direct useful application in Chinese cabbage breeding.

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Effect of NaCl on Growth and Mineral Composition of *Acacia saligna* in Sand Culture[1,2]

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Abstract. **Seedlings of *Acacia saligna* (Labill.) H. Wendle were grown in sand culture and irrigated, at the 4-5 phyllode stage, with modified Hoagland solutions containing 0, 48, 96, 144, 192 and 240 meq/liter NaCl. Growth, chlorophyll content, photosynthesis and respiration were reduced after 3 months of growth in greenhouse. Stems were shorter with increased tip to base diameter ratios. Salt concentration of 96-144 meq/liter caused 50% growth reduction. The contents of Na and Cl increased and that of K decreased. Shoots contained less Na and more Cl than roots indicating greater mobility of Cl than Na. The P, Mn and N contents of shoots and Fe and N contents of roots were not affected by NaCl. Salt treatments increased Zn and decreased Ca contents of both roots and shoots. Magnesium concentration decreased in shoots but increased in roots. Uptake of Na and Cl in the whole plant, and that of Zn in shoots were highest at 48 to 144 meq/liter NaCl. Other elements had greatest uptake in controls. The high salt tolerance of *A. saligna* makes it of potential value for salt-suffering arid and semi-arid regions.**

Acacia saligna (Syn. *A. cyanophylla* Lindl.) is indigenous to Western Australia but is planted in many arid and temperate regions of the world as ornamental and shade trees (9). In Cyprus and Australia it is planted for coastal sand drift control (2, 21) which indicates its tolerance to saline conditions. The species is recently introduced into Iran where majority of soils suffer from different levels of salinity.

Many reports are available on the effect of root medium salinity on growth and nutrient uptake of plants. It has been shown that higher osmotic potentials (OP) of the soil and/or nutrient solution cause reduced water uptake and growth (7). Further, high concentrations of NaCl, in addition to directly increasing the foliar accumulation of Cl and Na and decreasing that of some other elements, inhibit growth by altering physiology of treated plants (5). Depression of N (19, 24), P (16, 19), and K (3, 14) and promotion of Mg (3, 17), Ca (5), Zn, Fe and Mn (11,12) and N (5, 15) content of salt-treated plants have been previously reported.

The present investigation was conducted to study the effect of NaCl concentration on growth and nutrient composition of *A. saligna* because of its potential use as a source of wood in saline soils.

Materials and Methods

Seeds of *A. saligna* were boiled in water for 10 min and were germinated on filter paper at 15°C (23). Germinated seeds were transfered to plastic flats containing pure quartz sand placed in greenhouse where they grew for 1 month and produced 2-3 juvenile leaves and 1-2 phyllodes. Uniform seedlings were then planted in plastic pots containing 500 g sand and were irrigated once every 4 days with 50 ml Hoagland solution to wet the sand thoroughly without drainage. After 1 month, when plants had lost their juvenile leaves and each bore 4-5 phyllodes, NaCl was added to the base nutrient solution at the rates of 0, 48, 96, 144, 192 and 240 meq/liter to obtain 0, −2, −4, −6, −8 and −10 atmosphere OP. Intermittent applications of 50 ml distilled water were included in the irrigation regime.

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The research was conducted during late fall and winter of 1976-77. During this period the greenhouse temperature, relative humidity, and photoperiod ranged between 12.4 to 33.6°C, 40 to 70% and 10.6 to 12.4 hr, respectively.

After 90 days of salt treatment, plants were harvested and leaf number, shoot fresh weight, stem length and stem basal and apical diam were determined. Shoot and root dry weight were obtained after drying the plant materials at 70°C for 48 hr. Leaf (phyllode) area was measured by a Lambda optical planimeter Model LI-300 and chlorophyll contents by method of Arnon (1) using a Carl-Zeiss Model PM2D spectrophotometer. Photosynthesis and respiration were measured by a Beckman Model 215BI infrared analyzer, on 3 youngest fully mature leaves of each plant, using the method of Brown and Rosenberg (6). For elemental analysis the dried plant parts were ground and acid digested. Contents of Fe, Mn, Zn, Ca and Mg were determined by a Carl-Zeiss Model M4Q III atomic absorption spectrophotometer and those of Na and K by a Griffin and George Model A flame photometer. P, total N, and Cl were determined by vanado-molybdo-phosphate yellow (13), micro-Kjeldahl, and dry ashing-silver nitrate titration (20) methods, respectively.

The experiment was a completely randomized design with 8 replicates. Each plot consisted of 1 pot containing one plant.

Results and Discussion

Treated plants received 23 consecutive applications of salt-enriched nutrient solutions. This resulted in final accumulation of 0, 53.7, 107.3, 161.0, 214.7 and 268.3 meq/pot NaCl for the 0, −2, −4, −6, −8 and −10 atmosphere treatments, respectively. Salt treatments reduced all measured growth components except the stem tip to stem base diameter ratio (Table 1). This indicated that increased salt concentration reduced cell elongation but did not affect lateral enlargement as severely. Salt treatments reduced shoot weight to root weight ratios and phyllode number and areas. The decreased shoot to root ratio is shown to be a feature of adjustment of plants to salinity since the proportion of water-absorbing organs is thus increased (4).

Photosynthesis showed faster reduction than respiration with increasing salt treatments, resulting in equal rates of net CO_2 fixation and production at the higher salt concentration (Fig. 1). The salt effect on photosynthesis seemed to be the effect of Na and Cl ions on photosynthetic reactions rather than the reduction in chlorophyll content. With increasing salt concentration, photosynthesis was always reduced more than chlorophyll content (Fig. 2). Growth was not completely inhibited by salt concentration since at the highest NaCl level, true photosynthesis resulted in fixation of 2.2 mg CO_2/dm^2 per hr while only 1.1 mg CO_2/dm^2 per hr was produced by respiration (Fig. 1). Gates (10) has reported similarly slow growth at 588 meq/liter salt concentration for *A. harpophylla*. Plants grown under 192 and 240 meq/liter NaCl had constant number of phyllodes throughout the experiment. This was because as the new phyllodes emerged, the older ones gradually developed symptoms of Na and Cl toxicity (8) and desiccated. Salt treatments of up to 144 meq/liter did not cause any toxicity symptoms in leaves and the observed growth reduction seemed to be

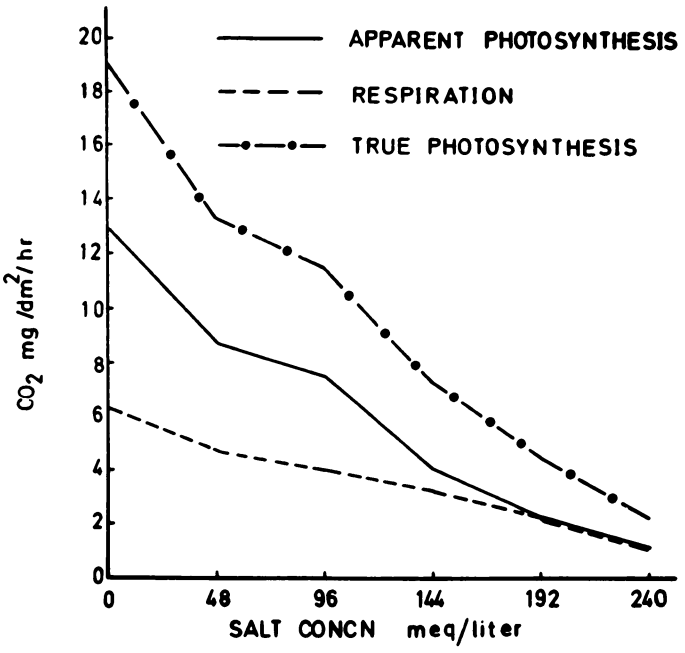

Fig. 1. Effect of salt treatments on photosynthesis and respiration of *A. saligna* seedlings.

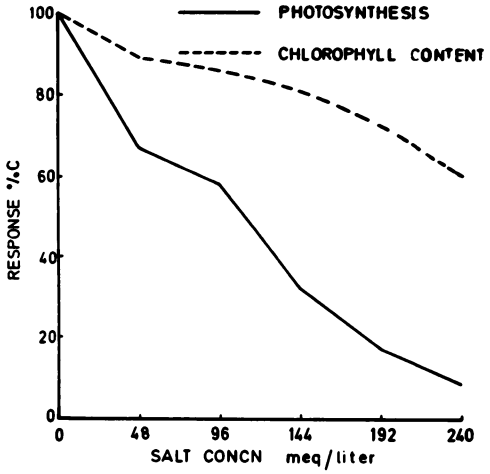

Fig. 2. Comparative reduction in chlorophyll content and photosynthesis in *A. saligna* as affected by salt concentration of the root medium.

Table 1. Effect of salt concentration on growth and chlorophyll content of *A. saligna*.

Salt concn (meq/liter)	Shoot fresh wt (g)	Shoot dry wt (g)	Root dry wt (g)	Shoot root ratio	Leaf no.	Leaf area (cm^2)	Leaf chlorophyll (mg/dm^2)	Stem diam tip:base ratio	Stem length (cm)
0	22.8a[z]	4.3a	1.2a	3.6a	13.4a	416a	5.8a	0.15c	59.8a
48	16.4b	3.5b	1.0b	3.6a	10.8b	287b	5.2b	0.23c	39.4b
96	14.7c	2.6c	0.8c	3.1b	8.4c	220c	5.0b	0.27c	29.4c
144	10.3d	1.6d	0.6d	2.8bc	7.0c	145d	4.7b	0.35bc	16.0d
192	7.3e	0.9e	0.4e	2.7bc	5.0d	88e	4.2c	0.53b	9.6e
240	4.8e	0.7e	0.3e	2.6c	4.2d	69e	3.5d	0.80a	6.2e

[z]Mean separations, within columns, by Duncan's multiple range test, 1%.

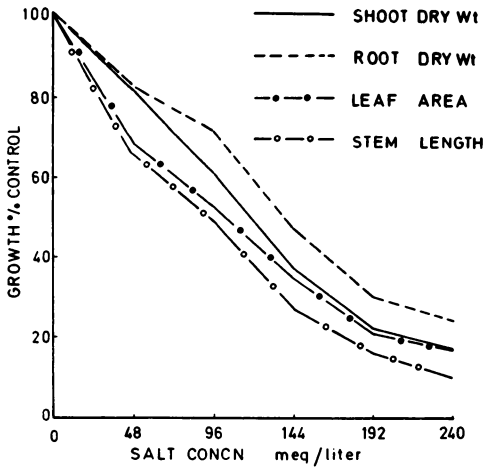

Fig. 3. Effect of root medium salinity on growth components of *A. saligna* seedlings in sand culture.

due to the increased OP of the medium and the reduced photosynthesis. Salt concentrations of 96 to 144 meq/liter were required for 50% reduction in growth responses (Fig. 3). Gates (10) reported decreased dry weight and phyllode number and area of *A. harpophylla* due to increased salt concentration in the soil. His data indicate that about 588 meq/liter of salt in soil solution caused 50% growth reduction. This may, in addition to species differences, be attributed to the greater salt concentration required in soil solution to produce effects of similar magnitude than in sand or nutrient cultures.

Chemical analyses showed differential uptake and distribution of mineral elements in treated plants (Tables 2 and 3). Contents of Na and Cl increased with salinity. Roots had significantly more Na and less Cl than shoots, indicating greater mobility of the latter. Roots at 0 meq/liter and shoots at all salt concentrations contained more Cl than Na. This is contrary to the results reported for sunflowers (18) in which both roots and shoots had more Cl than Na. Rouhani and Bassiri (22) treated four CAM species with salt solutions of up to −6 atmospheres OP (144 meq/liter NaCl) in sand culture.

Table 2. Effect of salt concentrations on shoot content and uptake of different mineral elements in *A. saligna*.

Salt concn (meq/liter)	Na	Cl	Zn	Mn	Fe	Ca	Mg	N	P	K
	Concn, dry wt basis									
	ppm					%				
0	1485f[z]	5360e	17f	42a	52a	0.69a	0.17a	2.74a	0.27a	5.56a
48	25500e	36700d	36e	38a	30c	0.40b	0.12b	2.60a	0.28a	3.66b
96	40150d	42500d	75d	38a	30c	0.37b	0.10c	2.74a	0.30a	3.38bc
144	51000c	77260c	127c	41a	32bc	0.36b	0.10c	2.82a	0.27a	3.15cd
192	66300b	122400b	166b	44a	38b	0.35b	0.09c	2.66a	0.29a	2.86d
240	77700a	149740a	208a	47a	35bc	0.33b	0.09c	2.65a	0.27a	2.68d
	Uptake (mg/plant)									
0	6.3d	22.8e	0.18d	0.18a	0.22a	29.4a	7.5a	117.8a	11.8a	239.4a
48	89.4b	128.6b	0.13c	0.13b	0.11b	14.0b	4.3b	91.2b	9.7b	128.6b
96	104.6a	139.0a	0.20ab	0.10c	0.08c	9.7c	2.6c	71.6c	7.9c	88.8c
144	81.4b	123.6b	0.22a	0.07d	0.05d	5.9d	1.5d	43.8d	4.4d	50.6d
192	62.2c	115.5c	0.17bc	0.04e	0.03d	3.2d	0.8e	25.0e	2.7e	26.4e
240	55.9c	107.8d	0.15c	0.03e	0.03d	2.4d	0.6e	19.1e	2.0e	19.3e

[z]Mean separations, within columns, by Duncan's multiple range test, 1%.

Table 3. Effect of salt concentration on root content and uptake of different mineral elements in *A. saligna*.

Salt concn (meq/liter)	Na	Cl	Zn	Mn	Fe	Ca	Mg	N	P	K
	Concn, dry wt basis									
	ppm					%				
0	1454f[z]	5740f	83bc	89c	128a	1.22a	0.21b	2.77a	1.11a	3.94a
48	61950e	10540e	78c	101c	132a	1.12a	0.26a	2.63a	1.14a	2.75b
96	70650d	18060d	90bc	100c	136a	0.79b	0.25a	2.80a	1.13a	2.59bc
144	91300c	42380c	99b	144b	132a	0.74b	0.25a	2.60a	1.03b	2.50bc
192	102700b	55240b	136a	198a	134a	0.73b	0.25a	2.92a	1.00bc	2.16cd
240	120500a	81260a	138a	216a	132a	0.70b	0.23a	2.98a	0.95c	1.83d
	Uptake (mg/plant)									
0	1.7d	6.8c	0.10a	0.11a	0.16a	13.4a	2.5a	33.0a	13.2a	46.9a
48	60.5a	10.3c	0.08b	0.10b	0.13b	10.9b	2.5a	25.7b	11.1b	26.8b
96	60.5a	15.5b	0.08b	0.09bc	0.12b	6.8c	2.2b	24.0b	8.8c	22.4bc
144	51.0b	23.6a	0.05c	0.08cd	0.07c	4.3d	1.4c	14.6c	6.3d	14.0cd
192	36.3c	19.6a	0.05c	0.07de	0.05c	2.6e	0.9d	10.1d	3.6e	7.7d
240	33.7c	22.8a	0.04d	0.06e	0.04c	2.0e	0.6e	8.4d	2.7e	5.1d

[z]Mean separations, within columns, by Duncan's multiple range test, 1%.

At the highest OP used in their experiment, leaves and roots contained 60,000 and 12,000 ppm Na, respectively. Their results for leaves are comparable with ours but our root Na contents are much higher, indicating that *A. saligna* can absorb much more Na than CAM plants, and that Na is less mobile in the former species. The uptake of Na had similar patterns in roots and shoots. Plants absorbed the highest amount of Na at 48 and 96 meq/liter salt. Further increase in salt concentration of the nutrient solutions reduced uptake. This could be attributed to reduced plant growth rather than hindered absorption rate. The N contents were unaffected by salinity but their uptake decreased due to reduced growth. Salt treatments did not affect P content of shoots but reduced it in roots. This has been attributed to specific inhibitory effects of NaCl on the metabolic carriers responsible for anion absorption (18). The levels of K and Ca decreased in both roots and shoots. This has been related to the attendant increases in Na uptake (18). The Mn contents of shoots and Fe content of roots were not affected by salinity while their uptake was reduced due to reduced growth. The Zn content increased in both roots and shoots. The Mn and Mg contents of roots increased and the shoot contents of Fe and Mg decreased. In general, roots contained more P, Mn, Fe, Ca and Mg than shoots indicating preferential accumulation of these elements in root tissues. More K and Ca were present in shoots showing preferential translocation of these elements out of roots.

Many reports deal with the effect of NaCl on growth and chemical composition of crop plants, usually pointing to reduced growth and significant salt-nutrient interactions. The pattern of elemental composition changes with plant type and experimental conditions. However, most such experiments have shown that Na and Cl usually increase and K usually decreases by salt treatments. Contradictory reports are available for most other elements, indicating that under any set of conditions, each species may respond to salinity in a specific way.

Our results indicate that *A. saligna* can tolerate relatively high levels of salinity and can accumulate greater amounts of Na and Cl, without drastic effects, than many other arid zone species. The tolerance of the species to saline conditions indicates its high potential use in arid and semi-arid conditions suffering from different levels of salt.

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