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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 5 (12): 1313-1315, 2002

Growth of Wheat as Affected by Sodium Chloride and Sodium Sulphate Salinity

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Abstract: A hydroponic study under controlled conditions was carried out to examine the effect of NaCl and Na_2SO_4 salinity on the growth of *Triticum aestivum* cv. Sarsabz. The salinity levels were maintained separately at 0, 25, 50 and 100 mM of either NaCl or Na_2SO_4. Stem fresh weight, root fresh weight, shoot dry weight and root dry weight were significantly ($P \leq 0.01$) affected by salinity levels., Na_2SO_4 salinity seems less deleterious than NaCl. There was significant ($P \leq 0.01$) effect of salinity treatment on the ionic concentration of sodium, potassium, calcium, magnesium. Significant negative correlation {r (NaCl)= -0.95, r (Na_2SO_4)= -0.88} were observed between shoot dry matter yield and sodium contents from both sources of salinity. Significant positive correlation {r (NaCl)= 0.95, r (Na_2SO_4) = 0.96} were noticed between shoot dry matter and shoot potassium contents. Similarly positive significant correlation {r (NaCl) = 0.75, r(Na_2SO_4) = 0.66} was noticed between shoot dry matter yield and calcium contents in shoot. Plant grown in root medium having Na_2SO_4, had more K and Ca and less Na and Mg in shoot tissue as compared to NaCl and hence produced more dry matter.

Key words: NaCl salinity, Na_2SO_4 salinity, wheat growth, ionic composition

Introduction

Arid and semi arid environment besides other factors may induce salinity problems. A large portion of geographical area of Pakistan could not be taken under cultivation due to intense problem of salinity. It is estimated that 6.2 mha of Pakistan is salt affected (Anonymous, 2001). Wheat is the staple food in the country. It responded differently to various sources of salinity. Accumulation of excess amount of salts in a rhizosphere of a plant species may result in tissue injury, lowering of water potential and antagonistic relations among different ions. The cultivators who are dependent on saline/saline sodic soils grow genotypes of wheat in such areas. Sodium ion present in different chemical forms is highly toxic to glycophytes which are suitable to normal soils or marginal saline soils for their growth and development. The saline soils of Pakistan contain sodium chloride as dominant salt (Mushtaq and Rafiq, 1977) along with other salts such as sodium sulphate, sodium carbonate etc. Indirect effect of sodium ion is the nutritional imbalance (Mass and Grrieve, 1987). Wheat in general is quite sensitive to salt stress during early growth stage (Mass and Grattan, 1995). Generally chloride salts are more toxic than sulphate salts. At early growth stage of a plant, the root medium is selective to sulphate ion. This study was conducted to compare the effect of sodium chloride and sodium sulphate salinity and their specific ion effects on the growth of wheat.

Materials and Methods

Viable seeds of wheat (*Triticum aestivum* cv. Sarsabz) were germinated in moist quartz sand. One-week-old plants were transplanted to pots (two plants per hole and four holes per pot) containing 2.5 L of full strength continuously aerated modified Hoagland nutrient solution (Hoagland and Arnon, 1950) without NaCl and Na_2SO_4 stress. The pH of the solution was adjusted to 5.9 by adding HCl/KOH. The salinity levels were maintained at 0, 25, 50 and 100 mM separately with NaCl and Na_2SO_4. The pots were arranged according to completely randomized design (RCD) in triplicate. The salinity was built up after seven days by adding 25 mM of either salt on alternate day. The plants were grown at 25± 2°C. The light intensity was around 450 μ mol^{-1} s^{-1} in the chamber. The plant harvest was taken on 36th day after germination. The plant roots were rinsed with deionized water and immediately excess water was blotted. The plants were then separated into shoot and root portions. After recording fresh shoot, root weight (FW) and shoot, root length, the plant parts were dried at 65°C to a constant dry weight. Dried plant samples were ground to pass through 40 mesh using Wiley Mills. Ground sub-samples of root and shoot were digested in 2:1 perchloric –nitric di-acid mixture to estimate sodium, potassium, calcium and magnesium using Atomic Absorption Spectroscopy. Chlorophyll a and b were determined as given by Maclachlan and Zalik (1963). The results were statistically analyzed using F-test as given by Gomez and Gomez (1976).

Results and Discussion

Wheat responded differently to salinity sources (NaCl and Na_2SO_4). With an increasing salinity level, the shoot fresh weight and the root fresh weight decreased drastically ($P \leq 0.05$) (Table 1). This decline was more prominent with NaCl than Na_2SO_4. There was 62 and 80% reduction in shoot fresh weight at 50 and 100 mM of NaCl, respectively, however, 17 and 53% shoot fresh weight reduction at similar levels of Na_2SO_4 as against control. While shoot fresh weight was not significantly affected at 25 mM of either sources of salinity. Similarly root fresh weights were reduced by 21, 61 and 63% at 25, 50 and 100 mM NaCl, respectively, on the other hand, 0, 17 and 40% reduction of root fresh weight at similar levels of Na_2SO_4 was recorded as against control. The data indicate that Na_2SO_4 salinity exhibited less deleterious effect on plant growth as compared to NaCl. Excess of salts creates osmotic stress by a decline in water potential producing negative effects on physiological processes. The same negative effects have also been reported by Shereen *et al.* (2001). For biomass buildup, the role of sodium sulphate was more prominent than sodium chloride.

Significant reduction ($P \leq 0.05$) in shoot dry weight was recorded at different salinity levels of either salts (Table 1). However, relatively larger extent of shoot dry weight reduction was observed with NaCl stress. There was 28, 52 and 80% shoot dry weight reduction at 25, 50 and 100 mM NaCl, respectively as against control. However, relatively lesser reduction of 12, 20 and 44% shoot dry weight at similar levels of Na_2SO_4 as compared to control was noticed. Similar pattern in root dry weight reduction was observed (Table 1). The reduction of 17, 50 and 66% was noticed at 25, 50 and 100 mM of NaCl while comparatively lesser reduction of 17, 17 and 33% was recorded at same levels of Na_2SO_4 as compared to control. Less than 50% reduction in root and shoot dry weight was observed up to 100 mM of Na_2SO_4 while there was more than 50% reduction observed at 50 mM NaCl stress. As compared to chloride ion, sulphate ion plays a pivotal role for the formations of organic constituents, which causes an increase in biomass. For osmotic adjustment, plant cells try to adjust harmful effects by utilizing organic and inorganic solutes (Xiaomu *et al.*, 1993).

Shoot and root length have significant ($p \leq 0.01$) inverse relationship with NaCl and Na_2SO_4 salinity. However, salinity

Table 1: Effect of NaCl and Na_2SO_4 salinity on growth parameters and chemical composition of wheat

		NaCl (mM)			Na_2SO_4 (mM)		
Parameters	Control	25	50	100	25	50	100
Growth parameters							
Shoot fresh weight (g)	2.00a	1.65b	0.76c	0.40d	1.66b	1.66b	0.93c
Root fresh weight (g)	0.70b	0.55c	0.27e	0.26e	0.73b	0.58c	0.41d
Shoot dry weight (g)	0.25ab	0.18c	0.12e	0.10f	0.22b	0.20c	0.14d
Root dry weight (g)	0.06a	0.05b	0.03d	0.02e	0.05b	0.05b	0.04c
Shoot length (cm)	38.96a	32.43c	31.25c	30.25c	34.83b	31.75c	30.75c
Root length (cm)	26.06a	22.23b	17.00c	13.91d	24.00a	23.00a	18.16c
Chlorophyl a	0.84N.S	0.79	0.79	0.80	0.79	0.84	0.79
Chlorophyl b	0.21N.S	0.21	0.21	0.24	0.23	0.25	0.24
Chemical composition(%)							
Shoot Na content	0.10e	3.98c	5.46b	6.18a	3.01d	3.45d	4.50c
Root Na content	0.71d	1.58c	1.61c	2.40b	2.35b	2.18c	2.84a
Shoot K content	5.93a	4.98b	3.52c	2.00d	5.81a	5.28a	4.86b
Root K content	1.52b	0.86c	0.56c	0.56c	2.35a	2.28a	0.76c
Shoot Ca content	0.04c	0.05b	0.02d	0.02d	0.06a	0.05b	0.02d
Root Ca content	0.07c	0.06c	0.04d	0.03d	0.12a	0.10b	0.07c
Shoot Mg content	0.61a	0.63a	0.56b	0.56b	0.56b	0.41c	0.34c
Root Mg content	0.44a	0.45a	0.38b	0.39b	0.40b	0.49a	0.52a

Means bearing same letter (s) in a row are statistically non-significant ($P \leq 0.05$) NS = Non significant

sources did not significantly affected shoot length. Shoot length decrease of 17, 20 and 22% was recorded at 25, 50 and 100 mM of NaCl, respectively over control. Similar extent of reduction was exhibited due to similar levels of Na_2SO_4 salinity. Root length reduction of 15, 35 and 47% was recorded at 25, 50 and 100 mM of NaCl while it was 8, 12 and 30% at similar levels of Na_2SO_4 as against control. Salinity reduces biomass besides decreasing length of root and stem (Ouerghi *et al.*, 1991). The uptake of sulphate through root system takes place as sulphate ion as observed by Bardsley (1960). Here the presence of sodium ion in the system produced unfavorable conditions for metabolic processes. Chlorophyll content of leaf is an important indicator of plant growth. There was non significant effect on chlorophyll contents of wheat due to salinity sources. However, chlorophyll a contents were higher than chlorophyll b.

There was a significant ($P \leq 0.01$) difference in shoot sodium (Table 2). There was relatively higher shoot sodium content when plants were fed with NaCl as against sodium sulphate. Shoot sodium contents were 28, 58 and 37% higher at 25, 50 and 100 mM NaCl, respectively as against the same levels of sodium sulphate. On the other hand, root sodium contents decreased in root with NaCl salinity than Na_2SO_4 salinity. The root sodium contents were 48, 35 and 18% higher when plants were grown in the presence of Na_2SO_4 in the root medium as against NaCl. This shows retention of sodium ion in root tissues when sulphate is present in the root medium. The role of sodium chloride may be just to increase the osmotic effects or to decrease the water potential than that of sodium sulphate which after ionization may become a part of organic constituents or solvents.

Potassium contents of the shoot and root were significantly decreased with increasing salinity levels (Table 2). The shoot K contents were 17, 50 and 143% higher when fed with 25, 50 and 100 mM sodium sulfate, respectively as against NaCl. Similarly, root K contents were 6, 173, 307 and 39% higher when plants were grown in the presence of Na_2SO_4 in the root medium as against NaCl. The role of potassium ion is well known for the osmotic adjustments. The data indicate more K uptake when sulphate was present in root medium as against chloride.

In shoot and root higher calcium contents was noticed where sodium sulphate was present in the root medium as against NaCl. Calcium contents of root and shoot were significantly different while grown in Na_2SO_4 and NaCl medium. However, there was decrease in calcium content with increasing salinity levels in the medium irrespective of salinity source. Plants having Na_2SO_4 in root medium took calcium relatively more efficiently in the presence of sulphate as against chloride. There were 20 and 66% more calcium uptake at 25 and 50 mM Na_2SO_4, respectively as compared to same levels of NaCl. Similarly 100% more calcium contents of roots were found at all the sodium sulphate levels as against NaCl levels. It is evident from the data that in the presence of sulphate ion in root medium, the plant got more calcium contents as compared to chloride ion in the medium. Kinraide (1999) reported that salinity inhibited root elongation and it could be restored to normal by raising calcium, provided NaCl + KCl< 130 mM and beyond that calcium had a limited ability to alleviate the inhibition.

There was significant effect of salinity levels on magnesium uptake (Table 2). With increasing salinity in the medium, there was decrease in magnesium contents of both root and shoot. As far as salinity sources are concerned, there was more shoot magnesium contents when NaCl was present in root medium as compared to Na_2SO_4. It was found that 12, 36 and 65% more shoot magnesium contents at 25, 50 and 100 mM NaCl, respectively as against same levels of Na_2SO_4. On the other hand, the trend is reverse regarding root calcium contents. It indicates that there was retention of magnesium ion in root tissues when Na_2SO_4 was present in the medium.

Toxic effects of sodium chloride salinity as compared to that of sodium sulphate on shoot dry matter can be seen in Fig. 1. Data indicate significant negative correlations {r (NaCl)}= - 0.98, r (Na_2SO_4) = -0.88} between shoot dry matter yield and sodium contents from both sources of salinity (Fig 1). With increasing shoot dry matter, there was decrease in sodium contents of plant. However, the presence of sodium sulphate in the root medium has alleviated the salinity effect on plant growth to some extent as against NaCl. A very high value of constant and the negative value

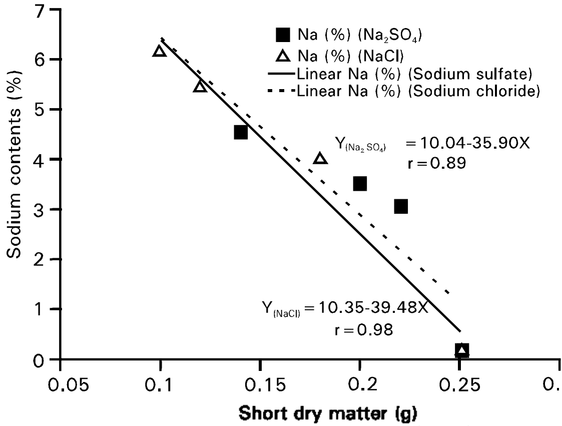

Fig. 1: Relationship between shoot dry matter (SDM) and sodium contents

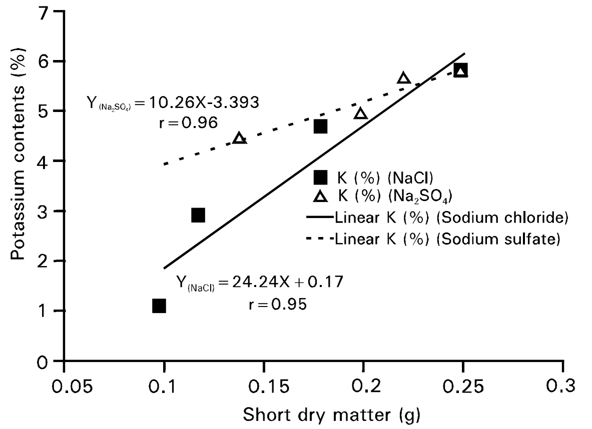

Fig. 2: Relationship between shoot dry matter (SDM) and potassium contents

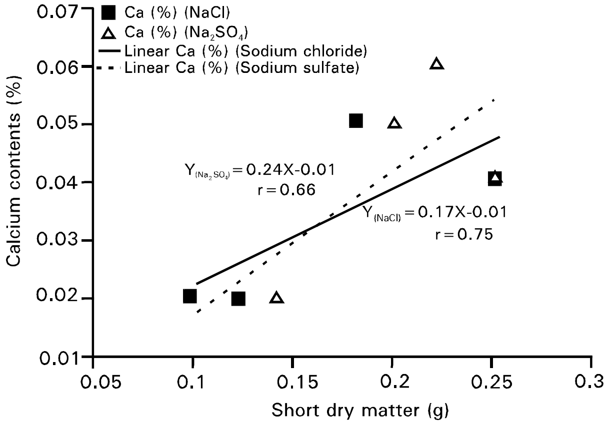

Fig. 3: Relationship between shoot dry matter (SDM) and calcium contents

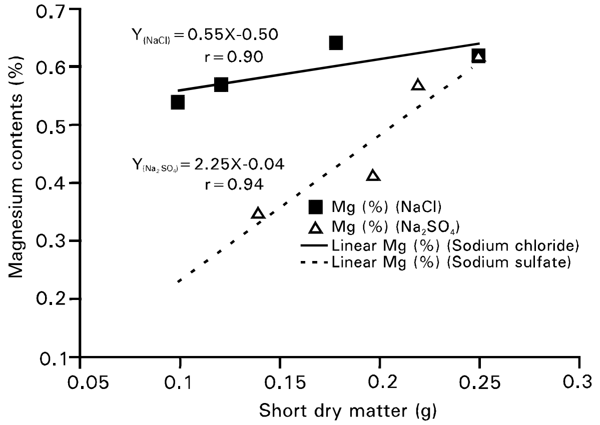

Fig. 4: Relationship between shoot dry matter (SDM) and magnesium contents

of coefficient of X signify the toxicity of sodium ion. Data in Fig. 2 indicate positive significant correlation {r (NaCl))= 0.95, r (Na_2SO_4) = 0.96} between shoot dry matter and shoot potassium contents. There was relatively higher shoot K contents when plants were grown in Na_2SO_4 as against NaCl at lowest shoot dry matter yield. As shoot dry matter increased as a result of lower magnitude of sodium presence in the root medium, the K content increased. However, at higher shoot dry matter level, the K level was least affected by salinity sources. This phenomenon is controlled by the nature of the salts and the anions play an important role. This phenomenon is quite logical, as there has been a synergistic relation between potassium and sulphate ion. This shows that this relation is dependent on the binding sites of the ion species.

Calcium uptake is also dependent on the nature of the salinity. Its uptake is higher with sodium sulphate as compared to sodium chloride from 0 to 100 mM of salinity level (Fig. 4).

There were visible differences in interactions between various ionic species and salinity sources as NaCl and Na_2SO_4 for the growth of wheat. Sodium sulphate is less toxic than sodium chloride for the growth of wheat provided potassium and calcium are available in soluble forms in the growth medium.

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