salt damage. Similarly, Munns, (1993) reported that the amount of water soluble carbohydrate increases with increasing salinity which is also in favored present findings.

Na^+ contents showed negative effect on grain yield wherever, K^+ contents and K^+/Na^+ ratio had significant positive correlation with grain yield (Fig. 1.a,b,c). The results of this study are also in accord with findings of Shamsi & Kobraee (2013).

Conclusion

From the results of present study it is concluded that among five wheat genotypes, ESW-9525 was successful in maintaining the higher, growth , yield, yield components and K/Na ratio, proline, glycinebetaine and total sugars and low Na contents which are the characteristics of salt tolerant genotypes. Therefore, it is categorized as salt tolerant wheat genotype and may be recommended for cultivation in salt-hit areas.

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