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EFFECT OF SALINITY ON THE GROWTH AND MINERAL UPTAKE IN SOY BEAN (GLYCINE MAX)*

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Abstract. Soy bean was grown in full and half-strength Hoagland solution in 4-litre plastic containers. This species was found to be highly sensitive to salinity and even at the lowest level of salinity (2 atm) the plant growth was severely affected. The chemical analysis showed that the concentration of N, Ca and K was reduced under saline condition while that of P and Na underwent a significant increase. When additional quantities of Ca or Mg were added to the nutrient solution it was observed that both Ca and Mg had no significant affect in increasing the salt tolerance in soy bean.

Using sand and water cultures, a close relationship between plant growth and the osmotic pressure of the culture solution has been demonstrated.[1] On a weight or equivalent basis chloride appears to inhibit plant growth more than sulphate salts but this difference tends to disappear when concentrations are expressed on an osmotic basis.[1] Wadleigh and Ayers[10] have shown that plant growth in soil is a function of total soil-moisture stress which is the sum of soil-moisture tension and the osmotic pressure of the soil solution.

Besides the general effect of salinity in limiting the availability of moisture to plants, salts can also exert specific ion effects in reducing the plant growth.[1] Information about the effects of salinity on wheat,[8] barley,[8] rice,[2,7-9] carrot,[4] bean[4,5] and various other species of plants are available. Nieman[6] has worked with 12 plant species and reported that growth as judged by the yield of fresh plant tops was stimulated by NaCl in some tolerant species while the sensitive species showed a marked depression in growth.

Salinity has also been reported to affect the mineral content of plants.[4,7] Potassium concentration of tops in carrot was found to decrease with an increase in salinity while calcium and magnesium concentration showed a slight increase under the same conditions.[4] In dwarf-red-kidney-bean[4] also, the calcium and magnesium concentration showed a slight increase with increasing salinity but unlike carrot the potassium concentration in the stem of this species underwent an increase as the salinity of the growth medium was increased. In rice an excess of sodium in the nutrient solution was found to reduce nitrogen, phosphorus and calcium concentration of the shoots while potassium showed a small increase.[7] It has also been reported that salt tolerance in plants could be induced by increasing the calcium content of the culture solution.[5]

Due to the lack of enough information regarding the effect of salinity on the mineral content of plants and the possible ameliorative role of calcium the present work was undertaken.

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Material and Methods

Soy bean seeds were germinated in sand moistened with distilled water at room temperature. Three days later the seedlings were irrigated with 1/10 Hoagland solution and after one week they were transferred to 4-litre plastic jars containing full and half-strength Hoagland solutions. Two seedlings were maintained in each container and the experiment was carried out in growth room ($25 \pm 2°C$) maintained at 12 hr of light followed by 12 hr darkness.

Desired levels of salinity were achieved by adding different quantities of NaCl in four equal instalments to the culture solution. The osmotic pressure of the Hoagland solution itself was equivalent to 0.5 atmosphere. NaCl was added to induce additional osmotic pressure of 0.0, 2.0, 3.0, 4.0 and 6.0 atmospheres. The first portion of the salt was added on the 4th day of the transfer of the seedling into the Hoagland solution and the remaining portions were added on the succeeding days.

Plants were harvested 3 weeks after transfer into the jars and the leaves, stems and roots were separated. After thorough washing in distilled water these parts were dried at 80°C for a week. The dry-plant material was analysed for total N, P, K, Na and Ca. Total nitrogen was determined by Jackson's method[3] with a minor modification of adding a few drops of 30% H_2O_2 following the digestion of samples in concentrated sulphuric acid. Phosphorus was determined colorimatrically,[3] while potassium, sodium and calcium were determined by flame photometer.

Results and Discussion

Soy bean was found to be highly sensitive to salinity and within a few days, even under low salt levels the leaves started to develop brownish spots which gradually became colourless. The leaves also tended to dry up and curl and at higher salinity levels severe leaf shedding was observed. Root growth was very poor and stunted under saline conditions. The number and weight of leaves, roots and stems all underwent a progressive and significant reduction with the increase in salinity (Table 1). The reduction in weight was somewhat greater when plants were grown in full-strength Hoagland solution. This effect of salinity could be due to the presence of larger amounts of salts compared to the half-strength Hoagland solution.

The changes in the mineral concentrations of the soy bean leaves and stems due to salinity is given in Tables 2 and 3, respectively. In the case of leaves (Table 2) the phosphorus and sodium concentrations were found to increase while nitrogen, potassium and calcium concentrations decreased significantly. In stems (Table 3), except for nitrogen, the direction of change in the mineral concentration was similar to that of leaves but the magnitude of change was quite different. The nitrogen concentration in this case showed no significant change due to increase in the salinity of the growth medium. From these data it can also be observed that except for phosphorus, there was no significant difference in the mineral concentrations of leaves and stems of plants grown in full-and half-strength Hoagland solution. The phosphorus concentrations in both leaves and stems were higher in plants grown in the full-strength Hoagland solution.

Due to very poor growth of soy bean roots under saline condition, enough material could not be obtained for a complete analysis. The change in the nitrogen concentration of roots are shown in Table 4 and the data though erratic show some similarity with that of leaves.

The higher sodium uptake with the increasing salinity is to be expected as the sodium content of the growth medium was greatly enhanced. As for the effect of salinity on the uptake of other elements, information is available in the literature. Lager-

TABLE 1. EFFECT OF SALINITY ON THE GROWTH OF SOY BEAN IN HALF-STRENGTH (A) AND FULL-STRENGTH (B) HOAGLAND SOLUTION.

Level of salinity (atm)	No. of leaves/ plant			Dry weights (g/plant) of plant parts: Leaves			Stems			Roots		
	A	B	Mean*	A	B	Mean*	A	B	Mean*	A	B	Mean*
0.0	16.8	20.5	18.5a	0.532	0.699	0.616a	0.218	0.306	0.262a	0.149	0.204	0.177a
2.0	12.5	15.7	14.1b	0.402	0.445	0.424b	0.142	0.184	0.163b	0.124	0.173	0.149ab
3.0	13.8	10.0	11.9bc	0.460	0.370	0.415b	0.147	0.104	0.126b	0.133	0.118	0.126bc
4.0	9.8	9.5	9.7c	0.336	0.187	0.262c	0.116	0.065	0.091b	0.101	0.066	0.084cd
6.0	9.8	9.2	9.5c	0.322	0.277	0.300c	0.085	0.086	0.086b	0.066	0.087	0.077d
Mean†	12.5a	13.0a		0.410a	0.396a		0.142a	0.149a		0.115a	0.130a	

*Means for comparing salinity treatments. †Means for comparing culture solutions. (Values representing same alphabets within vertical columns and across the table are not significantly different at 5% level of significance.)

TABLE 2. EFFECT OF SALINITY ON THE MINERAL CONCENTRATION OF LEAVES OF SOY BEAN GROWN IN HALF-STRENGTH (A) AND FULL-STRENGTH (B) HOAGLAND SOLUTION.

Level of salinity (atm)	Mineral concn % dry wt: N			P			K			Ca			Na		
	A	B	Mean*	A	B	Mean*	A	B	Mean*	A	B	Mean*	A	B	Mean*
0.0	5.171	5.446	5.309a	1.518	1.862	1.690a	4.995	5.100	5.048a	1.201	1.234	1.218a	0.702	0.175	0.439a
2.0	4.517	4.802	4.660b	2.260	2.350	2.305ab	3.943	4.566	4.255b	0.551	0.703	0.627b	2.113	1.341	1.727b
3.0	4.685	4.317	4.501b	2.770	2.958	2.864bc	4.044	3.416	3.730b	0.417	0.337	0.377bc	2.314	2.034	2.174bc
4.0	4.620	4.618	4.619b	3.667	3.944	3.806d	3.627	4.729	4.173b	0.247	0.475	0.361bc	2.407	3.324	2.856cd
6.0	4.760	4.480	4.620b	2.658	4.603	3.631cd	3.482	4.377	3.930b	0.254	0.264	0.259c	2.884	3.569	3.227d
Mean†	4.751a	4.733a		2.575a	3.143b		4.018a	4.436a		0.534a	0.603a		2.084a	2.089a	

*Mean for comparing salinity treatments. †Means for comparing culture solutions. (Values representing same alphabets within vertical columns and across the table not significantly different at 5% level of significance.)

TABLE 3. EFFECT OF SALINITY ON THE MINERAL CONCENTRATION OF STEMS OF SOY BEAN GROWN IN HALF-STRENGTH (A) AND FULL-STRENGTH (B) HOAGLAND SOLUTION.

Level of salinity (atm)	Mineral concn % dry weight: N			P			K			Ca			Na		
	A	B	Mean*	A	B	Mean*	A	B	Mean*	A	B	Mean*	A	B	Mean*
0.0	2.593	2.661	2.627a	1.140	1.240	1.190a	5.497	5.053	5.275a	1.010	0.837	0.924a	0.030	0.020	0.025a
2.0	2.510	2.746	2.628a	1.307	1.063	1.85a	3.667	3.360	3.514b	0.740	0.723	0.732b	2.033	1.783	1.908b
3.0	2.373	2.849	2.611a	1.247	1.323	1.285a	2.647	2.323	2.485c	0.567	0.747	0.657b	2.797	3.137	2.967c
4.0	2.626	3.480	3.053a	1.707	2.110	1.909b	1.847	2.030	1.939d	0.643	0.643	0.643b	3.597	4.163	3.880d
6.0	3.136	2.987	3.062a	1.260	2.210	1.735b	1.663	1.593	1.628d	0.793	0.570	0.682b	4.677	4.893	4.785a
Mean†	2.648a	2.945a		1.332a	1.589b		3.064a	2.782a		0.751a	0.704a		2.627a	2.799a	

*Mean for comparing salinity treatments. †Means for comparing culture solutions. (Values representing same alphabets within vertical columns and across the table are not significantly different at 5% level of significance.)

werff and Holland,[4] using carrot and dwarf-red-kidney-bean, have found that the potassium concentration in the carrot top decreased with salinity, an observation similar to the present one with soy bean. In the case of kidney bean, however, the potassium concentration of leaves remained virtually unaffected by salinity, while its concentration in stem increased with the increase in the salinity. The calcium and magnesium concentration in both carrot and kidney bean unlike the calcium concentration in soy bean appears to increase with salinity. The apparent dissimilarity with soy bean could be due to the fact that Lagerwerff and Holland[4] in their work have maintained the sodium absorption ratio of the growth medium at a constant level while increasing its salinity. This has resulted in marked increase in the calcium and magnesium level of the medium as its salinity was increased and could have cause the higher calcium and magnesium concentrations in the plant tissue. Soy bean also appears to differ from rice because in the later case the increasing salinity was found to decrease phosphorus concentration and increase the potassium concentrations of plants. From what other workers have reported, it appears that though the effect of salinity on the mineral concentration of plants depends on the nature of plant species, the effect in most cases, except for the degree of magnitude, is to reduce the mineral uptake. In soy bean also the same general trend of reduced mineral concentration with increased salinity is evident. The only exception being the phosphorus especially in leaves, which was found to increase very significantly with the increasing salinity of the medium.

LaHaye and Epstein[5] have reported that the presence of calcium in culture solution induces salt tolerance in plants. To see if a similar effect could be observed in soy bean, the plants were grown in presence of various calcium levels in addition to salinity. For first fifteen days of growth the plants appeared to be somewhat better in presence of cal-

TABLE 4. EFFECT OF SALINITY ON THE NITROGEN CONCENTRATION OF SOY BEAN ROOTS IN HALF-STRENGTH (A) AND FULL-STRENGTH (B) HOAGLAND SOLUTION.

Level of salinity (atm)	Nitrogen concn % dry wt		
	A	B	Mean*
0.0	4.002	3.928	3.955ab
2.0	4.339	3.877	4.108a
3.0	3.421	3.640	3.531c
4.0	3.595	3.684	3.640bc
6.0	4.778	3.546	4.162a
Mean†	4.027a	3.735b	

*Means for comparing salinity treatments. †Means for comparing culture solutions. (Values representing same alphabets within vertical column and across the table are not significantly different at 5% level of significance.)

TABLE 5. EFFECT OF SALINITY IN THE PRESENCE OF VARYING AMOUNTS OF CALCIUM ON THE GROWTH OF SOY BEAN GROWN IN HALF-STRENGTH HOAGLAND SOLUTION.

Calcium concn (m moles /litre)	Level of salinity (atm)	Dry wt of leaves (g/plant)					Dry wt of stems (g/plant)					Dry wt of roots (g/plant)				
		0.0	2.0	4.0	6.0	Mean*	0.0	2.0	4.0	6.0	Mean*	0.0	2.0	4.0	6.0	Mean*
0.0	0.0	0.544	0.184	0.061	0.040	0.207a	0.216	0.080	0.034	0.036	0.092a	0.135	0.055	0.025	0.025	0.060a
0.1	2.0	0.437	0.221	0.031	0.036	0.181a	0.187	0.103	0.025	0.040	0.089a	0.127	0.062	0.014	0.015	0.055a
0.3	3.0	0.373	0.253	0.065	0.077	0.192a	0.154	0.108	0.038	0.033	0.083a	0.100	0.075	0.027	0.029	0.058a
1.0	4.0	0.449	0.209	0.058	0.067	0.196a	0.171	0.079	0.042	0.053	0.086a	0.117	0.053	0.028	0.023	0.055a
3.0	6.0	0.294	0.157	0.062	0.072	0.146a	0.106	0.067	0.038	0.033	0.061b	0.066	0.031	0.022	0.025	0.036b
Mean†		0.419a	0.205b	0.055c	0.058c		0.167a	0.087b	0.035c	0.039c		0.109a	0.055b	0.023c	0.023c	

*Means for comparing calcium treatments. †Means for comparing salinity treatments. (Values representing same alphabets within vertical columns and across the table are not significantly different at 5% level of significance.)

TABLE 6. EFFECT OF SALINITY IN THE PRESENCE OF VARYING AMOUNTS OF MAGNESIUM ON THE GROWTH OF SOY BEAN GROWN IN HALF-STRENGTH HOAGLAND SOLUTION.

Magnesium concn (m moles /litre)	Level of salinity (atm)	Dry wt of leaves (g/plant)					Dry wt of stems (g/plant)					Dry wt of roots (g/plant)				
		0.0	2.0	4.0	6.0	Mean*	0.0	2.0	4.0	6.0	Mean*	0.0	2.0	4.0	6.0	Mean*
0.0	0.0	0.389	0.215	0.187	0.141	0.233a	0.218	0.096	0.089	0.079	0.121a	0.092	0.052	0.057	0.059	0.065a
0.1	2.0	0.377	0.173	0.157	0.142	0.212a	0.227	0.100	0.060	0.062	0.112a	0.090	0.045	0.042	0.051	0.057ab
0.3	3.0	0.349	0.171	0.147	0.174	0.210a	0.186	0.096	0.058	0.067	0.102a	0.068	0.051	0.039	0.044	0.051ab
1.0	4.0	0.415	0.094	0.074	0.080	0.166ab	0.237	0.056	0.060	0.014	0.092a	0.089	0.027	0.023	0.012	0.038bc
3.0	6.0	0.142	0.120	0.035	0.042	0.085b	0.081	0.069	0.015	0.008	0.043b	0.038	0.041	0.004	0.011	0.024c
Mean†		0.334a	0.155b	0.120b	0.116b		0.190a	0.083b	0.056b	0.046b		0.075a	0.043b	0.033b	0.035b	

*Means for comparing magnesium treatments. †Means for comparing salinity treatments. (Values representing same alphabets within vertical columns and across the table are not significantly different at 5% level of significance.)

cium. The usual symptoms of salinity mentioned earlier were delayed, but in the last week of growth, the plants began to deteriorate rapidly. In Table 5 the weights of leaves, stem and roots are given and it is evident that the calcium has hardly any effect in countering the effects of salinity.

In a similar experiment calcium was replaced with magnesium and the results indicate that as far as growth is concerned magnesium is very similar to calcium in its inability to ameliorate the harmful affect of salinity (Table 6).

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