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Introduction

Forests in arid countries, especially around the Sahel, are overexploited because of the great needs of local populations for wood. Native species adapted to aridity do not produce enough wood. Plantations of adapted and fast-growing species seem to be the best way to meet local demand. Difficulties arise not only from drought but also from the salinity of soils (Chapman, 1975). Plants must be selected for drought- and salt-tolerance and then grown in a favorable environment. Some woody species, such as *Eucalyptus*, are fast-growing and very plastic (Martin, 1987). *Eucalyptus* plantations may be one of the ways to produce wood under these difficult conditions and thus spare the natural stands. Three *Eucalyptus* species (*E. alba, E. camaldulensis* and *E. microtheca*) were tested for their salt-tolerance. Saline stress was applied at germination and to seedlings in a greenhouse.

Materials and Methods

Seeds were collected in the natural range of the 3 species; they were available as species-representative seedlots or provenance-representative seedlots.

Seeds were sown on perlite soaked with nutritive medium (Murashige and Skoog, 1962) in jars, with salt (NaCl, 50–200 mM) added to study salt-tolerance at the germination stage. For measurement of salt-tolerance of seedlings in the greenhouse, seeds were sown on vermiculite, plants were replanted in seed-pans filled with vermiculite and watered with a dilute nutritive solution (N, P, K and oligonutrients). 3 mo old seedlings were watered for 1 mo with and a saline solution (NaCl, 100–600 mM) added to the nutritive solution (Fathi, 1987).

Mineral elements (Ca, K and Na) in the plants were estimated by flame photometry. Chloride was titrated according to Fries and Getrost (1977; reagent: chloranilic acid, mercury salt) by photometry. Organic components were also analyzed by photometry: soluble sugars (reagent: anthrone; Savouré, 1980), soluble proteins, amino acids and proline (Troll and Lindsley, 1955). Analyses were generally carried out at the end of the stress application.

Effects of saline stress on germination

The application of saline stress led to a reduced germination rate. *E. alba* was the most sensitive species; only one provenance was able to germinate under a 200 mM saline stress. *E. camaldulensis* was more affected by saline stress in the sur-

Table I. Effects of saline stress on *E. microtheca* seedlings in the greenhouse.

Characteristic	*Saline stress*	*Provenance*				
		M6	*M7*	*M8*	*M9*	*M11*
Growth (ht increment, last 2 wk of stress, cm)	control	10.1	15.2	15.6	13.7	15.7
	300 mM	3.5	3.9	5.1	8.3	6.0
	600 mM	0.2	0.1	0.1	0.2	0.2
K content in roots (μmol/g fr. wt)	control	156	132	142	133	135
	300 mM	59	72	71	93	67
	600 mM	113	97	79	83	113
Cl content in leaves (μmol/g fr. wt)	control	54	58	89	94	85
	300 mM	422	288	438	584	533
	600 mM	491	392	418	676	569
Na content in leaves (μmol/g fr. wt)	control	12	22	19	7	5
	300 mM	345	235	247	265	329
	600 mM	375	300	417	311	361
Na content in roots (μmol/g fr. wt)	control	75	125	126	162	53
	300 mM	1 342	1 720	1 422	1 845	1 320
	600 mM	2 708	3 022	3 188	2 811	3 646
dead plants	600 mM	5 123	4 879	4 081	4 646	3 853
Soluble sugar content (mg/g fr. wt)	control	27.6	22.8	25.0	24.1	24.8
	300 mM	29.0	28.0	31.4	26.7	26.2
	600 mM	30.7	37.8	32.9	36.5	34.4
Proline content (μmol/g fr. wt)	control	0.9	0.8	1.1	1.2	1.7
	300 mM	1.6	3.7	6.8	4.8	4.9
	600 mM	2.5	3.0	1.0	0.1	3.0
Stress reducing germination rate to 50% of control (mM NaCl)		>200	>200	200	>200	>200
Stress reducing ht increment of seedlings in greenhouse to 50% of the control (mM NaCl)		220	180	200	350	200

Comparison of several provenances of *E. microtheca* under saline stress (the saline stress effect was highly significant (at the 0.01 or more generally 0.001 level) for all characteristics; the provenance effect was highly significant only on the growth; and the saline stress x provenance interaction was highly significant only on the growth and the proline content).

vival tolerance (45 d after sowing) than in the germination rates, but it was the opposite for *E. microtheca.* Some provenances were not sensitive to saline stress up to 200 mM. Seedlings exposed to saline stress accumulated large amounts of sodium, especially *E. alba,* where calcium contents were also higher (Fathi and Prat, 1988). *E. microtheca* seemed to be the most tolerant species and was therefore studied in the greenhouse.

The growth of plants was significantly reduced by saline stress (Table I). The accumulation of sodium was more limited in the leaves for the strongest saline stress, but not in stems or roots. In roots, the average sodium content became higher than in the saline stress solution. The concentration of chloride in leaves was higher than that of sodium. The potassium content was significantly lower in roots of plants exposed to a 300 mM saline stress.

The sodium concentration increased from the 1st wk of stress application and was higher in the stem than in leaves. During the saline stress application, the potassium content in leaves and stems decreased gradually. After the stress application, plants were watered normally: the sodium content in leaves increased immediately, probably due to a release of the sodium accumulated in the roots.

Increased sugar, protein, amino acid and proline contents were induced by saline stress application. Proline might represent a large part (up to 25%) of free amino acids, but its content in leaves was quite variable depending upon the provenance.

Conclusion

Saline stress reduced growth of plants and induced changes in mineral and organic component contents. The sensitivity varied according to the species or the provenance. The most sensitive provenances of *E. microtheca* showed the largest amount of sodium in leaves or stems; the sodium content of living plants was very close to that of plants killed by the saline stress. Plants of these provenances (M8 and M11) appeared to be unable to accumulate more sodium.

Our study did not identify a predictive characteristic for salt-tolerance without saline stress application. However, the most tolerant provenance (M9) was from the most arid stand in Australia. Ecological studies might be useful for prediction of salt-tolerance.

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