# Trees for salty land

Soil salinity, as Australians are becoming increasingly aware and as the articles on pages 4 and 13 further emphasise, is a major form of land degradation in some agricultural regions. There are places where salt occurs naturally at the surface, but too often its presence has resulted from tree-clearing or irrigation.

Trees act like powerful pumps. The daily loss of large quantities of water from their leaves by transpiration results in their roots taking up an equal volume of water from below ground. Without trees to perform this pumping, the water table may gradually rise because a greater proportion of the area's rainfall reaches it. As the groundwater rises it may encounter salts deep within the ground. These will dissolve and be carried up by the rising water.

Eventually, salty water will start to appear at the surface in 'discharge zones'— and we have what is known as dryland salinity. In southern Australia, its occurrence is often associated with periodic waterlogging. Vegetation in an affected area may change or be lost entirely.

Salinity associated with irrigation has a somewhat different set of causes. If the water used for irrigation is already partially saline, evaporation at the surface will concentrate the salts — and even if it's not, the irrigation water may finish up saline after dissolving salts present in small amounts in the soil that it passes over. Disposal of this drainage water, which may enter the water table or accumulate to form large salty lakes, contributes to the dark side of the agricultural boom that irrigation has wrought in some places.

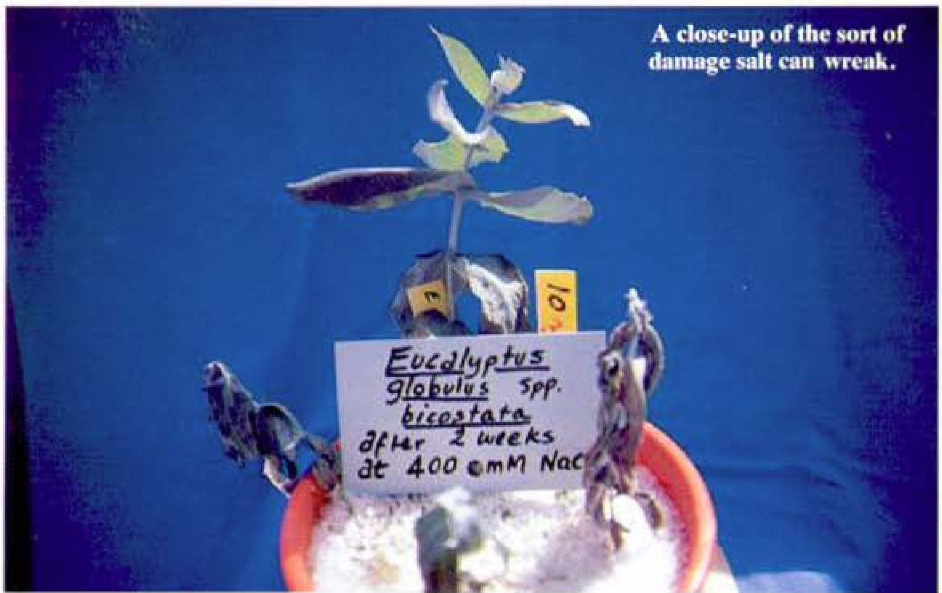
Trees or shrubs that can grow successfully in saline or salinity-prone areas have a vital role to play in managing land that is already salt-affected, as well as helping to prevent the problem starting in susceptible areas. They need to be planted where they will have greatest effect (see *Ecos* 63). Where dryland salinity is the problem, such areas may include both those where the salt water comes to the surface and 'recharge zones'— the areas where most of the rainwater moves down into the water table.

On irrigated land, farmers could plant trees where the drainage water accumulates and near irrigation channels.

Trees and shrubs planted in areas that are already too salty for crops or pastures could provide wood or fodder — putting unproductive land to use.

Looking further afield, in many of the world's less-developed countries rapid population growth means that people will need to make greater use of marginal lands unsuitable for crop plants because of problems like salinity and susceptibility to waterlogging. Planted with trees, these areas could provide fuelwood, timber, or animal fodder. Various Australian *Acacia*, *Melaleuca*, *Casuarina*, and *Eucalyptus* species could fit the bill, and so could *Sesbania formosa*, the dragon-flower tree, which grows well in swampy soils in the tropics.

So now the search is really on for salt-tolerant trees, especially hardy natives with



**A close-up of the sort of damage salt can wreak.**

## Roots hold back the salt

As part of his research for his doctorate, Dr Lex Thomson studied some of the mechanisms involved in salt tolerance in eucalypts. In preliminary experiments he found considerable variation in the extent of tolerance between species and between river red gums (*E. camaldulensis*) of various provenances. Interestingly, salt tolerance did not show a close correlation with the degree of salinity at the soil surface of the place where the trees were growing.

The secret of tolerance appeared to be a greater efficiency at keeping salt out of the leaves. Seedlings with greater tolerance always had lower concentrations of sodium and chloride ions in their leaves than did sensitive ones. (In solution, salt separates into sodium and chloride ions. In eucalypts it seems that the sodium is relatively innocuous and that the chloride ions cause the most damage to leaf cells.)

**A light-microscope picture of a small rootlet emerging from a larger root, only part of which is visible. A fluorescent dye dissolved in water stains the suberin blue, and shows the effectiveness of the Casparian band in the cells of the outer part of both roots. However, the small branching root has some permeability — shown by the absence of the dyed suberin in places.**

**A section of a *Eucalyptus camaldulensis* (river red gum) root viewed under a light microscope. The Casparian band in the cells of the hypodermis shows up as yellow.**

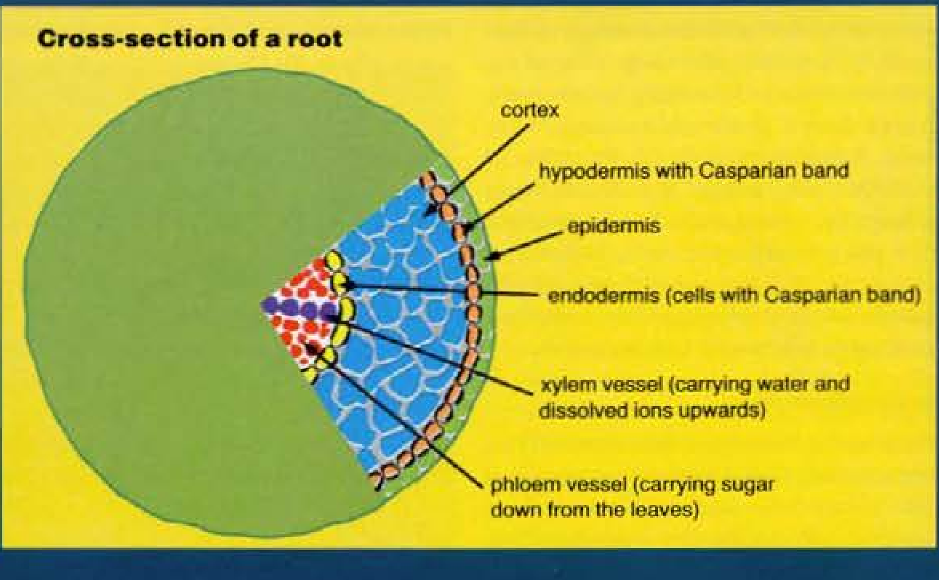
From work with cloned plants, Dr Thomson found that part of the explanation for salt exclusion seemed to lie in the roots. For decades plant anatomists have known about the Casparian band or strip; this is a 'waterproofing' deposit in the radial walls of cells in the endodermis, a layer that surrounds the central part of the root within which lie the water-carrying xylem vessels. The band, composed mainly of a complex compound called suberin, can act as a barrier, preventing the entry of certain substances into the xylem.

Dr Thomson showed that salt-tolerant eucalypts contain a similar band in the cell walls of the hypodermis, the cell layer just beneath the outer layer of the root. This may act as protection against the unregulated entry of salty water into the rest of the root and hence the plant as a whole.

But between this region of the root and the growing tip is another section, that Dr Thomson termed 'region B', which lacks the extra Casparian band. In the river red gum, he found that the length of this region was associated with a plant's ability to keep chloride ions out of its leaves. A long region B served to let salt in, but in trees with a short one the extra Casparian band, nearer the tip of the root, afforded protection earlier.

It appears that earlier development of the extra hypodermal Casparian band contributes to the degree of salt tolerance in these trees. Dr Thomson suggests that further research may show such development to be a common feature in plants that are moderately salt-tolerant.

'Salt Tolerance in *Eucalyptus camaldulensis* and Related Species.' L.A.J. Thomson. Ph.D Thesis, University of Melbourne, 1989.



**In the river red gum, the cells of the hypodermis, as well as those of the endodermis, have Casparian bands (black), so the passage of water and solutes can be better controlled.**

**In the laboratory, three *Acacia* species are being evaluated for salt tolerance. In each case, the plant on the right is the 'control' and has received no salt, while the left one has spent a week in a salt concentration approaching that of sea water.**

potential economic uses. The Australian Tree Seed Centre at the CSIRO Division of Forestry and Forest Products in Canberra has collected seed from trees all around our country, and the Division's Dr Nico Marcar (with Dr N. Ashwath, formerly of the Division) has screened samples in the glasshouse for salt tolerance and conducted physiological studies on them. Funding for the work has been provided by the Rural Credits Development Fund and the Australian Centre for International Agricultural Research (ACIAR).

Dr Marcar heads a team comprising Ms Debbie Crawford, Mr Peter Leppert, Mr Brian Davis, and Mr Peter Sieler. He and Dr Ashwath have also studied how factors such as waterlogging and frost affect salt tolerance, and have examined tolerance to waterlogging *per se*.

For seed-collectors, determining whether plants in the field are salt-tolerant is, unfortunately, not straightforward. One of the difficulties is actually working out whether a tree or shrub is growing in a saline environment. Measurements of salt by means of electrical conductivity are usually only taken at the surface; the salinity at the depth of a tree's main roots remains a matter of conjecture. We do know that salt concentrations can vary quite suddenly, both horizontally and vertically, within the soil.

## In the glasshouse...

Back in the laboratory, scientists carrying out screening trials give known quantities of salt solution to seedlings derived from material collected by the Australian Tree Seed Centre. They measure the plants' growth rates and record any visible signs of damage.

When he did this with a range of Australian tropical and subtropical native trees, Dr Ashwath found large differences between species' abilities to tolerate salt. Some survived five times the concentration that killed others. And he and Dr Marcar discovered that those species that sustained the smallest reduction in growth rate when stressed by moderate salinity were also, in general, the most likely to survive higher salt concentrations. Compared with controls, trees exposed to salinity usually grew more slowly, but the extent of the reduction in growth and the degree of damage to the leaves varied considerably between species.

The growth of many acacias actually improved with small concentrations of salt in the soil, and three species (*A. ampliceps*, *A. stenophylla*, and *A. maconochieana*) proved very salt-tolerant.

*Acacia* species, *via* the bacteria in their root nodules, are able to make atmospheric nitrogen available for plant growth — an attribute that renders them even more useful for plantation purposes. In a preliminary investigation, Dr Marcar and his colleagues evaluated the effect of salt on nitrogen fixation and found that it reduced both the weight of the nodules and the activity of the bacterial nitrogenase enzyme that plays a central role in 'fixing' the nitrogen. However, the salt's adverse effect on nitrogen fixation was greatest in plants that were themselves more salt-sensitive.

Dr Ashwath found that seed from some species of *Acacia* collected from non-saline soils survived high salt concentrations as seedlings in the glasshouse. So some species may possess salt tolerance even though they are found in environments where they do not need it.

Dr Marcar has extensively screened temperate eucalypts for salt tolerance. The genus *Eucalyptus* is divided into a number of subgenera, and the researchers noticed that the ability of species in two of these to tolerate salt correlates well with the one to which they belong. Species in the subgenus *Monocalyptus* are salt-sensitive, whereas many of those tested in the subgenus *Symphyomyrtus* are salt-tolerant.

Variation in tolerance within a species is a complicated matter. Some species seem to be relatively consistent and, when tested, examples with many provenances show the same results (the provenance defines the origin or 'source' of a particular seed or plant). Other species vary so widely between provenances that it is not possible to assign a meaningful salt-tolerance score to the species as a whole.

But we cannot conclude too much from these quick tests. Young seedlings often differ from mature trees in their response to salt, in ways that are not necessarily predictable. Furthermore, the salts applied in the glasshouse may not always mimic the particular mixture of salts found in the field. (Saline soils contain variable quantities of sodium sulfate, calcium chloride, magnesium chloride, and magnesium sulfate, as well as the sodium chloride of table salt.)

The degree of salt tolerance observed in the field will also vary with factors specific to the particular site such as rainfall, temperature, and soil pH. These can affect a plant's ability to adapt to a site and to endure salt in ways that researchers are only beginning to understand.

## ... and in the field

In New South Wales and Queensland, with funding from the National Afforestation Program and the CSIRO Land and Water Care Initiative, Dr Marcar and his team have started trials to evaluate salt-tolerant species, and a range of plants within species, on sites that are affected by dryland salinity. They are also testing various techniques for helping the seedlings flourish in the field, such as the application of fertiliser, mulch, and plastic 'grow-tubes'.

In addition, with funds from ACIAR, Dr Marcar has started collaborative field trials in India, Pakistan, and Thailand. Although the emphasis is on Australian trees, the scientists are evaluating trees and shrubs native to Pakistan and Thailand as well, as these may be more suitable in their natural environments.

And, in collaboration with Dr Trevor Booth (also of the Division) and several government and land care groups, Dr Marcar is developing a microcomputer data-base of the growth performance of trees and shrubs on salt-affected landscapes.

## Not the real thing

The plant world includes specialised species, termed halophytes, that require a salty environment. They often have succulent, fleshy leaves because they accumulate salts — and hence, by osmosis, water — in their cells. Their physiology is specially adapted to tolerate high salt levels throughout the plant.

A good example is the introduced athel tree or tamarisk (*Tamarix aphylla* — see *Ecos* 63) — which accumulates salt in its leaves, benefiting from the increase in 'turgor' that this brings during dry times (water is 'held' in the cells by the osmotic effect of large quantities of salt). Athels even have special salt glands in their leaves to extrude salt, if necessary.

But most of Australia's salt-tolerant trees are not halophytes. Although the best species may perform as well as moderate halophytes, our trees manage in saline areas by specifically excluding salts from their leaves, rather than the reverse. Their individual cells, especially within growing shoots, are probably as sensitive to salt as those of any other plant. However, the roots protect the rest of the plant from salt.

The tolerance of these native trees comes mainly from their roots' ability to exclude salt from the tissues of the shoot. Dr Lex Thomson, formerly of the Division of Forestry and Forests Products, has carried out considerable research into how the plants achieve this, and some of his findings are summarised in the box on page 20.

## Other stresses

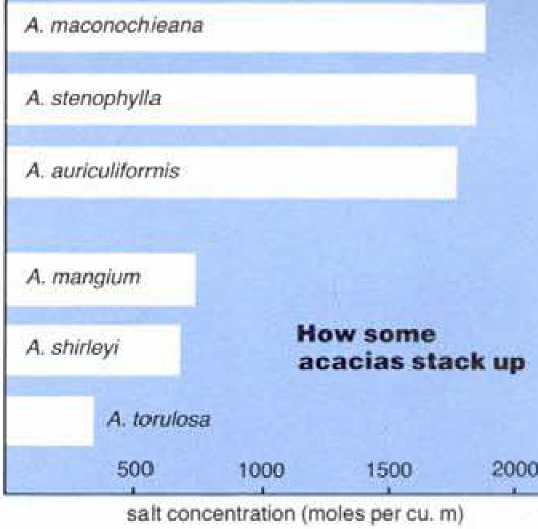
Salinity is seldom the only environmental stress that trees may face. Coupled with it in many areas, of course, is periodic waterlogging. Frost can be an additional hazard.

By depriving roots of oxygen, waterlogging prevents them carrying out the energy-intensive process of excluding salts; as a result, salt accumulates in the leaves, and this eventually kills them and the entire plant. When combined with waterlogging, even low levels of salt can kill trees that may otherwise tolerate moderate to high salt levels.

Tolerance of waterlogging is in itself a very useful attribute. The researchers generally found a considerably greater degree of waterlogging tolerance in eucalypts and melaleucas (paperbarks) than in acacias. *Sesbania formosa* is another very tolerant species. The ability of these plants to endure waterlogging is largely due to the development of specialised root structures that allow some oxygen to reach the root and shoot cells.

In the tableland districts of New South Wales and Victoria an ability to withstand frost is vital for trees. As many pastoral properties in these areas also suffer from salinity problems, Dr Marcar has screened known frost-resistant eucalypts for their salt tolerance. Eucalypts have been targeted first because many of them can produce commercially valuable wood products, enabling farmers to use salty or potentially saline land for agroforestry.

Frost-hardy species from the subgenus *Symophyomyrtus* (which contains many salt-tolerant species) seem likely to be the best ones to plant in saline areas of the tablelands. Examples are the river red gum (*E. camaldulensis*), the black gum ( *E. aggregata*), and the swamp gum (*E. ovata*). Unfortunately, many of the *Acacia* species that we now know are highly salt-tolerant can only put up with relatively minor frost stress. (The stress measure combines the intensity of individual frosts, the total number of frosty nights experienced, and the timing of frosts.)



**The chart shows the concentration of salt needed to kill 50% of a sample of seedlings. For all species the concentration at which growth ceased was lower. (The concentration of salt was increased by 25 moles per cu. m every 2 days in a step-wise fashion.)**

Selecting trees for their ability to handle salt in combination with other stresses is one thing; being certain that the progeny of resistant individuals will also tolerate salt is another. Unfortunately, tolerance is not always inherited.

Consequently, when scientists find a salt-tolerant individual, they may wish to clone it rather than use its seed. Mr Vic Hartney, also of the Division of Forestry and Forest Products, has been working on cloning eucalypts for a number of years. Work is continuing on the application of his results to selected salt-tolerators, and on testing cloned individuals in the field — but that's another story!

*Roger Beckmann*

**Native tree species considered salt-tolerant on the basis of both glasshouse experiments and field trials and observations.**

### The tolerators

| eucalypts | acacias | melaleucas | casuarinas |
|---|---|---|---|
| *E. camaldulensis* | *A. stenophylla* | *M. linariifolia* | *C. glauca* |
| *E. tereticornis* | *A. ampliceps* | *M. armillaris* | *C. obesa* |
| *E. occidentalis* | *A. auriculiformis* | | *C. equisetifolia* |
| *E. largiflorens* | *A. salicina* | | |
| *E. rudis* | *A. maconochieana* | | |
| *E. wandoo* | *A. ligutata* | | |
| *E. sargentii* | *A. sclerosperma* | | |
| *E. kondininensis* | *A. saligna* | | |
| *E. halophila* | | | |

## More about the topic

Salt tolerance of frost-resistant eucalypts. N.E. Marcar. *New Forests*, 1989, **3**, 141–9.

Salinity and waterlogging tolerance of Australian native trees. N.E. Marcar. *Proceedings of Australian Forest Development Institute Bicentennial Conference. April, 1988, Albury, N.S.W.*

Screening of Australian tropical and subtropical tree and shrub species for salt tolerance. N. Aswathappa, N.E. Marcar, and L.A.J. Thomson. In 'Australian Acacias in Developing Countries' (*ACIAR Proceedings* No. 16) ed. J.W. Turnbull, 70–4.

Salt and waterlogging tolerance of subtropical and tropical leguminous Australian native trees: a review. N.E. Marcar, D. Crawford, N. Ashwath, and L.A.J. Thomson. *International Conference on Current Developments in Salinity and Drought Tolerance in Plants, Tando Jam, Pakistan, January 1990.*