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Tolerance Potential of Wheat cv. LU-26S to High Salinity and Waterlogging Interaction

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ABSTRACT

A research was carried out to evaluate the combined effect of salinity and waterlogging on growth and ionic relations of wheat cv. LU-26s in hydroponics culture. The salinity (1.2 or 15 dS m^{-1}) was imposed for six aeration levels, control (No aeration) 1, 4, 8, 12 and 24 h per day with five repeats. Increase in salinity from 1.2 dS m^{-1} to 15 dS m^{-1}, resulted in significantly less shoot height and fresh shoot weight, while the number of tillers per plant, chloride, sodium, potassium, calcium and magnesium concentration in expressed leaf sap increased significantly. Increasing aeration period have significant positive effect on shoot length, number of tillers per plant and fresh shoot weight while the effect was non significant in case of leaf Cl^-, Na^+, K^+, Ca^{++} and Mg^{++} concentration.

Key Words: Salinity; Waterlogging; Wheat; Tolerance

INTRODUCTION

Soil salinity and waterlogging are amongst the most significant problems affecting crop production on irrigated lands in the world today. These problems are also considered to be the major constraints for low crop productivity in arid and semiarid regions of Pakistan.

It has been estimated that out of 19,180.4 million hectares of the total geographical area of world, abut 1,610.7 million hectares is affected by various degrees of waterlogging, which represents about 12.2% of the total area (Szabolcs & Varallyay, 1977). It was generally believed that development of salt affected soils has been the consequences of waterlogging due to seepage from the canal system started in 1881. On the other hand, flood irrigation is widely used method of irrigation in the canal irrigated areas of Pakistan, which may produce waterlogged conditions for a short period and affect the crop growth (Singh & Ghildyal, 1980; Belford, 1981).

The effects of high salinity on plant growth with adequate root zone aeration have been studied and reviewed extensively (Greenway & Munns, 1980; Gorham *et al.*, 1985; Schachtman & Munns, 1992). Salinity and hypoxia occur together affect plant growth adversely because oxygen deficiency in the root zone inhibits oxidative phosphorelation which in turn restricts the energy available for the ion pumps involved in excluding salts from the roots (Drew & Lauchli, 1985; Barret-Lenard, 1986). Comparatively less information (Aceves *et al*., 1975; Barret-Lenard, 1986) is available for the combined effect of salinity and waterlogging despite of the frequent and simultaneous occurrence of these two stresses in irrigated agriculture in arid and semi arid regions. The present paper describes the combined effect of salinity and waterlogging on growth and ionic relations of wheat cv. LU-26s in hydroponics system.

MATERIALS AND METHODS

Plants were grown at two salinity levels S_0 and S_1 (Control of EC 1.2 dS m^{-1} and 15 dS m^{-1}) and six aeration levels A_0, A_1, A_2, A_3, A_4 and A_5 i.e. 0 (no aeration) 1, 4, 8, 12, and 24 h aeration per day. Seedlings were transplanted in plastic tubs of 20 L capacity filled with ½ strength Hoagland nutrient solution (Hoagland & Arnon, 1950) through the holes of thermopole sheets (wrapped by foam) in completely randomized design with five repeats.

Three days after seedlings establishment, salinity was raised to required level through a step wise increase of 2.5 dS m^{-1} every day by adding NaCl to nutrient solution. EC and pH of nutrient solution was maintained throughout the experiment. For leaf sap extraction, fully expanded fresh leaves were collected and washed in distilled water, blotted and preserved in small plastic bags and stored immediately in the freezer. Frozen leaf samples after thawing, transferred to a eppendrof tubes and crushed thoroughly using a metal rod with tapered end (Gorham, 1984) and then centrifuged at 6500 rpm for 15 min. The supernatant leaf sap was collected in tubes. The determinations of Na^+ and K^+ concentration in expressed leaf sap were made on Jenway PFP-7 Flame Photometer. The Cl^- concentration was determined on Corning 925 Chloride Analyzer. The determinations of Ca^{2+} and Mg^{2+} were made according to the method described by USDA Salinity Lab. Staff (1954). Data were subjected to statistical analysis according to Steel and Torrie (1980).

RESULTS AND DISCUSSION

Comparatively less shoot length was recorded at higher salinity level whereas more shoot length was observed as the aeration period was increased at both the salinity levels (Table I). The shoot length was significantly higher at 4 h aeration under non saline condition and at 8 h aeration under saline conditions (15 dS m^{-1}) and the further increase in aeration at both saline and non saline level did not cause significant change in shoot length. Similar trend was observed for over all means of aeration period, while under saline condition, shoot length was 1.5 times less as compared to non saline condition. The results showed that with imposition of salinity, the required aeration period for maximum shoot length also increased which may be due to the reason that under saline conditions the plant required more energy to exclude toxic ions and in turn more oxygen is required for the respiration process. Similar findings were also reported by Trought and Drew (1980), Ehsan *et al.* (1986) and Akhtar *et al.* (1994).

Table I. Effect of salinity and aeration period on shoot length (cm) (average of five repeats)

Aeration levels	Salinity levels		
	Normal saline (1.2 dS m^{-1})	Saline (15 dS m^{-1})	Mean
0 hours/24 hours	39.8 c	18.2 f	29.0 C
1 hours/24 hours	40.7 bc	25.3 e	33.0 B
4 hours/24 hours	43.4 a	26.7 e	35.0 A
8 hours/24 hours	40.6 bc	29.6 d	35.1 A
12 hours/24 hours	41.2 ab	29.5 d	35.3 A
24 hours/24 hours	42.2 ab	30.8 d	36.4 A
Mean	41.3 A	26.8 B	

Means sharing the same letters are statistically non significant at p = 0.05

The number of tillers per plant (Table II) were maximum at 8 h aeration level in both saline and non saline conditions. The minimal number of tillers were recorded in plants grown under non saline conditions without aeration. There is non significant difference under saline conditions, among all the aeration periods for number of tillers per plant. On over all average basis, aeration level of 8 h is significantly better than other periods of aeration, while the overall salinity means showed that the number of tillers was significantly higher under saline as compared to non saline conditions. According to Sojka (1985), Akhtar *et al.* (1994) and Thomson *et al.* (1992) the decreasing oxygen level reduced the tillering capacity of wheat.

Under both saline and non saline conditions, the fresh shoot weight (FSW) increased with increase in aeration period and maximum FSW was observed in 24 h aeration period (45.4 g) which was significantly better than all other aeration periods (Table III). Over all means indicated that under saline conditions the SFW decreased significantly and the decrease was 57.7% as compared to non saline conditions. Under saline conditions without aeration, the SFW was minimum (9.2 g) due to the interactive effect of salinity and hypoxia.

Table II. Effect of salinity and aeration period on number of tillers per plant (average of five repeats)

Aeration levels	Salinity levels		
	Normal saline (1.2 dS m^{-1})	Saline (15 dS m^{-1})	Mean
0 hours/24 hours	5.1 c	7.1 b	6.1 C
1 hours/24 hours	5.6 c	7.3 b	6.45 C
4 hours/24 hours	7.4 b	7.3 b	7.35 B
8 hours/24 hours	8.2 a	7.6 ab	7.9 A
12 hours/24 hours	7.5 b	7.0 b	7.25 B
24 hours/24 hours	7.5 b	7.0 b	7.25 B
Mean	6.9 B	7.2 A	

Means sharing the same letters are statistically non significant at p = 0.05

Table III. Effect of salinity and aeration period on fresh shoot weight (g) (average of five repeats)

Aeration levels	Salinity levels		
	Normal saline (1.2 dS m^{-1})	Saline (15 dS m^{-1})	Mean
0 hours/24 hours	29.7 c	9.2 f	19.5 C
1 hours/24 hours	30.8 b	12.4 ef	21.6 BC
4 hours/24 hours	31.1 c	14.3 df	22.7 BC
8 hours/24 hours	30.0 c	16.4 df	23.2 B
12 hours/24 hours	35.9 b	15.8 df	25.9 B
24 hours/24 hours	45.4 a	17.8 d	31.6 A
Mean	33.8 A	14.3 B	

Means sharing the same letters are statistically non significant at p = 0.05

It seemed that 4 - 8 h per day aeration satisfied the oxygen demand of roots. This effect was obvious by the highest shoot length and number of tillers per plant at these aeration periods. Hypoxia over all lessened shoot length, shoot weight and number of tillers. The similar results were reported by Nawaz (1993).

Data regarding chloride concentration is given in Table IV. Under non saline conditions minimal Cl^- concentration was noted in 12 h followed by 24 h aeration while the concentration was maximal in 8 h followed by 4 h aeration periods, respectively. Under salt stress, significantly less Cl^- concentration was observed in 24 h followed by 4 h aeration, while this difference was non significant among all other aeration periods. On the basis of over all comparison, Cl^- concentration was minimum in 24 h and maximum in 8 h aeration period. The increase in Cl^- concentration under saline was 9.9 fold as compared to non saline conditions. Similar response was also reported by John *et al.* (1977). Letely *et al.* (1965) also found decrease in Cl^- concentration in barley with an increase in oxygen supply.

Table IV. Effect of salinity and aeration period on chloride conc. in expressed leaf sap (mol m^{-3}) (average of five repeats)

Aeration levels	Salinity levels		
	Normal saline (1.2 dS m^{-1})	Saline (15 dS m^{-1})	Mean
0 hours/24 hours	22.0 d	241.6 a	131.8 A
1 hours/24 hours	20.4 d	182.4 b	101.4 BC
4 hours/24 hours	25.0 d	226.4 a	125.7 AB
8 hours/24 hours	26.6 d	240.0 a	133.3 A
12 hours/24 hours	14.4 d	185.6 a	100.0 C
24 hours/24 hours	14.0 d	133.4 c	73.7 D
Mean	20.4 B	201.5 A	

Means sharing the same letters are statistically non significant at p = 0.05

The sodium concentration (Table V) was increased with imposition of salinity and decrease in aeration time. There was non significant difference of Na^+ concentration at all the aeration levels under non saline conditions whereas under saline conditions the maximum Na^+ concentration was found in 8 h and minimum in 24 h aeration, respectively. The over all comparison of aeration means indicated that Na^+ concentration was minimum in 24 h followed by 12 h aeration. The over all Na^+ concentration increased significantly with an increase in salinity from 1.2 to 15 dS m^{-1} and this increase was 13.5 fold as compared to Na^+ at non saline conditions. Cooper (1982), and Saqib and Qureshi (1998) also reported that with increasing salinity the Na^+ concentration in wheat shoot was increased.

Table V. Effect of salinity and aeration period on sodium conc. in expressed leaf sap (mol m^{-3}) (average of five repeats)

Aeration levels	Salinity levels		
	Normal saline (1.2 dS m^{-1})	Saline (15 dS m^{-1})	Mean
0 hours/24 hours	3.0 d	50.2 b	26.6 B
1 hours/24 hours	3.6 d	52.7 b	28.15 B
4 hours/24 hours	3.3 d	57.6 a	30.45 A
8 hours/24 hours	3.7 d	58.7 a	31.95 A
12 hours/24 hours	4.1 d	41.7 c	22.9 C
24 hours/24 hours	4.7 d	40.2 c	22.4 C
Mean	3.7 B	50.1 A	

Means sharing the same letters are statistically non significant at p = 0.05

There was a marked increase in K^+ concentration in expressed leaf sap in response to salinity (Table VI). This might be due to increased K^+ / Na^+ selectivity of LU-26s as reported by Berstein and Pearson (1956), Lunin *et al*. (1961), Saleem (1982) and Akhtar (1995).

The interactive effect of salinity and hypoxia on Ca^{2+} and Mg^{2+} concentration in the expressed leaf sap was non significant (Table VII & VIII).

Table VI. Effect of salinity and aeration period on potassium conc. in expressed leaf sap (mol m^{-3}) (average of five repeats)

Aeration levels	Salinity levels		
	Normal saline (1.2 dS m^{-1})	Saline (15 dS m^{-1})	Mean
0 hours/24 hours	1.5	18.7	10.1^{NS}
1 hours/24 hours	1.8	19.8	10.8
4 hours/24 hours	1.9	22.4	12.2
8 hours/24 hours	1.9	22.7	12.3
12 hours/24 hours	2.1	21.7	11.9
24 hours/24 hours	2.3	21.3	11.8
Mean	1.92 B	21.1 A	

Means sharing the same letters are statistically non significant at p = 0.05

Table VII. Effect of salinity and aeration period on calcium conc. in expressed leaf sap (mol m^{-3}) (average of five repeats)

Aeration levels	Salinity levels		
	Normal saline (1.2 dS m^{-1})	Saline (15 dS m^{-1})	Mean
0 hours/24 hours	5.6	9.2	7.4 D
1 hours/24 hours	7.3	11.5	9.4 D
4 hours/24 hours	10.9	16.3	13.6 C
8 hours/24 hours	12.6	18.0	15.3 C
12 hours/24 hours	19.6	23.1	21.3 B
24 hours/24 hours	22.7	27.8	25.2 A
Mean	13.11 B	17.65 A	

Means sharing the same letters are statistically non significant at p = 0.05

Table VIII. Effect of salinity and aeration period on magnesium conc. in expressed leaf sap (mol m^{-3}) (average of five repeats)

Aeration levels	Salinity levels		
	Normal saline (1.2 dS m^{-1})	Saline (15 dS m^{-1})	Mean
0 hours/24 hours	3.1	7.1	5.1 E
1 hours/24 hours	5.2	7.9	6.5 DE
4 hours/24 hours	7.1	9.9	8.5 CD
8 hours/24 hours	9.3	12.4	10.8 BC
12 hours/24 hours	10.4	14.7	12.5 B
24 hours/24 hours	12.2	17.8	15.0 A
Mean	7.8 B	11.6 A	

Means sharing the same letters are statistically non significant at p = 0.05

There was an increase in Ca^{2+} and Mg^{2+} concentration in response to salinity. This might be due to increased uptake of cations for osmoregulation under stress conditions. Reducing the aeration time/day decreased the concentration of Ca^{2+} and Mg^{2+} in the leaf sap. Drew and Siswaro (1979) reported that decrease in Mg^{2+} concentration of wheat shoot shown in the start of waterlogging was mainly due to inhibition of nutrient ions uptake.

CONCLUSION

Wheat variety LU-26s has more salt tolerance than other wheat genotypes. The present study was carried out to evaluate its performance under waterlogged conditions. It was noted that the variety has performed better at 16 h hypoxia period per day under saline conditions so it has the potential to be used as genetic material for further selection for saline as well as waterlogged tolerance.

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