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PLANT GROWTH AND IONIC DISTRIBUTION IN COTTON (*GOSSYPIUM HIRSUTUM* L.) UNDER SALINE ENVIRONMENT

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Abstract

Experiment was conducted on four cotton (*Gossypium hirsutum* L.) cultivars viz., B-557, Niab-78, Sarmast, Qalandari to evaluate their growth in terms of plant height, stem diameter, biomass production and ion transport from root to shoot when exposed to salinity levels of 4, 16, 21, 22 and 24 dS. m-1. Increasing salinity levels reduced growth of all the cultivars with higher inhibition in shoot as compared to root, Cvs. Niab 78 and Qalandari exhibited higher salt tolerance where lower salinity levels promoted root development. Increasing salt levels also increased the net ionic uptake in all the cultivars with more affinity for K^+. K/Na ratio was >1 in all cultivars. Niab-78, however, showed minimum uptake and accumulation of salts under increasing salinity regimes and can be rated as more salt tolerant.

Introduction

Salt affected areas in Pakistan have continued to increase during the past few years owing to a number of factors and their interactions. Generally increase in concentration of salts in the rhizosphere decrease growth of plants. Reduction in growth of cotton grown in saline culture of EC 3-5 dS.m-1 is attributed to osmotic effects, whereas, reduction due to EC levels of still higher salinities is due to the toxic effects of ions (Thomas, 1980). The growth of the plant depends upon the ion influxes in the roots as well as their translocation to shoot. The process which may affect this phenomenon includes active transport of ions across the roots, movement in the transpiration stream, retranslocation in the phloem, localization in certain tissues and photosynthetic rates which has an overall control on many of these processes (Pitman, 1972; Greenway & Munns, 1980).

One feasible approach of increasing the salinity tolerance of crop plants is through plant breeding (Jones, 1986), but selection of most salt tolerant cultivar within the available genome is another useful device in saline agriculture. In the present study, plant growth, uptake and distribution of Na^+, K^+, Ca^{++} and Mg^{++} in different plant parts under saline environment were investigated in four cultivars of upland cotton (*Gossypium hirsutum* L.).

Materials and Methods

Plants of four cotton cultivars belonging to upland cotton (*Gossypium hirsutum* L.) viz.B-557,Niab-78,Sarmast &Qalandari were grown in salinity at par with saline soils of Pakistan (Abdullah & Ahmad,1986).Each pot was filled with 25kg sandy soil. Soil was salinized by dissolving calculated amounts of salts in sufficient amount of water

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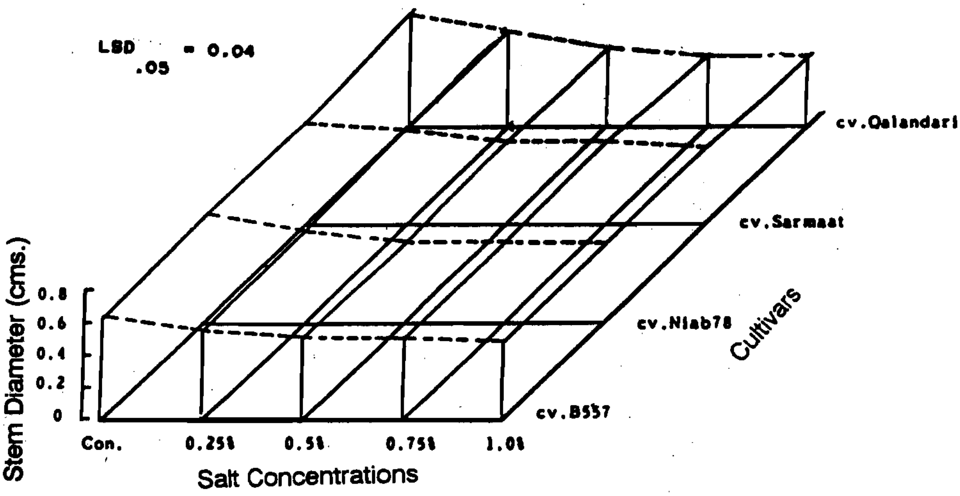

Fig.1. Height of cotton cultivars as affected by different salinity regimes.

to bring the whole soil of the pot at field capacity. Electrical conductivity of the saturation extracts of different salt levels was as follows:

1) Control [4 dS.m-1], 2) 0.25% salinity [16 dS.m-1], 3), 0.5% salinity 21 dS.m-1, 4) 0.75% salinity 22.0 dS.m-1, 5) 1.0% salinity 24 dS.m-1.

In addition, 600 gm compost was mixed in each pot to improve physical conditions of the soil. N, P and K were provided as urea, diammonium phosphate and sulphate of potash, respectively, equivalent to 139 Kg N, 50 Kg P and 25 Kg K per

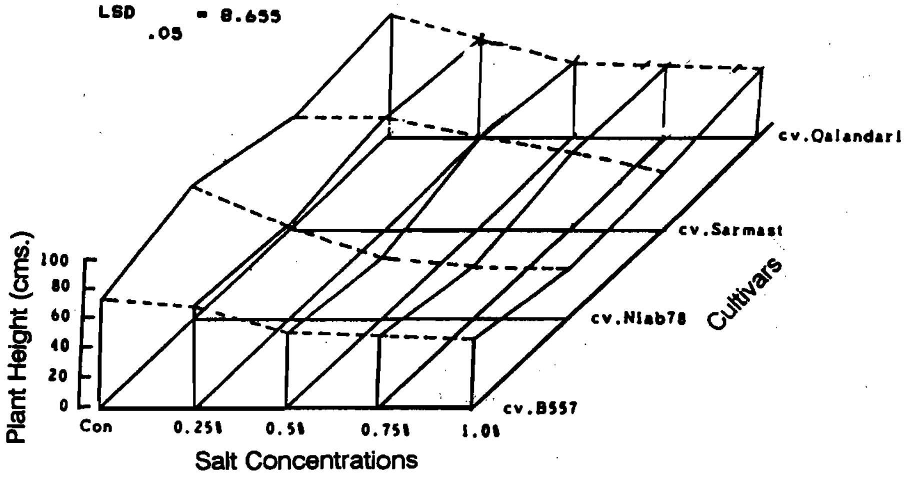

Fig.2. Stem diameter of cotton cultivars as affected by different salinity regimes.

Table 1. Degree of relative inhibition/promotion at different salinity regimes of shoot and root development.

Treatment (Salinity %)	Co-efficient of relative inhibition of shoot				Co-efficient of relative inhibition of root			
	B-557	Niab-78	Sarmast	Qalandari	B-557	Niab-78	Sarmast	Qalandari
0.25%	-0.088	-0.146	-0.117	-0.278	-0.215	+0.164	-0.203	+0.330
0.5%	-0.150	-0.184	-0.262	-0.378	-0.238	+0.235	-0.205	+0.284
0.75%	-0.609	-0.645	-0.565	-0.606	-0.244	+0.051	-0.439	-0.419
1.0%	-0.689	-0.695	-0.633	-0.757	-0.253	+0.046	-0.492	-0.440

- Values indicate relative inhibition over control, whereas, + values indicate relative promotion.

hectare. Micronutrients were added in irrigation water as recommended for Hoagland's solution. The pots were watered whenever necessary, to bring the moisture content to field capacity and leaching was not permitted. Seeds were delinted with commercial sulphuric acid before sowing and sown in normal field soil in plastic bags. Ten-day-old seedlings at 3 leaf stage were transplanted in pots containing different concentrations of salinized soil. Three replicates were made for each treatment and pots containing plants were randomized. Plant height, stem diameter and biomass production were studied to determine growth of plants Co-efficient of relative inhibition of plant biomass was calculated as recommended by Takeda (1954):

$$\frac{\text{Control biomass - Biomass of salinized plant}}{\text{Control biomass}}$$

For mineral analysis, samples of dried plant parts were ground and digested in 10 ml concentrated nitric acid followed by addition of 10 ml perchloric acid. The volume of digested sample was made to 100 ml with deionized water (USDA Handbook, 1954) Na^+, K^+, Ca^{++}, Mg^{++} were analysed using atomic absorption spectrophotometer (Jarrell, Ash AA 782).

Results and Discussion

Height of the main stem of cotton plant is regarded as a varietal character (El-Enani *et al*., 1981). Cv. Sarmast attained minimum height followed by B-557, Qalandari and Niab-78 under control conditions (Fig.1). Under saline conditions, height in these cultivar showed minimum reduction (35.7%) in B-557 followed by Qalandari (42.4%), Sarmast (48.2%) and Niab-78 (56.84%) under 1% salinity regime. Salinity of rooting medium also inhibited development of stem diameter (Fig.2). The reduction was minimum (25.26%) in cv. B-557 followed by Sarmast (25.43%), Niab-78 (26.95%) and Qalandari (35.11%) under 1% salinity regime. Increasing concentrations of salts in the rhizosphere in general have also been reported to retard plant height and stem diameter in mesquite (Khan *et al*., 1986) and corn (Kayani & Rehman, 1988).

Total biomass production at the harvest was also adversely effected by increasing salinity levels in all cotton cultivars (Fig.3). It was reduced by 63% in Sarmast followed by B-557 (65%), Niab-78 (66%) and Qalandari (71%) under 1% salinity regime as compared to their respective control. Reduction in total biomass is an established fact in glycophytes under higher salinity regimes (Khan *et al.*, 1989; Satti & Ahmad, 1992).

Shoot and root development is differently effected by salinity during plant growth. Greater inhibition of shoot growth as compared to the root growth was observed under saline environment (Table 1). Co-efficient of relative inhibition of shoot was minimum in cv. Sarmast at 1% salinity level followed by cvs. B-557, Niab-78 and Qalandari. Lower salt concentrations (0.25%) in the rhizosphere promoted root development in cvs. Qalandari and Niab-78. Root development in cv. Niab-78 was promoted even at 0.75% salt level. At 1% salinity level, root development was adversely affected in all cotton cultivars exhibiting minimum inhibition value in cv. Niab-78

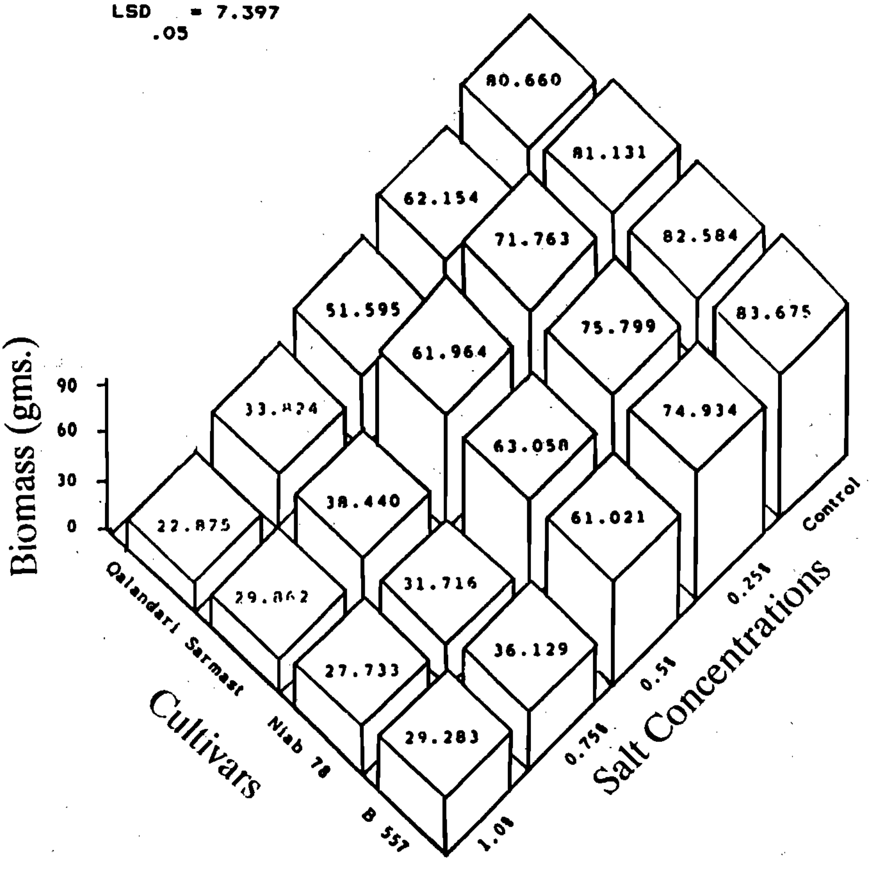

Fig.3. Biomass production by cotton cultivars grown under different salinity regimes at harvest.

followed by B-557, Qalandari and Sarmast. The relatively lower co-efficient of relative inhibition of root development as compared to shoot development in general may be due to less retention of Na+ in the roots. Chang & Dregne (1955) have also reported that most of the Na+ is transported to the shoot in cotton.

Salinity in general exposes the plants to inimical situations i.e. (i) an unfavourable water balance and (ii) toxic conditions due to excessive sodium accumulation. The former leads to physiological drought which reduces plant growth (Bernstein & Hayward, 1953; Russel, 1963). The latter condition is responsible for causing toxicity due to excessive salts in metabolic activities (Strogonov, 1974). The concept of dual mechanism of ion transport proposed by Epstein & Hagen (1952) further modified by Poole (1971) explains the uptake of essential cations in presence of excessive sodium in rooting medium.

Increase in the uptake of Na+ in all the cultivars, was directly proportional to increase in salinity regimes of rooting medium (Fig.4). Increase in accumulation of Na+ at 1% salinity regime was minimum in cv. Sarmast (97.4%) which gradually increased

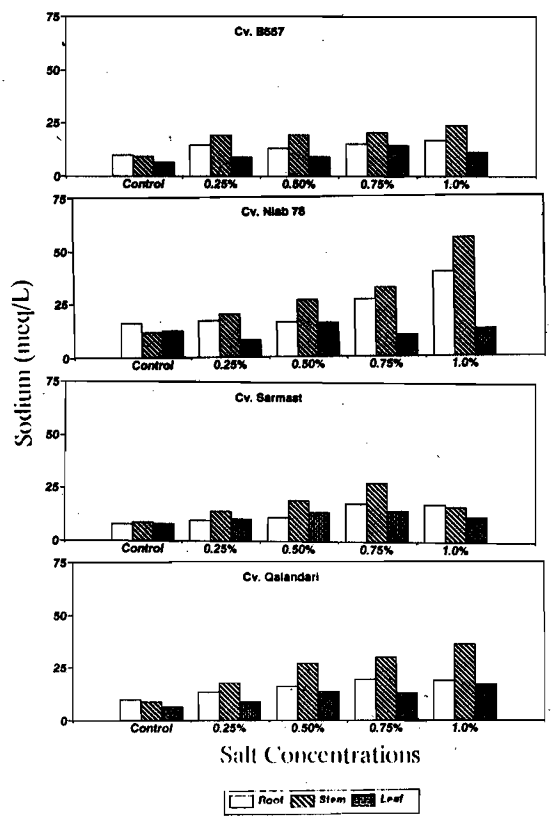

Fig.4. Sodium distribution in vegetative parts of cotton cultivars grown under different salinity regimes.

Table 2. K/Na ratio and total cation uptake by cotton cultivars as affected by different salinity regimes.

Treatment (Salinity %)	Plant Parts	CV. B-577		CV. Niab-78		CV. Sarmast		CV. Qalandari	
		K/Na Ratio	Total cation uptake in meq/l	K/Na Ratio	Total cation uptake in meq/l	K/Na Ratio	Total cation uptake in meq/l	K/Na Ratio	Total cation uptake in meq/l
	Root	4.195		3.288		5.106		4.434	
Control	Stem	4.549	345.661	5.404	413.12	4.362	341.021	5.539	356.43
	Leaf	4.278		2.768		4.225		4.880	
	Root	3.235		2.231		3.297		2.377	
0.25%	Stem	3.008	412.582	2.554	373.099	2.696	336.107	1.960	366.752
	Leaf	3.905		4.171		3.268		3.52	
	Root	3.725		2.701		3.208		2.260	
0.5%	Stem	2.609	383.137	1.560	404.203	1.975	375.369	1.470	381.952
	Leaf	3.992		3.159		2.600		3.227	
	Root	3.129		1.438		2.534		1.751	
0.75%	Stem	2.746	448.706	1.378	397.254	1.539	374.526	1.284	360.619
	Leaf	4.179		4.671		2.125		2.774	
	Root	2.240		0.843		2.981		1.869	
1.0%	Stem	2.205	420.561	0.681	434.182	1.883	361.007	1.117	380.157
	Leaf	3.884		2.211		4.067		2.510	

in cvs. B-557 (103.7%), Niab-78 and Qalandari (187.0%) as compared to their respective control. Since Na+ is mostly translocated to the aerial parts of the cotton plant, shoot growth was more affected as compared to root.

K+ uptake gradually reduced in cvs. Qalandari (4.59%) and Niab-78 (23.41%) under 1% salinity, in comparison to Sarmast and B-557 where it was greater than control by 19.5% and 20.37%, respectively. All the cultivars except Sarmast transported greater amounts of K+ to aerial parts of the plant where its concentration was almost equal in root and shoot (Fig.3).

The data presented in Table 2 indicates net ionic uptake and K/Na ratio as affected by different salt concentrations in the rooting medium. It is interesting to note that there was not much difference is net ionic uptake in control and the plants exposed to various salinity regimes. It was least affected in cv. Niab-78 (+5.09) which gradually increased in Sarmast (+5.86%), Qalandari (+6.65%) and B-557 (+21.66) as compared to their respective control.

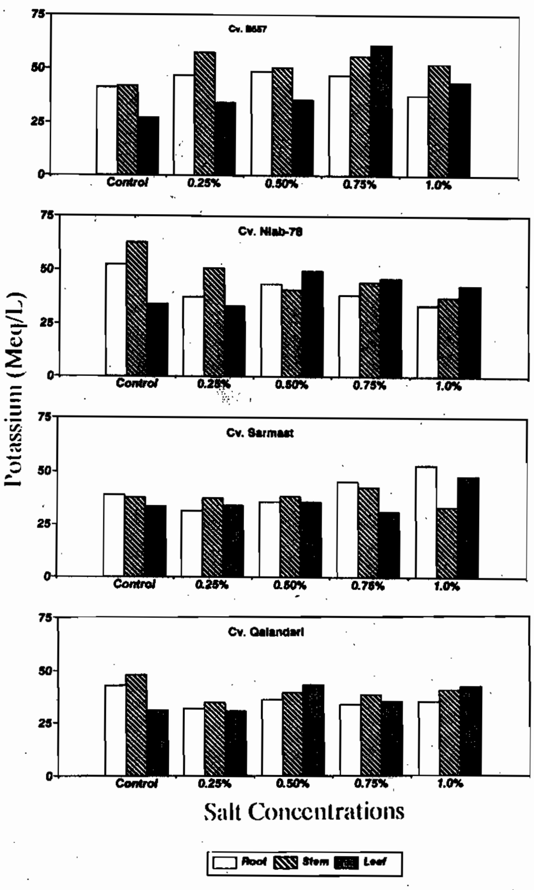

Fig.5. Potassium distribution in vegetative parts of cotton cultivars grown under different salinity regimes.

Higher affinity for K+ uptake in cotton cultivars managed to keep K/Na ratio above 1 in all salinity treatments inspite of greater Na+ uptake. The relation between this ratio and salt tolerance has been reviewed by Greenway & Munns (1980).

There was a decrease in Ca++ uptake with increasing salt concentrations in rooting medium of all cultivars except B-557 (Fig.6). Calcium was mostly translocated to aerial parts of the plants with maximum accumulation in leaves. There was generally an increase in total Ca++ uptake. It was 17.09% in Qalandari followed by Sarmast (19.86%) and Niab-78 (20.11%) under 1% salinity regime as compared to their respective control. Its uptake was slightly increased (4.5%) under 1% salinity regime in cv. B-557 only. These observations (with the exception of cv. B- 557) are in agreement with the results obtained by Ahmad & Abdullah (1979).

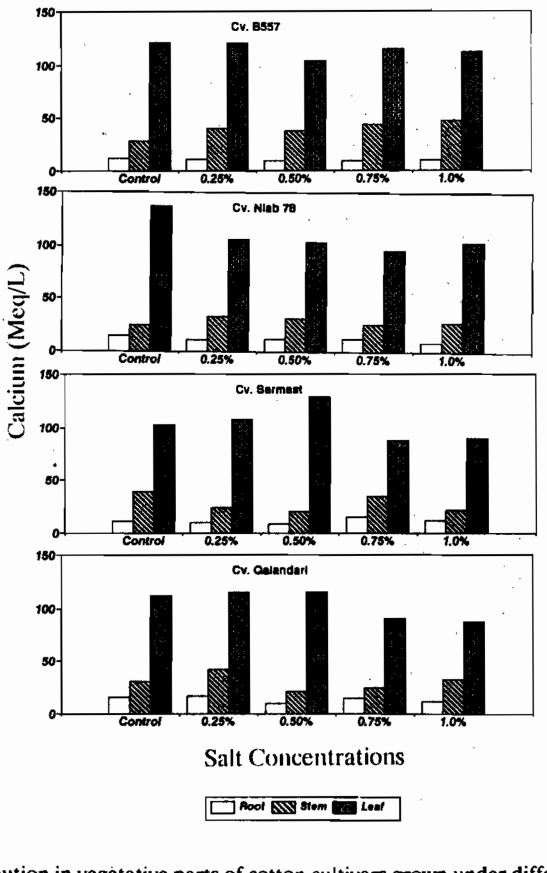

Fig.6. Calcium distribution in vegetative parts of cotton cultivars grown under different salinity regimes.

Calcium is reported to play a central role in regulating ion transfer into plant cells exposed to saline environment (Epstein, 1981). It also influences some metabolic processes (Ferguson, 1984), membrane structure (Marschner, 1964), translocation and redistribution of ions in plants (La Haye & Epstein, 1969).

Magnesium uptake was gradually increased with increasing salinity and mostly transported to the leaves (Fig.4). This increase was minimum in cv. Sarmast (10.28%) which gradually increased in Qalandari (21.72%), B-557 (40.32%) and Niab-78 (42.22%) under 1% salinity regime as compared to their respective control. Increase in Mg++ uptake was noticed by Thomas (1980) in cotton leaves under saline conditons. Magnesium is required by the plants for chlorophyll synthesis and also works as a co-factor in phosphorylation process (Mengel & Kirkby, 1978).

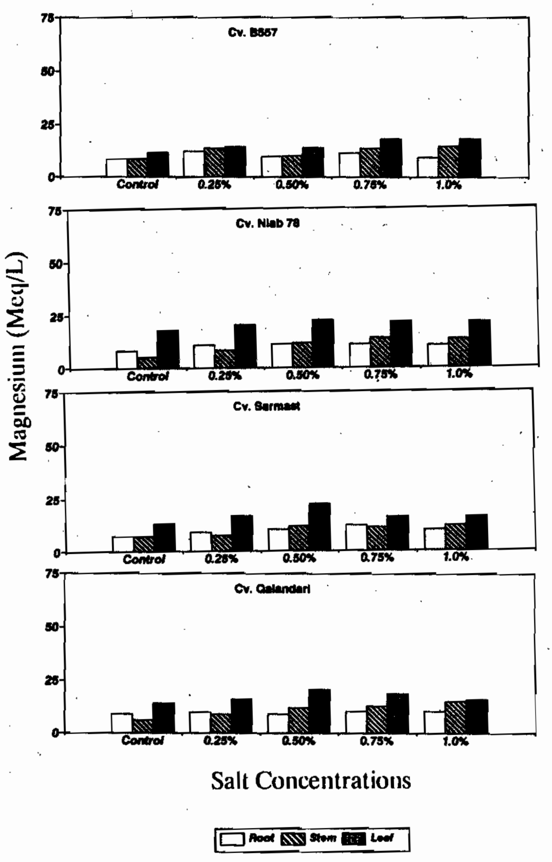

Fig.7. Magnesium distribution in vegetative parts of cotton cultivars grown under different salinity regimes.

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