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Compatible solutes in different organs of mangrove trees

M. Popp[1] and J. Polania[2]

[1] *Institut für Angewandte Botanik, Universität Münster, F.R.G., and*

[2] *Institut für Pflanzenphysiologie, Universität Wien, Austria*

Introduction

According to Brown and Simpson (1972), a compatible solute may be "loosely defined as one which, at high concentration, allows an enzyme to function effectively". This definition was developed from work on sugar-tolerant yeast and was later adapted to halophytes, which also need osmolytes in the cytoplasm to assure the intracellular osmotic adjustment between vacuole (rich in NaCl) and cytoplasm (poor in NaCl) (Stewart *et al.*, 1979).

Earlier work on mangroves has revealed that these halophytic trees stored high concentrations of either mannitol, pinitol, quebrachitol, proline or glycine betaine in their leaves (Popp *et al.*, 1985). In the meantime, further work on the Rhizophoraceae showed that the cyclitol formerly identified as pinitol was 1D-*O*-methyl-muco-inositol (Richter, Thonke and Popp, manuscript in preparation).

The present study was undertaken to elucidate the role of these organic solutes in various mangrove species by investigating their distribution in different plant organs and their reaction to long- and short-term variations in salinity.

Materials and Methods

Mangrove material was collected at the Dampier Archipelago (Western Australia) during March/April 1984. Sample preparation and analytical procedures were those described by Popp *et al.* (1985). Culture experiments were carried out in a glass-house in Vienna with additional light and a temperature regime of 28–30°C during the day and 20°C at night. Plants were grown on a substrate of volcanic beads and supplied with appropriate concentrations of seawater prepared from commercially available sea-salt for aquariums. 1 mM NH_4NO_3, 1 mM NH_4Cl, 0.1 mM KH_2PO_4 and 0.05 mM FeEDTA were added to the seawater. The solutions were changed every 2 wk. Whole plants were harvested and divided into the different organs. Roots were subjected to a standardized washing-procedure.

Results

For osmotic considerations data in Table I are given in $mol \cdot m^{-3}$ plant water. The concentrations of Na^+ and Cl^- in seawater were 459 and 535 $mol \cdot m^{-3}$, respectively, and were very often in the same range in the different plant organs (Table I). Where twigs could be separated

Table I. Compatible solutes, Cl^-, Na^+ and K^+ concentrations in $mol \cdot m^{-3}$ plant water in different parts of mangrove trees collected at the Dampier Archipelago (nd = not determined).

Species/plant part	*Cl⁻*	*Na⁺*	*K⁺*	*Solute*	
Aegiceras corniculatum					
very young leaves	336	359	144	186	mannitol
old leaves	487	457	175	248	mannitol
old twigs, bark	nd	534	234	123	mannitol
old twigs, wood	nd	268	146	175	mannitol
Aegialitis annulata					
young leaves	616	485	99	49	pinitol
old leaves	446	367	93	53	pinitol
young twigs, bark	761	917	95	18	pinitol
young twigs, wood	620	375	86	30	pinitol
Rhizophora stylosa					
young twigs, bark	800	656	73	99	1D-*O*-methyl-muco-inositol
young twigs, wood	385	362	104	186	"
stilt roots, outer layer	745	521	101	283	"
stilt roots, inner layer	472	376	56	277	"
Avicennia marina					
very young leaves	566	539	120	238	glycine betaine
old leaves	763	889	148	145	"
twigs, ø1.0 cm	519	441	159	238	glycine betaine
twigs, ø1.5 cm	454	435	133	213	"

Table II. Proline content ($\mu mol \cdot g^{-1}$ dry weight) in different organs of *A. annulata*, cultivated in 50% seawater and transferred into 150 and 0% seawater for 8 d.

Organ	*50% seawater*	*After 8 d in 0% seawater*	*After 8 d in 150% seawater*
Roots	3.32 ± 1.70	1.66 ± 0.46	11.93 ± 3.81
Stems	15.48 ± 7.42	9.68 ± 2.24	36.70 ± 8.43
Leaves	10.73 ± 4.85	16.26 ± 7.45	12.93 ± 9.17

into bark and wood, Na^+ and Cl^- accumulated to a higher extent in the bark, while the opposite was true for the organic solutes.

In addition to the 4 species listed in Table I, we know from *Rhizophora mangle, Bruguiera exaristata, Ceriops tagal* and *Laguncularia racemosa* that the organic solutes present in the leaves also accumulated in all other plant organs.

Compared to the other species, the pinitol content in *A. annulata* was low, but this species contained 2 additional organic solutes: chiro-inositol (11–25 $mol \cdot m^{-3}$) and proline (0.4–5.0 $mol \cdot m^{-3}$), which were again present in all different plant parts.

In a long-term experiment with *A. corniculatum*, we tested the influence of salinity on the mannitol concentration in the leaves. Plants were kept for 1 yr at either 10 or 100% seawater, leaves of approximately the same age were harvested from 4 or 5 different plants, respectively. The mannitol content of 10%

seawater plants was 41 ± 14.8 ($n = 4$) $mol \cdot m^{-3}$ plant water, while in 100% seawater plants it was 79 ± 7.0 ($n = 5$) $mol \cdot m^{-3}$ plant water.

The effects in the short-term experiment with *A. annulata* were not as pronounced. However, the up-shock (8 d in 150% seawater) treatment showed a clear increase in proline concentrations in roots and stems (Table II).

Discussion and Conclusion

Our results are in agreement with those obtained for herbaceous halophytes in that one and the same organic solute was present in all organs of a given plant (Briens and Larher, 1982).

Acyclic polyols, such as sorbitol and mannitol, are known to play an important role in the carbohydrate metabolism of trees other than mangroves (Loescher, 1987). Our results suggest that mannitol also functioned in the overall osmotic adjustment of *A. corniculatum*. Further experiments are in progress to determine if cyclic polyols (pinitol, 1D-*O*-methyl-muco-inositol) behave in the same way. Proline accumulation in *A. annulata* was similar to that observed for herbaceous halophytes (Stewart *et al.*, 1979). The reaction to changes in salinity and the rather low concentration of this solute imply a role different from that of the polyols. It might be postulated that proline is more restricted to the cytoplasm, while the polyols also accumulate in vacuoles.

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