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Salt Tolerance in Soybean (*Glycine max* L.): Effect on Growth and Water Relations

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Abstract: A water culture experiment was conducted to study salt tolerance of four cultivars of soybean (*Glycine max* L., cv. AGS-160, Loppa, Egyptian, ICAL-132) over a range of salinity (10-40 mM NaCl) at different stages of development. Salinity reduced growth, water balance and ion uptake mechanism of plant were affected adversely. The adverse effect of salinity became pronounced with passage of time and increase in salinity level. Water consumption, decreased with increase in salinity. This reduction was more in a tolerant (ICAL-132) than the sensitive (Loppa and AGS-160) cultivars. A quantitative relationship has been observed between ions and water uptake.

Key words: *Glycine max* L., sodium uptake and water relations

Introduction

Soil salinity is a worldwide problem and a characteristic of semi-arid and arid environments, especially where irrigation is practiced. Pakistan is primarily a semi-arid country, where out of 22 million hectares of cultivated land, about 6.2 million hectares are affected by various degrees of salinity and waterlogging (Anonymous, 2000). It results in huge loss because of limited productivity from the salt affected land as the growth of most crop plants is reduced under saline conditions (Maas and Hoffman, 1977; Schachtman and Munns, 1992; Munns *et al.*, 1995; Katerji *et al.*, 2000) and almost all crop plants are unable to tolerate permanently the saline conditions in soil. Nevertheless, wide range of variation exists among different crop plants, and this variation may gainfully be utilized for identifying and developing the salt tolerant plants.

Among various crops tested, legumes have generally been found to be more sensitive to salinity. Soybean is an important grain legume due to its high protein (35%), oil contents (21%) and nitrogen fixing ability (17-124 kg ha⁻¹/year) (Diehert *et al.*, 1979). This grain legume is also highly sensitive to salinity. As wide genetic variability exists among different legumes, some variation among different cultivars of soybean have also been reported (Lauchli, 1984; Shereen, 1991). There are different types of salts and an equally diverse set of mechanisms of avoidance or tolerance. Additionally, organs, tissues and cells at different plant developmental stages exhibit varying degree of tolerance to saline conditions (Ashraf, 1993; Shalhevet, 1993; Zaidi and Singh, 1993).

Availability of water to the growing tissue becomes a limiting factor under saline conditions even in the presence of moisture in the soil resulting in what is termed as "Physiological Drought" (Poljakoff-Mayber and Gale, 1975). Water uptake by plants hence, attains importance under saline conditions. The present study was conducted to elaborate the effect of salinity on growth response and water relations of soybean.

Materials and Methods

The experiment was conducted in the growth room of Nuclear Institute of Agriculture, Tandojam during the period of May to June. Seeds of four cultivars of soybean (*Glycine max* L. cv. Loppa, AGS-160, Egyptian and ICAL-132) were germinated in sand and seven days old seedlings were transferred to plastic boxes filled with three liter of ½ strength Hoagland solution. The lids of these boxes were perforated to hold 28 plants each. Four days after transplanting, treatments (0, 10, 20 and 40 mM NaCl) were imposed. These corresponded to EC 1.04, 2.06, 3.06 and 4.93 mS/cm respectively of the culture solution. The solutions were renewed weekly. The experiment

was performed in a growth room maintained at 25 ± 3 °C with a photo period of 12 hr and light intensity of 4500 lux at the level of plant tops. These boxes with plants were weighed daily and the losses were made up with ½ strength Hoagland solution (i.e. brought back to the initial weight).

Six sequential harvests of four plants each were made at one-week intervals. After every harvest, the remaining weight of each box was recorded and taken as the initial weight till the next harvest. The harvested plants were rinsed twice with distilled water and blotted dry. Weights of shoot were recorded and the shoot were analyzed for sodium through Flame emission after extraction of weighed dried material in 100 mM acetic acid for two hours at 90°C (Ansari and Flowers, 1986).

Results and Discussion

Depending upon the concentration of salt and duration of the growth period, salinity under the present experimental conditions had an adverse effect on growth of all the cultivars of soybean. These effects were not so much pronounced at the initial two harvests but at latter harvests showed specially at the higher level of salt (40 mM), where significant inter-cultivar differences were observed.

The addition of salts resulted in reduction in shoot weight and rate of transpiration. Increasing salinity decreased the fresh weight of the shoot (Table 1). The difference between the cultivars was not very obvious upto first three harvests, but subsequently cultivar ICAL-132 showed better tolerance than the remaining three (Loppa, AGS-160, Egyptian). Relative to controls, there was a decrease in fresh weight of shoots and this reduction was more prominent in cultivar Loppa and AGS-160, where the reduction in fresh weight was observed (58 and 49 %, respectively), while the cultivar ICAL-132 exhibited a reduction of 33 % at 40 mM NaCl. Similar adverse effect on shoot has been observed by other workers (Mass *et al.*, 1972; Delgado *et al.*, 1994).

Water consumption (expressed as ml water transpired/gm shoot fresh weight) was maximum in control plants and declined gradually as the salinity increased (Table 2). Transfer of plants to saline environment disturbs, at least temporarily, the balance that prevailed previously between water supply to, and water loss from the leaves. As a result the water contents of the leaves would be reduced and with it the turgor. Stomatal closure could follow and eventually transpiration and photosynthesis would be reduced resulting in reduced growth (Poljakoff-Mayber and Meiri, 1969; Katerji *et al.*, 2000). The reduction in water consumption may hence be ascribed to difficulty faced by plants to absorb and transport the solution of greatly reduced osmotic potential, to lower transpiration

Shereen and Ansari: Salt tolerance in soybean (*Glycine max* L.)

Table 1: Effect of NaCl salinity on fresh weight of shoot (g/plant) at different harvests.

Cultivars/ Treatments (mM NaCl)	Harvests					
	I	II	III	IV	V	VI
AGS-160						
Control	1.42	2.08	2.32	2.76	3.74	4.09
10	1.31	1.74	2.21	2.56	2.99	3.39
20	1.24	1.49	1.80	2.07	2.36	2.51
40	1.18	1.24	1.57	1.79	1.86	2.07
Loppa						
Control	1.40	1.88	2.19	3.02	3.80	5.11
10	1.29	1.60	1.88	2.45	3.36	4.40
20	1.26	1.47	1.59	2.11	2.28	2.93
40	1.19	1.04	1.28	1.51	1.89	2.13
Egyptian						
Control	1.77	2.06	2.27	2.46	3.80	5.41
10	1.47	1.70	2.07	2.38	3.61	4.68
20	1.46	1.46	1.54	1.95	2.93	3.50
40	1.46	1.20	1.21	1.92	2.39	3.19
ICAL-132						
Control	1.11	2.05	2.32	2.53	2.57	4.28
10	1.25	1.70	1.94	2.52	2.38	4.02
20	1.08	1.43	1.75	2.10	2.26	2.94
40	1.19	1.32	1.60	1.95	2.15	2.86

LSD values for cultivars and treatments 0.031

LSD values for harvests 0.038 at 0.05

Table 2: Effect of NaCl salinity on water consumption (expressed as ml water consumed/g shoot fresh weight) at different harvests.

Cultivars/ Treatments (mM NaCl)	Harvests					
	I	II	III	IV	V	VI
AGS-160						
Control	26.41	42.92	60.28	66.78	96.19	108.49
10	25.48	42.15	59.42	67.58	95.13	103.41
20	24.36	42.21	58.81	66.92	94.12	101.97
40	24.00	40.48	56.40	64.01	85.89	97.32
Loppa						
Control	26.55	50.95	59.07	66.53	85.98	132.42
10	24.93	49.60	58.95	64.63	79.13	100.84
20	21.77	48.93	56.53	65.30	79.01	96.92
40	20.22	46.01	56.37	58.75	76.39	96.26
Egyptian						
Control	27.66	44.06	63.11	68.40	70.23	108.42
10	25.05	43.17	58.79	61.20	63.36	108.86
20	20.64	35.06	50.72	50.04	61.58	85.64
40	1.27	26.56	37.61	42.86	48.22	64.89
ICAL-132						
Control	27.83	47.07	62.62	90.88	91.03	94.05
10	25.18	43.09	52.19	79.12	79.48	92.90
20	23.30	43.46	48.60	63.65	65.93	70.53
40	15.15	27.95	41.19	55.00	54.34	54.17

rate (due to stomatal closure) and smaller total transpiring area (reduced growth). Lower transpiration rates of NaCl affected plants, have also been reported by other workers (Clipson and Flowers, 1987; Virgona *et al.*, 1990; Lopez *et al.*, 1999; Katerji *et al.*, 2000).

Ion concentrations calculated on unit dry weight basis showed that salinity caused an increase in the concentration of sodium at all harvests (Table 3). This increase was dependent on the age of plants, duration of exposure and concentration of salt. The cultivar ICAL-132 accumulated comparatively less sodium in shoot than the other three cultivars. The present study suggested that quantitative relationship may exist between ion and water uptake is that the transpiration stream in the xylem carries salt and that the salt accumulation in the leaf increases with increasing transpiration. The cultivar ICAL-132 was able

Table 3: Effect of NaCl salinity on sodium concentration (%) in shoot at different harvests.

Cultivars/ Treatments (mM NaCl)	Harvests					
	I	II	III	IV	V	VI
AGS-160						
Control	0.10	0.06	0.06	0.07	0.09	0.13
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
10	0.13	0.24	0.32	0.35	0.42	0.46
	(30)	(300)	(433)	(400)	(367)	(254)
20	0.44	0.46	0.76	0.83	0.89	1.08
	(340)	(667)	(1167)	(1086)	(889)	(731)
40	0.72	1.31	1.44	1.50	2.10	2.31
	(620)	(2083)	(2300)	(2043)	(2233)	(1677)
Loppa						
Control	0.08	0.06	0.06	0.05	0.09	0.13
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
10	0.17	0.32	0.41	0.51	0.57	0.64
	(112)	(433)	(583)	(920)	(533)	(392)
20	0.30	0.51	0.67	0.91	0.95	1.27
	(275)	(750)	(1017)	(1720)	(956)	(877)
40	0.56	0.91	1.17	1.50	1.74	1.94
	(600)	(1417)	(1850)	(2900)	(1833)	(1392)
Egyptian						
Control	0.08	0.05	0.06	0.09	0.11	0.11
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
10	0.20	0.27	0.29	0.37	0.38	0.40
	(150)	(440)	(383)	(311)	(245)	(264)
20	0.24	0.73	0.73	0.80	0.82	0.85
	(200)	(1360)	(1117)	(789)	(645)	(673)
40	0.56	1.09	1.21	1.26	1.53	1.85
	(600)	(2080)	(1917)	(1300)	(1291)	(1582)
ICAL-132						
Control	0.10	0.06	0.10	0.10	0.11	0.11
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
10	0.22	0.22	0.23	0.25	0.28	0.30
	(120)	(267)	(130)	(150)	(155)	(172)
20	0.34	0.35	0.50	0.54	0.55	0.63
	(240)	(483)	(400)	(440)	(400)	(473)
40	0.46	0.69	0.74	0.79	0.81	0.99
	(360)	(1050)	(640)	(690)	(636)	(800)
LSD (5%)	3.60-02	3.89-02	7.46-02	7.11-02	0.13	0.12

* The figures in parenthesis indicate percent increase over control.

to utilize water efficiently and was successful in keeping control on the absorption of solution of reduced osmotic potential, which resulted in less accumulation of Na via transpiration stream, whereas the more sensitive cultivars were not as efficient. This better water use efficiency thus seems associated with salt tolerance.

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Shereen and Ansari: Salt tolerance in soybean (*Glycine max* L.)

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