Trees, Shrubs and Grasses for Saltlands: an Annotated Bibliography

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Preface

This publication, 'Trees, shrubs and grasses for saltlands: an annotated bibliography', is a revised and expanded version of the book 'A bibliography of forage halophytes and trees for salt-affected lands' which was produced in 1990 by Shoaib Ismail and Rafiq Ahmad (Botany Department, University of Karachi, Pakistan) and Clive Malcolm (Agriculture Western Australia). The previous publication had been undertaken as a component of two projects dealing with revegetation and reclamation of salt-affected soils in Pakistan, Thailand and Australia. These projects, FST 1986/033 and FOG/1986/019, were substantially funded by the Australian Centre for International Agricultural Research (ACIAR) between 1988 and 1993. Two new ACIAR projects (LWRI/1993/002 and FST/1993/016) were initiated in 1993 to build on the results of projects FST 1986/033 and FOG/1986/019. This bibliography was undertaken as part of project FST/1993/016 'Tree growing on salt-affected soils in Pakistan, Thailand and Australia'.

International databases, including CAB Abstracts and TREECD, were searched for literature on trees, shrubs and grasses with respect to salinity, sodicity and/or waterlogging. Copies of relevant research, conference and workshop papers, books and other documents were obtained through libraries, particularly through CSIRO Forestry and Forest Products (Canberra, Australia), Agriculture Western Australia (Perth, Australia) and the University of Karachi (Karachi, Pakistan), but also through personal contacts. These were combined with the authors' already extensive collection of research papers.

A wide range of information with respect to forest trees, shrubs and grasses (and to a limited extent, legumes) has been included in the revised publication. These references cover many aspects related to effects of salinity, sodicity and/or waterlogging including physiology and biochemistry, agronomy and silviculture, genetics and breeding, ecology and utilisation, and soils and hydrology. We realised that a number of appropriate references may have been overlooked during compilation and we welcome information on these. By retaining references dealing with salt-tolerant and halophytic grasses and forage shrubs, links were maintained with project LWRI/1993/002 'Forage production from saline and/or sodic soils in Pakistan'. We have included the address of only the leading author of each paper, to serve as a point of contact, although we recognise that in a number of cases the address might be out of date. We have generally avoided inclusion of unpublished reports and popular articles and not included theses.

Annotations are either our summary of the main, relevant issues in the article, or else they also contain sentences (part or whole) or expressions from the original paper in addition to our summary information, where these have been deemed to best express important imformation; in all cases we have tried to construct annotations to best reflect the purpose of this bibliography. We sincerely hope that this revised bibliography will provide a useful resource for scientists, planners, students, non-government organisations, community groups and other personnel who are directly or indirectly involved in revegetation and rehabilitation of salt-affected lands and studies of salt tolerance in trees, shrubs and grasses. Hard copies of most references are held in Karachi and Canberra.

We wish to thank ACIAR, CSIRO Forestry and Forest Products and the University of Karachi for providing funds and encouragement for us to pursue the production of this book. We especially thank ACIAR for organising final editing, layout and printing of this book and for their patience in dealing with the inevitable changes required to the manuscript. We gratefully acknowledge the assistance of Erika Leslie, Pamela Lockwood and Ailsa George (CSIRO Forestry and Forest Products library) with searches and requests for photocopying. Ed Barrett-Lennard and David Bicknell of Agriculture Western Australia reviewed a draft of this manuscript.

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Productive Use and Rehabilitation of Salt-affected Land with Trees, Shrubs and Grasses: a Short Overview[1]

INTRODUCTION

Approximately 1000 million hectares or seven per cent of the world's land area is salt affected (Dudal and Purnell 1986). Estimates given by Dregne et al. (1991) suggest that about 74 million hectares are salt-affected due to human causes (secondary salinity); of this, 43 million hectares is irrigated land in the world's semiarid and arid regions and 31 million hectares is non-irrigated land. Secondary salinisation has resulted through inappropriate water management in a variety of landscapes, such as by over-irrigation in semiarid climates (Szabolcs 1989) and by clearing of deep-rooted native vegetation in rainfed areas (Schofield 1992).

Salt-affected soils have been adversely altered for the growth of most plants by the action or presence of soluble salts (saline soils), the exchangeable sodium (Na) percentage (sodic or 'alkali' soils) or both (saline–sodic soils). A summary of properties of these soils and major factors influencing plant growth is presented in Table 1.

[1] Some information in this section has been drawn from Marcar and Khanna (1997)

Table 1. Major properties of saline, sodic and waterlogged soils relevant to plant survival and growth. Modified from Marcar and Khanna (1997).

Property	Saline	Sodic	Waterlogged
EC_e[a]	> 2–4 dS/m	< 2–4 dS/m	n.a.[b]
ESP[c]	< 15[d]	> 15[d]	n.a.
pH	< 8.2	> 8.2	pH fluctuations
Major products	Na, Cl, SO_4 predominate	Na, CO_3, HCO_3 predominate	Anaerobic respiration end products
Physical structure	Flocculated	Dispersed	Variable: low O_2 concentrations
Soil water	Osmotically-induced water stress likely	Reduced access to subsoil moisture likely due to impeding layers	Excess supply
Essential nutrients	Imbalance	Imbalance	Imbalance
Other	Often high Na:Ca	High Na:Ca	n.a.

[a] ECe = electrical conductivity of water extracted from a saturated soil paste
[b] n.a. = not applicable
[c] ESP = exchangeable sodium percentage
[d] under Australian conditions, sodic soils have ESP > 6

Saline soils contain high concentrations of soluble salts—usually chloride or sulphate salts of Na, magnesium (Mg) and calcium (Ca)—commonly at or close to the surface, sufficient to reduce survival and growth of most plants, depending on their salt tolerance. The amount of soluble salts in the soil profile may be subject to considerable temporal and spatial variation. For example, where pronounced dry and wet seasons occur, both watertable and surface soil salt concentrations can vary markedly, salt concentrations typically rising with increasing evaporative demand in hot, dry seasons.

Sodic soils contain sufficient exchangeable Na (that is Na-occupied negatively charged exchange sites on silt and clay) to adversely affect soil physical properties, particularly soil structure, infiltration and aeration, and therefore plant growth. A compact calcic horizon (calcium carbonate concretions or kankars), often present in sodic soils, can severely restrict root penetration and movement of water and air within the soil profile (Abrol et al. 1988).

Waterlogging may result when soils are poorly drained (as may be the case with sodic soils) or underlain with a shallow watertable. If a sufficiently large proportion of the root zone is saturated for long periods, there may be insufficient soil oxygen to support normal root growth. However, development of reduced oxygen conditions in soils is usually non-uniform; thus plants may be subjected in all or part of the rooting zone to conditions ranging from fully air-saturated to anaerobic (Drew 1983). When saline soils are waterlogged, there is a consequent energy deficiency in plants that leads to a loss of ability to screen out salt ions (Na and Cl) at the root surfaces (Barrett-Lennard 1986). Thus there are substantially higher salt concentrations in the leaves and shoots of such plants than in plants grown in drained soils at equivalent salinities (Barrett-Lennard 1986, Marcar 1993). This ion imbalance has adverse effects on the growth and survival of plants (e.g. Qureshi and Barrett-Lennard 1998). In addition, waterlogging may interfere with normal plant mineral nutrition.

Productive use

Establishment of perennial plants on salt-affected land has the advantage of reducing annual maintenance costs, and their deeper-rooted habit will assist with water management which is often the key to salinity control. Extremely salt-affected and bare land needs to be revegetated with halophytic plants such as *Atriplex* species (Malcolm 1993). As conditions become less severe, it will be possible to plant non-halophytic trees, shrubs and grasses.

Utilisation

Trees can be used for timber, pulp, firewood, fodder (e.g. *Acacia nilotica*, *Acacia saligna*), cut-flowers, honey and other products (e.g. leaf oils and tannins), shelter and shade, wind, water and watertable erosion control, wildlife corridors and aesthetics. The economics of farm forestry will be determined by such factors as the domestic and international market value of the tree products generated, distance from processing plants and/or ports and annual yield increment.

The use of shrubs and grasses depends upon the choice of species in reference to prevailing edaphic and climatic conditions of the area. Under good to moderate environmental conditions, shrub species could be used primarily for forage and fodder purposes. Branches of shrub species are also used for other purposes, such as match sticks, furniture and carvings. Both shrubs and grasses have been successfully and widely used for amelioration and reclamation of problem soils, and for lowering shallow watertables (Sandhu and Malik 1975; Abrol 1986; Sandhu and Qureshi 1986; Ahmad and Ismail 1993; Barrett-Lennard and Galloway 1996).

Evaluation, selection and breeding

Some genera, such as *Prosopis, Tamarix* and *Atriplex,* occur naturally on salt-affected soil and/or occur naturally within or near to coastal or inland sites where soils or groundwaters are saline. These genera contain species — termed halophytes — which have evolved several salt-tolerating mechanisms. In addition, several species can grow well in saline soils. These may or may not be halophytes. However, most tree, shrub and grass species are non-halophytes and they do not grow well on highly salt-affected land. Non-halophytes rely on avoidance mechanisms that include restricting the entry of salt into the root and transport in the xylem, and retaining most of the salt that enters the shoot in old leaves (Yeo 1994).

Detailed evaluation through selection programs is required before species can be considered for large-scale planting in particular locations. A program of screening (to capture naturally-occurring genetic variability), selection and improvement is required to increase the salt tolerance of a particular species if it is required for managing saline land for either amelioration or productive use, especially commercial production. The choice of the species for planting at a given site will depend on a number of factors, including the purpose of revegetation, a wide range of site conditions —including the severity of salinity, waterlogging and sodicity (Choukr-Allah 1996) — and management issues (including silviculture and weediness). Screening procedures for evaluating a species can also differ between species, sites and, in particular, between researchers. A 'suitable' species at one place might not be acceptable for an another site, depending on the set of criteria with which the species has been evaluated.

Glasshouse studies aimed at evaluating salt tolerance of tree seedlings at the species, provenance and family level have been reported (e.g. Aswathappa et al. 1986; Thomson et al. 1987; Rhodes and Felker 1988; van der Moezel 1988, 1989, 1991; Allen et al. 1994;

Marcar et al. 1995a). Selected glasshouse- and field-grown plants have also been cloned and field evaluated (Bell et al. 1994; Morris 1995). During the last 10–20 years a number of well-designed tree species evaluation trials on saline sites in several countries (including Australia and Pakistan) have enabled ranking on the basis of growth response to salinity (e.g. Marcar et al. 1994; Dunn et al. 1995) and, to a lesser extent, waterlogging and sodicity (e.g. Samra et al. 1991). Even in these studies, however, the impact of site-specific interacting factors, such as waterlogging or water deficit, has rarely been evaluated, let alone isolated. At this stage conventional tree selection and breeding provide the best chance for improvement in salt tolerance of trees (Allen et al. 1994). Open-pollinated seed orchards have been recently established for *Eucalyptus camaldulensis* and *Acacia ampliceps* in Pakistan (Naqvi et al. 1996), and for *E. camaldulensis* and *Eucalyptus occidentalis* in Australia.

Screening programs for shrub halophytes, both in Australia and Pakistan (e.g. Malcolm and Swaan 1989; Ismail et al. 1993) have resulted in a standard screening procedure (ADAPT 2) (Malcolm 1996). This program uses a set of criteria including establishment ability, survival, growth habit, productivity, recovery after grazing, flower and seed production and seed viability. It appears that the most important factors in determining the suitability of a species will depend upon the extent and type of salinity/sodicity, other soil characteristics and climatic conditions.

Table 2 lists selected tree species reported to be tolerant of varying levels of soil salinity, sodicity and waterlogging. Selection of species for inclusion in this table was based on information available to the authors; it is acknowledged that several species of importance may have been omitted. Some selected shrub and grass species reported to have different degrees of salt tolerance are listedin Table 3.

Table 2. **Rating of selected tree and shrub species to root-zone soil salinity, sodicity and waterlogging. Salinity is expressed as EC_e in dS/m [moderate (4–8), high (8–16), severe (>16)]. Soil sodicity is expressed in terms of pH [moderate (8.0–9.0), high (9.0–10.0) and severe (>10.0)]. Modified from Marcar and Khanna (1997).**

Species	Salinity (EC_e)	Sodicity	Waterlogging
Acacia ampliceps *	Severe [b]	Severe [b,k]	No [b]
A. auriculiformis *	Moderate [a]		Yes [i]
A. cyclops	High [b]		
A. machonochiena	Severe [l]	Severe [l]	
A. nilotica	Moderate [a]	High [a]	
A. salicina	High [b]	High [b]	
A. saligna	Moderate [a,b]	Moderate	
A. stenophylla	Severe [b]	Severe [b,k]	Yes [b]
A. tortilis	Moderate [d]		
Ailanthus excelsa	High [a]	Moderate [f]	
Albizia lebbeck	Moderate [a,c]	Moderate [a,f]	
A. procera		Moderate [f]	Yes [i]
Azadirachta indica	Moderate [a,c]		
Butea monosperma	Moderate [a,c]	High [f]	
Casuarina cristata	Moderate/high [b]	Moderate [b]	Yes [b]
C. cunninghamiana	Moderate/high [a,b,c,e]		Yes [b]
C. equisetifolia	Moderate [a]	High [a,f]	Yes [b]
C. glauca *	High [a,b,e]	Moderate/high [b]	Yes [b]
C. obesa *	High/severe [b,j]	High [b,k]	
Cepparis aphylla	High [a]		
Conocarpus lancifolius	High [a]		
Dalbergia sissoo	Moderate [a]	Moderate/high [f]	
Eucalyptus brassiana	Moderate [e]		
E. camaldulensis *	Moderate/high [a,b,d,l]	High [a,b,k]	Yes [b,h,i]
E. citriodora	Moderate [a]		
E. grandis *	Slight/moderate [b,e]		Yes [b]
E. coolabah	Moderate [b]	High [l]	
E. moluccana	Moderate/high [b,e]		
E. occidentalis *	High [b,g]		
E. platypus	Moderate [b]	Moderate [b]	Yes [b]
E. raveretiana	High [e]		
E. robusta	Moderate [e]		
E. rudis	High [b]		
E. spathulata	High [b]	Moderate [b]	Yes [b]
E. tereticornis *	Moderate/high [a,b,e]	High	
Leucaena leucocephala	Low/moderate	Moderate [f]	
Melaleuca arcana	Moderate [b]		
M. bracteata	Moderate/high [b,e]	Moderate/high [b]	Yes [i]
M. halmaturorum	Severe [b]	Moderate [b]	Yes [b]
M. lanceolata	High [b]		Yes [b]
M. leucadendra	High [b]		Yes [b]
M. quinquinervia	Moderate [b]	Low [l]	Yes [b]
Parkinsonia aculeata	Moderate [a]		Yes [b]

Table 2. **(cont'd) Rating of selected tree and shrub species to root-zone soil salinity, sodicity and waterlogging. Salinity is expressed as EC_e in dS/m [moderate (4–8), high (8–16), severe (>16)]. Soil sodicity is expressed in terms of pH [moderate (8.0–9.0), high (9.0–10.0) and severe (>10.0)]. Modified from Marcar and Khanna (1997).**

Species	Salinity (EC_e)	Sodicity	Waterlogging
Pinus halepensis	Moderate [a]		
Pongamia pinnata	Moderate [c]		
Populus euphratica	Moderate [a]		
Prosopis chilensis		High [k]	
P. juliflora	Severe [a,d]	High [k]	Yes [h]
Sesbania formosa	Moderate [l]		Yes [h]
S. grandiflora	Moderate [a]		Yes [i]
Tamarix aphylla	Severe [a,d]		Yes
T. articulata	Severe [a]		Yes [a]
Terminalia arjuna	High [a,c]	Moderate/high [f]	
Zizyphus jujube	High [a]		Yes [i]
Z. spina-vulgaris	High [a]		Yes [i]

Notes: Species marked with an asterisk (*) are known to exhibit marked provenance response on saline soils. Selected references are given for species classification, where available: [a]Gill and Abrol 1991; [b]Marcar et al. 1995b; [c]Yadav and Singh 1970; [d]Jain et al. 1985; [e]Dunn et al. 1995; [f]Yadav 1989; [g]Benyon et al. 1999; [h]Singh 1989; i. Vivekanandan 1989; [j]van der Moezel et al. 1988; [k]Hussain and Gul 1992; [l]Marcar et al. (unpublished data).

Table 3. **Grass and shrub species that have been evaluated for their salt tolerance and productivity. Modified from Ahmad and Ismail (1993).**

Less tolerant	Moderately tolerant	Highly tolerant
Grasses		
Cenchrus setigerus[b]	*Distichlis spicata*[f]	*Cynodon dactylon*[g]
Dichanthium annulatum[b]	*Leptochloa fusca*[a]	*Eleytrigia elongatum*[h]
Panicum turgidum[a]	*Sporobolus aeroides**	*Festuca elaitor*[g]
Pennisetum typhoides[c]		*Juncus acutus*[i]
Sporobolus arabicus[a]		*J. rigidus*[i]
		Paspalum vaginatum[g]
		Puccinellia ciliata[j]
		P. distans[k]
		Spartina alterniflora[f]
		Sporobolus helvolus[h]
Shrubs		
Clitorea ternatea[d]	*Atriplex cinerea**	*Arthrocnemum fruticosum*[g]
Indigofera oblongifolia[a]	*A. patula**	*Atriplex amnicola*[l,n]
Leucaena leucocephala[a]	*A. undulata**	*A. lentiformis*[l]
Sesbania aegyptica[e]	*Kosteletzkya virginica*[f]	*A. nummularia* [o]
*S. bispinosa**		*Maireana brevifolia**
S. sesban[a]		*Salsola iberica*[m]
		Tamarix aphylla[l]

Source: Modified from Ahmad and Ismail (1993). Notes: Relevant references are: [a]Ahmad et al. 1986; [b]Ahmad 1997; [c]Anon 1990; [d]Saeed 1994; [e]Ahmad and Zaheer 1994; [f]Gallagher 1985; [g]Pasternak et al. 1986; [h]Le Houérou 1986; [i]Zahran et al. 1993; [j]Marcar 1987; [k]Harivandi et al. 1982; [l]El-Razek 1993; [m]Fowler et al. 1985; [n]Aslam et al. 1986; [o]Greenway 1968; * Ismail et al. (unpublished data).

Ameliorative measures and site management

Since direct seeding of trees into salt-affected sites is usually unreliable, planting of nursery-grown seedlings is preferred. This is also the case for shrubs and grasses since the most difficult aspect of establishment is the seeding process (e.g. Barrett-Lennard et al. 1991). Often these species have very small seeds and therefore a large bulk of seed material is required to cover a reasonably-sized area. However, salt-tolerant shrubs have been successfully direct-seeded (Springfield and Bell 1967; Franclet and Le Houérou 1971; Orev 1971; Malcolm et al. 1980). Mechanised seed sowing has been an another step towards economic feasibility and the 'Mallen Niche Seeder' (Malcolm and Allen 1981) has been quite successful in Australia. Sprayed coatings and seed washing have increased chenopod establishment on saline soils (Malcolm et al. 1982; Malcolm and Swaan 1985).

Whilst the use of pre-conditioning treatments (e.g. exposure to increasing salt levels or to waterlogging) in the nursery may confer advantages upon planting of trees, no significant gains in survival and growth have yet been reported (e.g. Hoy et al. 1994). Inoculation of *A. ampliceps* with salt-tolerant *Rhizobium* increases seedling growth in the glasshouse (Zou et al. 1995) and of *Casuarina cunninghamiana* increases growth in the field (Marcar 1996).

Several land preparation techniques and cultural operations that have shown significant improvements in tree performance, in particular, are (i) ripping or augering of planting holes (Gill and Abrol 1991), (ii) use of mounds in areas affected by waterlogging (Ritson and Pettit 1988; Yadav 1989; Hoy et al. 1994),(iii) application of mulch (Marcar et al. 1991) and (iv) addition of organic and inorganic fertilisers (Grewal and Abrol 1986; Singh et al. 1989).

POTENTIAL FOR LAND REHABILITATION

Two main benefits that may be provided by trees, shrubs and grasses planted within areas that are salt-affected and/or have high saline watertables are: (i) lowering of saline watertables, through either control of accessions to or withdrawal from groundwater; and (ii) use of saline drainage water or pumped ground water. Trees planted alongside irrigation channels may also help keep watertables down by intercepting channel seepage. This is particularly important where canals and channels are unlined.

Many species will probably use water from watertables (and soils) with EC up to 10 dS/m without marked reduction in transpiration rate. However, the proportion of ground water directly used by trees and shrubs has been measured in only a few studies, particularly using isotopic means (e.g. Thorburn et al. 1993). With such knowledge it may be possible to determine salinities at which particular species can no longer use water (Thorburn 1996). In Australia, the best examples of lowering of saline watertables under and/or near plantations and agroforests are from dryland sites in Western Australia (Schofield et al. 1989; George 1990; Greenwood et al. 1994) and in Victoria (Morris 1991), and from irrigated sites in Victoria (2 m watertable lowering for an 8-year-old eucalypt plantation—Heupermann 1995). Important determinants of success will include tree density, the proportion of the area planted, crown cover, root architecture, soil hydraulic characteristics and ground water dynamics. One successful example is from an alley farming trial near Boundain, Western Australia (Schofield et al. 1989; Scott and Crossley 1996), where several salt-tolerant eucalypts, planted as single rows with alley spacings of 25 and 12.5 m (80 and 160 stems/ha) have lowered the watertable by about 1–2 m relative to annual pasture.

There is some suggestion that the control over watertable rise by tree plantations may be effective only in the short to medium term, because of the potential for salts to increase in the root-zone. However, there are few published data for changes in groundwater and soil salinity as a consequence of groundwater lowering. Depending on soil properties (e.g. clay content), active rooting depth, lateral and vertical groundwater flow, salt diffusion in the saturated zone and the degree of leaching possible, it is expected that salt will accumulate somewhere in the soil–groundwater system, because salt is usually actively excluded by plant roots. Although soil and groundwater salinity beneath eucalypt plantations established over a shallow saline watertable has been shown to increase in different parts of the root-zone (Heupermann 1995; Stolte et al. 1996), other studies have suggested that salt concentrations have not continued to increase because of leaching by watertable fluctuations and seasonal and episodic rainfall events (Morris 1991; Thorburn 1996).

Re-use of shallow groundwater (pumped via 'tubewells' or bores) or saline drainage water for tree production systems provide an increasing challenge for foresters and agroforesters. These systems are generally better targeted to sandy/loamy textured soils because of the danger associated with excessive salt accumulation in clay-dominated soils. Pilot studies have been established near Hyderabad in Pakistan (Yaseen and Nizamani 1993), in the San Joaquin Valley of California (Tangi and Karajeh 1993) and in Victoria, Australia (Heath and Heupermann 1994). In the latter two cases, agroforestry systems are being tested to determine the feasibility of reducing the volume of saline drainage water for ultimate disposal. The success of these plantations will depend on such factors as how well salt concentrations in the root-zone can be managed and on the salt tolerance of the species grown, and the concentration of sodium carbonate in the irrigation water and the degree of soil sodicity increase.

If leaching fractions are relatively high, soils are permeable and water tables are deep, the potential for salt accumulation due to irrigation with saline water will be relatively small (e.g. in a woodlot on loamy sand in Loxton Irrigation Area, South Australia (Sweeney and Frahn 1992)). If, however, water tables are high, drainage is limited and soils are less permeable, salt accumulation at the top of the capillary fringe (phreatic surface) can be very high (Heupermann 1995). Evidence from limited studies of tree plantations on or near dryland discharge seeps suggests that salt build-up in or below the root zone is much less than expected from simple models based on annual salt input and annual evapotranspiration (Schofield and Bari 1991).

Sodic soils may be ameliorated by activity of plant roots and soil micro-organisms. The production of carbonic and other acids resulting from root respiration and organic matter decomposition can liberate appreciable quantities of soluble Ca from insoluble calcium carbonate, allowing for continued exchange of Na with Ca. Coupled with adequate leaching, using low-Na irrigation water and/or monsoonal rain, much of the Na can be removed from the root-zone. Successful examples of this process include plantings of *Leptochloa fusca* (kallar grass) (Mahmood et al. 1994), *Acacia nilotica* (Gill et al. 1987) and agroforestry plantings of *Prosopis juliflora* and *Leptochloa fusca* (Singh 1995). Gill et al. (1987) found significant reductions in soil pH and electrical conductivity for both *A. nilotica* and *Eucalyptus tereticornis* but greater increase in organic carbon under *A. nilotica*. Farmers in the Sindh province of Pakistan have long known that saline–sodic soils can be improved by planting closely spaced, short rotations of *A. nilotica*, in a management system called 'hurries', prior to cropping; Keerio (1993) has documented some physical and chemical changes related to this improvement.

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Glossary and abbreviations

AAR	Average annual rainfall.
Agroforestry	Land use systems in which woody perennials are grown with agricultural crops and/or pastures on the same unit of land either in the form of spatial arrangement or in sequence.
Biomass (Productivity, Dry matter, Yield)	The amount of material produced by a plant in terms of fresh or dry weight. Plant biomass is an indicator of plant growth.
Bladders	Specialised structures originating from the epidermal cells of leaves in certain plant species. The structures are used to remove excess salts from within leaves in some genera of the Chenopodiaceae, essentially in *Atriplex,* some genera of *Salsola*, in most species of *Chenopodium* and in all species of *Obione* and *Halimione.*
Bluebush	Common name for species from the genus *Maireana.*
Brackish	Synonym for moderately saline; usually used for surface water that passes through the soil profile solubilising the soluble salts and adding to the ground water.
Chenopod	Common name for members of the family Chenopodiaceae, including *Atriplex, Salsola, Chenopodium* etc.
DBH	Diameter at breast height (usually ca. 1.3 m), a measure of the horizontal growth of trees and often well correlated with leaf area.
Desert	Area of land with very little rainfall and usually high evaporation, arid soil and little or no vegetation.
Desertification	Process of forming desert—may be due to any climatic or edaphic conditions.
Digestibility	Term used in reference to forage quality for animals. Proportion of food that can be digested and is therefore of value to the animal with respect to health and weight increase.
DM (Dry matter)	Components of vegetation left after drying. Term usually used for forage when dried (oven or air) as a result of which moisture is removed and only organic matter and inorganic salts are left. Forage yields are usually expressed as weight of dry matter per unit area.
DW	Dry weight.

EC (Electrical conductivity)	Term used to express the amount of soluble salts in water or soil solution. This is derived from the resistance offered by the salts in solution or water when an electric current is passed through. The most appropriate EC measure in relation to plant growth is EC_e (EC of water extracted from a saturated soil paste). Other often-used EC measures are $EC_{1:5}$ (EC of a 1:5 soil:water extract) or $EC_{1:2}$.Typical unit used is dS/m (decisiemens per metre) 1 dS/m = 1 mmho/cm or 1 mS/cm = 1000 mS/cm 1 dS/m of soil solution = 640 ppm soluble salts or 0.36 MPa. (A good reference is Richards 1954, page 22.)
ESP	Exchangeable sodium percentage (see 'Sodicity').
Establishment	Process through which new plants from seed to seedling stages (or later) are formed. In terms of agronomy, the word is used for special techniques applied under field conditions which facilitate seedling growth and lower mortality rates.
Evapotranspiration	The loss of water from combined soil and plant surfaces. The term is used when expressing water loss in an area with vegetation, thus showing the total moisture removal through the soil surface and via plants.
Feed value	The nutritional value of forage/fodder. This is estimated as the quantity of organic matter present, digestible matter, nitrogen content etc.
Fertilisers	Addition of mineral elements in inorganic or organic forms (e.g. farm yard manure—FYM) to promote plant growth. Fertilisers are usually used to provide important essential nutrients such as nitrogen, phosphorus and potassium.
Forage	Green material of some plant species that provide feed material for animals. Most of the members of Gramineae are used for this purpose. The material may be provided directly to grazing animals, or cut and carried. Dried materials are also provided to animals and referred to as 'fodder'.
Fuelwood	Plant material that can be used for burning purposes: usually the medium to thick portion of wood of shrubs and/or trees. The heat that is produced due to burning is measured in kilojoules, calories or equivalent units.
FW	Fresh weight.
FYM	Farmyard manure.
GA3	Gibberellic acid.
Germination	Process through which a seed starts to grow and is converted into a seedling. Germination usually requires favourable moisture, light and temperature conditions.
Glands	Specialized structures in epidermis of leaves or extension of epidermal layers that store and/or excrete inorganic salts. (See 'Bladders'.)

Grass	Monocotyledenous plant species belonging to family Gramineae (Poaceae). Leaves are in the form of blades and occur in tufts. Most of the species are highly palatable and digestible for animals and are usually used as forage/fodder. Regeneration is both through sexual and asexual (vegetative propagation) means.
Groundwater discharge	The removal of groundwater by evapotranspiration from the soil surface.
Groundwater recharge	The addition of water to the groundwater system. The most common mode of water addition is through rainfall or irrigation water which filters through the soil profile to add to the water level.
Halophytes (Euohalophtes, Miohalophytes, Pseudohalophytes)	Plant groups which grow naturally in high concentrations of salts. They require a certain amount of salts for optimum growth.
Legume	Common name for members of Leguminoseae. Characterised by producing seeds in pods. The number of seeds in each pod varies for different species. The family is also characterised by having special structures (nodules) in plant roots; these nodules are formed in association with bacteria (*Rhizobium* spp.), as a result of which atmospheric nitrogen is trapped and converted to various nitrogenous forms (ammonia, ureides and amides) which are available to the host plant. The host plant symbiotically provides carbohydrate to the bacteria for its maintenance. (Also known as 'symbiotic nitrogen fixation').
Mallee	Common name for some species of *Eucalyptus* which have a multi-stemmed habit.
Mesquite	Common name for *Prosopis* species.
Nitrogen fixation	Process through which atmospheric nitrogen is available to the plants. Occurs through asymbiotic and symbiotic means, the latter being more important for plants. Symbiotic associations occur both in leguminous and non-leguminous plants in association with bacteria (*Rhizobium* spp.) and actinomycetes (*Frankia* spp.), respectively. (See 'Legume'.)
Nodule	Special structure formed in the roots of nitrogen-fixing plants after associated micro-organisms (*Rhizobium* or *Frankia*) have invaded the host plant. After nodule formation takes place, leghaemoglobin biosynthesis takes place and, as a result, atmospheric nitrogen is fixed into ammonia and other nitrogenous products (ureides and amides).
OM	Organic matter.

Osmoregulation	Process through which cells make osmotic adjustments to cope with low water potential of the soil solution by salt uptake (primarily into vacuoles) or by biosynthesis of compounds (like sugars, proline, quarternary ammonium compounds) in substantial amounts.
Palatable	Word meaning 'readily grazed by animals'. Animals may choose to eat palatable fodders because of their higher nutritive value or because they contain low concentrations of compounds like phenolics and tannins that give plant materials an unpleasant taste.
Rehabilitation	Process through which a barren, unproductive area and/or degraded area can be restored to become productive. It includes agronomic and social factors.
Rhizobium	Group of bacteria that make symbiotic associations with roots of certain leguminous species to fix atmospheric nitrogen. (See 'Legume' and 'Nitrogen Fixation'.)
Salinity	Presence of soluble salts in soil and water. Measured in different ways, e.g. parts per million (ppm), molarity (e.g. mM = mol/m^3). Can be related to electrical conductivity. (See EC.)
Salt-affected	Areas where presence of soluble salts have rendered the land less productive or non-productive.
Salt exclusion	Physiological process in plants as a result of which excessive quantities of salts cannot enter the root system. The processes mostly operate in the membrane system of the roots and are both active and passive.
Salt excretion	Process through which excess soluble salts are removed from the plants to the soil. Usually this takes place through special structures on leaves (salt glands, bladders, trichomes etc.). Common in chenopod genera, such as *Atriplex*, *Suaeda* and *Salsola*.
Salt tolerance	A general term used to express the tolerance of a plant to salt stress. Species differ significantly from each other in salt tolerance, from non salt-tolerant (salt-sensitive non-halophytes eg. in many crop species) to highly salt-tolerant (halophytes). A useful approach is to express in terms of 'threshold salinity level' (the maximum salt level that a species could tolerate without any reduction in yield) and the degree of further reductions in yield with increase in salinity.
Saltbush	Common name for the members of the genus *Atriplex.*
SAR	Sodium adsorption ratio. (See 'Sodicity'.)
Screening	Method(s) by which the genetic material is assessed for tolerance to a range of stresses and also for such attributes as productivity, nutritional quality and economic return.

Shrubs	Group of perennial plant species intermediate between the herbs (small non-woody plants) and small trees (woody plants). The plants may or may not have woody stems and hence can be used as fuelwood or for grazing purposes, respectively. Leaves are also used as forage (e.g. *Atriplex lentiformis, Suaeda fruticosa, Zizyphus nummularia*).
Sodicity (SAR, ESP)	Term used to express the proportion of sodium (Na) to other cations in soil. The toxicity of sodium is far greater than that of calcium (Ca), potassium (K) or magnesium (Mg); the latter ions can minimise the impact of Na in plants and soils. When gypsum (calcium sulphate) is added to sodic soils, Na ions are replaced by Ca in the soil matrix. Under these conditions, there can be restoration of soil structure, and soluble salts in the soil solution can be leached out using good quality water. Sodicity is commonly measured as sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP). By definition: (i) SAR = Na/(Ca + Mg)/2 and (ii) ESP = exchangeable Na/cation exchange capacity. The term 'alkali' soil is often used as a synonym for sodic soil.
Sodium chloride	One of the salts commonly found in saline soil and water. Sodium (Na) and chloride (Cl) are highly toxic when found in excess amounts; they impair normal metabolic processes in plants. Their presence in animal feeds not only reduces the quality of feed but also causes health problems in animals. 100 mol/m^3 NaCl = 100 meq/L = ca. 5.85 g/L.
Soil amendment	Addition of materials to soils that can reduce specific toxicities, increase fertility of soil, increase moisture availability in soil, improve soil structure etc. Application of fertiliser, mulches, moisture gels and gypsum are examples of soil amendments.
Trees	Group of perennial plant species that have woody structure and usually greater than 5 m tall (cf. 'Shrub'). Used primarily for wood products, including furniture, timber and fuelwood. In addition, leaves of some trees are also used for forage, medicine, ground cover, wind breaks etc.
Water consumption/use	Amount of water used by plants during growth (synonym = 'transpiration'). Often measured as the amount of water used in a day, month or cropping season over an area (mm/day or mm/year).

Water-use efficiency Relationship between crop dry weight and the total crop transpiration gives an estimate of the water use efficiency, often expressed as total dry biomass per litre of water transpired.

Waterlogging A condition when soil pores are filled with water thus inhibiting gas exchange in soil and resulting in very low oxygen concentrations. Growth of most plants and many soil micro-organisms is inhibited and fermentation products are present. Also used to describe a condition when the watertable is at or close to the ground surface.

Chemical abbreviations

Ag	silver	$MgSO_4$	magnesium sulfate
Al	aluminium	Mn	manganese
ATP	adenosine triphosphate	mRNA	messenger ribonucleic acid
B	boron	N	nitrogen
Br	bromine	N_2	atmospheric nitrogen
C	carbon	Na	sodium
CO_2	carbon dioxide	NaCl	sodium chloride
Ca	calcium	Na_2CO_3	sodium carbonate
$CaCl_2$	calcium chloride	NAD	nicotinamide adenine dinucleotide
$CaCO_3$	calcium carbonate	NADP	nicotinamide adenine dinucleotide phosphate
$CaSO_4$	calcium sulfate	$NaHCO_3$	sodium hydrogen carbonate
CaO	calcium oxide	NaOH	sodium hydroxide
Cl	chorine	Na_2SO_4	sodium sulphate
Cs	caesium	NH_4	ammonium
Cu	copper	NH_4NO_3	ammonium nitrate
DNA	deoxyribonucleic acid	NO_3	nitrate
Fe	iron	O_2	atmospheric oxygen
H	hydrogen	P/P_i	phosphorus/inorganic phosphorus
H_3BO_3	boric acid	PO_4	phosphate
K/K	potassium/potassium ion	Rb	rubidium
KCl	potassium chloride	S	sulfur
K_2SO_4	potassium sulfate	Se	selenium
Li	lithium	Si	silicon
Mg	magnesium	SO_4	sulphate
$MgCl_2$	magnesium chloride	Zn	zinc

Trees, Shrubs and Grasses for Saltlands

Abdel-Rahman, A.A., El-Shourbagy, M.N. and El-Monayeri, M.O. (1972). Botany Department, Faculty of Science, Cairo University, Egypt. Salinity effects on carbohydrates and ion content in some desert fodder plants. Bulletin No. 45, 79–96. Faculty of Science, Cairo University, Egypt.

Reports changes in total available carbohydrate, total N, Na, K, Ca, Mg, Fe, P and Cl concentrations in solution-culture grown plants of various native and introduced desert fodder species (*Panicum, Oryzopsis, Chloris, Crotalaria, Medicago*) treated with NaCl (approx. –0.04 to 1.0 MPa).

Abdul-Halim, R.K. (1986). Department of Soil and Land Reclamation, Center for Agriculture and Water Resources Research, Council for Scientific Research, PO Box 2416, Baghdad, Iraq. Soil salinization and the use of halophytes for forage production in Iraq. Reclamation and Revegetation Research, 5:75–82.

This paper deals with revegetation programs for saline land in the Mesopotamian plain (20% salt-affected), to provide fodder and control soil erosion, and provides preliminary results of trials with salt-tolerant shrub species.

Abdul-Halim, R.K., Al-Badri, F.R., Yasin, S.H. and Ali, A.T. (1990). Department of Soil Land Reclamation, Center for Agriculture and Water Resources Research, Scientific Research Council, PO Box 2441, Baghdad, Iraq. Survival and productivity of Chenopods in salt affected lands of Iraq. Agriculture, Ecosystems and Environment, 31:77–84.

This paper reports on a trial with ten shrub species on a highly saline site [EC_e(0–10 cm) approx. 62 dS/m] at Dalmaj, 200 km south-east of Baghdad, between 1982 and 1986. *Atriplex lentiformis* had the best survival and growth with *Maireana brevifolia* having the poorest survival. Best growth was made by *A. lentiformis*. All species except *A. amnicola* produced seeds, and volunteer seedlings were observed from *A. semibaccata, A. lentiformis, A. halimus, A. nummularia* and *A. undulata*. Dry matter production ranged from 17 800 kg/ha for *A. lentiformis* to 360 kg/ha in *Salsola rigida* over the four-year period.

Abdullah, M., Qureshi, R.H. and Ahmad, N. (1986). Department of Soil Science, University of Agriculture, Faisalabad, Pakistan. Responses of *Leptochloa fusca* to various types of substrate salinities. In: Prospects for biosaline research (Ahmad, R. and San Pietro, A., ed.), 115–123. Proceedings of the USA-Pakistan Biosaline Research Workshop, 22–26 September 1985. Department of Botany, University of Karachi, Karachi, Pakistan.

The response of *Leptochloa fusca*, a salt-tolerant nutritive forage grass, to various isosmotic substrate concentrations of NaCl, Na_2SO_4, $CaCl_2$, $MgCl_2$ (0.5, 0.75 and 1.0 MPa) and $MgSO_4$ (0.25 and 0.5 MPa) was studied in gravel culture. NaCl caused least inhibition in growth followed in order by Na_2SO_4, $CaCl_2$ and $MgCl_2$. High uptake of salts (monovalent > divalent) contributed predominantly to osmotic adjustment while efficient excretion of salts through salt glands (as seen in scanning electron micrographs) and increased succulence were used as mechanisms to maintain a favourable ionic balance.

Abdulrahman, F.S. and Williams III, G.J. (1981). Department of Botany, Washington State University, Pullman, Washington 99164, USA. Temperature and salinity regulation of growth and gas exchange of *Salicornia fruticosa* (L.) L. Oecologia (Berl.), 48:346–352.

Salicornia fruticosa used in this glasshouse study was collected from a salt marsh on the Mediterranean sea coast in Libya. Presents data on changes in growth, net photosynthesis, dark and light respiration, stomatal properties and transpiration in relation to temperature and NaCl (0–855 mol/m^3). Maximum growth was at 171 mol/m^3 NaCl at 20/10°C and at 342 mol/m^3 NaCl at 30/15°C. In general both temperature and salinity increased the mesophyll resistance to CO_2 influx. Adaptation to the warm saline habitat of the Mediterranean sea coast is linked to maintenance of relatively high photosynthesis at moderate NaCl concentrations over a broad range of shoot temperatures.

Abougazia, H.A. and Abouelkhair, K.S. (1989). Department of Forestry and Wood Technology, Alexandria University, Alexandria, Egypt. Effect of salinity on seed germination of some *Casuarina* species and *Eucalyptus camaldulensis* Dehn. Alexandria Journal of Agricultural Research, 34:99–110.

Provides information on *Casuarina glauca*, *C. equisetifolia*, *C. cunninghamiana*, *C. glauca* × *C. cunninghamiana* and *C. glauca* × *C. equisetifolia* hybrids and *Eucalyptus camaldulensis*.

Abrol, I.P. (1986). Central Soil Salinity Research Institute, Karnal 132 001, India. Fuel and forage production from salt affected wasteland in India. Reclamation and Revegetation Research, 5:65–74.

This paper describes the distribution and characteristics of typical salt-affected soils. Prospects are evaluated for planting these areas with fuel-wood and forage species. The need to evaluate social and economic factors is also considered.

Abrol, I.P. and Sandhu, S.S. (1985). Central Soil Salinity Research Institute, Karnal 132 001, India. Growth responses of *Eucalyptus tereticornis* and *Acacia nilotica* to selected methods of site preparation in a highly sodic soil. The International Tree Crops Journal, 3:171–184.

Growth responses of *Eucalyptus tereticornis and Acacia nilotica* at 16 months in two experiments showed that using auger holes of dimensions 15 cm × 180 cm and filled with a mixture of 3 kg gypsum and 8 kg farmyard manure appeared to be a promising method for establishing plantations of both species in highly deteriorated sodic soils.

Ackerson, R.C. and Youngner, V.B. (1975). Department of Plant Science, California University, Riverside, CA 92502, USA. Responses of bermuda grass to salinity. Agronomy Journal, 67:678–681.

In solution-culture experiments, net photosynthesis and root DW of bermuda grass (*Cynodon* hybrid) 'Santa Ana', grown at varying salinities from 0 to 160 meq/L NaCl + $CaCl_2$ (1:1 mixture) or 0 to 320 meq/L K_2SO_4, were not affected by treatments, but leaf water potential, osmotic potential and shoot growth decreased with increasing salinity. Changes in shoot and root Na, K, Ca and Mg concentrations in response in treatments are documented. Total non structural carbohydrate increased in shoots but not roots under salt treatment.

Agami, M. (1986). Department of Biology, The George S. Wise Faculty of Life Sciences, Tel Aviv University, Tel Aviv 69978, Israel. The effects of different soil water potentials, temperature and salinity on germination of seeds of the desert shrub *Zygophyllum dumosum*. Physiologia Plantarum, 67:305–309.

The individual effects of different soil water potentials (–002 to –0.10 MPa), temperature (10–35°C) and NaCl concentration (0–516 mol/m^3) on seed germination of *Zygophyllum dumosum*, a common shrub in Israeli deserts, were investigated. At 20°C (optimal temperature), very low germination (0.5–1.5%) was observed at 258 mol/m^3 NaCl and higher.

Ahmad, I., Nawaz, R. and Niazi, K. (1977). Department of Botany, University of the Punjab, Lahore, Pakistan. Interaction of soil salinity and aeration on the performance of janter (*Sesbania aegyptica*) and guara (*Cyamopsis psoralioides*) as green manuring crops. Pakistan Journal of Science, 29:40–42.

Guara (*Cyamopsis psoralioides*) was found to have an overall better performance than janter (*Sesbania aegyptica*) as a green manure, both on normal as well as saline soils. Under saline conditions guara was found to be more sensitive than janter to soil aeration status.

Ahmad, I. and Wainwright, S.J. (1976). Department of Botany and Microbiology, University College, Swansea, UK. Ecotype differences in leaf surface properties of *Agrostis stolonifera* from salt marsh, spray zone and inland habitats. New Phytologist, 76:361–366.

The properties of the leaf surface associated with wettability were studied for excised leaves of pot-grown plants of *A. stolonifera* from salt marsh, spray zone and inland habitats in South Wales. Leaves of the maritime ecotypes retained less salt than the inland ecotype after immersion in salt water, whereas retention of salt after spraying was highest by leaves of the inland ecotype. Differences in retention of salt were correlated with differences in wettability and these differences were related to differences in the structure and distribution of extracuticular waxes on the surfaces of the leaves.

Ahmad, I. and Wainwright, S.J. (1977). Department of Botany and Microbiology, University College, Swansea, UK. Tolerance to salt, partial anaerobiosis, and osmotic stress in *Agrostis stolonifera*. New Phytologist, 79:605–612.

The use of a rooting technique and growth analysis agreed well during assessment of the NaCl tolerance of *Agrostis stolonifera* clones derived from salt marsh, spray zone, and inland habitats, grown in solution culture. The order of tolerance was: salt marsh > spray zone > inland. Salt marsh plants were the most tolerant to low dissolved O_2 concentrations in the culture solution. The pattern of response to polyethylene glycol (PEG) 6000 (inert osmoticum) was similar to NaCl.

Ahmad, I., Wainwright, S.J. and Stewart, G.R. (1981). Department of Botany, Manchester University, Manchester, UK. The solute and water relations of *Agrostis stolonifera* ecotypes differing in their salt tolerance. New Phytologist, 81:615–629.

> Describes experiments with clones of three *A. stolonifera* ecotypes grown in nutrient solution with NaCl from 0 to 300 mol/m^3. At high salinities, the inland ecotypes had greater reduction in shoot water content and root water uptake and higher Na and Cl concentrations than the saltmarsh ecotype. Concentrations of proline, asparagine, glutamine, serine and glycinebetaine increased in response to salinity, especially in the salt marsh ecotype. The inland and spray zone ecotypes had marked decreases in aspartate and glutamate concentrations when grown at high salinities. Responses to polyethylene glycol and mannitol (inert osmotica) are presented.

Ahmad, R. and Ismail, S. (1991). Department of Botany, University of Karachi, Karachi 75270, Pakistan. Consideration of crop and soil management in biosaline agriculture. In: Plant salinity research: New challenges. (Choukr-Allah, R. ed.), 435–443. Proceedings of the International Conference on Agricultural Management of Salt-affected areas held in Agadir, Morocco.

> Observations and results are presented on the growth of beetroot, potato, lettuce (vegetables), *Sporobulus* and *Atriplex* species (forage), and *Azadirachta* and *Prosopis* (fuel-wood trees), using highly saline underground water for irrigation in coastal sandy deserts. Possible cultivation practices and irrigation methods to diminish salinity hazards are described.

Ahmad, R. and Ismail, S. (1992). Department of Botany, University of Karachi, Karachi 75270, Pakistan. Provenance trials in Pakistan: a synthesis. In: Productive use of saline lands. (Davidson, N. and Galloway, R. ed.), 62–65. Proceedings of a workshop held at Perth, Western Australia, 10–14 May 1991. ACIAR Proceedings No. 42.

> The potential of forage halophytes (*Atriplex* and *Maireana*) for revegetating saline/sodic soils in Pakistan is reported. The six sites chosen for the provenance trials were typical of degraded saline land in each region and differed greatly in soil type, climate and land use. *A. lentiformis* was the most promising species since it was productive, had excellent forage production and a substantial woody component which could be valuable as domestic firewood.

Ahmad, R. and Ismail, S. (1995). Department of Botany, University of Karachi, Karachi 75270, Pakistan. Rehabilitation of high salinity tolerant plants under saline conditions. In: Biology of salt-tolerant plants. (Khan, M.A. and Ungar, I.A., ed.), Chapter 36, 325–330. University of Karachi, Karachi, Pakistan.

Based on experimental evidence, methods are proposed for the cultivation of salt-tolerant plants in saline wastelands or with irrigation using saline water in barren sandy areas of coastal regions in south-west Pakistan. Recent techniques for altering the genetic make-up of salt-susceptible plant tissues and for grafting shoot stock of salt-susceptible fruit trees onto the root stock of salt-tolerant plants are also discussed.

Ahmad, R. and Ismail, S. (1995). Department of Botany, University of Karachi, Karachi 75270, Pakistan. Pakistan's experience in the agricultural use of halophytic species. In: Halophytes and biosaline agriculture. (Choukr-Allah, R., Malcolm, C.V. and Hamdy, A., ed.), 349–359. Marcel-Dekker Inc., New York, USA.

A review of research efforts in Pakistan on selection of *Atriplex* species for growth and adaptation to salt-affected sites. *A. amnicola* and *A. lentiformis* were consistently ranked as good.

Ahmad, R., Ismail, S., Bodla, M.A. and Chaudhry, M.R. (1994). Department of Botany, University of Karachi, Karachi 75270, Pakistan. Potential for cultivation of halophytic crops on saline wastelands and sandy deserts in Pakistan to overcome feed gap for grazing animals. In: Halophytes as a resource for livestock and for rehabilitation of degraded lands, (Squires, V.R. and Ayoub, A.T., ed.), 223–240. Kluwer Academic Publishers, The Netherlands.

This paper provides an overview of the potential to grow forage crops (grasses, legumes, saltbushes and fodder beet) on saline land and in sandy deserts in Pakistan and indicates that high levels of biomass production can be achieved with halophytes.

Ahmad, R., Ismail, S. and Khan, D. (1986). Department of Botany, University of Karachi, Karachi 75270, Pakistan. Use of highly saline water for irrigation at sandy soils. In: Prospects for biosaline research (Ahmad, R. and San Pietro, A., ed.), 389–413. Proceedings of the US–Pakistan Biosaline Research Workshop, 22–26 September 1985. Department of Botany, University of Karachi, Karachi, Pakistan.

This paper reports on the growth and biochemical consituents of several tree and grass species in experiments conducted in drum pots as well as at sandy field sites on the Pakistan coast with saline water irrigation and application of chemical amendments.

Ahmad, R., Ismail, S. and Khan, D. (1991). Department of Botany, University of Karachi, Karachi 75270, Pakistan. Establishment of saltbush pastures and mesquite forest at coastal sandy belt of Markan using underground water for irrigation. In: Proceedings, three-day national conference on problems and resources of Markan coast and plan of action for its development, Pakistan Council for Science and Technology, Islamabad, 241–252.

This paper reports on prospects for cultivating plants for food, fodder and fuel using highly saline ground water.

Ahmad, R., Ismail, S., Moinuddin, M. and Shaheen, T. (1994). Department of Botany, University of Karachi, Karachi 75270, Pakistan. Screening of mesquite (*Prosopis* spp.) for biomass production at barren sandy areas using highly saline water for irrigation. Pakistan Journal of Botany, 26:265–282.

Seeds of indigenous *Prosopis juliflora* and *P. glandulosa* had better germination than those of *P. cineraria* and the exotic *P. pallida* under non-saline conditions as well as under NaCl (EC up to 30 dS/m). Seedling emergence was completely inhibited above EC 10 dS/m in *P. juliflora* and *P. cineraria* and above EC 15 dS/m in *P. glandulosa*. When irrigated with dilutions of seawater in soil-filled pots, *P. glandulosa* did not survive when irrigated with EC of 20 dS/m, whereas *P. juliflora* obtained from Brazil continued to grow at 40 dS/m. In a field experiment with saline water (EC 14–16 dS/m) irrigation, *P. juliflora* (D.L. Khan), *P. glandulosa* (Sujawal), *P. alba* and two South American species had greatest height and stem diameter.

Ahmad, R., Khan, D. and Ismail, S. (1985). Department of Botany, University of Karachi, Karachi 75270, Pakistan. Growth of *Azadirachta indica* and *Melia azedarach* at coastal sand using highly saline water for irrigation. Pakistan Journal of Botany, 17:229–233.

Azadirachta indica and *Melia azedarach* were grown on a coastal sand using 10–30% dilutions of saline water (4.5–14.0 dS/m) for irrigation. Plants irrigated with saline water showed an increase in moisture content and decrease in chlorophyll, sugar and protein content associated with an increase in proline. Under saline water irrigation, *M. azedarach* grew faster than *A. indica*.

Ahmad, R. and San Pietro, A. (ed.) (1986). Department of Botany, University of Karachi, Karachi 75270, Pakistan. Prospects for biosaline research. Proceedings of the US-Pakistan Biosaline Research Workshop, Department of Botany, University of Karachi, Karachi, Pakistan, 587 p.

The book is based on the papers presented during US–Pakistan Biosaline Research Workshop. The proceedings are divided into five different sections dealing with different aspects of salinity research. These include: (i) genetic bases of salt tolerance; (ii) physiological and biochemical bases of salt tolerance; (iii) agriculture and afforestation using highly saline water for irrigation; (iv) extraction of economically important compounds from marine algae and halophytes; and (v) proven technologies. The book provides useful information on both basic and applied aspects of salt tolerance.

Ahmed, P. (1991). Forest Department, 30 Bays Building, Sector 17, Chandigarh, India. Agroforestry: a viable land use of alkali soils. Agroforestry Systems, 14:23–27.

This paper provides an economic analysis of planting *Prosopis juliflora*, a multipurpose tree species, on alkaline wastelands of the Indo-Gangetic plain, including detailed costs, mean annual production of *P. juliflora* on soils of different pH, and calculation of an 9.5% internal rate of return, which is said to be reasonably high for degraded lands of strongly alkali soils and also viable within the economic structure of the region.

Akhter, J., Waheed, R.A., Niazi, M.L.K., Malik, K.A. and Naqvi, S.H.M. (1988). Soil Biology Division, Nuclear Institute for Agriculture and Biology, PO Box 128, Faisalabad, Pakistan. Moisture properties of a saline sodic soil as affected by growing kallar grass using brackish water. Reclamation and Revegetation Research, 6:299–307.

This paper reports that soil EC, pH, SAR and ESP were reduced after growing kallar grass (*Leptochloa fusca*) on a highly sodic (ESP 72), saline (EC_e 22 dS/m) soil (0–50 cm depth data) at Faisalabad, Pakistan. Observed responses are related to increases in soil moisture content in sub-soil layers and soil saturation percentage, and relative hydraulic conductivity which presumably facilitated leaching of salts. Dramatic changes occurred after one year and appeared to stabilise after four years.

Akilan, K., Farrell, R.C.C., Bell, D.T. and Marshall, J.K. (1997). Department of Botany, The University of Western Australia, Nedlands, WA 6907, Australia. Responses of clonal river red gum (*Eucalyptus camaldulensis*) to waterlogging by fresh and salt water. Australian Journal of Experimental Agriculture, 37:243–248.

Reports on the effects of waterlogging with fresh and salt water on growth, water use, stomatal conductance and net gas exchange of two clones (M80 and M66) of *Eucalyptus camaldulensis*, apparently differing in tolerance to salt and waterlogging under greenhouse conditions for 16 weeks. Whilst both clones tolerated extended periods of waterlogging with fresh water, differences were apparent in the presence of salt. Results are related to survival and water use of clones in salinised discharge areas of Western Australia.

Al-Homaid, N., Sadiq, M. and Khan, M.H. (1990). Research Institute, King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia. Some desert plants of Saudi Arabia and their relation to soil characteristics. Journal of Arid Environment, 18:43–49.

In studies of desert plant communities in the eastern province of Saudi Arabia, the nine most abundant species and soil samples were analysed for their mineral content. Three species, viz. the grass *Eragrostis* spp. and the shrubs *Hammada elegans* and *Zygophyllum coccineum*, were found on saline soils. Relationships between ion concentrations in soil solution and plant tissue are presented. *Z. coccineum* and *H. elegans* showed the best potential for sand stabilisation in saline environments.

Ala, F., Ismail, S., Ahmad, S. and Maryam, H. (1994). Department of Botany, University of Karachi, Karachi, Pakistan. Interactive effects of salinity and waterlogging on growth and biomass production in *Atriplex amnicola* Paul G. Wilson. Pakistan Journal of Botany, 26:293-309.

Reports on the interactive effects of salinity (EC of 0, 10 and 20 dS/m) and waterlogging (75, 100 and 125% water holding capacity (WHC)) on growth of *Atriplex amnicola* in soil-filled pots. Plant growth was better in silty loam than sandy loam soil, and was significantly reduced by combined EC of 20 dS/m and 125% WHC. Data on organic matter and ash contents in relation to soil type, salinity and waterlogging are provided.

Ala, F., Ismail, S., Ahmad, S. and Shaheen, R. (1995). Department of Botany, University of Karachi, Karachi, Pakistan. Effects of salinity and waterlogging on physiological processes and ionic regulation in *Atriplex amnicola*. Pakistan Journal of Botany, 27:283–295.

Reports on the effects of varying salinity and waterlogging levels on stomatal conductance, transpiration rate and ion concentrations in *Atriplex amnicola*. Stomatal conductance and transpiration were significantly reduced by salinity, with and without waterlogging, for plants grown in sandy loam. Na and Cl concentrations were highest in leaves followed by roots and lowest in stems. Salinity did not have any pronounced effect on oxalate content, whereas waterlogging had variable effects. (Refer previous reference.)

Albert, R. (1975). Pflanzenphysiologisches Institut der Universitat, A010 Wien, Austria. Salt regulation in halophytes. Oecologia, 25:57–71.

Reports on ion concentration and saturation water content in variously aged leaves of halophytes growing in saline soils east of Lake Neusiedlersee (Austria). Na and Cl concentrations were typically higher in older (mature) organs and K concentrations were lower. Saturation water content was markedly higher in succulent species (*Suaeda maritima, Chenopodium glaucum, Spergularia media, Lepidium crassifolium*) than in xerophytic monocotyledons (*Puccinellia distans, Crypsis aculeata, Bolboschoenus maritimus*): succulence was only able to prevent a rise in Cl concentrations in *S. maritima* and *C. glaucum*). Rosette plants (*Triglochin maritimum, Plantago maritima, Scorzonera parciflora, Aster tripolium*), with the ability to renew their leaves continuously throughout the growth period, had only small changes in saturation water content with increasing leaf age. It is suggested that shedding of old salt-saturated leaves is the main strategy for salt regulation in these plants.

Ali, Q., Wazir, M.Y. and Khan, M.H. (1987). Department of Botany, University of Peshawar, Peshawar, Pakistan. Phytosociological studies of Azakhel, District Peshawar. Pakistan Journal of Forestry, 37:9–19.

The natural occurrence of halophytic vegetation on waterlogged and saline land near Peshawar, Pakistan, in relation to soil physical and chemical properties is described. Four halophytic communities were identified: (a) *Desmostachya/Suaeda*, found on raised sites and with soil-soluble salts (SSS) 0.58–3.04% and no trees or shrubs; (b) *Saccharum/Desmostachya*, with SSS 0.22–0.70% and only graminaceous plants; (c) *Desmostachya/Saccharum/Alhagi*, with SSS 0.93–1.38%; and (d) a *Phragmites* community mostly confined to waterlogged soils (SSS 0.26–1.25%). It is suggested that reclaiming land in type (a) communities can be achieved by growing salt-tolerant trees, for site types (b) and (c) with salt-forage species, whilst site type (d) was considered not reclaimable.

Ali, S., Chaudhry, M.A. and Aslam, F. (1987). Barani Agricultural College, Rawalpindi, Pakistan. Growth of *Leucaena* at different salinity levels. Leucaena Research Report, 8:53.

Reports the effects of NaCl (5–20 dS/m) on height and nodule number for *L. leucocephala* seedlings in soil-filled pots in a glasshouse.

Allen, J.A., Chambers, J.L. and McKinney, D. (1994). National Biological Survey, National Wetlands Research Center, 700 Cajundome Boulevard, Lafayette, LA 70506, USA. Intraspecific variation in the response of *Taxodium distichum* seedlings to salinity. Forest Ecology and Management, 70:203-214.

In this glasshouse experiment, seedlings of 15 open-pollinated families of baldcypress (*Taxodium distichum*) were evaluated for their tolerance to combined salinity (0 to 8 g/L artificial seawater) and flooding (5 cm above soil surface). Ten of the families were from coastal locations in Louisiana or Alabama, USA, that were slightly brackish, whilst five were from non-saline locations. Families from brackish sources generally had greater total biomass, leaf area and tolerance (based on calculated survival and biomass indices) than families from freshwater sources at higher salinity.

Allen, J.A., Chambers, J.L. and Stine, M. (1994). National Biological Survey, National Wetlands Research Center, 700 Cajundome Boulevard, Lafayette, LA 70506, USA. Prospects for increasing the salt tolerance of forest trees: a review. Tree physiology, 14:843–853.

This useful review deals with: (i) evidence that substantial variation in salt tolerance exists within many species, mostly from glasshouse experiments, (ii) a brief discussion of the physiological basis of salt

tolerance in trees, emphasising Na and Cl exclusion and genetic control (including the potential importance of single gene control) and (iii) progress to date in improving salt tolerance of forest tree species, with emphasis on studies of the evaluation of 'salt-tolerant' clones in field trials.

Allen, J.A., Pezeshki, S.R. and Chambers, J.L. (1996). National Biological Survey, National Wetlands Research Center, 700 Cajundome Boulevard, Lafayette, LA 70506, USA. Interaction of flooding and salinity stress on baldcypress (*Taxodium distichum*). Tree Physiology, 16:307–313.

This paper includes information on species-level responses in baldcypress (*Taxodium distichum*), which is a dominant species of many coastal forested wetlands of southeastern United States, to flooding and salinity, alone and in combination, from various sources. Strategies for protection, management and restoration of coastal baldcypress forests are discussed.

Anderson W.P., Willocks, D.A. and Wright, B.J. (1977). Research School of Biological Sciences, Australian National University, Canberra ACT 2601, Australia. Electrophysiological measurements on the root of *Atriplex hastata*. Journal of Experimental Botany, 28:894–901.

Reports on changes in Na and Cl concentrations and membrane potentials of the cells of young, solution-grown seedlings of *Atriplex hastata* var. *salina* at several different NaCl concentrations.

Andrew, M.H., Noble, I.R. and Lange, R.T. (1979). Botany Department, University of Adelaide, Adelaide, South Australia 5000, Australia. A non-destructive method for estimating the weight of forage on shrubs. Australian Rangeland Journal, 1:225–231.

A technique for estimating shrub forage weight is described and the results of testing it on saltbush and bluebush are presented.

Ansari, R., Khazada, A.N. and Azmi, A.R. (1988). Atomic Energy Agricultural Research Centre, Tandojam, Pakistan. Introducing multipurpose Australian tree species to salt-affected lands of Pakistan. In: The International Forestry Conference for the Australian Bicentenary 1988. Proceedings of papers contributed and/or presented and histories of Australian Forestry and Forest Products Institutions and Associations, Albury–Wodonga, Australia, Vol. V, 1–3.

In a pot culture study, 6-month-old seedlings of several *Acacia* species were observed to be more salt-tolerant than those of *Casuarina. C. glauca* and *C. equisetifolia* were unaffected by 2% salts, while *C. cunninghamania* suffered a 35% reduction in height at this salinity level.

Ansari, R., Marcar, N.E., Khan, M.A., Shirazi, M.U., Khanzada, A.N. and Crawford, D.F. (1998). Atomic Energy Agricultural Research Centre, Tando Jam, Sindh, Pakistan. Acacias for saltland in southern Pakistan. In: Recent developments in acacia planting (Turnbull, J.W., Crompton, H.R. and Pinyopusarerk, K., ed.), 60–65. ACIAR Proceedings No. 82, Canberra, Australia.

This paper reports results of survival and growth at 21 and 36 months for several *Acacia* species grown on a moderately to severely saline (root-zone EC_e 5–40 dS/m) near Hyderabad, Pakistan. Some acacias, including *A. stenophylla* and *A. ampliceps*, were very salt-tolerant and performed better than *Eucalyptus* and *Casuarina* species. *A. stenophylla* and *A. nilotica* survived well and continued to grow after two months of flooding.

Antlfinger, A.E. and Dunn, E.L. (1983). Biology Department, University of Nebraska at Omaha, Omaha, Nebraska 68182, USA. Water use salt balance in three salt marsh succulents. American Journal of Botany, 70:561–567.

Water-use characteristics and potential salt accumulation rates are reported in three halophytes, *Salicornia virginica, Batis maritima* and *Borrichia fruitescens,* inhabiting a salinity gradient in the high marsh. Species growing at higher salinity developed more negative xylem and leaf osmotic potentials than species growing at lower soil salinities.

Arce, P., Medina, M.C. and Balboa, O. (1990). Programa de Microprogramacion Vegetal, P. Universidad Catolica de Chile, Santiago, Chile. Effect of salinity on germination of three *Prosopis* species (*P. alba*, *P. chilensis* and *P. tamarugo*). Ciencia e Investigacion Agraria, 17:71–75.

Compares germination of *Prosopis* spp. from arid and semiarid zones of Chile under NaCl (0 to 600 mol/m^3 concentration ≈ 0 to –3.0 MPa osmotic potential). Includes *P. chilensis* and *P. alba* (found to be most tolerant). (In Spanish, English summary.)

Armitage, F.B. (1985). International Development Research Centre, Ottawa, Ontario, Canada. Irrigated forestry in arid and semi-arid lands: a synthesis. IDRC, 160 p.

This book contains 11 chapters: Introduction; The arid zone environment; Irrigated forest plantation experience—with examples from South Asia and the Middle East (5 countries), the Mediterranean region (6 countries), Africa (7 countries), North America (USA), South and Central America, and Australia; Some basic concepts; Irrigation systems; Assessment of needs and potentialities; Development of irrigated plantations; Implementation and production, including growth and yields in South Asia and the Middle East (5 countries) and Africa (4 countries); Economics of irrigated plantations; Organisation and management; and Planning. There are also four appendices: Tree species used under irrigation; Provisional rating of salt tolerance of trees and shrubs in Kuwait; Successful tree species under saline irrigation at Eilat, Israel; Species tolerant of interrupted irrigation at Khartoum, Sudan.

Arokia, A. and Arumugam, M. (1989). Soil Salinity Research Centre, Tiruchirapalli, Tamil Nadu, India. Evaluation of grass and cereal fodders in sodic soil. Indian Journal of Agronomy, 34:139–140.

Fodder production data for *Brachiaria mutica, Diplachne [Leptochloa] fusca, Panicum maximum*, three bajra Napier hybrid grass (*Pennisetum purpureum* × *P. americanum*) cultivars and bajra (*P. americanum*) grown on a moderately sodic soil and irrigated with sodic/saline waters are given.

Aronson, J. A. (1985). Boyko Institute for Agriculture and Applied Biology, Ben-Gurion University of the Negev, Beer Sheeva 84110, Israel. Economic halophytes—a global review. In: Plants for arid lands (Wickens, G.E., Goodin, J.R. and Field, D.V., ed.), 177–188, Proceedings of the Kew International Conference on 'Economic Plants for Arid Lands', Allen and Unwin Publishers.

After a brief account of the distribution of saline land in the world and references dealing with salt-tolerant conventional plants, uses of a wide variety of halophytic flora in the past for commercial purposes are discussed. Some additional halophytic plants which appear promising for providing fodder, fuel-wood and oil for commercial purposes are highlighted.

Aronson, J.A. (1989). Institute for Applied Research, Ben-Gurion University of the Negev, Beer Sheva, 85110, Israel. HALOPH: a data base of salt-tolerant plants of the world. In: Arid land studies (Whitehead, E.E., ed.), 77 p. Office of Arid Land Studies, The University of Arizona, Tucson, Arizona, USA.

This database contains more than 1560 species, known or suspected to grow and produce/reproduce under saline conditions with irrigated water salinity (EC_i) or soil salinity (EC_e) >7–8 dS/m, in 550 genera and 117 families indexed alphabetically by family, genus, and species. Additional field headings are: life form, plant type, distribution, maximum reported salinity tolerance, photosynthetic pathway, economic uses, and bibliographic references. Conventional crops are excluded from HALOPH, even if reports have been made of successful cultivation with EC_i or EC_e higher than 7–8 dS/m.

Aronson, J.A., Pasternak, D. and Danon, A. (1988). The Boyko Institute for Agriculture and Applied Biology, Ben-Gurion University of the Negev, Beer Sheva, Israel. Introduction and first evaluation of 120 halophytes under seawater irrigation. In: Arid lands: today and tomorrow (Whitehead, E.E., Hutchinson, C.F., Timmermann, B. and Varady, R.G., ed.), 737–746. Proceeding of the International Research Development Conference, Tucson, Arizona. Westview Press, Colorado, USA.

Reports on results of screening 120 species (mostly with economic potential) at a site on the Mediterranean coast of Israel for two years under irrigation with sea water (EC 56.0 dS/m) and with 15 percent seawater (EC 5.5 dS/m). In addition, the life form, geographic distribution, 'plant type' based on primary habitat, and photosynthetic pathway of each of these species are reviewed in relation to their field performance. Data on annual productivity and feed value are presented for seven *Atriplex* species showing promise as fodder. Known and suspected economic uses of some very successful species are reviewed.

Arshad, M. and Hussain, A. (1984). Department of Soil Science, University of Agriculture, Faisalabad, Pakistan. Growth of *Sesbania sesban* under saline condition. Nitrogen Fixing Tree Research Report, 2:17.

Germination, height and nodulation of seedlings in soil-filled pots were reduced by salinity (Na_2SO_4, $CaCl_2$, NaCl and $MgCl_2$–10:5:4:1) above EC 4 and 8 dS/m, respectively.

Ashihara, H., Adachi, K., Otawa, M., Yasumoto, E., Fukushima, Y., Kato, M., Sano, H., Sasamoto, H. and Baba, S. (1997). Department of Biology, Faculty of Science, Ochanomizu University, Otsuka, Bunkyo-ku, Tokyo 112, Japan. Compatible solutes and inorganic ions in the mangrove plant *Avicennia marina* and their effects on the activities of enzymes. Zeitschrift für Naturforschung (Section C Biosciences), 52:433–440.

Reports on concentrations of Na and Cl, organic solutes (glycinebetaine, asparagine and stachyose), free amino acids and several enzymes in naturally grown two-month-old seedlings of *Avicennia marina*. No significant protection by glycinebetaine was detected against NaCl inhibition of these enzymatic activities.

Ashraf, M. (1990). Department of Botany, University of Liverpool, PO Box 147, Liverpool L60 3BX, UK. Selection for salt tolerance and its genetic basis in perennial ryegrass (*Lolium perenne* L.). Hereditas, 113:81–85.

Root growth of two *Lolium perenne* lines [high (with longest roots) and low (without roots)], selected under NaCl, was compared with unselected controls after three weeks' growth in solution culture at NaCl concentrations from 0 to 300 mol/m^3. The high selection line always had higher root growth than either the low selection or unselected lines. In a second experiment, many more individual seedlings derived from seed from the high selection line produced markedly longer roots than those from the control lines at 325 mol/m^3. Results from pair crosses made between high selection and low selection lines at 150 and 250 mol/m^3 indicated that the additive genetic component was quite high, which suggests that significant improvement in salt tolerance is possible after repeated cycles of selection.

Ashraf, M., McNeilly, T. and Bradshaw, A.D. (1986). Department of Botany, University of Liverpool, PO Box 147, Liverpool L60 3BX, UK. Heritability of NaCl tolerance at the seedling stage in seven grass species. Euphytica, 35:935–940.

Reports on narrow-sense heritabilities, estimated from parent-progeny regression and realized heritability, for tolerance to NaCl in commercial cultivars of seven grass species (*Lolium perenne*, *Dactylis glomerata*, *Agrostis stolonifera*, *A. castellana*, *Holcus lanatus*, *Festuca rubra* and *Puccinellia distans*) based on root length of solution-cultured seedlings after three weeks' growth at 225–425 mol/m^3 NaCl. The data suggested that in all species (heritabilities ca. 0.3 to 0.7), except perhaps *H. lanatus* (heritability of ca. 0.2), improvement in seedling NaCl tolerance could be obtained through further selection and breeding.

Ashraf, M., McNeilly, T. and Bradshaw, A.D. (1986). Department of Botany, University of Liverpool, PO Box 147, Liverpool L69 3BX, UK. The potential for the evolution of salt (NaCl) tolerance in seven grass species. New Phytologist, 103:299–309.

When seedlings of seven grass species [refer above reference] were treated for 14 days with 150 and 250 mol/m^3 NaCl, root growth was decreased but to different degrees for each species. In a second experiment, 'high' and 'low' selection lines were established, based on root length values of individual seedlings of each species treated with a NaCl concentration that generally inhibited root growth in the first experiment. In a third experiment, the high line plants had significantly longer roots than the unselected plants in all species, and than the low selected line in all species except *Agrostis capillaris*, when treated with NaCl. The pattern of response to selection showed no consistent relationship to the known ecology of these species. The authors suggest that variability in salt tolerance is widely present, but for other reasons salt tolerance does not always evolve in natural situations.

Ashraf, M., McNeilly, T. and Bradshaw, A.D. (1986). Department of Botany, University of Liverpool, PO Box 147, Liverpool L60 3BX, UK. The response of selected salt-tolerant and normal lines of four grass species to NaCl in sand culture. New Phytologist, 104:453–461.

This paper reports that after seven weeks' growth in varying NaCl concentrations in sand culture, dry matter production and tiller number were greater for progenies of NaCl-tolerant selection lines (selected on the basis of root length growth of small seedlings) than the progenies of unselected control lines of *Holcus lanatus*, *Lolium perenne*, *Dactylis glomerata* and *Festuca rubra*, particularly at high levels of NaCl. It is concluded that selection based upon differences in seedling root growth is a valid means of selecting for improved NaCl tolerance in adult plants, and that this tolerance does not lead to any reduced performance in the absence of NaCl.

Ashraf, M., McNeilly, T. and Bradshaw, A.D. (1986). Department of Botany, University of Liverpool, PO Box 147, Liverpool L60 3BX, UK. Tolerance of *Holcus lanatus* and *Agrostis stolonifera* to sodium chloride in soil solution and saline spray. Plant and Soil, 96:77–84.

Inland and sea cliff populations of *Agrostis stolonifera* and *Holcus lanatus* were equally sensitive (DW basis) to soil-applied NaCl (100 and 200 mol/m^3) but the sea cliff populations were more resistant (leaf damage basis) to salt spray (2.5, 5 and 10% NaCl).

Ashraf, M., McNeilly, T. and Bradshaw, A.D. (1987). Botany Department, University of Liverpool, PO Box 147, Liverpool L69 3BX, UK. Selection and heritability of tolerance to sodium chloride in four forage species. Crop Science, 227:232–234.

> Shoot growth of solution-cultured seedlings of forage rape (*Brassica napus*), berseem clover (*Trifolium alexandrinum*), alfalfa (*Medicago sativa*), and red clover (*Trifolium pratense*) was markedly inhibited after two weeks at 200, 225, and 250 mol/m^3 NaCl, but there was considerable variability between seedlings. In a subsequent experiment, each species was screened at high NaCl concentrations. Use of polycrossed populations based on high and low tolerant selections of each species allowed estimation of realised heritability and narrow-sense heritability. Realised heritabilities were sufficiently high (0.31–0.98) to conclude that significant responses to recurrent selection for seedling NaCl tolerance may be expected in these species.

Ashraf, M., McNeilly, T. and Bradshaw, A.D. (1989). Department of Botany, University of Liverpool, PO Box 147, Liverpool L60 3BX, UK. The potential for evolution of tolerance to sodium chloride, calcium chloride, magnesium chloride and seawater in four grass species. New Phytologist, 112:245–254.

> NaCl-tolerant lines of *Agrostis stolonifera*, *Agrostis capillaris*, *Holcus lanatus* and *Lolium perenne* had significantly greater root growth in NaCl, $CaCl_2$ and sea water than unselected lines, but in $MgCl_2$ only the NaCl-tolerant lines of *H. lanatus* had significantly longer roots than the unselected line. Variability between seedlings of each species was present for enhanced tolerance to each salt. Enhanced tolerance to increased seawater concentration remained for all lines except those of *A. capillaris* and *H. lanatus*, in older plants.

Ashraf, M. and Naqvi, M.I. (1991). Institute of Pure and Applied Biology, Bahauddin Zakariya University, Multan, Pakistan. Responses of three arid zone grass species to varying Na/Ca ratios in saline sand culture. New Phytologist, 119:285–290.

> This paper reports on the effects of four Na:Ca ratios (24, 49, 99 and 199) at 200 mol/m^3 NaCl on growth and ion (Na, K, Ca and Cl) concentrations of shoots and roots of *Cenchrus pennisetiformis*, *Leptochloa fusca* and *Panicum turgidum* seedlings in sand-filled pots in a glasshouse after seven weeks' treatment. Growth of *L. fusca* was unaffected by low Ca supply but that of the other two species was reduced at higher Na:Ca ratios. *L. fusca* was better able to control Na accumulation except at higher Na:Ca ratios.

No consistent patterns of change were found in shoot and root Na:K and Na:Ca ratios. Shoot selectivity ($S_{K,Na}$) increased consistently in *C. pennisetiformis* with increasing Na:Ca ratios and it decreased in *L. fusca* only at the highest Na:Ca ratio.

Aslam, Z., Barrett-Lennard, E.G. and Greenway, H. (1988). School of Agriculture, University of Western Australia, Nedlands, WA 6009, Australia. Effects of external concentration of (K^+ + Na^+) and K^+/Na^+ on the growth and ion relations of *Atriplex amnicola*. Journal of Plant Physiology, 133:228–234.

This paper reports on growth and ion relations of solution-cultured *Atriplex amnicola* in response to different K:Na ratios at 40 or 400 mol/m^3 (K + Na) Cl. Growth was considerably lower at 400 than at 40 mol/m^3. At 400 mol/m^3, growth was markedly lower at a K:Na ratio of 1.0 compared with lower ratios. Although K and Na concentration in different plant parts were related to the K:Na ratio, K + Na concentrations were not. In general, K:Na ratios were highest in root apices, lower in the bulk of the roots and lowest in leaves.

Aslam, Z., Jeschke, W.D., Barrett-Lennard, E.G., Setter, E.L., Watkin, E. and Greenway, H. (1986). School of Agriculture, University of Western Australia, Nedlands, WA 6009, Australia. Effects of external NaCl on the growth of *Atriplex amnicola* and the ion relations and carbohydrate status of the leaves. Plant, Cell and Environment, 9:571–580.

This paper reports that growth of solution-cultured *Atriplex amnicola* was best at 25–50 mol/m^3 NaCl and reduced by 10–15% at 750 mol/m^3. Concentrations of more than 200 mol/m^3 reduced the rate of leaf extension and increased the time taken for a leaf to reach its maximum length. Data on Na and K concentrations in salt bladders and leaves without bladders for young and old leaves are provided. Na concentration (excluding bladders) increased linearly with leaf age and concurrent increases in succulence were closely correlated with the Na concentration in the leaves excluding the bladders. Carbohydrate (starch and sugar) was much lower at night in most plant parts. The authors concluded that reduced growth at 400 mol/m^3 was not limited by availability of photosynthate, since carbohydrate concentrations were similar for plants grown at 25 and 400 mol/m^3.

Aslam, Z., Salim, M., Qureshi R.H. and Sandhu, G.R. (1987). Nuclear Institute for Agriculture and Biology, PO Box 128, Faisalabad, Pakistan. Salt tolerance of *Echinochloa crusgalli*. Biologia Plantarum, 29:66–69.

The salt tolerance of *Exchinochloa crusgalli* was studied using gravel culture with solution EC of 3–25 dS/m. A 50% reduction in shoot yield occurred at 15.9 dS/m. Tissue water content and K concentration were maintained but Na, Ca and Cl increased and Mg decreased with increasing root zone salinity. The plant's fodder potential for saline soils is discussed.

Aslam, Z., Salim, M., Sandhu, G.R. and Qureshi, R.H. (1979). Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan. Sodicity effects on growth and chemical composition of *Diplachne fusca*. Pakistan Journal of Botany, 11:123–128.

Reports on evaluation of kallar grass (*Diplachne [Leptochloa] fusca*) for sodicity tolerance in soil-filled pots. DM yield was relatively unaffected by increasing soil sodicity and a 50% reduction was observed at ESP 73, confirming its high tolerance to sodicity. Data on ion concentrations are provided.

Aswathappa, N. and Bachelard, E.P. (1986). Department of Forestry, Australian National University, GPO Box 4, Canberra ACT 2601,Australia. Ion regulation in the organs of *Casuarina* species differing in salt tolerance. Australian Journal of Plant Physiology, 13:533–545.

In sand-filled pots under glasshouse conditions, *Casuarina equisetifolia* and *C. glauca* (highly salt tolerant) accumulated little Na and Cl in their shoots and the concentrations of Na and Cl decreased from old to young growing needles, in contrast with *C. cunninghamiana* (moderately salt tolerant). The same pattern of distribution of Cl in *C. equisetifolia* was found in seedlings exposed to both short term (13 days at 100 mol/m^3 NaCl in solution culture), and long term (6 months at 250 mol/m^3 NaCl in sand culture) salinisation. The three species showed little difference in their root ion concentrations. The better exclusion of Cl from the shoots of *C. equisetifolia* than *C. cunninghamiana* was due to a lower rate of Cl uptake and lower net transport into the shoot rather than to its retention in the roots, or reabsorption at the proximal root or hypocotyl.

Aswathappa, N., Marcar, N.E. and Thomson, L.A.J. (1986). CSIRO Divison of Forestry and Forest Products, PO Box E4008, Kingston, ACT 2604, Australia. Salt tolerance of Australian tropical and subtropical acacias. In: Australian acacias in developing countries. (Turnbull, J.W., ed.), 70–73. ACIAR Proceedings No. 16, Canberra, Australia.

> Reports on injury symptoms (leaves, shoot apices), survival and growth of seedlings of 37 Australian species treated with stepwise increases of a mixed salt solution (NaCl, Na_2SO_4, $CaCl_2$, $MgSO_4$ in the molar ratio of 8:2:1:1). Large differences were found in survival and symptom development between species, and between provenances of some species, in response to salt. The most-salt-tolerant species included *Acacia ampliceps, A. stenophylla, A. salicina* and *A. ligulata*. Members of the sections *Phyllodineae* and *Plurinerves* had higher survival and grew more rapidly than those of *Juliflorae*.

Ayoub A.T. (1977). Hudeiba Research Station, POBox 31, Ed-Damer, Sudan. Some primary features of salt tolerance in senna (*Cassia acutifolia*). Journal of Experimental Botany, 28:484–492.

> Germination of *Cassia acutifolia* (senna) was reduced above 16 dS/m at 25°C but at much lower salinities at higher temperatures. Seedling growth was more sensitive to salinity and alkalinity than the germination stage. Young plant survival and total pod yield were significantly reduced above EC 11 dS/m of applied irrigation water. Sensitivity to higher levels of salinities was particularly correlated with higher leaf Cl concentrations.

Bachelet, D., Jarrell, W.M. and Virginia, R.A. (1986). Department of Biology, New Mexico State University, Las Cruces, NM 80523, USA. Simulation model of a laboratory-grown phreatophytic woody legume. Tree Physiology, 2:205–214.

> Reports that COLSIM, a model that simulates C and N uptake and water use, accurately predicted shoot biomass and N dynamics of *Prosopis glandulosa* grown in a 2 m soil column with 10 cm of water-saturated soil at the base for three years at soil salinities (EC 2.6–52 dS/m). Root biomass was underestimated at high soil salinity because the model did not account for increased allocation of C to roots in these conditions.

Badger, K.S. and Ungar, I.A. (1990). Department of Biology, Missouri Valley College, Marshall, MO 65340, USA. Seedling competition and the distribution of *Hordeum jubatum* L. along a soil salinity gradient. Functional Ecology, 4:639–644.

Reports on the effects of interspecific competition on seedling growth of the inland halophyte *Hordeum jubatum* under field conditions and in a replacement series along an artificial salinity gradient. Competition with *A. triangularis* significantly inhibited root growth of *H. jubatum* at salinity levels below its upper physiological limit.

Bal, A.R. and Dutt, S.K. (1987). Central Soil Salinity Research Institute, Regional Research Station, Canning, West Bengal, India. A prospective fodder for saline and waterlogged soils. Indian Farming, 37:26–35.

Seedlings of *Coix lacryma-jobi* planted in waterlogged saline fields gave yields of 7.6 t fresh herbage and 1.78 t DM/ha. The fresh herbage at the tillering stage contained 7.2% crude protein (CP), 11.38% ash, 2.92% K, 0.32% Ca and 0.40% Mg.

Bala, N. and Sharma, P.K. (1990). Department of Microbiology, Haryana Agricultural University, Hisar 125004, India. Nodulation and nitrogen fixation by salinity-tolerant rhizobia in symbiosis with tree legumes. Agriculture, Ecosystems and Environment, 33:33–46.

Reports on salt tolerance screening, over the range from EC of 0 to 12 dS/m, of 57 *Rhizobium* strains isolated from one-year-old seedlings of tree legumes (*Acacia, Albizia, Dalbergia, Desmodium, Gliricidia, Leucaena, Pithecollobium, Prosopis* and *Sesbania*). Four strains isolated from *Acacia, Dalbergia, Leucaena* and *Prosopis* tolerated salinity of 9–12 dS/m in laboratory tests with seedlings of *Acacia nilotica, Leucaena leucocephala* and *Prosopis juliflora*. Shoot growth, nodulation and nitrogenase actvity were higher under salinity for *A. nilotica* seedlings inoculated with salt-tolerant compared with salt-sensitive rhizobia.

Balasubramanian, A., Srinivasan, P.S. and Kumaravelu, G. (1996). Forest College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu 641002, India. Modulation of certain physiological parameters to salinity in *Casuarina equisetifolia* seedlings inoculated with five *Frankia* strains. Journal of Tropical Forest Science, 9:16–22.

Reports on changes in transpiration, stomatal conductance and water potential in *Casuarina equisetifolia* seedlings inoculated with nodule suspension of five *Frankia* strains and treated with 0, 0.15, 1.5 and 15 mg NaCl per gram of soil. Good growth was observed with two *Frankia* sources (Sugar-cane Research Station and Marakanam).

Balati, S. (1992). Biology Teaching and Research Section, Chemistry Department, Kaxgar Normal College, Kaxgar, Xinjiang, China. Study on ecological characteristics of seed germination of xeric sagebrush (*Artemisia*) Gobi-type. Grassland of China, 5:37–41.

> Germination of *Artemisia transiliensis* was very low under the following conditions: 20°C; 10% soil moisture content; 2% Na_2SO_4; 1.5% NaCl and mixed salts. (In Chinese, English summary.)

Ball, M.C. (1988). Department of Envionmental Biology, Research School of Biological Sciences, Australian National University, GPO Box 475, Canberra, ACT 2601, Australia. Salinity tolerance in the mangroves *Aegiceras corniculatum* and *Avicennia marina*. I. Water use in relation to growth, carbon partitioning, and salt balance. Australian Journal of Plant Physiology, 15: 447–464.

> Data on the water use characteristics, salt accumulation and transport to the shoots in *A. corniculatum* and *A. marina*, which usually occupy low and high salinity areas in mangrove communities respectively, for seedlings in solution culture treated with 50, 250 and 500 mol/m^3 NaCl and leaf to air vapour pressure deficits of 0.006, 0.012 and 0.024 MPa are presented. Growth of *A. corniculatum* declined more rapidly in response to NaCl salt than did that of *A. marina* and this is related to less efficient water use and greater transport of Cl to the shoot with increasing salinity for *A. corniculatum*.

Ball, M.C. and Anderson, J.M. (1986). Department of Envionmental Biology, Research School of Biological Sciences, Australian National University, GPO Box 475, Canberra, ACT 2601, Australia. Sensitivity of photosystems II to NaCl in relation to salinity tolerance. Comparative studies with thylakoids of the salt tolerant mangrove, *Avicennia marina*, and the salt-sensitive pea, *Pisum sativum*. Australian Journal of Plant Physiology, 13: 689–698.

> This paper reports that the O_2 evolving activity (photosystem II) as compared using isolated thylakoids, was similarly sensitive for these two species. Rates of O_2 evolution declined linearly with increasing NaCl from 10 to 500 mol/m^3. At 500 mol/m^3, inhibition was greater under light conditions than in the dark. The authors concluded that accumulation of ions in the chloroplasts of either salt-tolerant or salt-sensitive species would probably result in rapid damage to photosystem II, particularly in the light.

Ball, M.C., Chow, W.S. and Anderson, J.M. (1987). North Australian Research Unit, Department of Biogeography and Geomorphology, Research School of Pacific Studies, Australian National University, GPO Box 4, Canberra, ACT 2601, Australia. Salinity-induced potassium deficiency causes loss of functional photosystem II in leaves of the grey mangrove, *Avicennia marina*, through depletion of the atrazine-binding polypeptide. Australian Journal of Plant Physiology, 14:351–361.

> Reports on photosynthetic properties of leaves of *Avicennia marina* grown in solution culture at low (50 mol/m^3) and high (500 mol/m^3) NaCl with either 0.01 or 10 mol/m^3 K, in relation to leaf ionic composition. A drastic reduction in light and CO_2 saturated photosynthetic capacity and photochemical dysfunction under limiting light conditions occurred at 103 mol/m^3 K in leaves. Thylakoids isolated from these low K leaves showed no decrease in per chlorophyll concentrations of photosystem I, cytochrome f/b complex and ATPase, but had fewer atrazine-binding sites (corresponding to photosystem II reaction centres) than those from leaves with higher K concentrations.

Bandyopadhyay, A.K. (1986). Central Soil Salinity Research Institute, Regional Research Station, Canning Town, 24 Parganas, West Bengal, India. *Casuarina equisetifolia* grows well in heavy-textured coastal saline soils. Indian Farming, 36:19.

> After about 11 years, trees reached heights of 15.3 m and diameter 80.4 cm (EC ground water 4 dS/m) and 13.9 m and 66.5 cm (EC 8 dS/m).

Bangash, S.H. (1977). Pakistan Forest Institute, Peshawar, Pakistan. Salt tolerance of forest tree species as determined by germination of seeds at different salinity. Pakistan Journal of Forestry, 27:93–97.

> Provides data on seed germination and seedling survival of *Acacia arabica* [*A. nilotica*], *Albizia lebbeck*, *Parkinsonia aculeata*, *Prosopis spicigera*, *Robinia pseudoacacia* and *Ziziphus jujuba* in soil-filled pots to which was added 0.05–0.8% (w/w) NaCl.

Bao, C.Z. and Xu, H.G. (1992). Grassland Research Institute, Chinese Academy of Agricultural Sciences, Hohhot, Inner Mongolia, China. Efficacy of introducing salt-tolerant forage for improvement of saline-alkali soils in Hetao Plain of Inner Mongolia, China. Grassland of China, 1:16–21.

Reports on laboratory experiments and field trials to evaluate the salt tolerance of forage plants (*Puccinellia tenuiflora, P. chinampossis, Echinochloa utilis, Achnatherum splendens, Elymus excelsus, Elymus sibiricus, Hordeum brevisubulatum, Melilotus suaveolens, Astragalus adsurgens, Medicago sativa, Onobrychis viciifolia* and *Vicia villosa*) for growing on saline-alkali soils in Hetao Plain areas in Inner Mongolia, China. (In Chinese.)

Bar-Nun, N. and Polyakoff-Mayber, A. (1974). Department of Botany, The Hebrew University of Jerusalem, Jerusalem, Israel. Some aspects of protein metabolism in *Tamarix tetragyna* roots grown in a saline substrate. Australian Journal of Plant Physiology, 1:237–246.

This paper reports on effects of NaCl on amino acid metabolism in isolated root-tips of rooted cuttings of *Tamarix tetragyna* grown on vermiculite moistened with Hoaglands nutrient solution under laboratory conditions. Unpublished data shows that *T. tetragyna* cuttings can not in NaCl solutions up to an osmotic potential of –2.0 MPa.

Barbour, M.G. (1978). Botany Department, University of California, Davis, CA 95616, USA. The effect of competition and salinity on the growth of a salt marsh plant species. Oecologia, 37:93–99.

Reports on a study in which young rhizome sprouts of *Jaumea carnosa,* a salt marsh species from the Californian coast, were treated with dilutions of sea water (at 400, 4 000 and 11 600 ppm), in sand-filled flats, either as a monospecific control or in combination with *Lolium perenne*, and under poor and good aeration (400 and 11 600 ppm treatment only). Under good aeration, growth of *Lolium* was more affected than *Jaumea*. Both species grew poorly under poor aeration with 11 600 ppm. The effect of interspecific competition on *Jaumea* was marked at low salinity, but at high salinity the competitive effect was insignificant.

Bari, M.A. and Schofield, N.J. (1991). Water Authority of Western Australia, Leederville, WA 6007, Australia. Effects of agroforestry–pasture associations on groundwater level and salinity. Agroforestry Systems, 16:13–31.

Reports on the effects of silvopastoral systems: (i) mixed pine species (*Pinus radiata* and *P. pinaster*) and *Eucalyptus camaldulensis*; and (ii) mixed eucalypt species (*E. sargentii, E. wandoo, E. camaldulensis* and *E. calophylla*) on reducing ground water level and salinity in Western Australia.

Bari, M.A. and Schofield, N.J. (1992). Water Authority of Western Australia, Leederville, WA 6007, Australia. Lowering of a shallow, saline water table by extensive eucalypt reforestation. Journal of Hydrology (Amsterdam), 133:273–291.

Extensive reforestation was evaluated as a method for controlling salinisation in the Wellington Dam catchment in south western Western Australia, which was 35% cleared and converted to pasture in the 1950s. Within 10 years, reafforestation with 63 *Eucalyptus* and two *Pinus* species at an initial stem density of 625 stems/ha in 0.5 ha blocks covering some 70% of the cleared land has been effective in lowering shallow, saline ground water tables and reducing ground water salinity.

Barrett-Lennard, E.G. (1986). Resource Management Division, Department of Agriculture, South Perth, WA 6151, Australia. Effects of waterlogging on the growth and NaCl uptake by vascular plants under saline conditions. Reclamation and Revegetation Research, 5:245–261.

This paper focusses on the interaction between salinity and waterlogging as it affects the regulation of Na and Cl uptake and the growth of shoots and roots. Examples are given of non-halophytes (mostly crops) in which waterlogging increases Na and Cl uptake by shoots, thereby causing shoot senescence and growth reduction. It is suggested that this increased uptake is due to oxygen deficits on Na efflux and plasma membrane potentials in the roots. Emphasis is placed on the role of aerenchyma in avoiding oxygen deficits, and in maintaining root growth and ion regulation. A case study for *Puccinellia peisonis* is presented.

Barrett-Lennard, E., Frost, F., Vlahos, S. and Richards, N. (1991). Department of Agriculture, Baron Hay Court, South Perth, 6151, Western Australia. Revegetating salt-affected land with shrubs. Journal of Agriculture, Western Australia, 32:124–129.

In Western Australia, the establishment of salt-tolerant shrubs such as saltbush and bluebush on salt-affected land reduces the risk of soil erosion, and can also fit into farm programs. Three methods are discussed for establishing shrubs on salt-affected land (niche seeding, planting nursery-raised seedlings and allowing natural regeneration). Factors affecting establishment are also discussed. Data presented suggest that the use of nursery-raised seedlings is more reliable than niche seeding.

Barrett-Lennard, E. and Galloway, R. (1996). Western Australian Department of Agriculture, South Perth, WA 6151, Australia. Saltbush for water table reduction and land rehabilitation Australian. Journal of Soil and Water Conservation, 9:21–24.

> This paper advocates the use of saltbushes (*Atriplex* species) as 'agro-forestry companion species' to lower watertables in saltland pastures, especially in areas with warm climates. Evidence is presented to show that river saltbush grows faster in warmer than in cooler climates, with little growth below 15°C. Stands of river saltbush can use up to 0.7 mm water per day and reduce shallow water tables by 60 cm over a summer. Recommendations are made regarding saltbush use.

Barrett-Lennard, E.G. and Malcolm, C.V. (1995). Agriculture Western Australia, Baron-Hay Court, South Perth, WA 6151, Australia. Saltland pastures in Australia: a practical guide. Bulletin 4312, Western Australian Department of Agriculture, South Perth, 112 pp.

> This book is one of the best compilations of data on the establishment, growth and utilisation of halophytic species as sources of forage. It is written in an accessible style, very well illustrated and it gives a comprehensive treatment on the role and utilisation of selected saltbush species.

Barrett-Lennard, E.G., Malcolm, C.V., Stern, W.R. and Wilkins, S.M. (ed.) (1986). Western Australian Department of Agriculture, South Perth, WA 6151, Australia. Forage and fuel production from salt-affected wasteland. Reclamation and Revegetation Research, Special Issue No. 5 (1–3). Proceedings of Research for Development Seminar, Cunderdin, Western Australia, 19–27 May 1984, 459 p.

> These proceedings provide a very useful resource on (i) the extent and nature of salinity and management options in 17 countries, (ii) causes of salinity, and (iii) plants and techniques available to permit production of useful forage and fuel.

Barson, M.M., Abraham, B. and Malcolm, C.V. (1994). Bureau of Resources Sciences, PO Box E11, Queen Victoria Terrace, Canberra ACT 2600, Australia. Improving the productivity of saline discharge areas: an assessment of the potential use of saltbush in the Murray-Darling Basin. Australian Journal of Experimental Agriculture, 34:1143–1154.

Reports on the use of the model PLANTGRO and results of field trials testing the growth of *Atriplex* species on saline soils in Western Australia to predict the success of *Atriplex amnicola, A. canescens, A. cinerea, A. lentiformis, A. nummulona* and *A. undulata* species on saline soils in the Murray–Darling Basin (eastern Australia), and the subsequent testing of model predictions by examining data from field trials. It was concluded that saltbush production will be very poor on heavy clay soils due to poor aeration. Field trial data suggest that these limitations will be increased by the interaction of aeration and soil salinity at EC_e >10 dS/m, and the planting of *Atriplex* on these sites is not recommended.

Barson, M.M. and Barrett-Lennard, E. (1995). Bureau of Resources Sciences, PO Box E11, Queen Victoria Terrace, Canberra ACT 2600, Australia. Productive use and rehabilitation of Australia's saline lands. Australian Journal of Soil and Water Conservation, 8:33–37.

This technical article reviews efforts being made in Australia on revegetation of salt-affected land by trees, shrubs, grasses and herbs and outlines the objectives of the National Program for the Productive Use and Rehabilitation of Saltland.

Batra, L. and Dikshit, R.P. (1994). Central Soil Salinity Research Institute, Karnal, Haryana 132001, India. Effect of exchangeable sodium on growth and concentration of important macronutrients in needles and stems of four *Casuarina* spp. Plant and Soil, 167:197–202.

In a glasshouse experiment, dry matter (DM) increased for *Casuarina obesa, C. glauca* and *C. cunninghamiana* with increasing soil sodicity (ESP of 11, 17, 35, 58 and 70; produced by mixing $CaSO_4$ with a highly sodic soil) but DM yields of *C. equisetifolia* decreased. The effect of sodicity was more pronounced on needles than on stems. Na concentration in plant parts increased with increasing sodicity, whereas concentrations of K, Ca, Mg, N and P decreased.

Bell, D.T., McComb, J.A., van der Moezel, P.G., Bennett, I.J. and Kabay, E.D. (1994). Department of Botany, University of Western Australia, Nedlands, WA 6009, Australia. Comparisons of selected and cloned plantlets against seedlings for rehabilitation of saline and waterlogged discharge zones in Australian agricultural catchments. Australian Forestry, 57:69–75.

Salt- and/or waterlogging-tolerant clones of *Eucalyptus camaldulensis, E. spathulata* subspp. *spathulata, Casuarina obesa* and *C. glauca* have been developed over several years on the basis of glasshouse screening and initial collection of seed from trees growing naturally in seasonally waterlogged and/or saline soils. This paper reports on the results of glasshouse and field (in Western Australia for all species, and in New South Wales, Victoria and South Australia for *E. camaldulensis*) evaluation of several of these clones. Clones generally had better survival in the field than provenance-matched seedlings. Some *C. obesa* clones had better height growth tolerance (based under regressions against Ec_e) than seedling populations.

Bell, D.T., Wilkins, C.F., van der Moezel, P.G. and Ward, S.C. (1993). Department of Botany, University of Western Australia, Nedlands, WA 6009, Australia. Alkalinity tolerance of woody species used in bauxite waste rehabilitation, Western Australia. Restoration Ecology, 1:51–58.

In glasshouse trials in which sand-cultured seedlings of 29 taxa were treated with step-wise increases in pH using NaOH solutions to mimic high pH of bauxite processing waste, the most tolerant were *Casuarina obesa, Melaleuca lanceolata, M. armillaris, M. nesophila, Eucalyptus loxophleba, E. halophila, E. platypus, Tamarix aphylla*, and a clone of *E. camaldulensis*, whilst the most sensitive were *E. spathulata, E. tetragona, E. preissiana, E. gomphocephala, E. diptera*, and *E. occidentalis,* on the basis of survival, relative height growth rate and symptoms. Species normally occurring in alkaline soils tended to have higher growth rates at applied nutrient solution pH of 8–10. Susceptible plants showed increasing symptoms related to nutrient deficiency, followed by wilting and death at higher pH. Data are provided for height growth response to surface soil pH for selected species in field trials in the bauxite residue impoundments at Kwinana, Western Australia. The relative survival and growth of seedlings after eight months were generally predicted by the response in the glasshouse.

Ben-Asher, J. (1994). Jacob Blaustein Institute for Desert Research, Ben Gurion University of the Negev, Sede Boqer Campus, Israel. Simplified model of integrated water and solute uptake by salts- and selenium-accumulating plants. Soil Science Society of America Journal, 58:1012–1026.

This paper presents modelled values for ion salt and Se uptake with respect to water uptake by plants of different salt tolerance and relates these to allowable salinities of irrigation water required to minimise root-zone salinisation. The rates of salt removal were calculated to be 5, 15, and 40 $\times 10^3$ dS/m/day for salt-sensitive, semi-sensitive and tolerant crops, respectively.

Bennett, D.L. and George, R. (1992). WA Department of Agriculture, PO Box 1231, Bunbury, WA 6230, Australia. Early survival and growth of river red gum clones on salt-affected land in high rainfall areas of south-west Australia. Land and Water News, 12:12–16.

> Results at nine months for survival and height growth of several *Eucalyptus camaldulensis* (river red gum) clones, selected on the basis of earlier glasshouse trials, on four saline sites in WA, are presented in this short article.

Bennett, D.L. and George, R.J. (1995). WA Department of Agriculture, PO Box 1231, Bunbury, WA 6230, Australia. Using the EM38 to measure the measure the effect of soil salinity on *Eucalyptus globulus* in southwestern Australia. Agricultural Water Management, 27:69–86.

> This paper reports on the salt tolerance at five sites of *Eucalyptus globulus* planted to control dryland salinity and obtain additional income from timber and pulp in the >600 mm/year rainfall zone of south western Australia. *E. globulus* can survive moderate soil salinities—as determined by the use of Geonics electromagnetic induction meter (EM38); moderate salinities equal to EC_a (apparent conductivity) $\cong$ 150 mS/m (horizontal mode). However, growth rates declined at 50 to 75 mS/m. A combination of soil salinity and waterlogging caused a reduction in growth rate at 25 mS/m. Plantings up to 14 years old were adversely affected by continuing rises of the watertable and increased root-zone salinity. (EC_a of 150 mS/m is equivalent to about EC_e 5–8 depending on soil type.)

Benyon, R.G., Marcar, N.E., Crawford, D.F. and Nicholson, A.T. (1999). CSIRO Forestry and Forest Products, PO Box E4008, Kingston, ACT, 2604, Australia. Growth and water use of *Eucalyptus camaldulensis* and *E.occidentalis* on a saline discharge site near Wellington, NSW, Australia. Agricultural Water Management, 39:229–244.

> This paper reports on growth and water use of seven-year-old *Eucalyptus camaldulensis* and six-year-old *E. occidentalis* on saline and non-saline locations within a species evaluation trial on a discharge site in central-west NSW, Australia. Ten percent reduction in height growth occurred at root-zone EC_e of approx. 2 and 10 dS/m for *E. camaldulensis* and *E. occidentalis*, respectively; similar responses to salinity were found for stem diameter and estimated crown volume. Transpiration rate (expressed on a leaf area basis and measured for selected trees over several months using the heat pulse [sap velocity] technique) was similar for *E. camaldulensis* on non-saline and moderately saline (EC_e

approximately 4.5 dS/m) soil and between *E. camaldulensis* and *E. occidentalis* on moderately saline soil. However, total water use per tree differed significantly between species and locations because of differences in leaf area and stem diameter such that larger trees used more water.

Bernstein, L., Francois, L.E. and Clark, R.A. (1972). United States Department of Agriculture, Riverside, California, USA. Salt tolerance of ornamental shrubs and ground covers. Journal of the American Society of Horticultural Science, 97:550–556

Reports on the salt tolerance of 25 shrub and ground-cover species grown in soil plots artificially salinized with NaCl + $CaCl_2$ and in sand cultures with four different salt treatments. Detailed information on symptoms and growth is provided. Tolerant species such as *Bougainvillea spectabilis* were almost unaffected by EC_e of 8 dS/m, whereas sensitive species were severely damaged or killed at EC_e of 4 dS/m. Salt tolerance was not well correlated with injury by Cl or Na, although many species exhibited leaf burn, nor was survival under highly saline conditions necessarily a good index of salt tolerance.

Bhattacharya, A.N. (1988). Range and Animal Development Research Center, Al-Jouf, Ministry of Agriculture and Water, Saudi Arabia. Nutrient utilization of *Acacia, Haloxylon* and *Atriplex* species by Nadji sheep. Journal of Range Management, 42:28–31.

Two digestibility and N balance studies were conducted to evaluate nutrient utilisation of three commonly browsed range plants by the desert sheep (Najdi wether lambs) in northern Saudi Arabia. Diets comprised various combinations of ground barley grain, lucerne hay, dried *Acacia saligna, Haloxylon persicum* clippings and green *Atriplex halimus* clippings. The Na, K, and Cl concentration in high and low saline soil were not related to their contents in *Atriplex* forage.

Bhatti, A.S., Sarwar, G., Tahir, M., Khan, K.A. and Akram, M. (1986). Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan. Characteristics of Na and K absorption in *Leptochloa fusca* (L.) Kunth. In: Prospects for biosaline research (Ahmad, R. and San Pietro, A., ed.), 351–357, Proceedings of the US-Pakistan Biosaline Research Workshop, 22–26 September 1985. Department of Botany, University of Karachi, Karachi, Pakistan.

Reports on the effects of NaCl and KCl, either alone or in combination, on the concentrations and distribution of K and Na in various parts of kallar grass plants measured after loading the roots of intact seedlings with KCl or NaCl in nutrient solutions.

Bhatti, A.S., Sarwar, G., Wieneke, J. and Tahir, M. (1983). Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan. Salt effects on growth and mineral contents of *Diplachne fusca* (kallar grass). Journal of Plant Nutrition, 6:239–254.

Up to 150 mol/m^3 NaCl and KCl had little effect on growth of soil-cultured kallar grass plants, but $CaCl_2$ depressed growth strongly, whereas growth under the NaCl–KCl combination decreased but remained little affected in NaCl–$CaCl_2$. Solution culture results showed that plant tissue had a strong selectivity for K over Na. Leaf transections are presented providing some information on the tissue anatomy.

Bhatti, A.S. and Wieneke, J. (1984). Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan. Na^+ and Cl^-: leaf extrusion, retranslocation and root efflux in *Diplachne fusca* (kallar grass) grown in NaCl. Journal of Plant Nutrition, 7:1233–1250.

Reports on distribution of Na and Cl in different parts of kallar grass plants treated with 100 mol/m^3 NaCl simultaneously labelled with ^{22}Na and ^{36}Cl and their movement when washed in non-labelled, saline solution. Na and Cl appeared to be present in equal proportions. Leaf sheaths accumulated more Na and Cl than the leaf blades. Some of the Na and Cl removed by root efflux was retranslocated from the shoots to the roots and was attributed to phloem transport.

Biddiscombe, E.F., Rogers, A.L., Greenwood, E.A.N. and Deboer, E.S. (1981). Division of Land Resources Management, CSIRO, Wembley, WA 6014, Australia. Establishment and early growth of species in farm plantations near salt seeps. Australian Journal of Ecology, 6:383–389.

The paper describes a comparison of survival and early growth of 28 species (mainly *Eucalyptus* spp.) on and near saline seeps. Plantations were located in 850, 500 and 420 mm annual rainfall zones about 150 km SE of Perth, Western Australia. The sites had saline confined aquifers and seasonal perched watertables which are typical of many landscapes in the region. *Eucalyptus* spp. from many regions of southern Australia were successful at the wettest location. Success at the two driest locations was limited to species from dry climates of southern South Australia and Western Australia. Planting on seep areas decreased the establishment of *Eucalyptus wandoo, E. globulus* and *E. camaldulensis.*

Biddiscombe, E.F., Rogers, A.L., Greenwood, E.A.N. and DeBoer, E.S. (1985). Division of Groundwater Research, CSIRO, Private Bag, Wembley, WA 6014, Australia. Growth of tree species near salt seeps, as estimated by leaf area, crown volume and height. Australian Forestry Research, 15:141–154.

Reports on the survival, leaf area, crown volume and height of 25 tree species planted at three sites SE of Perth, Western Australia (refer Biddiscombe et al. 1981). Tree survival was generally >90% up to year 7 on two of these sites located on or adjacent to saline seeps (wet in winter). *Eucalyptus globulus* was the most productive species, but the most salt-tolerant were *E. platypus, E. spathulata, E. occidentalis* and *E. sargentii.*

Bidner-Barhava, N. and Ramati, B. (1967). The tolerance of some species of *Eucalyptus*, *Pinus* and other forest trees to soil salinity and low soil moisture in the Negev. Israel Journal of Agricultural Research, 17:65–76.

Based on survival and visual health assessment up to three years after planting of small trial plantations located on Cl solonchak soils in the central Negev (annual rainfall 100 to 150 mm, mostly between November and March), *Eucalyptus camaldulensis* var. *subcinerea* and *Pinus halepensis* were found to be highly salt- and water-stress-tolerant. Three provenances of *E. camaldulensis*, and *E. occidentalis*, *E. leucoxylon*, *E. gomphocephala*, *E. rudis* and *E. tereticornis* were moderately tolerant (good survival but poor health), and *Acacia saligna*, *Pinus brutia*, *Dodonaea viscosa* and *Terminalia australis* were sensitive (poor survival). Limited irrigation by sewage water over two years removed excess salts from the upper soil profile, though there was upward movement of salts between irrigations.

Bilal, R., Rasul, G., Mahmood, K. and Malik, K.A. (1990). Nuclear Institute for Agriculture and Biology, PO Box 128, Faisalabad, Pakistan. Nitrogenase activity and nitrogen-fixing bacteria associated with the roots of *Atriplex* spp. growing in saline sodic soils of Pakistan. Biology and Fertility of Soils, 9:315–320.

High root-associated nitrogenase activity was found for excised washed and unwashed roots of *Atriplex lentiformis* and *A. amnicola*, growing in low-fertility, saline-sodic soils; it is suggested that this may explain the high

protein content and biomass content of these plants growing in such soils. The highest number of diazotrophs, mostly identified as *Enterobacter agglomerans*, was observed on the root surface.

Billard, J.P., Binet, P. and Boucaud, J. (1982). Laboratoire de Physiologie Vegetale, Unite d'Enseignement et de Recherche de Sciences, Universite de Caen, 14032 Caen, France. Electrophoretic modifications of soluble leaf proteins of *Suaeda maritima* var. *macrocarpa*, *Atriplex hortensis* and *Phaseolus vulgaris* in relation to the NaCl content of the culture medium. Canadian Journal of Botany, 60:1590–1595.

Young plants showed increased sensitivity to NaCl in the order *Suaeda maritima* var. *macrocarpa, Atriplex hortensis, Phaseolus vulgaris*. The formation of soluble leaf proteins in response to salinity was also much higher in the halophytic and more salt-tolerant species and this is related to Na accumulation (In French, English summary).

Biswas, C.R. and Bandyopadhyay, A.K. (1987). Central Soil Salinity Research Institute, Regional Research Station, Canning 743 329, West Bengal, India. Agronomy of casuarina (*Casuarina equisetifolia*) plantation in heavy textured coastal saline soil: effect of spacing and fertiliser application. Journal of the Indian Society of Coastal Agricultural Research, 5:421–425.

Reports on a trial at Canning, West Bengal (soil pH about 7.0–7.2, shallow watertable and high but fluctuating salinity (EC 6–7 dS/m)) with three spacings (1 × 1, 1.5 × 1.5 and 1.75 × 1.75 m) and eight fertiliser treatments (a: urea, 200 g; b: superphosphate, 750 g; c: muriate of potash (KCl), 100 g; a + b; a + c; b + c; a + b + c; and no fertiliser) on a per plant basis. No significant differences in growth between fertiliser and spacing treatments up to 5 years were found.

Bjereegaard, R.S., West, N.E., Caldwell, M.M. and Mayland, H.F. (1984). Lily Research Laboratories, PO Box 708, Greenfield, Indiana 46140, USA. Standing crops and dynamics of phytomass and minerals in two salt desert shrub communities. Great Basin Naturalist, 44:327–337.

Reports on differences between *Atriplex confertifolia* dominated and *Ceratoides lanata* communities in Curlew Valley, Utah, with respect to biomass and net primary production, litter quantity and quality, mineral composition and litter decomposition.

Blake, T.J. (1981). Faculty of Forestry, University of Toronto, Toronto, Ontario M5S 1A1, Canada. Salt tolerance of eucalypt species grown in saline solution culture. Australian Forestry Research, 11:179–183.

Reports that marked differences in survival were found between young seedlings of 52 species and subspecies of eucalypts grown in solution culture with step-wise increases in NaCl concentration from 0 to 400 mol/m^3.

Blake, T.J. and Reid, D.M. (1981). Faculty of Forestry, University of Toronto, Toronto, Ontaria M5S 1A1, Canada. Ethylene, water relations and tolerance to waterlogging of three *Eucalyptus* species. Australian Journal of Plant Physiology, 8:497–505.

In a glasshouse experiment, tolerance to flooding was found to decrease in the order *Eucalyptus camaldulensis* > *E. globulus* > *E. obliqua*. Water stress was not associated with flooding damage. Early stomatal closure, as shown by high leaf stomatal resistances, occurred in each species and leaf water potential did not decrease in any of the three species in response to flooding. It is suggested that the high degree of flood tolerance in *E. camaldulensis* may be due to increased ethylene production which results in tissue hypertrophy and basal stem thickening; aerenchymatous tissue could assist in reducing the build-up of potentially toxic ethylene and could also enhance the transport of oxygen to the roots.

Blits, K.C. and Gallagher, J.L. (1990). Halophytic Biology Laboratory, University of Delaware, College of Marine Studies, Lewes, Delaware 19958, USA. Salinity tolerance of *Kosteletzkya virginica*. I. Shoot growth, ion and water relations. Plant, Cell and Environment, 13:409–418.

This paper reports on the effects of external NaCl (0, 85, 170 or 255 mol/m^3) on shoot growth and ion concentration of individual leaves of solution-cultured *Kostelelzkya virginica*, a dicot halophyte native to brackish tidal marshes. Growth was stimulated by 85 mol/m^3 NaCl and progressively reduced at higher salinity, mainly due to decreased leaf number and area rather than from accelerated leaf death. Features which assisted in the maintenance of favourable K–Na relations were (i) maintenance of constant Na concentration of individual leaves due to concomittant increase in water content with Na and K accumulation, (ii) partitioning of Na away from the most actively growing leaves and (iii) a strong K affinity.

Blits, K.C. and Gallagher, J.L. (1990). Halophytic Biology Laboratory, University of Delaware, College of Marine Studies, Lewes, Delaware 19958, USA. Salinity tolerance of *Kosteletzkya virginica*. II. Root growth, lipid content, ion and water relations. Plant, Cell and Environment, 13:419–425.

This paper deals with the effects of external NaCl (0, 85, 170 or 255 mol/m^3) on root growth, ion and water relations, and lipid content of *Kostelelzkya virginica*. Root growth was enhanced at 85 mol/m^3 but reduced at higher salinities. K/Na selectivity and Na:K ratios were higher for salt-grown plants. Cl concentrations in salinised plants were double or more those for Na, suggesting a more effective Na-excluding mechanism in roots. Phospholipids and sterols, principal membrane constituents, were maintained or elevated and the free sterol:phospholipid ratio increased in salinised plants, suggesting retention of overall membrane structure and decreased permeability; it is suggested that these changes may be important in preventing K leakage.

Boardman, R., Shaw, S. and Schrale, G. (1996). Primary Industries SA Forestry, Adelaide, SA, Australia. Opportunities and constraints for plantations irrigated with effluent from Adelaide. Proceedings Australian Water and Wastewater Association Conference, Sydney, May 1996, 287–294.

This paper describes results from a trial near Adelaide, South Australia, close to the coast with a very saline watertable within 2–3 m of the surface, and established in 1990 with the objectives of providing quantitative information on a range of factors influencing tree growth, tree health and site use with irrigation using effluent water for a number of Australian native tree species. Na, Cl and B concentrations in trees were close to or exceeded conventional diagnostic levels for phytotoxicity. Nutrient concentrations in tree parts varied considerably between species.

Bodla, M.A., Baig, M.S. and Shamsi, S.R.A. (1994). International Waterlogging and Salinity Research Institute (IWASRI), Lahore, Pakistan. Forage production from salt affected and waterlogged areas as in Punjab—Pakistan. In: Halophytes as a resource for livestock and for rehabilitation of degraded lands. Proceedings of the International Workshop on Halophytes and Reclamation of Saline Wastelands and as a resource for livestock problems and prospects. Nairobi, Kenya, 22–27 November 1992, 231–234.

This study deals with the distribution and types of halophytic vegetation covering 1.14 million ha of saline-sodic and waterlogged areas of the Punjab province and assesses the forage and livestock production potential of these areas under both unmanaged and managed environments. In arid and semiarid environments herbage and browse production inside the protected areas were estimated to be almost twice that outside, whereas in sub-humid regions it was 13 times that of the unprotected counterparts.

Bogemans, J., Neirinckx, L. and Stassart, J.M. (1989). Dienst Plantenfysiologie, Vrije Universiteit Brussel, Paardenstraat 65, B-1640, St. Genesius-Rode, Belgium. Effect of deicing NaCl and $CaCl_2$ on spruce (*Picea abies* (L.) sp). Plant and Soil, 120:203–211.

This paper reports on the effect of NaCl and $CaCl_2$ deicing salts on injury to spruce trees (*Picea abies*), from two field experiments carried out for 10 weeks during winter, with a total dose of 1.5 kg/m^2 NaCl, $CaCl_2$, or a 75:25 NaCl:$CaCl_2$, mixture used. Salt injury ratings corresponded well to Cl concentrations found in needles and twigs. The presence of Ca reduced the degree of salt injury and lowered Cl concentrations.

Bolyn, J.H.L. (1975). Faculte des Sciences Agronomiques de l'Etat, Gembloux, Belgium. Plant growth in saline media. Annales de Gembloux, 81:105–114.

Provides growth response functions for *Atriplex breweri* and *Acacia saligna* to increasing concentrations of NaCl or other mineral salts. (In French.)

Boucaud, J. and Ungar, I.A. (1976). Laboratorie de Physiologie Vegetale, Equipe de Recherche Associee au CNRS No. 405, Universite de Caen, 14032 Caen, France. Hormonal control of germination under saline conditions of three halophytic taxa in the genus *Suaeda*. Physiologia Plantarum, 37:143–148.

Amongst the data presented it is shown that seed dormancy induced by osmotic stress in *Suaeda maritima*. var. *flexilis* and var. *macrocarpa* and *S. depressa* could also be alleviated by treatments with gibberellic acid. Endogenous concentrations of cytokinins in seeds exposed to osmotic stress (850 mol/m^3 NaCl) in these three taxa were reduced and gibberellin-like activity was reduced in *S. depressa* when seeds were exposed to this treatment.

Bower, C.A., Ogata, G. and Tucker, J.M. (1970). US Department of Agriculture, Riverside, California 92502, USA. Growth of Sudan and tall fescue grasses as influenced by irrigation and leaching fraction. Agronomy Journal, 62:793–794.

> When Sudan and tall fescue grasses were grown in lysimeters, yields highly correlated with the average salinity of the root zone despite marked differences in the vertical distribution of salt.

Bowman, W.D. (1988). Department of Botany, Duke University, Durham, NC 27706, USA. Response to short-term inundation with iso-osmotic solutions of sea water and sorbitol in a C_4 nonhalophyte: evidence for a salt tolerance mechanism. Oecologia, 77:365–369.

> In a glasshouse study, a salt-tolerant ecotype of the C_4 nonhalophyte *Andropogon glomeratus* was treated with sorbitol (a neutral osmoticum) and synthetic sea water, for five days. Leaf osmotic adjustment occurred only in plants watered with sea water, and was associated with an increase in Na and Cl concentrations (these accounted for about 95% of the leaf osmotic adjustment). Plants treated with seawater also had greater net photosynthetic CO_2 uptake and greater photosynthetic recovery following treatment. Photosynthetic inhibition was related primarily to metabolic factors, including a decrease in carboxylation efficiency. A model is presented for a mechanism promoting tolerance to transient sea water inundation.

Bowman, W.D. and Strain, B.R. (1987). Department of Botany, Duke University, Durham, NC 27706, USA. Responses to long- and short-term salinity in population of the C_4 nonhalophyte *Andropogon glomeratus* Walter B.S.P. Oecologia (Berlin), 75:73–77.

> Relative growth reductions for salt marsh and inland populations of soil-cultured *Andropogon glomeratus plants* treated with 0, 1/4 and 1/2 strength synthetic seawater under glasshouse conditions for five weeks, were similar. However, survival of seedlings of four populations treated for up to five days with full-strength sea water differed and reflected response to tidal inundation in a salt marsh. When transplanted into a salt marsh, plants from the marsh population had better survival than those from inland.

Bowman, W.D. and Strain, B.R. (1987). Department of Botany, Duke University, Durham, NC 27706, USA. Physiological responses in two populations of *Andropogon glomeratus* Walter B.S.P. to short-term salinity. Oecologia (Berlin), 75:78–82.

This paper reports on a study to investigate possible physiological mechanisms which enable salt-tolerant individuals of *Andropogon glomeratus* to survive short-term inundation. With half-strength synthetic sea water, photosynthetic CO_2 uptake was substantially inhibited in both populations, mainly due to effects on metabolism rather than stomates. When salt treatment was stopped, photosynthetic capacity increased more rapidly in the tolerant population. Osmotic adjustment occurred rapidly in the tolerant population, but there was no adjustment in the non-tolerant population. The authors concluded that salt tolerance in the marsh population was associated with rapid osmotic adjustment and recovery of photosynthetic capacity when salt treatment was stopped, rather than maintenance of greater photosynthesis during exposure to salinity.

Boyce, S.G. (1954). Department of Botany, Ohio University, Athens, Ohio, USA. The salt spray community. Ecological Monograph, 24:29–67.

This paper presents results of glasshouse and field studies which investigate the effect of salt spray on the growth, growth form and distribution of plants found on the coast of North Carolina and Cape Cod, Massachusetts, USA. The process of salt spray movement from ocean to plant leaves is investigated in detail. Data on Cl ion entry and distribution in leaves and anatomy of several species is presented.

Bradbury, M. and Ahmad, R. (1990). Department of Biology, Sultan Qaboos University, Al-Khod, Muscat, Oman. The effect of silicon on the growth of *Prosopis juliflora* growing in saline soil. Plant and Soil, 125:71–74.

Pot-grown *Prosopis juliflora* plants treated with 0.47 mol/m^3 SiO_2 had significantly less DW reduction at 260 mol/m^3 NaCl (highest level imposed) compared to no SiO_2 added, and a greater distribution of dry matter to the leaves.

Brady, C.J., Gibson, T.S., Barlow, E.W.R., Speirs, J. and Jones, R.G.W. (1984). Divison of Food Research, CSIRO, North Ryde, NSW 2113, Australia. Salt-tolerance in plants. I. Ions, compatible organic solutes and the stability of plant ribosomes. Plant, Cell and Environment, 7:571–578.

This paper compares the effects of saline solutions on the protein synthesising systems of plants of varying salt tolerance by investigating effects on the stability of ribosomes and polysomes. Polysomes were less stable in the presence of Na than K salts, and were much less stable in Cl than in acetate salts. Polysomes from all species (except *Ulva lactuca*), and including *Atriplex nummularia* were similarly sensitive to KCl. Slight differences in ribosomal stability were observed between species, but these were unrelated to their salt tolerance.

Braidek, J.T., Fedec, P. and Jones, D. (1984). POS Pilot Plant Corporation, Saskatoon, Saskatoon S7N 2R4, Canada. Field survey of halophytic plants of disturbed sites on the Canadian prairies. Canadian Journal of Plant Science, 64:745–751.

Ten native and introduced species were in 25% or more of the saline habitats surveyed. These included *Kochia scoparia* and *Atriplex patula* var. *subspicata*, both of which have been investigated by other researchers as potential salt-tolerant crops.

Braun, Y., Hassidim, M., Lerner, H.R. and Reinhold, L. (1986). Department of Botany, The Hebrew University of Jerusalem, Jerusalem 91904, Israel. Studies on H^+-translocating ATPases in plants of varying resistance to salinity. I. Salinity during growth modulates the proton pump in the halophyte *Atriplex nummularia*. Plant Physiology, 81:1050–1056.

The proton translocating activity per mg membrane protein from isolated membrane vesicles of *Atriplex nummularia* roots was doubled in the presence of 400 mol/m^3 NaCl. Several other effects on the sensitivity of the proton pump are described. The findings indicate that this halophyte requires salt in the root-zone for the proper functioning of its H-translocating ATPase and concurs with its growth stimulation by salt.

Bray, R.A., Jones, R.J. and Probert, M.E. (1985). CSIRO, Division of Tropical Crops and Pastures, Queensland, Australia. Shrub legumes for forage in tropical Australia. In: Shrub legume research in Indonesia and Australia (Craswell, E.T. and Tangendjaja, B., ed.), 33–38. Proceeding of International Workshop, ACIAR Proceedings No. 3, Canberra, Australia.

The paper describes the importance of shrub and tree legumes in comparison to herbaceous legumes with special reference to the genus *Leucaena*. One strain of *Rhizobium* (NGR 8) may perform better in alkaline soils than other strains.

Breckle, S.W. (1986). Department of Ecology, University, PO Box 8640, D-4800, Bielefeld, B.R.D. Studies on halophytes from Iran and Afghanistan. II. Ecology of halophytes along salt gradients. In: Plant life of south-west Asia (Hedge, I.C., ed.), 203–217. Proceedings of the Royal Society of Edinburgh, Vol. 89.

Various types of halophytes from Iran and Afghanistan were compared and some eco-physiological characteristics are presented. The differences between stem-halosucculents, leaf-halosucculents, and types of salt avoiders (pseudohalophytes and non-halophytes or glycophytes) are highlighted.

Burleigh, S.H. and Dawson, J.O. (1991). Department of Forestry, University of Illinois, Urbana, Illinois 61801, USA. Effects of sodium chloride and melebiose on the *in vitro* growth and sporulation of *Frankia* strain HFPCc13 isolated from *Casuarina cunninghamiana*. Australian Journal of Ecology, 16: 531–535.

Reports that the *in vitro* growth and sporulation of an isolate of (HFPCcl3, highly infective) of *Frankia*, a N_2-fixing symbiont of *Casuarina*, was inhibited by both the toxic and osmotic effects of NaCl as demonstrated by its tolerance to metabolically neutral melibiose osmoticum at NaCl and melibiose concentrations from 0 to 500 mol/m^3. The tolerance of this strain to NaCl was found to be greater than that reported for *Frankia* strains isolated from actinorhizal plants from moist, temperate regions lacking sodic soils.

Campbell, N. and Thomson, W.W. (1975). Department of Biology, University of California, Riverside, California, USA. Chloride localization in the leaf of *Tamarix*. Protoplasma, 83:1–14.

The distribution of Cl in the leaf and salt gland of *Tamarix aphylla* was investigated by electron microscopy using the silver precipitation technique (to produce electron-dense AgCl deposits) to evaluate salt tolerance mechanisms. More AgCl was deposited in the leaf apoplast, the plasmodesmata of the transfusion zone, and the sub-cuticular spaces of the salt glands of salt-treated, secreting tissue compared with distilled water-treated, non-secreting tissues.

Casas, A.M., Bressan, R.A. and Hasegawa, P.M. (1991). Center for Plant Environmental Stress Physiology, Department of Horticulture, Purdue University, West Lafayette, IN 47907, USA. Cell growth and water relations of the halophyte, *Atriplex nummularia L.*, in response to NaCl. Plant Cell Reports, 10:81–84.

Unadapted *Atriplex nummularia* cell cultures grew more slowly in the presence of NaCl (up to 350 mol/m^3) than cells adapted to 342 or 428 mol/m^3 NaCl. During adaptation, reduced growth is due to reduced cell division rather than reduced cell enlargement. Turgor of NaCl-adapted cells was equivalent to that of unadapted cells, indicating that the cells did not respond to salt by osmotic overadjustment.

Casas, A.M., Nelson, D.E., Raghothama, K.G., D'Urzo, M.P., Singh, N.K., Bressan, R.A. and Hasegawa, P.M. (1992). Center for Plant Environmental Stress Physiology, Department of Horticulture, Purdue University, West Lafayette, IN 247907-1165, USA. Expression of osmotin-like genes in the halophyte *Atriplex nummularia L.* Plant Physiology, 99:329–337.

This paper reports that proteins immunologically related to osmotin are found in both halophytes and non-halophtyes, that unique isoforms are synthesised in the halophyte *Atriplex nummularia* and that osmotin halophytic genes have different regulatory properties than those found in tobacco. Detailed information on peptides and CDNA clones in unadapted and NaCl-adapted cells of *A. nummularia* are provided.

Catalan, L., Balzarini, M., Taleisnik, E., Sereno, R. and Karlin, U. (1994). Instituto de Fitopatologia y Fisiologia Vegetal, INTA, CC 70, 5014 Cordoba, Argentina. Effects of salinity on germination and seedling growth of *Prosopis flexuosa* (D.C.). Forest Ecology and Management, 63:347–357.

Salt tolerance during seed germination was examined in seeds of *Prosopis flexuosa* collected from two populations growing either on highly saline or non-saline soil in Argentina. Germination was reduced above 200 mol/m^3 NaCl. Variability was greater between individual trees than between populations and highest at 400 mol/m^3 NaCl. Average survival for seedlings treated for 90 days was >96%. A 50% reduction in final height was observed at (nominal) 400 mol/m^3 NaCl but actual final soil salinities of 1000 mol/m^3 NaCl.

Cavalieri, A.J. and Huang, A.H.C. (1979). Biology Department and Belle W. Baruch Institute for Marine Biology and Coastal Research, University of South Carolina, Columbia 29208, USA. Evaluation of proline accumulation in the adaptation of diverse species of marsh halophytes to the saline environment. American Journal of Botany, 66:307–312.

> In a growth chamber experiment, with plants exposed to increasing NaCl, the following species differences were found: *Limonium carolinianum* and *Juncus roemerianus* began to accumulate proline at 250 mol/m^3 with up to 63.6 µmol per g FW at higher salinities; for the C_4 grasses, *Spartina alterniflora, Spartina patens* and *Distichlis spicata*, proline accumulation occurred at approx. 500 mol/m^3 (to 27.4 µmol per g FW); and the succulents, *Salicornia bigelovii, Salicornia virginica* and *Borrichia fruitescens* did not accumulate proline until 700 mol/m^3. Similar species rankings were found under water stress. Field measurements of proline contents and soil salinities correlated well with the findings from growth chamber experiments. Calculations of the contribution of proline accumulation and breakdown in *L. carolinianum* to osmotic adjustment are provided.

Chaturvedi, A.N. (1984). Conservator of Forests, Research and Development Circle, Lucknow, India. Firewood crops in areas of brackish water. Indian Forester, 110:364–366.

> On a site near Mathura, Uttar Pradash, India, irrigated with brackish (pH ranged from 7.00 to 7.85 and EC from 4.0 to 6.1) water, species performing well at 18 months were *Prosopis juliflora, Acacia nilotica, Terminalia arjuna, Syzygium cumini, Albizia lebbeck, Pongamia pinnata, Cassia auriculata, C. siamea* and *Adhatoda vasica*.

Chaturvedi, A.N., Bhatt, D.N. and Mishra, C.M. (1986). Conservator of Forests, Research and Development Circle, Lucknow, India. Root development in some tree species on usar soils. Journal of Tropical Forestry, 2:119–130.

> On a seasonally-waterlogged, saline –alkaline site in Uttar Pradash, excavation of root systems of 17- to 19-year-old trees of 15 species showed a relationship between good development of surface lateral roots (e.g. *Albizia procera, Albizia lebbeck, Dalbergia sissoo, Pongamia pinnata, Eucalyptus* 'hybrid' (*E. tereticornis*) and *Terminalia arjuna*) and good growth.

Chaturvedi, A.N., Sharma, S.C. and Srivastava, R. (1988). Forest Department, 17 Rana Pratab Marg, Lucknow, Uttar Pardesh, India. Water consumption and biomass production of some forest tree species. The International Tree Crops Journal, 5:71–76.

This paper reports water use, stem diameter and biomass growth and water use efficiency, from a lysimeter study for *Azadirachta indica, Prosopis juliflora* and *Acacia nilotica* and compares them with rates previously reported for other species.

Chaudhry, A.H., Iqbal, M. and Sandhu, G.R. (1986). Department of Biological Sciences, Quaid-i-Azam University, Islamabad, Pakistan. The performance of *Casuarina* in problem soils of Pakistan. In: Prospects for biosaline research, (Ahmad, R. and San Pietro, A., ed.), 265–271, Proceedings of the US-Pakistan Biosaline Research Workshop, 22–26 September 1985. Department of Botany, University of Karachi, Karachi, Pakistan.

This paper describes the growth and N_2 fixing capacity of inoculated *C. glauca* under saline conditions (EC_e 2.5–15 dS/m) in pots, and growth under waterlogged conditions.

Chavan, P.D. and Karadge, B.A. (1986). Botany Department, Shivaji University, Kolhapur 416 004, India. Growth, mineral nutrition, organic constituents and rate of photosynthesis in *Sesbania grandiflora* L. grown under saline conditions. Plant and Soil, 93:395–404.

Growth of *S. grandiflora* in soil-filled pots was decreased when irrigated with EC 15 dS/m. Na and Cl accumulated in the leaf rachis rather than leaflets. Increasing salinity resulted in higher concentrations of organic acids and soluble sugars, no change in proline concentrations and decreased chlorophyll content of the leaves.

Cheeseman, J.M. (1988). Department of Plant Biology, University of Illinois, 505 S. Goodwin Ave., Urbana IL 61801, USA. Mechanisms of salinity tolerance in plants. Plant Physiology, 87: 547–550.

This review emphasises the importance of understanding the whole plant response to salinity. Two aspects of cellular and organismal metabolism are described, namely the control and integration of Na uptake and allocation in plants, and that involved in readjustment of other aspects of metabolism, especially those involving carbon as a resource.

Cheeseman, J.M., Bloebaum, P., Enkoji, C. and Wickens, L.K. (1984). Department of Plant Biology, University of Illinois, 289 Morrill Hall, 505 South Goodwin, Urbana, IL. 61801, USA. Salinity tolerance in *Spergularia marina*. Canadian Journal of Botany, 63:1762–1768.

Reports on growth, morphology, and ion (Na and K) concentration of coastal halophyte *Spergularia marina* plants grown in solution culture and treated with dilutions of artificial sea water. Growth stimulation was found at '0.2 × sea water' and this was related to Na concentration. In shoots of '0.2 × sea water'-plants no regions were either free of or exceptionally high in Na. The ion concentration and distribution patterns are compared with those in a number of other halophytes.

Chen, Z.Z., Wang, T.T. and Yang, J.C. (1984). Division of Silviculture, Taiwan Forest Research Institute, Taipei, Taiwan. Variation in salt tolerance of *Casuarina* species. Bulletin No. 422, Taiwan Forest Research Institute, 7 p.

Reports on a study in which seedlings of *C. glauca, C. equisetifolia* (and their putative hybrids), *C. stricta, C. torulosa, C. huegeliana* and *C. oligodon* were flooded with 2.5% salt water for three days. (In Chinese, English summary.)

Chetelat, R. and Wu, L. (1983). Environmental Horticulture Department, University of California at Davis, California, USA. Salt tolerance and organ ion compartmentation in *Agrostis stolonifera*. Plant Physiology, 72:136.

Differences in tolerance, particularly when measured by root elongation, were found among several clones from a seashore population grown in solution with 0, 100 and 200 mol/m^3 added NaCl. Leaf sheaths had higher ion concentrations than leaf blades, particularly in a relatively tolerant clone.

Chrometzka, P., Wagner, A. and Reinshagen, A. (1974). Universitat der Saarlandes, Saarbrucken, German Federal Republic. Trees and shrubs tolerant to salt. Deutsche Baumschule, 26:12–14.

Of several species of small trees and shrubs planted along the centre of motorways examined for their reactions to salt spread on the road to thaw snow, *Elaeagnus angustifolia, Hippophae rhamnoides* and *Viburnam lantana* consistently showed no injury. Data are also provided on responses of grasses. Beneficial effects of mulch application are shown.

Choukr-Allah, R., Malcolm, C.V. and Hamdy, A. (ed.) (1996). Institute Agronomique et Veterinaire Hassan II, Agadir, Morocco. Halophytes and biosaline agriculture. Marcel Dekker Inc., New York, USA, 400 pp.

The following subjects are covered in this proceedings of a 'Workshop on Halophyte Utilisation in Agriculture' held in Agadir, Morocco in September 1993: (i) the potential of halophytes in the development and rehabilitation of arid and semiarid areas, (ii) their biology and ecophysiology, (iii) their agronomy for forage use, (iv) irrigation studies using saline and sea water, (v) case studies from Iran, Australia, USA, Tunisia, Israel and Pakistan and (v) economic and environmental aspects of the sustainable use of halophytic forages. The book is aimed at landholders and extension workers involved in the reclamation and rehabilitation of salt-affected areas.

Clarke, A.J. (1982). Resource Management Division, Department of Agriculture, South Perth, WA 6151, Australia. The grazing value of saltbushes. Journal of Agriculture, Western Australian Department of Agriculture, 23:7–9.

The paper describes the prospects of different saltbush species with respect to their grazing value in the wheatbelt saltland. Wavy leaf saltbush (*Atriplex undulata*), river saltbush (*A. amnicola*), marsh saltbush (*A. paludosa*) and bluebush (*Maireana brevifolia*) were quite resistant to heavy grazing and recovered significantly.

Clarke, L.D. and Hannon, N.J. (1970). School of Biological Sciences, University of New South Wales, Kensington, New South Wales, Australia. The mangrove swamp and salt marsh communities of the Sydney district. III. Plant growth in relation to salinity and waterlogging. Journal of Ecology, 58:351–369.

Reports on results of germination and seedling growth studies with salinity (20–80% sea-water) and waterlogging treatments, in which *Casuarina glauca* was found to be least tolerant compared with non-woody species from the mangrove and *Arthrocnemum australasicum* zones. The performance of the species in culture was closely correlated with their distribution and abundance in micro-habitats that differ in these environmental factors.

Clark, N.B., Read, S.M. and Vinden, P. (1999). CSIRO Forestry and Forest Products, Private Bag 10, Clayton South MDC, Victoria, 3169. Effects of drought and salinity on wood and kraft pulps from young plantation eucalypts. Appita Journal, 52:93–97, 113.

This paper reports on yield, wood density, pulp yield, bleaching properties and paper making properties for 6–14-year-old trees of several eucalypt species at four experimental sites (dryland and irrigated) in southern Australia. Only *Eucalyptus camaldulensis* was evaluated under saline conditions and the only significant effect was increased basic density. (The effluent EC used at the Bolivar site is 2.3 rather than 23 dS/m, as given.)

Clemens, J., Campbell, L.C. and Nurisjah, S. (1983). Department of Agronomy and Horticultural Science, University of Sydney, Sydney, NSW 2006, Australia. Germination, growth and mineral ion concentrations of *Casuarina* species under saline conditions. Australian Journal of Botany, 31:1–9.

Reports on the response of 11 *Casuarina* species to NaCl at germination and/or as seedlings. Both germination percentage and rate were reduced in all species by increasing NaCl (up to 400 mol/m^3). *C. equisetifolia* (most tolerant) had little growth reduction and no symptoms, whereas *C. inophloia* (most sensitive) had greatly reduced growth and shoot tip chlorosis and/or death at 150 mol/m^3 (highest level applied); this was related to high Na and Cl concentrations. There appeared to be little correlation between response to salinity at germination and seedling stages for five species evaluated at both stages.

Clemens, J., Kirk, A. and Mills, P.D. (1978). Department of Agronomy and Horticultural Science, The University of Sydney, Sydney, NSW 2006, Australia. The resistance to waterlogging of three *Eucalyptus* species: effect of waterlogging and an ethylene-releasing growth substance on *E. robusta, E. grandis* and *E. saligna*. Oecologia (Berlin), 34:125–131.

Seedlings of *Eucalyptus grandis* were found to be more resistant to waterlogging than those of *E. robusta* and seedlings of both species were more resistant than those of *E. saligna*. Resistance was related to development of adventitious roots. Plant height and total DW decreased linearly with plant ethylene content. There was no difference between the species in their response to ethephon, an ethylene-releasing growth substance.

Clemens, J. and Pearson, C.J. (1977). Department of Agronomy and Horticultural Science, University of Sydney, NSW 2006, Australia. The effect of waterlogging on the growth and ethylene content of *Eucalyptus robusta* Sm. (swamp mahogany). Oecologia, 29: 249–255.

This paper reports on a glasshouse study in which sand-cultured *E. robusta* (known to tolerate poor root-zone aeration) were treated with and without waterlogging for 80 days. Water logged plants had reduced stem elongation and developed symptoms of leaf chlorosis, epinasty and premature abscission, stem hypertrophy and adventitious shoots. Chlorophyll content was reduced and the soluble protein content of the upper leaves increased. Waterlogging doubled the rate of release of ethylene from roots and stems within 6 days, but had no effect on leaf ethylene concentrations.

Clipson, N.J.W. (1987). School of Biological Science, University of Sussex, Falmer, Brighton, Sussex BNL 9QG, UK. Salt tolerance in the halophyte *Suaeda maritima* (L.) Dum. Growth, ion and water relations and gas exchange in response to altered salinity. Journal of Experimental Botany, 38:1996–2004.

Reports on short-term (11 day) growth and shoot ion response in seedlings of *Suaeda maritima* when salinity in nutrient solution culture was increased from 0 to 200 mol/m^3 NaCl. Growth, growth rates and Na and Cl concentrations increased whilst K concentrations declined. Changes in transport of Na to the shoot, osmotic potential, photosynthesis, and transpiration for up to 72 hours after transfer of plants originally growing at 0 and 200 mol/m^3 to 200 and 400 mol/m^3, respectively are described. Results are discussed in terms of the ability of halophytes to adjust to fluctuating salinity and to salt tolerance mechanisms in general.

Clipson, N.J.W. and Flowers, T.J. (1987). School of Biological Sciences, University of Sussex, Falmer, Brighton, Sussex BN1 9QG, UK. Salt tolerance in the halophyte *Suaeda maritima* (L.) Dum. The effect of salinity on the concentration of sodium in the xylem. New Phytologist, 105:359–366.

Based on calculations from rates of ion transport and transpiration during the day and night in whole seedlings of *Suaeda maritima* growing over a range of salinities, xylem Na concentrations were found to increase up to 200 mol/m^3 external NaCl and to be more strongly excluded from the transpiration stream as salinity increased, whereas xylem K concentrations declined as external NaCl concentration increased, although selectivity for K increased at higher salinities. Results are discussed in relation to osmotic adjustment in *S. maritima*.

Clipson, N.J.W., Tomos, A.D., Flowers, T.J. and Wyn Jones, R.G. (1985). School of Biological Sciences, University of Sussex, Brighton, Sussex BN1 9QG, UK. Salt tolerance in the halophyte *Suaeda maritima* (L.) Dum. The maintenance of turgor pressure and water-potential gradients in plants growing at different salinities. Planta, 165:392–396.

Reports on osmotic potentials and individual epidermal cell turgor pressures in the leaves (young, old and apices) of seedlings of *Suaeda maritima* growing over a range of salinities. Calculation of leaf water potential, based on these measurements, indicated that the gradient between young leaves and the external medium was not altered by salinity, and it was greater than that for older leaves under NaCl.

Clucas, R.D. and Ladiges, P.Y. (1979). School of Botany, University of Melbourne, Parkville, Victoria 3052, Australia. Variations in populations of *Eucalyptus ovata* Labill., and the effects of waterlogging on seedling growth. Australian Journal of Botany, 27:301–315.

Part of the work reported here involves a glasshouse experiment in which seedlings from several provenances (seed sources) of *Eucalyptus ovata* were waterlogged. Waterlogging reduced seedling biomass, leaf size and lignotuber development; all populations responded similarly and typical responses included development of stem hypertrophy and adventitious roots which were often negatively geotropic.

Cooper, A. (1982). School of Environmental Sciences, Ulster Polytechnic, Northern Ireland, UK. The effects of salinity and waterlogging on the growth and cation uptake of salt marsh plants. New Phytologist, 20:263–275.

The response to salinity of seedlings of *Festuca rubra*, *Juncus gerardii*, *Armeria maritima*, *Plantago maritima*, *Aster tripolium*, *Triglochin maritima*, *Puccinellia maritima* and *Salicornia europaea*, grown on drained and waterlogged salt marsh soils, is related to their position on a salt marsh ecotone. The growth of upper marsh species was markedly affected by both salinity and waterlogging after two months. *S. europaea* had maximum growth under salinity and *P. maritima* preferred waterlogged soils. Reduced growth under salinity was associated with large increases in shoot Na concentrations.

Cordukes, W.E. and Maclean, A.J. (1973). Plant Research Institute, Canada Department of Agriculture, Ottawa, Canada. Tolerance of some turf grass species to different concentrations of salt in soils. Canadian Journal of Plant Sciences, 53:69–73.

> There was no effect of EC_e 7.2 dS/m (produced with added $CaCl_2$) on growth of Kentucky blue grass (*Poa pratensis*), creeping red fescue (*Festuca rubra*) and perennial ryegrass (*Lolium perenne*) in pots filled with sand through to clay loam, but marked deterioration was observed at about 20 dS/m. Leaf Cl concentrations were highest in perennial ryegrass and lowest in red fescue. Leaf Cl concentrations were lowest for plants grown in sand at higher salt concentrations.

Coutts, M.P. (1982). Forestry Commision, Northern Research Station, Roslin, Midlothian, EH259S Y, UK. The tolerance of tree roots to waterlogging. V. Growth of woody roots of sitka spruce and lodgepole pine in waterlogged soil. New Phytologist, 90:467–476.

> This paper (one of a series) reports results of an elegant experiment to determine effects of waterlogging on root cuttings of *Picea sitchensis and Pinus contorta* using a split root system (waterlogged versus free draining). The waterlogging treatment was applied outdoors from April to November. Effects on woody and primary roots are described. For both species, all primary roots in waterlogged soil were killed, whereas most of the woody roots survived. Enlarged lenticels were present on woody roots of both species under waterlogging. The results are discussed in relation to differences in oxygen transport known to occur in woody roots of the two species.

Craig, G.F., Atkins, C.A and Bell, D.T. (1990). Department of Botany, University of Western Australia, Nedlands, WA 6009, Australia. Effect of salinity on growth of four strains of *Rhizobium* and their infectivity and effectiveness on two species of *Acacia*. Plant and Soil, 133:253–262.

> The growth of two *Rhizobium* strains in broth culture, isolated from nodules of *Acacia redolens* growing in saline areas of south western Australia, and two other strains isolated from *A. saligna* and from *A. cyclops*, was largely unaffected up to 300 mol/m^3 NaCl. In general, Na and amino acid concentrations increased and sugar levels decreased in response to salt. In combination with a highly salt-tolerant provenance of *A. redolens*, inoculation with strains from *A. redolens* and *A. cyclops* formed symbioses which did not vary significantly in nodule number and mass, specific nodule activity or total N content up to 160 mol/m^3. However, on

a more salt-sensitive provenance of *A. redolens* and on *A. cyclops*, the infectivity and effectivity of the *Rhizobium* strains tested usually decreased with increasing salt concentration.

Craig, G.F., Bell, D.T. and Atkins, C.A. (1990). Department of Botany, University of Western Australia, Nedlands, 6009 WA, Australia. Response to salt and waterlogging stress of ten taxa of *Acacia* selected from naturally saline areas of Western Australia. Australian Journal of Botany, 38:619–630.

Reports on a glasshouse experiment in which symbiotic seedlings of 10 *Acacia* taxa from areas of moderate to high soil salinity (EC_e between 10 and 48 dS/m at 5–60 cm depth) and sodicity were treated with increasing salinity, with and without waterlogging. *Acacia cyclops*, *A. brumalis*, *A. redolens* and *A. aff. lineolata* had highest survival on salt alone (final EC = 95 dS/m). Most species were sensitive to waterlogging, with *A. patagiata*, *A. cyclops* and *A. brumalis* the most sensitive. Combined salt and waterlogging decreased survival further than either treatment alone; *A. aff. lineolata* and *A. mutabilis* ssp. *stipulifera* were most tolerant. Reduced growth under salt was associated with higher phyllode Na concentrations; Na concentration was greater for plants treated with salt plus waterlogging than salt alone. There was evidence of provenance variation in Na concentrations of phyllodes related to salinity of the collection site. Other species evaluated were *A. ampliceps*, *A. eremaea*, *A. ixiophylla* and *A. mutabilis* subspp. *mutabilis*.

Criddle, R.S., Hansen, L.D., Breidenbach, R.W, Ward, M.R. and Huffaker, C. (1989). Department of Biochemistry and Biophysics, University of California, Davis, CA, 95616, USA. Effects of NaCl on metabolic heat evolution rates by barley roots. Plant Physiology, 90:53–58.

Reports on the effect of NaCl on metabolic heat output of root tips from several barley cultivars differing in salt tolerance using isothermal microcalorimetry (related to respiratory activity). It is concluded that this is a promising method for convenient and rapid determination of cultivar differences in response to salinity. (Further work on this technique in relation to salinity is in progress with trees and is referred to in Marcar and Khanna (1997).)

Cromer, R.N., Eldridge, K.G. Tompkins and Barr, N.J. (1982). CSIRO Forestry and Forest Products, PO Box E4008, Kingston, Canberra ACT 2604, Australia. Intraspecific variation in the response of *Pinus radiata* to saline and water waste. Australian Forest Research, 12:203–215.

Significant intraspecific variation in diameter growth and shoot weight of potted *Pinus radiata* seedlings was found in response to increasing concentrations of NaCl in irrigation water. Seedlings from the coastal subpopulations of Ano Nuevo and Monterey were less resistant to high NaCl concentrations than inland subpopulations. All seedlings irrigated with 136 mol/m^3 NaCl survived whilst only 20% survived at 272 mol/m^3. Decreased growth in response to NaCl was associated with more negative water potentials in the needles and increased concentrations of Na and Cl in plant tissues.

Crouch, R.J. and Honeyman, M.N. (1986). Gunnedah Research Centre, PO Box 462, Gunnedah, NSW 2380, Australia. The relative salt tolerance of willow cuttings. Journal of Soil Conservation, 42:103–104.

Reports on health and growth of cuttings of 29 *Salix* species and cultivars and of *Populus nigra italica* grown in soil-filled pots and irrigated with EC of 0 to 4 dS/m for eight weeks. The most tolerant *Salix* species were *S. matsudana pendula*, *S. fragilis*, *S. matsudana tortuosa* and *S. purpurea* cv *Pohangina* and the least tolerant were *S. piperi*, *S. purpurea* cv *Irette* and *S. seringeana*. *P. nigra italica* was more tolerant than any *Salix*.

Crowley, G.M. (1994). Centre for Palynology and Palaeoecology, Department of Geography and Environmental Sciences, Monash University, Clayton, Victoria 3168, Australia. Groundwater rise, soil salinisation and the decline of *Casuarina* in southern Australia during the late Quaternary. Australian Journal of Ecology, 19:417–424.

This paper reviews literature and re-examines evidence for the decline in interglacial importance of *Casuarina* over the late Quaternary across south eastern Australia. The decline at most sites occurred synchronously with a rise in ground water or soil salinisation, or both, and *Casuarina stricta* is the main species considered to have been affected. A link is demonstrated between ground water salinity and the distribution status of *Casuarina* in Victoria.

Cui, Z.X., Li, S.M., Fan, R.W. and Zhang, S.F. (1993). Inner Mongolia Academy of Agricultural Science, Hohhot, Inner Mongolia, China. Study on sowing methods of *Puccinellia tenuiflora* in Tumochuan saline alkaline land. Grassland of China, 4:27–30.

Puccinellia tenuiflora germinated at soil salinities of 0.5 to 0.8%. Biological characteristics and recommended agronomy are discussed. (In Chinese.)

Cyrus, D.P., Martin, T.J. and Reavell, P.E. (1997). Coastal Research Unit of Zululand, Department of Zoology, University of Zululand, Private Bag X1001, KwaDlangezwa 3886, KwaZulu-Natal, South Africa. Salt-water intrusion from the Mzingazi River and its effects on adjacent swamp forest at Richards Bay, Zululand, South Africa. Water SA, 23:101–108.

Reports on the the death of a number of swamp forest trees as well as the defoliation of others due to saltwater intrusion up the Mzingazi River.

Dafni, A. and Negbi, M. (1978). Department of Agricultural Botany, Faculty of Agriculture, Hebrew University of Jerusalem, Rehovot, Israel. Variability in *Prosopis farcta* in Israel: seed germination as affected by temperature and salinity. Israel Journal of Botany, 27:147–159.

Increasing NaCl in the range 0 to 600 mol/m^3 delayed the onset of germination, and decreased the rate of germination and final germination percentage for 10 populations of *Prosopsis farcta*. There was no relationship between the salinity of the habitat from which the seed population was collected and the salt tolerance of that population.

Dagar, J.C., Singh, N.T. and Singh, G. (1995). Central Soil Salinity Research Institute, Karnal 132001, India. Agroforestry options for degraded and problematic soils of India. In: Agroforestry systems for sustainable land use (Singh P., Pathak, P.S. and Roy, M.M., ed.), 96–120. Science Publishers Inc., USA.

Various agroforestry technologies for sustained production of eroded lands, sand dunes, acid soils, salt-affected soils, sodic soils, saline soils, waterlogged areas and mine spoils are discussed.

Dale, M. (1991). Sunraysia Horticultural Centre, Department of Food and Agriculture, Mildura, Victoria, Australia. Preliminary results on irrigation drainage water re-use on different tree species. Proceedings of the 'Woodlots Workshop' Conference, Series 32. Department of Agriculture and Rural Affairs (Victoria), 177–182.

This paper describes results from two sites in the northern Victorian irrigation area of Sunraysia for a range of Australian native hardwood species (acacia, eucalypt, casuarina and melaleuca) irrigated with saline drainage water.

Dantzman, C.L. and Hodges, E.M. (1978). Agricultural Research Centre, Ona, Florida 33865, USA. Effect of saline irrigation water on the growth of pangola digitgrass (*Digitaria decumbens* Stent.). Proceedings of the Soil and Crop Science Society of Florida, 37:131–134.

Plots of pangola digitgrass (*Digitaria decumbens*), a widely grown pasture grass in central and southern Florida, were irrigated with saline water (0–10 000 ppm—approx. 170 mol/m^3—NaCl). Growth reduction occurred in the plots receiving 10 000 ppm NaCl after three months but growth recovered after the rainy season presumably due to leaching of salts.

Davidson, N.J. and Galloway, R. (ed.) (1994). Botany Department, University of Tasmania, GPO Box 252C, Hobart, Tasmania 7001, Australia. Productive use of saline land. ACIAR Proceedings 42, Australian Centre for International Agricultural Research. Canberra, Australia, 124 p.

This workshop was convened to discuss research on the adaptation, establishment, culture and use of salt-tolerant vegetation in Australia, Pakistan, Thailand and India. There are 25 papers covering: perspectives on the rehabilitation of saline land; provenance trials with halophytes and trees; animal grazing of halophytes; environmental effects on establishment, productivity and seed quality of *Atriplex amnicola*; and the ecology and physiology of *Atriplex* species.

Davidson, N.J., Galloway, R. and Lazarescu, G. (1996). Botany Department, University of Tasmania, GPO Box 252C, Hobart, Tasmania 7001, Australia. Growth of *Atriplex amnicola* on salt-affected soils in Western Australia. Journal of Applied Ecology, 33:1257–1266.

This paper reports on the growth of river saltbush (*Atriplex amnicola*) at Tammin in Western Australia. It is suggested that the poor growth of river saltbush on saline valley floor soils in this area is due to a combination of waterlogging, adverse soil physical properties, salinity and drought, which varied on a meso- and micro-environmental scale. Soils are shallow sandy over a clay subsoil through which roots find it difficult to penetrate. Where plant roots were confined to sandy surface soils they were exposed to drought during summer (leaf water potentials as low as –5.5 MPa).

Davidson, N.J. and Reid, J.B. (1978). Botany Department, University of Tasmania, GPO Box 252C, Hobart, Tasmania 7001, Australia. The influence of hardening and waterlogging on the frost resistance of subalpine eucalypts. Australian Journal of Botany, 35:91–101.

Field observations and frost chamber trials (soil-filled pots, with and without waterlogging for 8 weeks) provided evidence for interaction between frost resistance and waterlogging. Species from subgenus *Monocalyptus* showed a reduced ability to harden under waterlogged conditions compared with species from subgenus *Symphyomyrtus*. Results are related to species adaptation to frost-prone sites at Snug Plains, Tasmania.

Davies, M.S. and Singh, A.K. (1983). Department of Plant Science, University College, Cardiff CF1 1XL, UK. Population differentiation in *Festuca rubra* L. and *Agrostis stolonifera* L. in response to soil waterlogging. New Phytologist, 94:573–583.

Two populations of *Agrostis stolonifera* and seven of *Festuca rubra* from salt marsh and inland habitats were grown in soil-filled pots under free-draining and waterlogged (partial and complete) conditions. Waterlogging stimulated growth in both populations of *A. stolonifera*, but the inland population had higher shoot Fe concentrations than did the salt marsh population. When waterlogged, growth of the salt marsh populations of *F. rubra* was generally less reduced and shoot Fe and Mn concentrations were lower than in the inland population.

Davison, E.M. and Tay, F.C.S. (1985). Department of Conservation and Environment, Perth, WA 6000, Australia. The effect of waterlogging on seedlings of *Eucalyptus marginata*. New Phytologist, 101:743–753.

This paper reports on anatomical changes in *Eucalyptus marginata* (jarrah) seedlings grown in sand/peat-filled pots in a glasshouse either with continuous waterlogging for up to 14 days, or waterlogged for a shorter time and then drained. Decreased growth under waterlogging, especially at high vapour pressure deficit and with longer periods of waterlogging, was related to the blockage of root and stem xylem vessels by tyloses, resulting in decreased water movement into and through the plants.

Dawson, J.O. and Gibson, A.H. (1987). Department of Forestry, University of Illinois, Urnana-Champaign, IL 61801, USA. Sensitivity of selected *Frankia* isolates from *Casuarina*, *Allocasuarina* and North American host plants to sodium chloride. Physiologia Plantarum, 70:272–278.

> Describes three experiments to examine the effects of NaCl (0 to 500 mol/m^3) on the in vitro growth of isolates of *Frankia* from *Casuarinaceae* and selected North American host plants. *Casuarina* isolates were only slightly affected up to 200 mol/m^3 but did not grow at 500 mol/m^3, whereas non-*Casuarina* isolates generally were severely affected above 50 mol/m^3. The authors conclude that selected *Frankia* strains from *Casuarina* and *Allocasuarina* could successfully establish in saline soils if introduced with species of host plants tolerant to these soils.

De Aragao, M.E.F., Jolivet, Y., Da Guia Silva Lima, M., De Melo, D.F. and Dizengremel, P. (1997). Departmento de Bioquimica e Biologia Molecular, Universidade Federal do Ceara, CP 1065, Campus do Pici, CEP 60001-970, Fortaleza-Ceara, Brazil. NaCl-induced changes in NAD (P) malic enzyme activities in *Eucalyptus citriodora* leaves. Trees, 12:66–72.

> In leaves of 3-month-old *Eucalyptus citriodora* seedlings treated with 50 and 100 mol/m^3 NaCl in a glasshouse, malate content decreased whilst specific activities of NAD and NADP-malic enzymes increased within three weeks of treatment. These results are discussed, mainly in terms of the role of these enzymes in the reducing power of the leaf cell.

De Jong, T.M. (1978). Smithsonian Radiation Biology Laboratory, Parklawn Drive, Rockville, MD 20852, USA. Comparative gas exchange and growth responses of C_3 and C_4 beach species grown at different salinities. Oecologia (Berlin), 36:59–68.

> This paper reports on gas exchange and relative growth rate for three native Californian coastal strand species under salinity (0 to –2.0 MPa). Mesophyll conductance of *Atriplex leucophylla* (C_4) and *Atriplex californica* (C_3) were stimulated at about –0.5 MPa, whereas that of *Abronia maritima* (C_3) was depressed by increasing salinity. Increasing salinity generally decreased net photosynthesis and leaf conductances but increased water-use efficiencies. The effect of salinity on relative growth and net assimilation rates (glasshouse) was not directly correlated with the effects on net photosynthesis (laboratory).

Decker, J.P. (1961). Rocky Mountain Forest and Range Experimental Station, Fort Collins, Colorado, USA. Salt secretion by *Tamarix pentandra* Pall. Forest Science, 7:214–217.

> Foliage of tamarisk is often covered by a bloom of salt that is secreted by salt glands embedded in epidermal pits. This paper provides a detailed description of three glands and of the salt deposition into 'whiskers'.

Dewey, D.R. (1960). Crops Research Division, ARS, USDA, Logan, Utah, USA. Salt tolerance of twenty-five strains of *Agropyron*. Agronomy Journal, 51:631–635.

> Wide differences in salt tolerance were observed among 14 *Agropyron* species in field and laboratory experiments. Differences in salt tolerance among strains within species indicate that selection within species would prove successful in developing more salt-tolerant strains.

Dionigi, C.P., Mendelssohn, I.A. and Sullivan, V.I. (1985). Department of Biology, University of Southwestern Louisiana, Lafayette, Louisiana 70504, USA. Effects of soil waterlogging on the energy status and distribution of *Salix nigra* and *S. exigua* (*Salicaceae*) in the Atchaflaya River Basin of Louisiana. American Journal of Botany, 72:109–119.

> *Salix nigra* was shown to be more tolerant of flooding than *Salix exigua* in field and glasshouse studies. *S. nigra* had significantly higher leaf energy status and a greater ability to oxidise waterlogged soil when flooded. However, *S. exigua* appeared to be more tolerant of moisture stress as indicated by significantly higher leaf resistances to water vapour exchange and higher leaf water potentials. These results are discussed in terms of the natural distribution of these two species.

Dirr, M.A. (1974). Department of Ornamental Horticulture, University of Illinois, Urbana, Illinois, USA. Tolerance of honeylocust seedlings to soil-applied salts. Horticultural Science, 9:53–54.

> Reports on effects of treatment of two-month-old, soil-grown seedlings of honeylocust *(Gleditsia triacanthos)* with NaCl, KCl and Na_2SO_4 at concentrations of 50, 150 and 250 mol/m^3. Cl salts were more detrimental than SO_4 salts in terms of symptoms and shoot DW. Shoot Cl concentration was a reliable index of the degree of salt injury. Root Na and Cl levels were inconsistent and did not reflect the degree of injury observed.

Dirr, M.A. (1976). Department of Ornamental Horticulture, University of Illinois, Urbana, Illinois, USA. Selection of trees for tolerance to salt injury. Journal of Arboriculture, 2:209–216.

This paper recommends that evaluation of plants for salt injury and tolerance to salt resulting from application of deicing salts along highways, on lawns, and along sidewalks, should be based on salts used, concentrations, application methods, osmotic effects, shoot or leaf Cl concentrations, and perhaps shoot Na concentrations. Since the appearance of the plant does not always indicate salt-induced damage, it is suggested that growth parameters should be used to augment visual evaluations.

Dirr, M.A. (1978). Department of Ornamental Horticulture, University of Illinois, Urbana, Illinois, USA. Tolerance of seven woody ornamentals to soil-applied sodium chloride. Journal of Aboriculture, 4:162–165.

Reports on injury symptoms and leaf Na and Cl concentrations for two-year-old soil-grown seedlings irrigated daily with 250 mol/m^3 NaCl. The order of tolerance was *Elaeagnus angustifolia, Rosa rugosa, Acer platanoides, P. besseyi, Rhus glabra, E. umbellatus* and *Prunus tomentosa*. Leaf Cl concentration in all injured species more accurately reflected the severity of injury than those of Na.

Doddema, H., Saadeddin, R. and Mahasneh, A. (1986). Department of Biological Sciences, University of Jordan, Amman, Jordan. Effects of seasonal changes of soil salinity and soil nitrogen on the N-metabolism of the halophyte *Arthrocnemum fruticosum* (L.) Moq. Plant and Soil, 92:279–293.

Reports on changes in concentrations of inorganic and organic compounds (including soluble carbohydrate and protein, proline and nitrate reductase) in relation to DM production for *Arthrocnemum fruticosum* growing in a saline area north-east of the Dead Sea in Jordan over its vegetative growth period. Increasing Na concentrations in shoots was related to DM increase in summer. I

Donaldson, D.R., Hasey, J.K. and Davis, W.B. (1983). Environmental Horticulture, University of California, Davis, USA. Eucalyptus out-perform other species in salty flooded soils. California Agriculture, 37:20–21.

Reports on results of evaluating 55 *Eucalpytus* species over a 10-year period on a site with soil salinity varying with depth from 3.9 to 15.4 dS/m and with ground water salinity of 40 dS/m.

Doria, J.R.C. and Aldon, E.F. (1993). Instituto Nacional de Investigaciones Forestales y Agropecuarias, Plaza Comercial 'Altamirano', Locales 9A Y 10A, La Paz, Baja California Sur, Mexico. Fourwing saltbush seedling survival using saline irrigation. Arid Soil Research and Rehabilitation, 7:243–251.

Survival and establishment of fourwing saltbush (*Atriplex canescens*) was studied for two seedling ages using several saline irrigation treatments (% of sea water). Large seedlings survived and grew better than small seedlings under all treatments.

Dowden, H. G. M., Lambert, M.J. and Truman, T. (1978). Wood Technology and Forest Research Division, Forestry Commission of NSW, PO Box 100, Beecroft, NSW 2119, Australia. Salinity damage to Norfolk Island pines caused by surfactants. II. Effects of sea water and surfactant mixtures on the health of whole plants. Australian Journal of Plant Physiology, 5:387–395.

Reports on glasshouse experiments to test the effects of spraying distilled water and deep-sea water, with and without added surfactants, onto the foliage of young potted Norfolk Island pines, *Araucaria heterophylla*. When the surfactant was sprayed in a seawater solution onto foliage, damage was caused similar to that observed in affected seaside trees. (Refer Truman and Lambert 1978.)

Drake, D.R. and Ungar, I.A. (1989). Department of Botany, University of Ohio, Athens, OH 45701, USA. Effect of salinity, nitrogen, and population density on the survival, growth and reproduction of *Atriplex triangularis (Chenopodiaceae)*. American Journal of Botany, 76:1125–1135.

In a growth chamber experiment, biomass of *Atriplex triangularis* decreased with increasing NaCl (0 to 3%) at high N (10 mol/m^3) but not at low N (1 mol/m^3). There was little effect of applied N on performance of field-grown plants at low and high salinity. Data are also provided on density-dependent relationships with respect to N supply.

Dunn, G.M. and Neales, T.F. (1993). Faculty of Agriculture and Forestry, University of Melbourne, Parkville, Victoria 3052, Australia. Are the effects of salinity on growth and leaf gas exchange related? Photosynthetica, 29:33–42.

Growth of *Atriplex nummularia* (C_4) and *A. hastata* (C_3) increased as salinity was increased from 0 to 200 mol/m^3 NaCl, in contrast with barley for which growth was already reduced at 25 mol/m^3. At 400–600 mol/m^3 NaCl, the growth of the halophytes was reduced by around 50%. Gas exchange was not affected at low salinity, in contrast to growth (above), but at high salinity net photosynthesis, leaf conductance and intercellular CO_2 were significantly reduced. The lack of relationship between growth and gas exchange in response to NaCl is discussed.

Dunn, G.M., Taylor, D.W. Nester, M.R. and Beetson T.B. (1995). Queensland Forest Research Institute, Fraser Road, Gympie, Queensland 4072, Australia. Performance of twelve selected Australian tree species on a saline site in southeast Queensland. Forest Ecology and Management, 70:255–264.

The paper reports on the establishment and early growth at 18 months of 12 species within the genera *Eucalyptus, Casuarina, Melaleuca* and *Tipuana* on a saline site, stratified into five salinity classes ($EC_{1:5\ (0\text{-}50\ cm)}$ 0.75–1.0, 1.0–1.25, 1.25–1.5, 1.5–1.7 5 and over 1.75 dS/m), in south eastern Queensland. The EC level where height was reduced by 25% relative to that at 0.75 dS/m was calculated. *C. glauca, M. bracteata, E. moluccana, E. camaldulensis, E. tereticornis and E. raveretiana* were all highly salt-tolerant (25% reductions above 1.5 dS/m). *C. cunninghamiana, E. grandis, E. melliodora and E. robusta* were moderately salt-tolerant (25% reductions between 1.0 and 1.5 dS/m). *Tipuana tipu* and *E. intermedia* (25% reductions at less than 1.0 dS/m) were least salt-tolerant.

Durham, R.M. and Durham, J.W. (1979). PO Box 302, Durham Farms, Smyer, Texas 79367, USA. Kochia: its potential for forage production. In: Arid land plant resources (Goodin, J.R. and Northington, D.K., ed.), 444–450, Proceedings of International Arid Land Conference on Plant Resources, Texas Technical University, Texas, USA.

Includes a small literature review and discusses aspects of growth and management of kochia (*Kochia scoparia*) for cattle grazing at Durham farms in Texas.

Eccles, W.J., Matthew, C. and Chu, A.C.P. (1990). Department of Agronomy, Massey University, Palmerston North, New Zealand. Response of Matua prairie grass and Ellett perennial ryegrass to excess soil moisture in sand, silt and clay soils. Proceedings of the New Zealand Grassland Association, 51:127–130.

Bromus willdenowii was shown to be more sensitive to waterlogging than *Lolium perenne* in soil-filled pots. Typical effects on *B. willdenowii*, especially on clay soils and over longer (18-day) than shorter (9-day) periods, included reduced leaf extension and higher leaf senescence, shoot:root ratio and proportion of dead plant material.

El-Haddad, E.S.H.M. and O'Leary, J.W. (1994). Environmental Research Laboratory, University of Arizona, Tucson, AZ 85706, USA. Effect of salinity and K/Na ratio of irrigation water on growth and solute content of *Atriplex amnicola* and *Sorghum bicolor*. Irrigation Science, 14:127–133.

> When treated with salt in sand-filled pots in a glasshouse, the growth of *A. amnicola* was not reduced until over 100 mol/m^3, in contrast with sorghum. Growth reductions were greater as the ratio of K:Na increased from 1:100 to 1:1 in the irrigation water for both species. Leaf K and Na concentrations reflected the relative amounts in irrigation water, and nitrate levels were decreased by the combination of high salinity and K:Na ratio.

El-Hamrouni, A. (1986). Institut des Regions Aerides, 4119 Medenine, Tunisia. *Atriplex* species and other shrubs in range improvement in North Africa. Reclamation and Revegetation Research, 5:151–158.

> This paper describes naturally-occurring vegetation on salt-affected land mainly in relation to the degree of salinity, water table depths and gypsum concentrations. Attempts to improve rangeland production by the introduction of woody forage species, especially *Atriplex halimus*, *A. nummularia*, *A. canescens* and *Acacia saligna* are described.

El-Lakany, M.H. (1986). American University of Cairo, Desert Development Center, 113 Sharia Kasr el Aini, Cairo, Egypt. Fuel and wood production on salt affected soils. Reclamation and Revegetation Research, 5:305–317.

> A discussion of published work in Egypt with particular reference to *Eucalyptus* spp., *Casuarina* spp. and mangroves.

El-Lakany, M.H., Hassan, M.N., Ahmed, A.M. and Mounir, M. (1986). American University of Cairo, Desert Development Center, Cairo, Egypt. Salt affected soils and salt marshes in Egypt: their possible use for forage and fuel production. Reclamation and Revegetation Research, 5:49–58.

> This paper examines the distribution of naturally occurring forage and fuel species in Egypt particularly on salt affected areas and salt marshes, and the feasibility of using this land for forage and fuel production.

El-Lakany, M.H. and Luard, E.J. (1982). Department of Forestry, Faculty of Agricuture, Alexandria University, Alexandria, Egypt. Comparative salt tolerance of selected *Casuarina* species. Australian Forestry Research, 13:11–20.

Casuarina glauca, *C. obesa* and *C. equisetifolia* var. *incana* were found to be the most salt tolerant since they survived up to 500 mol/m3 NaCl in solution culture. *C. cunninghamiana*, the natural hybrid *C. glauca* × *C. cunninghamiana* and *C. cristata* tolerated up to 450 mol/m^3, *C. stricta* up to 350 mol/m^3, *C. littoralis* and *C. torulosa* up to 250 mol/m^3, whilst *C. decaisneana* survived only 50 mol/m^3. Data on height and shoot and root DW are provided. There was some growth enhancement at low salinity for the most salt tolerant species.

El-Rahman Ghaly, M.A. (1981). Agriculture Research Center, Soil and Water Research Institute, Soil Survey Section, Ministry of Agriculture, Cairo, Egypt. Salt absorbent pasture grasses and their impact on soil improvement. In: Conference on biosalinity: the problem of salinity in agriculture (Rains, D.W., ed.), 48–50. University of California, Davis, California, USA.

This paper advocates the use of salt-tolerant pasture grasses for a dual role in highly saline soils, as biochemical amendments and as forage supply.

El-Razek, M.A. (1993). Department of Soil and Water, University of Assiut, Assiut, Egypt. Response of four species of *Atriplex* to irrigation with highly saline water in Upper Egypt. In: Towards the rational use of high salinity tolerant plants (Lieth, H. and Al-Masoom, A.A., ed.), Vol. 2, 315–317. Proceedings of the ASWAS Conference, Al-Ain, United Arab Emirates.

Transplants of *Atriplex canescens, A. lentiformis, A. polycarpa and A. amnicola* were irrigated with water containing 1:1 mixed $CaCl_2$ and NaCl salts (0, 5, 10, 20 and 30 or 40 g/L) in pots filled with a sandy soil in a greenhouse. *A. amnicola* was most tolerant, with growth not affected up to concentrations of 20 g/L, but with about 50% reduction at 40 g/L. Growth of the other species was decreased by approx. 40–50% at 20 g/L . The responses of plant N, Na and K concentrations to salinity varied with species.

El-Sharkawi, H.M. and Michel, B.E. (1975). Botany Department, University of Assiut, Assiut, Egypt. Effects of soil salinity and air humidity on CO_2 exchange and transpiration of two grasses. Photosynthetica, 9:277–282.

In a closed-flow system, reduced soil water osmotic potential (increasing salinity) decreased net photosynthesis, respiration and transpiration rates of alkali sacaton (*Sporobolus airoides*) and blue grama (*Bouteloua gracilis*). Atmospheric humidity considerably affected photosyhthesis but its effect was obscured at lower osmotic potentials.

Eleizalde, B. (1982). Centro de Edafologia y Biologia Aplicada de Tenerife Canarias, Spain. K uptake by rye-grass irrigated with saline waters. Agrochimica, 26:353–361.

K application increased growth of ryegrass under irrigation with saline water in a glasshouse, and this was related to K concentrations in plants.

Ellern, S.J., Samish, Y.B. and Lachover, D. (1974). Agricultural Research Organization, Volcani Center, Bet Dagan, Israel. Salt and oxalic acid content of leaves of the saltbush *Atriplex halimus* in the Northern Negev. Journal of Range Management, 27:267–271.

Describes results of evaluating saltbush (*Atriplex halimus*) in the semi-arid south of Israel for leaf Na, Cl and oxalic acid in order to identify and propagate low-salt-content bushes likely to be browsed more readily by cattle and sheep. No correlation was found between leaf Cl and plant size and leafiness, or between Cl and Na. High-Cl bushes had a lower Na:Cl ratio and leaf oxalic acid content.

Elzam, O.E. and Epstein, E. (1968). Department of Soils and Plant Nutrition, University of California, Davis, California, USA. The relations of two grass species differing in salt tolerance. I. Growth and salt content at different salt concentrations. Agrochimica, 13:187–195.

The salt tolerance of two tall wheatgrass species, *Agropyron elongatum* and *A. intermedium*, was investigated in nutrient culture with NaCl concentrations of up to 500 mol/m^3. Low Ca concentration in roots was linked with severe effects of NaCl on growth.

Epstein, E. and Rains, D.W. (1987). Department of Land, Air and Water Resources, University of California, Davis, CA 95616, USA. Advances in salt tolerance. Plant and Soil, 99:17–29.

Advances in and prospects for the development of salt-tolerant crops are discussed.

Eshel, A. and Waisel,Y. (1984). Department of Botany, The George S. Wise Faculty of Life Sciences, Tel-Aviv University, Tel-Aviv, Israel. Effect of salt and soil water status on transpiration of *Salsola kali* L. Plant, Cell and Environment, 7:133–137.

Reports on the interactive effects of salinity and water stress on transpiration of *Salsola kali* plants, grown in small pots under controlled environmental conditions, through a soil drying cycle, and treated with

150 mol/m^3 NaCl and KCl. Both NaCl and KCl markedly reduced transpiration (per unit leaf DW) at all soil water contents (20% (w/w) max.). Data for transpiration plotted against soil moisture potential are presented.

Everitt, J.H. (1983). ARS-USDA, Weslaco, TX 78596, USA. Seed germination characteristics of two woody legumes (retama and twisted *Acacia*) from south Texas. Journal of Range Management, 36:411–414.

Germination of *Parkinsonia aculeata* and *Acacia schaffneri* (both with impermeable seed coats) was only slightly reduced by a solution of 5 g NaCl/L (approx. 85 mol/m^3), but radicle elongation was more seriously affected. Percentage germination and radicle length of both species were relatively unaffected by pH values from 3 to 11.

Fagg, C.W. and Stewart, J.L. (1994). Oxford Forestry Institute, Department of Plant Sciences, University of Oxford, South Parks Road, Oxford OX1 3RB, UK. The value of *Acacia* and *Prosopis* in arid and semi-arid environments. Journal of Arid Environment, 27:3–25.

This paper discusses the great biological diversity in *Acacia* amd *Prosopis* as reflected in their wide distribution and ecological amplitude, and particularly in the tolerance of some species to extremes of drought and salinity. Their uses and management are discussed.

Fahn, A. (1988). Department of Botany, The Hebrew University of Jerusalem, Jerusalem 91904, Israel. Secretory tissues in vascular plants. New Phytologist, 108:229–257.

A review of secretory tissues in vascular plants with some discussion of the way in which salt glands in *Atriplex* function.

Farnworth, J. and Ruxton, I.B. (1973). University College of North Wales, Bangor, UK. Comparison of graminaceous forage crops and Hasawi alfalfa for summer reclamation of heavy saline soils at Hofuf. Publication, Joint Agricultural Research and Development Project, University College of North Wales, Bangor, United Kingdom and Ministry of Agriculture and Water, Saudi Arabia, No. 19, 12p.

Reports on yields and crude protein of Rhodes grass, Bermuda grass, sorghum, and blue panic grass grown under irrigation for 190 days and harvested at 5–10 days after heading at Hofuf, Saudi Arabia.

Farnworth, J. and Ruxton, I.B. (1974). University College of North Wales, Bangor, UK. A comparison of graminaceous forage species sown in mid-summer for saline reclamation under irrigated arid zone conditions. Publication, Joint Agricultural Research and Development Project, University College of North Wales, Bangor, United Kingdom and Ministry of Agriculture and Water, Saudi Arabia, No. 38, 11 p.

> Reports on results of trials at Hofuf, Saudi Arabia, with Rhodes grass, Sudan grass, millet (*Pennisetum americanum*), sorghum and sorghum × Sudan grass hybrids under arid zone saline irrigated conditions. Establishment problems were found with all species, but Rhodes grass, sorghum, and Sudan grass all yielded about 7 t DM/ha in 180 days. Crude protein, crude fibre and ash contents are given.

Farrell, R.C.C., Bell, D.T., Akilan, K. and Marshall, J.K. (1996). Department of Botany, The University of Western Australia, Nedlands, WA 6907, Australia. Morphological and physiological comparisons of clonal lines of *Eucalyptus camaldulensis*. I. Responses to drought and waterlogging. Australian Journal of Plant Physiology, 23:497–507.

> Six clonal lines of *Eucalyptus camaldulensis* grown in soil-filled pots, originally from five geographically separated locations, differed significantly in leaf and root growth under drought and waterlogging in a glasshouse, but they did not differ in stomatal conductance, net gas exchange and leaf nutrient allocation. Relationships between leaf number and leaf specific weight, and between leaf area and root weight, are explored. Water use per unit leaf area was similar between clones, and generally, water use per tree was well correlated with leaf area and dry weight per tree. (Refer Akilan et al. 1997.)

Farrell, R.C.C., Be ll , D.T., Akilan, K. and Marshall, J.K. (1996). Department of Botany, The University of Western Australia, Nedlands, WA 6907, Australia. Morphological and physiological comparisons of clonal lines of *Eucalyptus camaldulensis*. II. Responses to waterlogging/salinity and alkalinity. Australian Journal of Plant Physiology, 23:509–518.

> Reports on the effects of waterlogging, salinity and alkalinity on biomass, water use, stomatal conductance and gas exchange of six clones from five provenances of *Eucalyptus camaldulensis* under glasshouse conditions in soil-filled pots. Significant clonal differences were found, even from within one provenance (e.g. M80 versus M16 from Wooramel, Western Australia) in response to waterlogging with increasing salinity and also under alkalinity stress. Water use was closely related to biomass

production. Effects of salinity and alkalinity on leaf ion concentration and of solution conductivity on stomatal conductance and water use are discussed.

Farrington, P. and Salama, R.B. (1996). CSIRO Division of Water Resources, Private Bag, Wembley, WA 6014, Australia. Controlling dryland salinity by planting trees in the best hydrogeological setting. Land Degradation and Development, 7:183–204.

This paper discusses principles and practices for revegetation of catchments by trees and shrubs as the best long-term option for controlling dryland salinity, and uses case studies from catchments in Western Australia to illustrate the application of control measures.

Felger, R.S. and Mota-Urbina, J.C. (1982). Arizona-Sonora Desert Museum and Environmental Research Laboratory, University of Arizona, Tucson, Arizona, USA. Halophytes: new sources of nutrition. In: Biosaline research: a look to the future (San Pietro, A., ed.), 473–477. Proceedings of 2nd International Workshop on Biosaline Research, La Paz, Mexico. Plenum Press, New York, USA.

About 5 per cent of plants of the flora of Sonoran desert are halophytes and out of 131 species, at least 36 have been used as food. Many of them provide fodder to grazing animals. Proper selection and domestication of these species could be of great benefit for propagation under similar arid/xeric conditions.

Felker, P. (1979). Caesar Kleberg Wildlife Research Institute, Texas A & M University, Kingsville, Texas 78363, USA. Mesquite: an all-purpose leguminous arid land tree. In: New agricultural crops (Ritchie, G.A., ed.), 89–132. American Association for the Advancement of Science, Symposium 38, Westview Press, Boulder, Colorado, USA.

This paper discusses the use of managed orchards of selected varieties of mesquite (*Prosopis glandulosa* and related species) as a low water, nitrogen, and tillage requiring protein and carbohydrate source for humans and/or livestock. Mature mesquite orchards receiving no irrigation or nitrogen after establishment may yield 4–10 t/ha in regions where there is ground water or 250–500 mm annual rainfall.

Felker, P., Clark, P.R., Laag, A.E. and Pratt, P.F. (1981). Department of Soil and Environmental Sciences, University of California, Riverside, California 92521, USA. Salinity tolerance of the tree legumes: mesquite

(*Prosopis glandulosa* var. *torreyana, P. velutina* and *P. articulta*), algarobo (*P. chilensis*), kiawe (P. *pallida*) and tamarugo (*P. tamarugo*) grown in sand culture on nitrogen-free media. Plant and Soil, 61:311–317.

> Sand culture pot experiments were carried out with *Proposis* seedlings in a greenhouse on a N-free nutrient solution with increasing levels of NaCl. There was no growth reduction for any species at 6 000 mg/L (approx. 100 mol/m^3). *P. velutina* was the only species that did not tolerate 12 000 mg/L very well. *P. articulata, P. pallida,* and *P. tamarugo* had very little growth reduction at 18 000 mg/L and grew slightly at 36 000 mg/L (concentration greater than sea water).

Fernandez, H.G., Olivares, E.A., Johnston, B.M. and Contreras, P. (1986). Facultad de Ciencias Agrarias y Forestales, University de Chile, Santiago, Chile. The role of the pericarp in germination of *Atriplex repanda*. IV. The effect of NaCl and saponin on the germination of four species. Phyton Argentina, 46:19–26.

> Germination percentage, speed of emergence and seedling growth due to 1% NaCl and 10% saponin was reduced for *Atriplex repanda* and *A. semibaccata*; results are related to effects of these on natural reseeding. (In Spanish, English summary.)

Fernando, M.J.J. (1989). Janatha Estates Development Board, Sri Lanka. The tolerance of some eucalypts to salinity, as determined by germination and seedling growth. The Sri Lankan Forester, 19:17–30.

> Based on assessment of (i) germination percentage and rate (up to 350 mol/m^3 NaCl) and (ii) survival, growth (height, root length, root DW, total DW and shoot:root ratio) and injury to pot-grown seedlings irrigated with water of EC 0.4–2.6 dS/m, the order of salt tolerance was: *Eucalyptus camaldulensis* > *E. tereticomis* > *E. citriodora*.

Fisher, M.J. and Skerman, P.J. (1986). Division of Tropical Crops and Pastures, CSIRO, 306 Carmody Road, St Lucia, Queensland 4067, Australia. Salt tolerant forage plants for summer rainfall areas. Reclamation and Revegetation Research, 5:263–284.

> This paper provides a review and summary of published data on salt tolerance of summer-growing forage species and lists those species that are reputed to be salt tolerant. Includes a large number of references.

Fleck, B.C. (1967). NSW Soil Conservation Service, NSW, Australia. A note on the performance of *Agropyron elongatum* (Host.) Beave. and *Puccinellia* (Parl.) sp. in revegetation of saline areas. NSW Soil Conservation Journal, 23:261–269.

Reports on a series of field trials in NSW with several grass species and demonstrates that *Agropyron elongatum* and *Puccinellia* sp. are highly salt-tolerant and are suitable for practical use in saline conditions.

Flowers, T.J. (1985). School of Biological Sciences, University of Sussex, Falmer, Brighton, Sussex BN1 9QG, UK. Physiology of halophytes. Plant and Soil, 89:41–56.

This review focusses on the importance of inorganic ions for osmoregulation in vacuoles and osmotic adjustment of the cytoplasm by compatible solutes. It is argued that since Na and Cl play an essential role in osmotic adjustment, the transport of these ions and their regulation are very important. Limited data from the literature indicate (i) that minimising xylem Na (and Cl) concentrations, together with continued leaf expansion, are particularly important, (ii) that the role of phloem in retranslocation is uncertain and (iii) that decreases in transpiration rate per unit area of leaf help to lower ion input into leaves. Furthermore, reductions in photosynthesis per se do not appear to be the cause of growth inhibition at high salinity.

Flowers, T.J. and Dalmond, D. (1992). School of Biological Sciences, University of Sussex, Falmer, Brighton, Sussex BN1 9QG, UK. Protein synthesis in halophytes: the influence of potassium, sodium and magnesium in vitro. Plant and Soil, 146:153–161.

This paper provides detailed accounts of the activity of polysome translation systems from salt-sensitive and salt-tolerant (e.g. *Atriplex isatidea* and *Suaeda maritima*) plants in response to increasing K, Mg and Na salts. The context of this work is to determine if protein synthesis on halophyte ribosomes is more tolerant of salts than is protein synthesis on non-halophyte ribosomes.

Flowers, T.J., Hajibagheri, M.A. and Clipson, N.J.W. (1986). School of Biological Sciences, The University of Sussex, Falmer, Brighton, Sussex BN1 9QG, UK. Halophytes. The Quarterly Review of Biology, 61:313–337.

A review of some characteristics of halophytes and physiology, mainly with respect to ion relations. Differences between dicotyledonous and monocotyledonous halophytes are discussed with respect to salt-

stimulated growth, succulence and ions including compartmentation, in particular in vacuoles in relation to osmotic adjustment and toxicity. The means by which relatively constant ion concentrations in the shoot are maintained is considered. The conclusion is drawn that ion uptake by the roots is not controlled by the shoots; rather, shoot growth is regulated by the supply of ions from the roots.

Flowers, T.J. and Hall, J.L. (1978). School of Biological Sciences, The University of Sussex, Falmer, Brighton, Sussex BN1 9QG, UK. Salt tolerance in the halophyte *Suaeda maritima* (L.) Dum.: the influence of the salinity of the culture solution on the content of various organic compounds. Annals of Botany, 42:1057–1063.

In NaCl-treated plants of the halophyte *Suaeda maritima*, the content of sugars and amino acids were unchanged, but the content of glyceine betaine was increased. The content of these and organic acid compounds is discussed in relation to the relative values of the cytoplasmic and vacuolar components of overall tissue water potential.

Flowers, T.J., Troke, P.F. and Yeo, A.R. (1977). School of Biological Sciences, Sussex University, Brighton BN1 9RH, UK. The mechanism of salt tolerance in halophytes. Annual Review of Plant Physiology, 28:89–121.

This comprehensive review of angiosperm halophytes deals with basic physiology, ion relations and the role of organic solutes with examples from several species, including *Atriplex* spp. One of the main contentions is that inorganic ions can accumulate to high concentrations, particularly in leaf cells, and that they are largely contained in vacuoles, therefore avoiding the need for highly modified metabolism as occurs in halophytic bacteria.

Flowers, T.J. and Yeo, A.R. (1986). School of Biological Sciences, The University of Sussex, Falmer, Brighton, Sussex BNL 9QG, UK. Ion relations of plants under drought and salinity. Australian Journal of Plant Physiology, 13:75–91.

This review mostly considers ion relations of mature leaf cells of plants growing under saline conditions. Considerable attention is given to the succulent halophyte, *Suaeda maritima*; the demand for osmotic adjustment in the leaves matches closely (perhaps exceeds) the supply from the roots, so that ion excess is avoided, and expanding leaves accumulate Na at a greater rate than expanded leaves and apoplastic salt concentrations do not exceed those in the protoplast.

Forti, M. (1986). The Institute for Applied Research, Ben-Gurion University of the Negev, PO Box 1025, Beer-Sheva 84110, Israel. Salt tolerant and halophytic plants in Israel. Reclamation and Revegetation Research, 5:83–96.

This paper reviews work conducted on the introduction, development and use of non-conventional, drought- and salt-tolerant crops (e.g. jojoba (*Simmondsia chinensis*) and on halophytic crops (e.g. *Atriplex nummularia*)) as fodder or industrial plants, and as trees and ornamentals for revegetation, landscaping and gardening. Considers projects on salt-affected land in the Dead Sea area and 'Arava' Valley and irrigation with sewerage and brackish water.

Foster, R.C. and Sands, R. (1977). CSIRO Division of Soils, Private Bag 2, Glen Osmond, South Australia 5064, Australia. Response of radiata pine to salt stress. II. Localization of chloride. Australian Journal of Plant Physiology, 4:863–875.

Reports that three main sites of Cl deposition were found in salt-treated seedlings of *Pinus radiata* (radiata pine) using a silver precipitation technique: (i)in the roots (in the hyphae of the mycorrhizae as well as between the cell wall and the plasmalemma of the outer cortical cells): (ii) in the stem (in the ray cells and in the tracheids — this would be a major sink for depositing excess Cl) and (iii) in the needles (in the epidermal and sub-epidermal cells, and in the mesophyll, mainly in the cell walls.) Refer Sands and Clark 1977.

Fox, J.E.D., Neilsen, J.R. and Osborne, J.M. (1990). School of Biology, Curtin University of Technology, Perth, WA 6001, Australia. Eucalyptus seedling growth and salt tolerance from the north-eastern goldfields of Western Australia. Journal of Arid Environment, 19:45–53.

In a glasshouse experiment in which seedlings were treated with 100, 200, 400 or 600 mol/m^3 NaCl with and without waterlogging, *Eucalyptus camaldulensis* from an alluvial site grew faster and appeared to tolerate saline conditions better than the same species originating from a creekline site. *E. clelandii* (from kopi dunes on the fringes of a salt lake) was somewhat tolerant of saline conditions but it is not fast-growing.

Francois, L.E. (1986). US Salinity Laboratory, Agricultural Research Service, US Department of Agriculture, 4500 Glenwood Drive, Riverside, CA 92051, USA. Salinity effects on four arid zone plants. Journal of Arid Environment, 11:103–109.

Reports on salt tolerance of *Parthenium argentatum* (in salinised field plots) and of *Kochia prostrata*, *K. brevifolia* and *Simmondsia chinensis* (in salinised soil cultures in a glasshouse). Salt tolerance of *K. prostrata* and *K. brevifolia* was similar (threshold EC for growth approx. 1–2 dS/m with further reductions of approx. 2% per unit EC), whilst the threshold for *P. argentatum* was approx. EC 6 dS/m. Growth of *S. chinensis* was unaffected till the second year, when a threshold of 14 dS/m was established.

Francois, L.E. (1988). US Salinity Laboratory, Agricultural Research Service, US Department of Agriculture, 4500 Glenwood Drive, Riverside, CA 92501, USA. Salinity effects on three turf bermuda grasses. Hortscience, 23:706–708.

Relative shoot growth of the cultivar 'Tifway II' and the accessions 'Tifton 10' (obtained from China) and 'Tifton 86' (obtained from Israel) of Bermuda grass (*Cynodon* spp.), a salt-tolerant species, is reported for soil-grown plants in a glasshouse irrigated with water salinised with NaCl:CaCl (1:1) to make four EC treatments, was unaffected by soil salinity until the EC_e exceeded 2.7, 8.4, and 10.3 dS/m, respectively.

Fraser, G.W., Thorburn, P.J. and Cramer, V. (1995). Resource Management Institute, Department of Primary Industries, Indooroopilly, Queensland 4068, Australia. Comparison of diffuse groundwater discharge from trees and bare soil in south east Queensland: preliminary results. In: Proceedings Murray–Darling 1995 Workshop. Wagga Wagga, 11–13 September 1995.

Reports on studies of water uptake by *Eucalyptus camaldulensis* and *Casuarina glauca* at three saline sites in southern Queensland. Water uptake was determined with heat pulse probes and allocation to soil and ground water using the natural isotope (oxygen, hydrogen) method. The degree of enhanced discharge due to the presence of the trees varied between sites. Reasons for this are discussed in terms of watertable depth and salinity, and leaf area index.

Froend, R.H., Heddle, E.M., Bell, D.T. and McComb, A.J. (1987). Department of Botany, University of Western Australia, WA 6009, Australia. Effects of salinity and waterlogging on the vegetation of Lake Toolibin, Western Australia. Australian Journal of Ecology, 12:281–298.

Soil salinity levels in Lake Toolibin, an ephemeral lake in the Western Australian wheatbelt, are low in winter but increase in summer due to capillary rise of ground water when the lake is dry in summer. Increased salinities (>0.1% NaCl) were shown to be responsible for poor vigour,

higher leaf water potentials and deaths of *Melaleuca* sp. and *Casuarina obesa* on the lake bed. Low vigour and death of *Eucalyptus rudis* was due to both increasing salinity and prolonged inundation.

Fukushima, Y., Sasamoto, H., Baba, S. and Ashihara, H. (1997). Department of Biology, Faculty of Science, Ochanomizu University, Otsuka, Bunkyo-ku, Tokyo 112, Japan. The effect of salt stress on the catabolism of sugars in leaves and roots of a mangrove plant, *Avicennia marina*. Zeitschrift fur Naturforschung (Section C Biosciences), 52:187–192.

Respiration and related aspects of metabolism were investigated in the roots and leaves of two-year-old *Avicennia marina* trees in the presence of 100, 250 and 500 mol/m^3 NaCl. The rate of respiration of leaves, but not of roots, increased with increasing NaCl. By examining the relative rates of catabolism of glucose by the glycolysis-tricarboxylic acid (TCA) cycle and the oxidative pentose phosphate pathway (PP pathway) using ^{14}C-labelled glucose in segments of roots and leaves, it was found that the PP pathway was more involved in sugar catabolism in the roots than in the leaves.

Gaff, D.N. and Wood, J.N. (1990). Botany Department, Monash University, Clayton, Victoria 3616, Australia. Salt-resistant desiccation tolerant grasses. In: Proceedings of the international conference on plant physiology (Sinha, S.K., Sane, P.V., Bhargava, S.C. and Agrawal, P.K., ed.), 984–988. Society for Plant Physiology and Biochemistry, New Delhi, India.

Reports on the salt tolerance of several of the more productive grass species known to be very drought tolerant on the basis of protoplasm properties (i.e. dessication-tolerant or 'resurrection' grasses). Levels of salt tolerance were generally high in some but not in all species. The salt tolerance of the most tolerant resurrection grass was comparable with that of *Diplachne [Leptochloa] fusca*. For the species investigated salt tolerance was linked mainly to exclusion of salt by roots. Desiccation tolerance of most resurrection grasses was not reduced very much below 200 mol/m^3 NaCl.

Gale, J., Naaman, R. and Poljakoff-Mayber, A. (1970). Department of Botany, Hebrew University of Jerusalem, Jerusalem, Israel. Growth of *Atriplex halimus* L. in sodium chloride salinated culture solutions as affected by the relative humidity of the air. Australian Journal of Biological Sciences, 23:947–952.

Atriplex halimus plants, grown in nutrient solution in growth chambers, under dry (27% relative humidity—RH) and humid (65% RH) conditions, were treated with 0 to –2.0 MPa NaCl. Under dry RH maximum growth was always at about –0.5 MPa whereas under humid RH growth was greatest in the non-saline controls and decreased with increasing NaCl.

Galinato, M.I. and Van der Valk, A.G. (1987). Department of Botany, Iowa State University, Ames, IA 50011, USA. Seed germination traits of annuals and emergents recruited during drawdowns in the Delta Marsh, Manitoba, Canada. Aquatic Botany, 26:89–102.

Germination behaviour of several mudflat annual and perennial species in response to light, temperature and soil depth is presented. Seed germination of *Hordeum jubatum*, *Phragmites australis* and *Aster laurentianus* was unaffected by salinities as high as 4 000–5 000 mg/L NaCl whereas germination of *Typha glauca*, *Scolochlosa festucacea* and *Chenopodium rubrum* was reduced significantly by 1 000–2 000 mg /L.

Gallagher, J.L. (1979). The University of Georgia Marine Institute, Sapelo Island 31327, USA. Growth and elemental compositional responses of *Sporobolus virginicus* (L.) Kunth. to substrate salinity and nitrogen. The American Midland Naturalist, 102:68–75.

Field observations, that salinity may have reduced growth of *Sporobolus virginicus* due to lack of available N, were tested with a controlled environment experiment where seedlings were grown in a range of NaCl concentrations in solution culture. Data on survival and growth of plant parts and ion concentrations are provided; no evidence of an enhancement in growth due to NaCl was found. There was no increase in biomass due to added N although tissue N concentration was significantly increased.

Gallagher, J.L. (1985). College of Marine Studies, University of Delaware, Lewes, DE 19958, USA. Halophytic crops for cultivation at seawater salinity. Plant and Soil, 89:323–336.

This paper reports on progress in the development of the cultivars of halophytes, their basic biology (both being studied in Delaware, USA) and their agronomic testing, feeding trials, and development of the best agronomic practices (taking place in the saline desert near Cairo, Egypt). Present efforts focus primarily *Sporobolus virginicus* (cultivars for both hay and pasture), *Distichlis spicata* (a cultivar for hay has been identified), and *Spartina patens* (being evaluated as a hay); *Kosteletzkya virginica* (a perennial producing seed that resembles millet—its whole seeds contain approximately 25% protein and 15% oil); and *Atriplex triangularis* (a vegetable similar to spinach).

Galloway, R. and Davidson, N.J. (1993). Department of Agriculture, Baron Hay Court, South Perth, Western Australia 6151 The response of *Atriplex amnicola* to the interactive effects of salinity and hypoxia. Journal of Experimental Botany, 44:653–663.

This paper reports on short-term (up to three weeks) responses of solution cultured river saltbush (*Atriplex amnicola*) cuttings to hypoxia (simulating waterlogging) under NaCl. One week of hypoxia at between 50 and 400 mol/m^3 stopped root growth, reduced shoot growth and adversely affected water relations, but not ion relations or carbohydrate concentrations. Two weeks of hypoxia at 400 mol/m^3 caused death of root tips, a 20-fold increase in the resistance to water flow from the extenal solution to the leaves, and a further deterioration of water relations (stomatal conductance, water potential transpiration). In addition, Cl concentrations in the xylem sap and Na and Cl concentrations in leaves were doubled. The sensitivities of *A. amnicola* to hypoxia and salinity (especially at higher concentrations) is linked to excessive ion uptake (and toxicity) and reduced ability to use carbohydrates (sugar and starch).

Garcia-Carreno, F.L., Troyo-Dieguez, E. and Ochoa, J.L. (1992). Centre Investigaciones Biology de Baja California Sur, AC La Paz, BCS, 23000, Mexico. Relationships between saline ground water, soil, and leaf tissue composition of the phreatophyte mezquite. Ground Water, 30:676–682.

The chemical (inorganic and organic solutes) and biochemical composition of leaf tissue from 24 mesquite (*Prosopis articulata*) trees were correlated with ion concentrations of soils and ground waters from six separate sites in Mexico. The EC of ground water was significantly correlated with activity of the enzyme peroxidase and EC in leaves. It is argued that measuring EC and some biochemical compounds in mesquite leaves may provide an alternative to direct evaluation of ground water quality.

Gates, C.T. (1972). Division of Tropical Pastures, CSIRO, Cunningham Laboratory, St Lucia, Queensland 4067, Australia. Ecological response of the Australian native species *Acacia harpophylla* and *Atriplex nummularia* to soil salinity: effects on water content, leaf area and transpiration rate. Australian Journal of Botany, 20:261–272.

In two glasshouse experiments, *Acacia harpophylla* (brigalow) and *Atriplex nummularia* (old man saltbush) seedlings tolerated (in terms of leaf area and number) salinities (chlorides of Na, K, Ca and Mg) up to and beyond seawater concentration, with *A. nummularia* apparently more tolerant. High salinity increased plant water content, especially that of the laminae, and reduced transpiration per unit of leaf area in both species.

Gates, P.J. and Brown, K. (1988). Botany Department, University of Durham, Durham DH1 3LE, UK. *Acacia tortilis* and *Prosopis cineraria*: leguminous trees for arid areas. Outlook on Agriculture, 17:61–64.

Results are presented from part of a study of physiological and genetic characteristics of these two species in woodlands of the Wahiba Sands in Oman, with particular reference to foliar water uptake and salt tolerance. Their suitability for reafforestation programs in arid regions is discussed in relation to extremely rapid early root growth, drought tolerance, low seedling transpiration rate, and ability to take in water through leaf surfaces (e.g. from nocturnal dew).

George, R.J. (1990). Department of Agriculture, PO Box 1231, Bunbury, WA 6230, Australia. Reclaiming sandplain seeps by intercepting perched groundwater with eucalypts. Land Degradration and Rehabilitation, 2:13–25.

Reports on lowering of perched ground water (EC ranged from 6.6 to over 25 dS/m) on a saline sandplain seep near East Belka in the Western Australian wheatbelt using eucalypts (*Eucalyptus globulus, E. cladocalyx* var. *nana* and three provenances of *E. camaldulensis*) planted across the contour upslope from the seep on about 10% of the catchment.

Ghai, S.K., Rao, D.L.N. and Batra, L. (1985). Central Soil Salinity Research Institute, Karnal 132001, India. Effect of salinity and alkalinity on seed germination of three tree-type sesbanias. Nitrogen Fixing Tree Research Report, 3:10–12.

Seed germination was reduced above EC 5 dS/m (NaCl, Na_2SO_4 and $CaCl_2$) and pH 11 (Na_2CO_3). *Sesbania grandiflora* was most sensitive to salinity and high pH followed by *S. glabra* and *S. aegyptica.*

Ghassemi, F., Jakeman, A.J. and Nix, H.A. (1995). Centre for Resource and Environmental Studies, The Australian National University, Canberra, ACT, 2600, Australia. Salinisation of land and water resources: human causes, extent, management and case studies. University of New South Wales Press Ltd, Sydney, pp. 369–395.

This book represents probably the most comprehensive account of salinity as a landscape problem in the world today. The first part analyses the problem in the context of the world's population, its climate, and its land and water resources. It reviews irrigation methods and crop water requirements, the processes of salinisation, and its management. The second part describes irrigated land, dryland and water-resource salinity problems in 11 countries, which contain approximately 70% of the world's irrigated land. In each case study, background data, environmental conditions and past management practices are given to provide an understanding of why salinity occurs in particular places, and of the management methods employed against it.

Gihad, E.A. (1993). Animal Production Department, Faculty of Agriculture, Cairo University, Giza, Egypt. Utilization of high salinity tolerant plants and saline water by desert animals. In: Towards the rational use of high salinity tolerant plants (Lieth, H. and Al-Masoom, A., ed.), Vol. 1, 443–447. Proceedings of the ASWAS Conference, Al-Ain, United Arab Emirates.

Preliminary results of using *Atriplex halimus* (up to 10% NaCl) as a sole feed for camels, sheep and goats showed an increase in water (often high in NaCl) intake and a decrease in feed intake compared with clover hay. Camels, sheep and goats (in descending order) were able to tolerate saltbush fodder. The authors conclude that concentrated supplementary feeds should be offered to livestock given *Atriplex* together with a reliable water source to maintain balanced nutrition.

Gill, C.J. (1970). Department of Botany, University of Liverpool, UK. The flooding tolerance of woody species—a review. Forestry Abstracts, 31:671–688.

This paper provides a useful review of literature with particular reference to Britain and deals with effects of flooding, factors determining survival of trees under flood, mechanisms of tolerance and field planting in localities subject to floods.

Gill, H.S. and Abrol, I.P. (1990). Central Soil Salinity Research Institute, Karnal, Haryana 132001, India. Evaluation of coastal sandy soils and their saline groundwaters for afforestation: a case study from India. New Forests, 4:37–53.

Reports on a study in coastal Andhra Pradesh to evaluate current practices and suitability of coastal sandy soils for establishing tree plantations, where only saline ground water (EC approx. 5–14 dS/m) is

available for irrigation. A technique, in which saucer shaped pits are dug to just below the water table and a central pit is made to collect and skim off the relatively less saline water, appears to be well suited for irrigating trees at establishment in sandy soils. After 10 years, *Casuarina equisetifolia* performed better than *Eucalyptus tereticornis*; better build up of soil organic carbon and reduced soil temperatures were found under *C. equisetifolia* plantations.

Gill, H.S. and Abrol, I.P. (1991). Central Soil Salinity Research Institute, Karnal, Haryana 132001, India. Salt affected soils, their afforestation and its ameliorating influence. The International Tree Crops Journal, 6:239–260.

This paper outlines the principal constraints to plant growth in the highly sodic (alkali) soils of the Indo-Gangetic plains (including toxicities due to excess Na, carbonates and bicarbonates; poor soil structure and water infiltration; and a calcic horizon at about 1 m depth which impedes root growth) and summarises results of experiments since 1971 which showed that planting trees in auger-holes refilled with original sodic soil mixed with gypsum and farmyard manure was an easier and more economic form of establishment than the previously used pit method. Survival and growth data for several tree species are provided. *Acacia nilotica*, *Eucalyptus tereticornis*, *Prosopis juliflora*, *Casuarina equisetifolia* and *Albizia lebbeck* had highest tolerance to sodicity, followed by *Azadirachta indica*, *Dalbergia sissoo* and *Syzygium fructicosum*, whereas *Populus deltoides*, *Morus indica* var. *alba* and *S. cuminii* did not survive. *Acacia nilotica* and *Prosopis juliflora* produced the most biomass. The ameliorative effects of *E. tereticornis* and *A. nilotica* (reduction of pH, EC and salinity, increase of soil organic C) are described.

Gill, H.S., Abrol, I.P. and Samra, J.S. (1987). Central Soil Salinity Research Institute, Karnal 132001, India. Nutrient recycling through litter production in young plantations of *Acacia nilotica* and *Eucalyptus tereticornis* in a highly alkaline soil. Forest Ecology and Management, 22:57–69.

In a four-year field study near Karnal, Haryana, India, it was shown that more litter with higher concentrations of N, P, S and K was produced in an *A. nilotica* than in an *E. tereticornis* plantation of the same age and stocking rate, on a low salinity, alkaline (mean pH 10.1, ESP 92) soil. Concentrations of Ca, Mg, Na, Fe and Mn were higher in eucalyptus litter, but annually recycled quantities of all nutrients were significantly greater in the acacia plantation. Surface-soil pH and EC were reduced under both plantations, but it is suggested that the considerably greater accumulation of Na in litter of *E. tereticornis* seems to deter not only the soil reclamation process but also tree growth.

Girgis, M.G.Z., Ishac, Y.Z., Diem, H.G. and Dommergues, Y.R. (1992). Microbiology Department, Faculty of Agriculture, Ain Shams University, Cairo, Egypt. Selection of salt-tolerant *Casuarina glauca* and *Frankia*. Acta Oecologica, 13:443–451.

The responses of *Frankia* strains to salinity in vitro and in vivo (i.e. in association with *Casuarina glauca* host plants) were not correlated. For example, under saline conditions a *Frankia* strain, Thr, isolated from an Egyptian soil and poorly salt-tolerant in vitro, appeared to improve N_2 fixation better than other strains when associated with a *C. glauca* provenance known for its salt tolerance in the field. The implication is that compatible *Frankia* strains should be used with salt-tolerant *Casuarina* hosts to obtain effective *Casuarina–Frankia* symbioses tolerant to salinity.

Giurgevich, J.R. and Dunn, E.L. (1982). Botany Department, University of Georgia, Athens, Georgia 30602, USA. Seasonal patterns of daily net photosynthesis, transpiration and net primary productivity of *Juncus roemerianus* and *Spartina alterniflora* in a Georgian salt marsh. Oecologia (Berlin), 52:404–410.

This paper reports on studies of the seasonal CO_2 and water vapour exchange patterns of *Juncus roemerianus* and *Spartina alterniflora* in an undisturbed marsh community on Sapelo Island, Georgia.

Glenn, E.P. (1987). Environmental Research Laboratory, 2601 E. Airport Drive, Tucson, Arizona 85706, USA. Relationship between cation accumulation and water content of salt-tolerant grasses and a sedge. Plant, Cell and Environment, 10:205–212.

In glasshouse experiments, seedlings of fourteen grass (halophytic) species from the genera *Sporobolus, Aeluropus, Leptochloa, Paspalum, Puccinellia, Hordeum, Elymus, Distichlis* and *Spartina* survived up to 540 mol/m^3 NaCl, whereas eleven species (salt-tolerant glycophytes) from the genera *Triticum, Phragmites, Dactyloctenium, Cynodon, Polypogon, Panicum, Jovea* and *Heleocharis* only survived up to 180 mol/m^3. In terms of growth rate, only *Distichlis palmeri* grew better with salt present. All species tended to have higher Na and lower K concentrations and water contents under saline treatments; these changes are related to mechanisms for osmotic adjustment.

Glenn, E.P., Fontes, M.R., Katzen, S. and Colvin, L.B. (1982). Environmental Research Laboratory, 2601 E. Airport Drive, Tucson, Arizona 85706, USA. Nutritional value of halophytes grown on hypersaline water. In: Biosaline research: a look to the future (San Pietro, A., ed.), 485–490. Proceedings of 2nd International Workshop on Biosaline Research, La Paz, Mexico, Plenum Press, New York, USA.

Data on *Atriplex barclayana, A. lentiformis* and *Salsola europea* grown in open field plots and irrigated twice daily with nutrient-enriched hypersaline sea water (40,000 ppm) at Puerto Penasco, Sonora, Mexico, are reported. In addition, fruits of *Distichlis palmeri* and *C. trunillensis* were collected from naturally grown plants of nearby hypersaline estuary. Soaking of dried material in water removed considerable amount of Na and K. Un-desalted *A. barclayana* ground leaves and stems incorporated at up to 15% of the diet supported the growth of mice and chickens, but, *A. lentiformis* inhibited their growth and also caused very high mortality in chickens.

Glenn, E.P., Fontes, M.R. and Yensen, N.P. (1982). Environmental Research Laboratory, Tucson International Airport, Tucson, Arizona 85706, USA. Productivity of halophytes irrigated with hypersaline water in the Sonoran desert. In: Biosaline research: a look to the future (San Pietro, A., ed.), 491–494. Proceedings of 2nd International Workshop on Biosaline Research, La Paz, Mexico, Plenum Press, New York, USA.

This paper describes yield potential of halophytes in an extreme desert environment at Puerto Penasco, Sonora, Mexico, irrigated with hypersaline (40 000 ppm) sea water. *Salicornia equropaea* and *Batis maritima* were the most productive species followed by different species of *Atriplex* and compared well with conventional fresh water crops like alfalfa. With increase in time intervals between irrigations, salt accumulation increased in the soil surface, whereas moisture content of the soil decreased.

Glenn, E.P. and O'Leary, J.W. (1984). Environment Research Laboratory, University of Arizona, Tucson International Airport, Tucson, Arizona 85796, USA. Relationship between salt accumulation and water content of dicotyledonous halophytes. Plant, Cell and Environment, 7:253–261.

In a controlled environment study, growth of 10 (euhalophytes) species from the families *Chenopodiaceae, Aizoaceae,* and *Batidaceae* was best at 180 mol/m^3 NaCl, whilst that of 10 others (miohalophytes) from the families *Chenopodiaceae, Aizoaceae, Asteraceae, Brassicaceae, Polygonaceae, Boraginaceae, Malvaceae,* and *Plumbaginaceae* was best with no NaCl. Salt, particularly Na, accumulation was significantly greater in euhalophytes than miohalophytes. Data on water contents are provided. It is concluded that water content and cation accumulation in euhalophytes appears to be coordinated to produce a constant osmotic potential gradient within shoot tissues relative to root-zone salinity, in contrast with miohalophytes.

Glenn, E.P. and O'Leary, J.W. (1985). Environment Research Laboratory, University of Arizona, Tucson International Airport, Tucson, Arizona 85796, USA. Productivity and irrigation requirements of halophytes grown with seawater in the Sonoran desert. Journal of Arid Environment, 9:81–91.

Reports on productivity of native and exotic halophytes (genera *Atriplex, Salicornia, Distichlis, Cressa,* and *Batis*) grown in field trials at Puerto Penasco, Sonora, Mexico, using various dilutions of sea water under flood and/or sprinkler irrigation, and discusses economic options on the basis of genetic improvement and advances in irrigation technology. The most productive species yielded 1364–1794 g DW/m^2/year. The minimum effective water rate was 18 m/year, using undiluted sea water and the flood method of application. Using 10% artificial sea water and the sprinkler method of application, *Salicornia bigelovii* yielded over 1000 g DW/m^2 with only 2.4 m of water. *Atriplex* plants had 12–17% protein but ash content was also high.

Glenn, E.P., Olsen, M., Frye, R., Moore, D. and Miyamoto, S. (1994). Environment Research Laboratory, University of Arizona, Tucson International Airport, Tucson, Arizona 85796, USA. How much sodium accumulation is necessary for salt tolerance in subspecies of the halophyte *Atriplex canescens*? Plant, Cell and Environment, 17:711–719.

In both NaCl-treated outdoor lysimeters (pots) and in seawater flood-irrigated field plots, *A. canescens* ssp. *linearis*, which grows naturally on sea water in the high intertidal zone of estuaries, was markedly more tolerant than ssp. *canescens*, which grows on dunes. The greater salt tolerance of *linearis* was associated with greater net transport of Na from root to shoot, greater Na accumulation in the leaves and a higher Na:K ratio in the leaves compared with *canescens*. On the other hand, leaf osmotic adjustment for the two subspecies was similar, equal to 2 to 3 times the external salinity, as were water use efficiencies. Even at relatively low salinities, both subspecies accumulated larger quantities of Na for osmotic adjustment than K. The importance of Na accumulation as an important characteristic for salt tolerance improvement is discussed.

Glenn, E.P., Pfister, R., Brown, J.J., Thompson, T.L. and O'Leary, J.W. (1996). Environment Research Laboratory, University of Arizona, Tucson International Airport, Tucson, Arizona 85796, USA. Na and K accumulation and salt tolerance of *Atriplex canescens* (Chenopodiaceae) genotypes. American Journal of Botany, 83:997–1005.

Reports on a glasshouse study in which 16 accessions of *Atriplex canescens* were compared in soil-filled pots treated with 72 to 2017 mol/m^3 NaCl. Relative growth rates (RGRs) were reduced by salinity for all accessions with some differences between accessions in the degree of reduction. Initial leaf Na concentrations were positively correlated with subsequent RGRs of accessions under salinity, whereas those of leaf K were negatively correlated. Varieties ('subspecies' in Glenn et al. 1994) *linearis* and *grandidentatum* generally had higher Na and lower K concentrations, and higher growth rates under salinity than var. *occidentalis* accessions.

Glenn, E.P., Watson, M.C., O'Leary, J.W. and Axelson, R.D. (1992). Environment Research Laboratory, University of Arizona, Tucson International Airport, Tucson, Arizona 85796, USA. Comparison of salt tolerance and osmotic adjustment of low-sodium and high-sodium subspecies of the C_4 halophyte, *Atriplex canescens*. Plant, Cell and Environment, 15:711–718.

Atriplex canescens ssp. *canescens* had significantly lower Na levels, higher K levels and lower Na:K ratios in leaf and stem tissues than ssp. *macropoda* and *linearis*, which are Na accumulators, over the NaCl range 2.2–720 mol/m^3, after 80 days in a glasshouse study. However, despite different patterns of Na and K accumulation, all three subspecies had similar responses to increasing NaCl and had similar leaf and stem osmotic potentials over the salinity range.

Gogate, M.G., Mittal, R.C. and Pyarelal (1984). Forest Research Institute and College, Dehra Dun, India. Screening through germination trials—Australian species for saline areas. Indian Forester, 110:982–988.

Germination responses under salinity (1:1 mixture of NaCl and KCl, 0–15 dS/m^3) indicated that *Acacia nilotica* was the most tolerant, followed by *Casuarina obesa*, *C. cristata*, *C. cunninghamiana* and *Melaleuca glomerata*.

Gonzales, C.L. and Heilman, M.D. (1977). Agricultural Research Service, United States Department of Agriculture, Weslaco, Texas, USA. Yield and chemical composition of coastal Bermuda grass, Rhodes grass and volunteer species grown on saline and non-saline soils. Journal of Range Management, 30:227–30.

Bermuda grass produced significantly higher forage yields on saline than on non-saline soils whereas Rhodes grass did best on non-saline soil. Differences in salinity did not affect herbage Ca, Mg or K contents.

Good, B.J. and Patrick, Jr, W.H. (1987). Centre for Wetland Resources, Louisiana State University, Baton Rouge, Louisiana 70803-7511, USA. Gas composition and respiration of water oak (*Quercus nigra* L.) and green ash (*Fraxinus pennsylvanica* Marsh.) roots after prolonged flooding. Plant and Soil, 97 :419–427.

This paper reports on the effects of 9.5 months of continuous flooding on one-year-old seedlings of green ash (*Fraxinus pennsylvanica*) and water oak (*Quercus nigra*). The internal root gas composition of green ash (more flood tolerant) was higher in O_2 and lower in CO_2. The authors suggest that this maintains higher rhizosphere O_2 concentrations and prevents the accumulation of potentially phytotoxic compounds. Data on alcohol dehydrogenase activity, Fe, Mn and P concentrations and protein contents are provided.

Goodin, J.R. (1979). Department of Biological Sciences, Texas Technical University, Lubbock, Texas 79409, USA. The forage potential of *Atriplex canescens*. In: Arid land plant resources (Goodin, J.R. and Northington, D.K., ed.), 418–423. Proceedings International Arid Land Conference on Plant Resources, Texas Technical University, USA.

Reports that yields and crude protein content of *Atriplex canescens* during the first year under various irrigation levels of normal and brackish water, were comparable or even better than alfalfa, but palatability was variable, and it is suggested that selection for lower oxalic acid content would be useful.

Goodin, J.R. (1979). Department of Biological Sciences, Texas Technical University, Lubbock, Texas 79490, USA. *Atriplex* as a forage crop for arid lands. In: New agricultural crops (Ritchie, G.A., ed.), 133–148. American Association for the Advancement of Science, Symposium 38, Westview Press, Boulder, Colorado, USA.

Reports on the potential of several species of saltbushes for routine agronomic forage crop production, since they have high biomass, high protein, and mineral levels adequate for animal nutrition, and most are halophytes.

Goodin, J.R. and McKell, C.M. (1970). Department of Agronomy, University of California, Riverside, California, USA. *Atriplex* spp. as a potential forage crop in marginal agricultural areas. Proceedings of XI International Grassland Congress, University of Queensland Press, St Lucia, Queensland, Australia, 158–161.

Based on yields (up to 16 t/ha per season), protein content (as high as 19.2% in *Atriplex polycarpa*) and other characteristics, in field trials, it is suggested that *A. lentiformis* and *A. polycarpa* can be cultivated as forage crops in marginal lands subject to prolonged drought or excessive salinity.

Gorham, J. (1987). Centre for Arid Zone Studies, Department of Biochemistry and Soil Science, University Collge of North Wales, Bangor, Gwynedd LL57 2UW, UK. Photosynthesis, transpiration and salt fluxes through leaves of *Leptochloa fusca* L. Kunth. Plant, Cell and Environment, 10:191–196.

Since the rate of salt excretion by glands on the leaves of Kallar grass (*Leptochloa fusca*) was strongly dependent on temperature (up to 39°C) and the concentration of salt in the xylem required to sustain the observed rate of excretion was low, the author concludes that salt excretion is a secondary mechanism of salt tolerance, with exclusion at the roots being the major mechanism.

Gorham, J. (1992). Centre for Arid Zone Studies, University College of North Wales, Bangor, Gwynedd LL57 2UW, UK. Grass responses to salinity. In: Desertified grasslands: their biology and management, 165–180. The Linnean Society Symposium Series No. 13, London, UK.

This very useful review discusses salt tolerance in grasses; over 130 species are salt-tolerant and frequently in the tribes *Cynodonteae* and *Eragrostideae*, particularly among C_4 species which have higher water-use efficiency. Salt tolerance mechanisms dealt with include K/Na discrimination during uptake, cellular K/Na exchange, phloem loading, Na exclusion from xylem and distribution of Na and K in leaves. Physiological root and shoot models of salt tolerance in grasses are described. Salt tolerance mechanisms in the *Triticeae* include vacuolar accumulation of Na in root cells and discrimination between Na and K uptake into roots.

Gorham, J., Budrewicz ,E., McDonnell, E., and Jones R.G.W. (1986). Central Arid Zone Studies, Department of Biochemistry and Soil Science, University College of North Wales, Bangor, LL57 2UW, UK. Salt tolerance in the Triticeae: salinity-induced changes in the leaf solute composition of some perennial Triticeae. Journal of Experimental Botany, 37:1114–1128.

This paper reports on results of solution-culture experiments with 250 mol/m^3 NaCl (+/– Ca to give a 20:1 ratio of Na:Ca) using seedlings of *Elymus canadensis*, *Thinopyrum sartorii*, *T. scirpeum*, *T. junceum* complex accessions, *Pascopyrum smithii*, *Leymus cinereus*, *Psathyrostachys juncea* and *Psathyrostachys fragilis*. Although there was variation both within and between species in the extent of Na and Cl accumulation in the leaves, most species had good salt tolerance associated with exclusion of these ions, and maintenance of high K concentrations. Decreases in leaf nitrate concentrations and increases in orthophosphate, glycinebetaine and proline concentrations were commonly found in response to NaCl.

Gorham, J., McDonnell, E. and Wyn Jones, R.G. (1984). Department of Biochemistry and Soil Science, University College of North Wales, Bangor, Gwynedd LL57 2UW, Wales, UK. Salt tolerance in Triticaceae:*Leymus sabulosus*. Journal of Experimental Botany, 35:1200–1209.

Reports that *Elymus dahuricus, Leymus giganteus, L. angustus, L. sabulosus* and, to a lesser extent, *L. triticoides,* were found to tolerate 200 mol/m^3 NaCl in solution culture. *E. dahuricus* had a greater uptake of Cl and Na and a greater loss of K from the shoots than *Leymus* species. In a more detailed and longer (57 days) experiment on *L. sabulosus*, transpiration rates decreased rapidly in response to increasing NaCl whereas the accumulation of Na and Cl in the leaves lagged behind. Glycinebetaine levels increased in leaves of salinised plants.

Gorham, J., McDonnell, E. and Wyn Jones, R.G. (1984). Department of Biochemistry and Soil Science, University College of North Wales, Bangor, Gwynedd LL57 2UW, Wales, UK. Pinitol and other solutes in salt-stressed *Sesbania aculeata*. Zeitschrift für Pflanzenphysiologie Bd., 114. S.:173–178.

In addition to higher Na and Cl concentrations, pinitol and, to a lesser extent, glycinebetaine increased in the leaves of salt-stressed *Sesbania aculeata* plants grown in solution culture with or without 100 mol/m^3 NaCl. The possibility of pinitol acting as a compatible cytosolute in this and other salt-tolerant legumes is discussed.

Gorham, J., Tomar, O.S. and Wyn Jones, R.G. (1988). Centre for Arid Zone Studies, University College of North Wales, Bangor, Gwynedd LL57 2UW, UK. Salinity induced changes in the chemical composition of *Leucaena leucocephala* and *Sesbania bispinosa*. Journal of Plant Physiology, 132:678–682.

Reports on the effects of NaCl and additional Ca (as $CaCl_2$) on growth and solute composition (Na, K, Ca, Mg, Cl, anions, sugars and betaines) in *Leucaena leucocephala* and *Sesbania bispinosa* grown in solution culture experiments. Additional Ca greatly ameliorated the effects of NaCl on growth and Na concentration in shoots. In *S. trispinosa* pinitol increased with salt stress, particularly in the apices, and may act as a compatible solute, but it did not accumulate in *L. leucocephala*.

Gorham, J. and Wyn Jones, R.G. (1983). Department of Biochemistry and Soil Science, University College of North Wales, Bangor, Gwynedd LL57 2UW, UK. Solute distribution in *Suaeda maritima*. Planta, 157:344–349.

Using semi-microtechniques, K:Na ratios were found to be much higher in the apical regions and in axillary buds than in more mature, fully vacuolated tissues of *Suaeda maritima*; younger tissues also contained very high levels of glycinebetaine. Using electron-probe X-ray microanalysis of bulk frozen and fractured preparations, higher K:Na ratios and higher levels of S and P were observed in the cytoplasm of leaf primordial cells than in vacuoles of either young or old leaves, although the total counts were higher in the vacuolar samples. The results are discussed in relation to current models of subcellular solute compartmentation and salt tolerance in the *Chenopodiaceae*.

Graetz, R.D. and Wilson, A.D. (1980). CSIRO, Division of Land Resources Management, Private Bag, PO, Deniliquin, NSW 2710, Australia. Comparison of the diets of sheep and cattle grazing a semi-arid chenopod shrubland. Australian Rangeland Journal, 2:67–75.

This paper describes studies with oesophageally fistulated sheep and cattle grazing a semiarid chenopod shrubland dominated by bladder saltbush (*Atriplex vesicaria*) to ascertain dietary preferences. Sheep mostly selected a diet of appreciably higher digestibility and N content than cattle.

Graham, T.W.G and Humphreys, L.R. (1970). Department of Agriculture, University of Queensland, St. Lucia, Qld 4067, Australia. Salinity response of cultivars of buffel grass (*Cenchrus ciliaris*). Australian Journal of Experimental Agriculture and Animal Husbandry, 10:725–728.

When exposed to NaCl (0.5 to 160 mol/m^3) in solution culture, dry weights of cultivars did not differ at the highest salinity, but relative growth reduction of the more productive cultivars was greater in response to salinity. Shoot Na concentrations did not differ between cultivars at 40 mol/m^3 but at 160 mol/m^3 the most productive cultivars (at low salinities) had the highest concentrations.

Grattan, S.R., Shannon, M.C., Grieve, C.M., Poss, J.A., Suarez, D. and Leland, F. (1997). Department of LAWR, University of California, Davis, CA 95616, USA. Interactive effects of salinity and boron on the performance and water use of Eucalyptus. Acta Horticulturae, 449:607–613.

This paper reports on a study (sand-culture, outdoors) to determine the effect of both salt (EC up to 22 dS/m) and B (up to 30 mg/L) on growth (biomass, leaf area, branch number), water use (including sap flow) and ion concentrations of *Eucalyptus camaldulensis* after eight months. The study is related to re-use of saline drainage water using agroforestry systems in California.

Greenway, H. (1968). Department of Agronomy, Western Australia University, Nedlands, Australia 6009. Growth stimulation by high chloride concentrations in halophytes. Israel Journal of Botany, 17:169–177.

This paper establishes the responses of old man saltbush (*Atriplex nummularia*) to chlorides of Na, K, Mg and Ca in aerated nutrient solution culture. Growth and ion concentration data are presented. The growth of old man saltbush was optimal at ~100 mol/m^3 NaCl.

Greenway, H. (1973). Department of Agronomy, Institute of Agriculture, University of Western Australia, Nedlands, WA 6009, Australia. Salinity, plant growth and metabolism. Journal of Australian Institute of Agricultural Science, 39:24–34.

This review deals with various aspects of the physiology of salt tolerance, particularly in terms of ion and water relations (specific ion versus osmotic effects) and uses examples from halophytes and non-halophytes.

Greenway, H. and Munns, R. (1980). Department of Agronomy, Western Australia University, Nedlands, 6009, Australia. Mechanisms of salt tolerance in nonhalophytes. Annual Review of Plant Physiology, 31:149–190.

Salt tolerance in nonhalophytes is discussed in this important review. The reduced growth associated with conditions of high salinity is discussed in terms of ion excess and/or water deficit. There is an excellent summary figure that divides higher plants into different groups based on their physiological responses to salinity. The primary effect of salinity could not be located to a particular plant tissue. In several species, salt sensitivity of certain cultivars was due to the absorption of relatively high amounts of Cl and/or Na. Sensitivity toward high Cl and/or Na concentrations in leaves was much greater for nonhalophytes than halophytes. The more tolerant genotypes of many nonhalophytic species are suggested to avoid ion excess but consequently be deficient in solutes for osmotic regulation.

Greenway, H. and Munns, R. (1983). Department of Agronomy, Institute of Agriculture, University of Western Australia, Nedlands, WA 6009, Australia. Interactions between growth, uptake of Cl^- and Na^+, and water relations of plants in saline environments. II. Highly vacuolated cells. Plant, Cell and Environment, 6:575–589.

This paper argues that in a highly saline environment, high rates of ion uptake are required to generate sufficient osmotic pressure to maintain the turgor that is needed for the continued growth of plants. Reports on the relative contribution of passive and active fluxes of Na and Cl to osmotic regulation; it is calculated (example at 500 mol/m^3 external NaCl) that active fluxes are still essential and would consume a substantial amount of energy. Limitation to growth (cell expansion) at high salinity arising from lack of energy, or from insufficient capacity for ion uptake, are discussed.

Greenway, H. and Rogers, A. (1963). CSIRO Division of Plant Industry, Kojonup, WA 6395, Australia. Growth and ion uptake of *Agropyron elongatum* on saline substrates, as compared with a salt-tolerant variety of *Hordeum vulgare*. Plant and Soil, 18:21–29.

Agropyron elongatum was found to be more salt-tolerant than a very tolerant variety of *Hordeum vulgare* under controlled (early tillering stage) and field conditions, and this was related to lower Na and Cl concentrations in young leaves and shoots.

Greenwood, E.A.N. (1986). CSIRO, Division of Groundwater Research, Private Bag, PO Wembley, WA 6014, Australia. Water use by trees and shrubs for lowering saline groundwater. Reclamation and Revegetation Research, 5:423–434.

This paper provides an assessment and review of important factors related to the ability of vegetation to transpire water in recharge and discharge situations and hence impact on watertable lowering for dryland salinity management.

Greenwood, E.A.N. and Beresford, J.D. (1979). Division of Land Resources Management, CSIRO, Wembley, WA 6014, Australia. Evaporation from vegetation in landscapes developing secondary salinity using the ventilated-chamber technique. I. Comparative transpiration from juvenile *Eucalyptus* above saline ground water seeps. Journal of Hydrology, 2:360–382.

Reports on differences in transpiration rate between several eucalypts grown in plantations at three locations in Western Australia ranging in average annual rainfall from 420 to 850 mm. Differences between species in both total transpiration and transpiration per unit leaf area were found. (The ventilated chamber methodology used in this and other studies is deemed to be suspect by some researchers with the result that evapotranspiration data are probably higher than they should be.)

Greenwood, E.A.N. and Beresford, J.D. (1980). Division of Land Resources Management, CSIRO, Wembley, WA 6014, Australia. Evaporation from vegetation in landscapes developing secondary salinity using the ventilated-chamber technique. II. Evaporation from *Atriplex* plantations over a shallow saline water table. Journal of Hydrology, 45:313–319.

From measured evapotranspiration rates during summer of ungrazed plantations of *Atriplex vesicaria,* of varying spacing between bushes, coupled with reductions in watertable depth under plantations, it is suggested that *Atriplex* may have a hydrologic role in salt-land reclamation in addition to its value as a grazing plant. There was evidence of a low rate of nocturnal transpiration.

Greenwood, E.A.N., Biddiscombe, E.F., Rogers, A.L., Beresford, J.D. and Watson, G.D. (1992). Division of Water Resources, CSIRO, Wembley, WA 6014, Australia. The influence on groundwater levels and salinity of a multi-specied tree plantation of south-western Australia. Agricultural Water Management, 25:185–200.

In addition to providing data on ground water salinity and depth changes, this paper describes growth of species at 15 years at the same site (Dryandra) as discussed by Biddiscombe et al. (1985) at year 7. Species that continue to be the most promising for growth and watertable lowering are *Eucalyptus cladocalyx* (var. *nana*), *E. platypus* (var. *heterophylla*), *E. sargentii* and *E. spathulata*.

Greenwood, E.A.N., Klein, L., Beresford, J.D. and Watson, G.D. (1985). Division of Land Resources Management, CSIRO, Wembley, WA 6014, Australia. Differences in annual evaporation between grazed pasture and *Eucalyptus* species in plantations on a saline farm catchment. Journal of Hydrology, 78:261–278.

This paper reports on evaporation (including evaporation from the ground surface using ventilated chambers) from grazed annual pastures and from 7-year-old trees of five *Eucalyptus* species in two farm plantations (well upslope and immediately above a saline seep). Expressed as a proportion of annual rainfall (680 mm), annual evaporation was 0.6 for pasture and ranged from 2.4 to 4.0 for trees, while interception by trees ranged from 0.16 to 0.36 and stem flow was less than 0.02. Annual evaporation, but not interception, was correlated with leaf area. (Refer Biddiscombe et al. 1981).

Greenwood, E.A.N, Milligan, A., Biddiscombe, E.F., Rogers, A.L., Beresford, J.D., Watson, G.D. and Wright, K.D. (1992). Division of Water Resources, CSIRO, Wembley, WA 6014, Australia. Hydrologic and salinity changes associated with tree plantations in a saline agricultural catchment in southwestern Australia. Agricultural Water Management, 22:307–323.

A naturally forested catchment in Western Australia was cleared for agriculture in 1966; saline seeps developed in all its first order catchments. For one seep, 11% of the catchment was replanted with *Eucalyptus* spp. in 1976 to reclaim it. Data up to 1987 are presented and discussed for watertable levels and contents, outflow of water and salt, and changes in salinity and plant species in the seep.

Greub, L.J. and Drolsom, P.N. (1977). Wisconsin University, River Falls, USA. Salt tolerance of selected grass species and cultivars as affected by soil type, soil phosphorus and level of salt application. In: Agronomy abstracts, 111 p. 1977 Annual Meetings, Los Angeles, California, American Society of Agronomy, Madison, USA.

Of eight species and varieties that received four treatments of salt, *Agropyron repens* and *Festuca arundinacea* 'Alta' and 'Kentucky 31' showed least injury, contained least Cl and gave the highest yields.

Grewal, S.S. and Abrol, I.P. (1986). Central Soil Salinity Research Institute, Karnal, Haryana 132 001, India. Agroforestry on alkali soils: effect of some management practices on initial growth, biomass accumulation and chemical composition of selected tree species. Agroforestry Systems, 4:221–232.

Results are presented from a study on a typical alkali soil (ESP 99) at Karnal, Haryana (India), in which *Eucalyptus tereticornis*, *Acacia nilotica* and *Parkinsonia aculeata* were planted on flat natural surfaces without rainwater conservation or on ridges with parallel trenches to store 300 mm of monsoon rainwater. Further management variants included planting with or without forage grass (*Diplachne [Leptochloa] fusca*) and planting in shallow (15 × 60 cm) or deep (15 × 180 cm) auger holes filled with soil treated with gypsum, FYM, N, and zinc sulphate. After two years, height and basal area were only significantly superior with deep compared with shallow auger holes.

Grewal, S.S. and Abrol, I.P. (1988). Central Soil Salinity Research Institute, Karnal, Haryana 132 001, India. Forage yield, chemical composition and reclaiming effects of Karnal grass (*Diplachne fusca*) grown with trees in alkali soil. Indian Journal of Agricultural Science, 58:278–282.

Forage yield of Karnal grass grown between rows of trees was higher when planted in trenches between ridges than on a flat surface, and it is suggested that this was at least partly related to prolonged submergence of the grass, which encouraged vigorous growth and faster soil amelioration. Data on root and shoot Na concentrations are provided. (Refer Grewal and Abrol 1986.)

Grieve, A.M. and Pitman, G.M. (1978). School of Biological Sciences, University of Sydney, NSW 2006, Australia. Salinity damage to Norfolk Island pines caused by surfactants. III. Evidence for stomatal penetration as the pathway of salt entry to leaves. Australian Journal of Plant Physiology, 5:397–413.

This paper (i) confirms that the damage observed along the sea-coast in Sydney is similar to that produced by high NaCl levels in the foliage; (ii) describes the effect of surfactant in increasing NaCl uptake from seawater spray; and (iii) suggests pathways of sea-spray entry into needles. (Refer Dowden et al. 1978.)

Gupta, G.N., Mohan, S. and Prasad, K.G. (1987). Forest Research Institute College, Dehra Dun, Uttar Pradesh, India. Salt tolerance of selected tree seedlings. Journal of Tropical Forestry, 3:217–227.

Reports results of greenhouse experiments with added salt (up to EC 14 dS/m and comprising $CaCl_2$ and NaCl) on seedlings of *Leucaena leucocephala, Peltaphorum pterocarpum, Eucalyptus tereticornis, Azadirachta indica* and *Albizia lebbeck* grown in pots filled with sand, loam and clay soils. Toxicity symptoms were least in clay soil and greatest in sandy soil, but patterns between species varied with different soil type.

Gupta, G.N., Prasad, K.G., Mohan, S. and Manivachakam, P. (1986). Forest Soil cum Vegetation Survey, S. Region, Coimbatore, Tamil Nadu, India. Salt tolerance in some tree species at seedling stage. Indian Forester, 112:101–113.

Reports on an experiment with seedlings grown in pots filled with sand, loam or clay soils and treated with mixed NaCl and $CaCl_2$ (2:1) at EC values up to 15 dS/m. Based on plant survival, height, leaf, stem and total plant weight, root length and root:shoot ratio, it was concluded that the order of observed salt tolerance was *Acacia nilotica* > *Eucalyptus camaldulensis* > *Casuarina equisetifolia* > *Ceiba pentandra* > *Acacia auriculiformis*.

Gupta, U. and Ramakrishnan, P.S. (1977). Department of Botany, School of Life Science, North Eastern Hill University, Shillong, India. The effect of added salt on competition between two ecotypes of *Cynodon dactylon* (L). Proceedings of the Indian Academy of Sciences, 86:278–280.

Reports on competitive ability of a population of *Cynodon dactylon* originating from an alkaline soil compared with one originating from a neutral soil when both were grown in mixtures in pots of neutral soil to which $NaSO_4$, NaCl, $NaHCO_3$ or KCl were added.

Guy, R.D., Warne, P.G. and Reid, D.M. (1984). Plant Physiology Research Group, Biology Department, University of Calgary, Calgary, Alberta T2N 1N4, Canada. Glycinebetaine content of halophytes: improved analysis by liquid chromatography and interpretations of results. Physiologia Plantarum, 61:195–202.

Of 27 plant species tested using simple isocratic high performance liquid chromatography, which is claimed to be a very sensitive and accurate method for glycinebetaine analysis, 13 were found to be glycinebetaine accumulators. The glycinebetaine content of *Salicornia europaea* actually declined with progressively higher NaCl on a DW basis, but when expressed as a proportion of plant organic matter, it increased.

Haas, J. (1993). Department of Life Sciences, University of North London, 166–220 Holloway Road, London N7 8DB, UK. Effect of saline irrigation on early growth of *Eucalyptus gomphocephala* and *Acacia saligna*. Environmental Conservation, 20:143–148.

Reports results after 3.5 years for a trial on Formentera in the Balearic Islands with *Eucalyptus gomphocephala* and *Acacia saligna* at two sites (coastal and inland) differing mainly in soil depth, in which four irrigation treatments (nil, EC < 1, 5 and 10 dS/m) were applied.

Hacker, R.B. (1987). Department of Agriculture, South Perth, WA 6151, Australia. Species responses to grazing and environmental factors in an arid halophytic shrubland community. Australian Journal of Botany, 35:135–150.

Based on grazing and environmental factors in an arid halophytic shrubland community in Western Australia, it is concluded that long-term grazing pressure is apparently reduced on localised areas of high salinity, and that environmental factors affecting species distribution are complex but appear to include effects of soil salinity and soil cationic balance on seedling establishment.

Hafeez, S.M. (1993). Punjab Forest Research Institute, Faisalabad, Pakistan. Identification of fast growing salt-tolerant tree species. Pakistan Journal of Forestry, 43:216–220.

Reports on three years' survival and growth in a species evaluation trial near Shorkot, Punjab (Pakistan), planted on a moderately saline soil. Better performing species included *Eucalyptus camaldulensis, E. rudis, Casuarina cunninghamiana, C. glauca, C. obesa, Acacia salicina* and *Tamarix aphylla*.

Hagemeyer, J. and Waisel, Y. (1989). Department of Ecology, Faculty of Biology, Bielefeld University, 4800 Bielefeld, German Federal Republic. Influence of NaCl, $Cd(NO_3)_2$ and air humidity on transpiration of *Tamarix aphylla*. Physiologia Plantarum, 75:280–284.

Transpiration rates of young, hydroponically-grown *Tamarix aphylla* plants were measured under NaCl and $Cd(NO_3)_2$ stress (not applied factorially). Transpiration rates were negatively correlated with the relative humidity of the ambient air at all NaCl concentrations, and were reduced at higher

salinities, probably as a result of the reduced capacity of roots to transport water rather than because of reduced stomatal opening. Data for the effect of Cd concentrations are also provided.

Hajibagheri, M.A. and Flowers, T.J. (1985). School of Biological Sciences, The University of Sussex, Brighton, BN1 9QG, UK. Salt tolerance in the halophyte *Suaeda maritima* (L.) Dum. The influence of the salinity of the culture solution on leaf starch and phosphate content. Plant, Cell and Environment, 8:261–267.

Reports that starch concentration (expressed on a chlorophyll basis) in *Suaeda maritima* leaves increased with increasing NaCl, particularly in young leaves. Electron micrographs showed the starch to be in the chloroplasts and this was confirmed by measurements on isolated chloroplasts. Total P concentration (mg/mg chlorophyll) in leaves of all ages decreased in response to salt application. The cause of starch accumulation in chloroplasts at salinities which were optimal for growth (340 mol/m^3) was unclear.

Hajibagheri, M.A., Flowers, T.J. and Hall, J.L. (1985). School of Biological Sciences, The University of Sussex, Brighton BN1 9QG, UK. Cytometric aspects of the leaves of the halophyte *Suaeda maritima*. Physiologia Plantarum, 64:365–370.

The number of mitochondria per cell section almost doubled when *Suaeda maritima* plants were grown in 340 mol/m^3 NaCl compared with non-saline conditions. Chloroplast and microbody volume per cell increased under saline conditions, but number per cell was insensitive to salt. Chloroplasts of salt-treated plants contained a greater number of starch grains than those of control plants.

Hajibagheri, M.A., Hall, J.L. and Flowers, T.J. (1983). School of Biological Sciences, The University of Sussex, Brighton BN1 9QG, UK. The structure of the cuticle in relation to cuticular transpiration in leaves of the halophyte *Suaeda maritima* (L.) Dum. New Phytologist, 94:125–131.

When treated with 340 mol/m^3 NaCl, both cuticle and cell wall of the epidermal cell of leaves of *Suaeda maritima* plants were markedly thicker (approximately 1.8 times) in plants grown without added NaCl. Differences in the structure of the cuticle were also observed. The rate of transpiration in the dark was markedly reduced with increasing NaCl. It is concluded that cuticular transpiration appears to be related to cuticular thickness and to decrease with increasing salinity.

Hajibagheri, M.A., Hall, J.L. and Flowers, T.J. (1984). School of Biological Sciences, The University of Sussex, Brighton BN1 9QG, UK. Sterological analysis of leaf cells of the halophyte *Suaeda maritima* (L.) Dum. Journal of Experimental Botany, 35:1547–1557.

> This paper describes changes within cells of the mesophyll, vascular bundles and central parenchyma in leaves of the halophyte *Suaeda maritima* in response to salinity using sterological analysis. Vacuoles formed a greater proportion of cell volume in salinised plants, and there was a concurrent increase in the surface density of the tonoplast. In contrast, the volume fraction of chloroplasts and cell wall fell under saline conditions, while that of the intercellular spaces and the fraction of the cell volume occupied by the mitochondria increased.

Hajibagheri, M.A., Harvey, D.M.R. and Flowers, T.J. (1984) School of Biological Sciences, The University of Sussex, Brighton BN1 9QG, UK. Photosynthetic oxygen evolution in relation to ion contents in the chloroplast of *Suaeda maritima*. Plant Science Letters, 34:353–362.

> Maximum rates of photosynthetic oxygen evolution (coupled and uncoupled) by chloroplasts isolated from *Suaeda maritima* were found for plants grown in 340 mol/m^3 NaCl, with concentrations of 84–257 mol/m^3 for Na, 86–212 mol/m^3 for Cl and 23–36 mol/m^3 for K, as measured in vivo by X-ray microanalysis. Maximum rates were also found in vitro at 340 mol/m^3.

Hajibagheri, M.A., Yeo, A.R. and Flowers, T.J. (1985). School of Biological Sciences, The University of Sussex, Falmer, Brighton BN1 9QG, UK. Salt tolerance in *Suaeda maritima* (L.) Dum. Fine structure and ion concentrations in the apical regions of roots. New Phytologist, 99:331–343.

> Reports on anatomy and ion concentrations in roots of *Suaeda maritima* growing under saline and non-saline conditions. The roots were fine with only three layers of cortical cells. Cellular vacuolation commenced closer to the apex in salinised than in non-salinised plants and led to an increase in root dimensions through increased cell (vacuole) size but not increased cell numbers. The Casparian strip developed much closer to the apex and was twice as long in salinised plants. Data on ion concentrations in various sections (1 mm) of root are given.

Hallsworth, E.G. (1981). CSIRO, Land Resource Laboratories, Urrbrae, SA 5064, Australia. The use of saline groundwater in arid areas. Experimental Agriculture, 17:145–147.

Reports height growth data for 7–8 year *Casuarina glauca* and *Eucalyptus camaldulensis*, irrigated with up to 16 000 ppm saline water in the desert areas of Abu Dhabi, in eastern Arabia. It appears that more highly saline water can be used with trickle irrigation, perhaps because plant roots are subject to less fluctuations in root-zone moisture stress.

Hamilton, G.J. (1972). NSW Soil Conservation Department, Goulburn, Australia. Investigations into the reclamation of dryland saline soils. Soil Conservation Journal, (October):191–212.

The results of investigations into the reclamation of saline soils at four sites in central New South Wales, Australia are presented. Tall wheat grass (*Agropyron elongatum*) and marsh grass (*Puccinellia capillaris*) grew well on severely salt-affected soils with average osmotic potential (OP) of about –1.4 MPa. Wimmera ryegrass (*Lolium rigidum*) and lucerne (*Medicago sativa*) grew well only on moderately salt-affected soils with OP < –0.5 MPa. N fertiliser application resulted in better plant growth than P application. Mulch application improved revegetation at sites where the watertable depth fluctuated with season by reducing surface salinities.

Han, M.S., Kim, J.G., Lee, S.B. and Han, H.J. (1989). Livestock Experiment Station, RDA, Suwon, Korea Republic. Studies on salt tolerance, dry matter yield and Weender components of temperate grasses grown on newly reclaimed tidal lands. Research Report of the Rural Development Administration, Livestock, 31:36–40.

Of 16 species and cultivars of temperate grasses grown on newly reclaimed tidal lands under different mulching treatments, tall wheatgrass (*Elymus elongatus, Agropyron elongatum*) was most salt-tolerant, but tall fescue (*Festuca arundinacea*) and lucerne (*Medicago sativa*) were also tolerant. Mulch application improved growth through decreased root-zone salinity, especially during the dry season. Data on leaf:weight ratio, crude protein and DM digestibility are given. (In Korean, English summary.)

Handley, J.F. and Jennings, D.H. (1977). Botany Department, The University, Liverpool L69 3BX, UK. The effect of ions on growth and leaf succulence of *Atriplex hortensis* var. *cupreata*. Annals of Botany, 41:1109–1112.

Na salts (at least 100 mol/m^3) increased leaf succulence of solution-grown plants of *A. hortensis* var. *cupreata* more than K salts, whether the anion was Cl, Br or SO_4, and Mg and Ca salts had no effect. Dry weight production was greatly reduced by Na and K salts but stimulated by Mg salts.

Hannon, N.J. and Barber, N.H. (1972). School of Botany, University of New South Wales, Kensington, NSW 2033, Australia. The mechanism of salt tolerance in naturally selected populations of grasses. Search, 3:259–260.

This paper reports on a glasshouse experiment that examined ion uptake differences between clones (from saltmarsh and upland areas) of *Festuca rubra*, a typical saltmarsh grass of North Wales (UK), challenged with different concentrations of sea water. Saltmarsh clones had lower concentrations of Na and Cl and higher K:Na ratios.

Hansen, D.J. and Weber, D.J. (1975). Department of Botany, Brigham Young University, Provo, Utah 84602, USA. Environmental factors in relation to the salt content of *Salicornia pacifica* var. *utahensis*. Great Basin Naturalist, 35:86–96.

This paper reports on ion concentrations in plants of *Salicornia pacifica* var. *utahensis* communities in relation to changes in seasonal soil moisture content and soil salinity with depth.

Hansen, E.H. and Munns, D.N. (1984). Department of Land, Air and Water Resources, University of California, Davis, CA 95616, USA. Screening of *Leucaena leucocephala* for NaCl tolerance. Leucaena Research Reports, 5:77–78.

Growth of seedlings of varieties K8 and K63, grown in buckets for 110 days, was severely depressed at NaCl concentrations of 6 000 mg/L and at 12 000 mg/L several plants were killed.

Hansen, E.H. and Munns, D.N. (1985). Department of Land, Air and Water Resources, University of California, Davis, CA 95616, USA. Screening of *Sesbania* species for NaCl tolerance. Nitrogen Fixing Tree Research Reports, 3:60–61.

Reports on the effects of NaCl (1–200 mol/m^3) on solution-grown seedlings of *Sesbania sesban*, *S. grandiflora*, *S. pachycarpa*, *S. emerus*, *S. rostrata*, *S. exasperata* and *S. bispinosa*.

Hansen, E.H. and Munns, D.N. (1988). Department of Land, Air and Water Resources, University of California, Davis, CA 95616, USA. Effects of $CaSO_4$ and NaCl on growth and nitrogen fixation of *Leucaena leucocephala*. Plant and Soil, 107:95–99.

> This paper reports on the effects of and interactions between $CaSO_4$ (0.5, 1.0, 2.5 and 5.0 mol/m^3) and NaCl (1, 25, 50 and 100 mol/m^3) on growth and N fixation of *Leucaena leucocephala* 'K8' seedlings in solution culture. While NaCl significantly reduced plant growth, additions of $CaSO_4$ increased plant height, leaf number and biomass of salt-treated plants. Nodule number was significantly reduced by 100 mol/m^3 and nodule weight of salt-treated plants significantly increased as $CaSO_4$ concentration increased from 0.5 to 2.5 mol/m^3.

Hansen, E.H. and Munns, D.N. (1988). Department of Land, Air and Water Resources, University of California, Davis, CA 95616, USA. Effect of $CaSO_4$ and NaCl on mineral content of *Leucaena leucocephala*. Plant and Soil, 107:101–105.

> Reports on the the effects of different $CaSO_4$ and NaCl concentrations on the mineral concentrations of *L. leucocephala* [refer previous reference]. Leaf and stem Na and leaf Cl concentrations were higher at 100 mol/m^3 at low compared with high Ca supply. Leaf K concentrations were unaffected by NaCl or Ca. Leaf Mg concentrations decreased as $CaSO_4$ concentrations increased.

Harivandi, M.A., Butler, J.D. and Soltanpour, P.N. (1982). Colorado State University, Fort Collins, Colorado, USA. Effects of seawater concentrations on germination and ion accumulation in alkaligrass (*Puccinellia* spp.). Communication in Soil Science and Plant Analysis, 13:507–517.

> Germination of weeping alkaligrass (*Puccinellia distans*) was higher than Lemmon alkaligrass (*P. lemmoni*) both on germination pads and in sand at different concentrations of sea water. Older seedlings of both species tolerated salinity better than younger seedlings at higher seawater concentration; this was related to higher Cl and Na accumulation.

Harradine, A.R. (1982). Department of Agriculture, Research Laboratories, New Town, Tasmania 7008, Australia. Effect of salinity on germination and growth of *Pennisetum macrourum* in southern Tasmania. Journal of Applied Ecology, 19:273–282.

The salt tolerance of the grass *Pennisetum macrourum*, at germination and at seedling (solution culture) stages, was generally less than other grasses studied (*Lolium perenne*, *Agropyron elongatum* and *Phragmites australis*). The authors conclude that these results, together with knowledge of salinity (EC) of water and soil samples from the Derwent River estuary, indicate that *P. macrourum* is unlikely to spread downstream as a weed from present infestations.

Harvey, D.M.R., Flowers, T.J. and Hall, J.L. (1977). School of Biological Sciences, University of Sussex, Falmer, Brighton, Sussex BN1 9QG, UK. Ion localization in the halophyte *Suaeda maritima*. In: Transmembrane ionic exchanges in plants (Thellier, M., Monniir, A., Demarty, M. and Dainty, J. ed), 451–457. Publication de L' Universitie de Roven.

This paper describes the evaluation of silver precipitation and freeze substitution procedures in relation to the localisation of ions in plant cells. The methods have been applied to the leaf cells of the halophyte *Suaeda maritima* and ion redistribution judged by measurement of ion losses during preparation.

Hassan, A.A. (1986). Plant Production Department, College of Agriculture, King Saud University, Riyadh, Saudi Arabia. *Atriplex*, a prospective forage crop in arid and semi-arid lands. In: Rangelands: a resource under siege (Joss, P.J., Lynch, P.W. and Williams, O.B. ed.), 275 p. Proceedings of the 2nd International Rangeland Congress, Adelaide, Australia. Australian Academy of Science.

Based on germination, growth, fibre and protein content of seven *Atriplex* spp. under controlled environment conditions, it is concluded that *A. canescens*, *A. vesicaria*, *A. nummularia* and *A. halimus* have best prospects for forage production in drylands of Saudi Arabia.

He, Y.L., Hua, Z.R., Shao, Y. and Hu, X.H. (1992). Department of Plant Science, Shanghai Agricultural College, Shanghai 201101, China. Identification of salt tolerance of seedlings of Shangnong new lines of rye grass (*L. multiflorum*). Journal of Shanghai Agricultural College, 10:197–202.

Reports that three lines of *Lolium multiflorum* were more salt-tolerant (taller seedlings, longer roots and higher fresh weights) than three lines of Orygon (Italian) ryegrass at 0.3 and 0.6% NaCl; data are related to peroxidase isoenzyme patterns of roots cultured in 0 and 0.3% NaCl. (In Chinese, English summary.)

Headley, D.B. and Bassuk, N. (1991). Urban Horticulture Institute, Cornell University, Ithaca, NY 14853, USA. Effect of time and application of sodium chloride in the dormant season on selected tree seedlings. Journal of Environmental Horticulture, 9:130–136.

Reports on symptoms, growth, shoot Cl concentrations and visual ratings for dormant and actively-growing seedlings of *Acer platanoides*, *A. rubrum*, *Quercus palustris* and *Q. rubra* treated with up to 5000 mol/m^3 NaCl.

Heath, J. and Heuperman, A.F. (1996). Institute for Sustainable Agriculture, Tatura, Victoria 3616, Australia. Serial biological concentration of salts—a pilot project. Australian Journal of Soil and Water Conservation, 9:27–31.

This paper describes the 'Serial Biological Concentration of Salt' (SBC) concept as applied in the original Californian project, its subsequent introduction to Australia and the design of a farm-scale pilot project at Undera, in the Shepparton Irrigation Region of northern Victoria. The system concentrates drainage water by reuse on progressively increasing salt-tolerant crops, thereby reducing its volume. (In the Undera project, *Atriplex* and *Eucalyptus camaldulensis* are used.)

Herbel, C.H. (1986). Jornada Experimental Range, Agricultural Research Service, US Department of Agriculture, Box 3JER (NMSU), Las Cruces, New Mexico, 99003, USA. Seeding shrubs in the field. Reclamation and Revegetation Research, 5:377–385.

This paper describes technologies for direct seeding of shrubs into degraded rangeland. Discusses the importance of mulches, water ponding, soil compaction and other factors in ameliorating harsh environmental conditions.

Heth, D. and Macrae, S. (1993). Agricultural Research Organisation, The Volcanic Center, Bet Dagan 50250, Israel. Selection of salt-tolerant clones of *Eucalyptus camaldulensis* Dehn. South African Forestry Journal, 164:21–26.

This paper reports on a glasshouse experiment in which seedlings derived from 11 *Eucalyptus camaldulensis* seed sources growing in north Israel (orginally established from eight Australian provenances), and a *E. grandis* × *E. camaldulensis* hybrid seed source from South Africa, were treated with salt (EC_w increasing weekly from 0.9 to 43.9 dS/m) using sub-irrigation. The most salt tolerant provenances, based on higher survival and less leaf shed, were from Port Lincoln (South Australia), Silverton (var. *subcinerea*; New South Wales) and Ashburton River (Northern Territory). Some individual seedlings of the hybrid were also quite

tolerant. Seedlings of most seed sources stopped growing above EC_w 3.7 dS/m; it is suggested that growth was probably restricted by factors other than salt.

Heuperman, A.F. (1992). Institute for Sustainable Agriculture, Tatura, Victoria 3616, Australia. Trees in irrigated areas: the bio-pumping concept. Trees and Natural Resources, 14:20–25.

This article describes processes of salt and water movement under tree plantations growing over saline watertables and irrigated with saline water and possibilities for agroforestry systems to re-use saline drainage and ground water in northern Victoria.

Heuperman, A.F. (1995). Institute for Sustainable Agriculture, Tatura, Victoria 3616, Australia. Salt and water dynamics beneath a tree plantation growing on a shallow watertable. Institute of Sustainable Irrigated Agriculture (Department of Agriculture, Energy and Minerals Victoria), Tatura. 61 p.

This report presents the results of a 12-year monitoring program investigating the tree–watertable interactions at a tree plantation site in Kyabram, Northern Victoria, with a range of eucalypt species irrigated for seven years after planting only. The trees *(Eucalyptus grandis*, main study) reversed the hydraulic gradient underneath the plantation, essentially converting the plantation site into a discharge area. This resulted in increased salinity in soil and ground water under the plantation. The long-term sustainability of deep-rooted, non-irrigated tree plantings growing over shallow watertables is questioned.

Hodgkinson, H.S. (1987). Soil Conservation Service, 2717 N. 4th Street, Suit 140, Flagstaff, AZ 86001, USA. Relationship of saltbush species to soil chemical properties. Journal of Range Management, 40:23–26.

This paper reports on the relationship between pure stands of six saltbush species and soil SAR, EC, and pH. Species ranked from highest to lowest adaptability to these factors are: mat saltbush (*Atriplex corrugata*), mound saltbush (*A. obovata*), Castle Valley clover (*A. cuneata*), sickle saltbush (*A. falcata*), shadscale (*A. confertifolia*) and fourwing saltbush (*A. canescens*).

Hodson, M.J., Opik, H. and Wainwright, S.J. (1985). Department of Botany and Microbiology, University College of Swansea, Singleton Park, Swansea SA2 8PP, UK. Changes in ion and water content of individual shoot organs in

a salt-tolerant and a salt-sensitive clone of *Agrostis stolonifera* L. during and subsequent to treatment with sodium chloride. Plant, Cell and Environment, 8:657–668.

> This paper reports on the effect of 100 and 200 mol/m^3 NaCl on Na, Cl, K and water content of individual leaves and stems in two clones of *Agrostis stolonifera* differing in salt resistance. In both clones, Na and Cl accumulated to the greatest degree in the older leaves. Older leaves of the salt-tolerant clone had lower Na and Cl concentrations, higher K concentrations and higher water content under NaCl than the sensitive clone.

Hodson, M.J., Smith, M.M., Wainwright, S.J. and Opik, H. (1982). Department of Botany and Microbiology, University College of Swansea, Singleton Park, Swansea SA2 8PP, UK. Cation cotolerance in a salt-tolerant clone of *Agrostis stolonifera* L. New Phytologist, 90:253–261.

> In solution culture experiments, a clone of *Agrostis stolonifera* obtained from a salt marsh was found to be more tolerant than an inland clone to chlorides of Li, Na, K, Rb, Cs, Mg and Ca, based on a root elongation index. Tolerance to LiCl, NaCl and KCl was confirmed on the basis of DW increments. It is suggested that evolution of tolerance to NaCl in the salt marsh clones conferred cotolerance to the other alkali metal chlorides.

Hoffman, G.J. (1986). USDA-ARS Water Management Research Laboratory, 2021 S. Peach , Fresno, CA 93727, USA. Managing saline irrigation water for crop production. In: Prospects for biosaline research (Ahmad, R. and San Pietro, A., ed.), 361–388, Proceedings of the US–Pakistan Biosaline Research Workshop, 22–26 September 1985. Department of Botany, University of Karachi, Karachi, Pakistan.

> In relation to strategies for application of saline water, this paper provides information on: (i) predicting the minimum amount of water that must be applied, in addition to the requirement for evapotranspiration, to provide adequate leaching; (ii) importance of correct design and the operation of the irrigation system; and (iii) guidelines to reclaim both saline and sodic soils, including use of amendments.

Hoffman, G.J., Jobes, J.A. and Alves, W.J. (1983). US Salinity Laboratory, USDA–ARS, 4500 Glenwood Drive, Riverside, CA 92501, USA. Response of tall fescue to irrigation water salinity, leaching fraction and irrigation frequency. Agricultural Water Management, 7:439–456.

This paper describes results of a long-term rhizotron study to determine the yield and evapotranspiration of tall fescue as a function of irrigation water salinity, leaching fraction, and irrigation frequency.

Holmes, F.W. (1961). Shade Tree Laboratories, Department of Entomology and Plant Pathology, University of Massachussets, Amherst, USA. Salt injury to trees. Phytopathology, 5:712–718.

This report describes the results of a seven-year study on applications of NaCl and $CaCl_2$ to sites containing maple, oak, hickory, black birch, ash, and white pine. Winter applications of salts to roads appeared to cause minimal harm to trees. Effects on symptoms, growth and foliar Cl concentrations are described.

Holmes, F.W. and Baker, J.H. (1966). Shade Tree Laboratories, Department of Entomology and Plant Pathology, University of Massachussets, Amherst, USA. Salt injury to trees. II. Sodium and chloride in roadside sugar maples in Massachusetts. Phytopathology, 56:633–636.

This paper provides information on foliar Cl concentrations for sugar maples (*Acer saccharum)* near Massachusetts roads salted only in winter in relation to foliar injury. Foliar Cl concentrations ranged from about 7 to 500 times the Na concentrations.

Hook, D.D. and Brown, C.L. (1973). Department of Forestry, Clemson University, Clemson, South Carolina, USA. Root adaptations and relative flood tolerance of five hardwood species. Forest Science, 19:225–232.

In a growth chamber and a greenhouse experiment, height growth in response to flooding is related to root morphology and respiration for seedlings of yellow poplar (*Linodendron tulipitera*), sycamore (*Plantanus occidentalis*), green ash (*Fraxinus pennsylvanica*), sweet gum (*Liquidamber styracitlua*), and water tupelo (*Nyssa aquatica*)

Hookey, G.R., Bartle, J.R. and Loh, I.C. (1987). Department of Resources and Energy, Water Authority of Western Australia, Perth, Australia. Water use of eucalypts above saline groundwater. AWRC Research Project 84/166, 40 p.

Water use characteristics were determined for selected eucalypt species established over shallow, saline ground water in SW Western Australia. Species including *Eucalyptus sideroxylon*, *E. microcarpa*, *E. botryoides* and *E. woolsiana* maintained relatively high water use as soil moisture declined over summer-autumn, indicating they were extracting moisture from ground water. These results are supported by estimates of leaf water use by the Penman–Monteith approach and observed changes in underlying ground water levels. Species differences in response to vapour pressure deficit (VPD) are described. (The methodology of using leaf conductances from different parts of the tree canopy and scaling up to whole trees has been questioned and largely replaced by the heat pulse (sap velocity) method.)

Hopmans, P., Douglas, L.A. and Chalk, P.M. (1983). Forests Commission Victoria, GPO Box 4018, Melbourne, Victoria 3001, Australia. Nitrogen fixation associated with *Acacia dealbata* Link. seedlings as estimated by the acetylene reduction assay. Australian Journal of Botany, 31:331–339.

Acetylene reduction activity of seedlings of *Acacia dealbata*, grown in soil-filled pots and inoculated with a suspension of homogenised nodules collected from naturally occurring *A. dealbata* trees, was markedly affected by soil moisture, nitrate-N and salinity.

Hopmans, P., Douglas, L.A., Chalk, P.M. and Delbridge, S.G. (1983). Forests Commission Victoria, GPO Box 4018, Melbourne, Victoria 3001, Australia. Effects of soil moisture, mineral nitrogen and salinity on nitrogen fixation (acetylene reduction) by *Allocasuarina verticillata* (Lam). L. Johnson seedlings. Australian Forest Research, 13:189–196.

Acetylene reduction (measured non-destructively, stable after 6 hours at 10 kPa acetylene) activity of *Allocasuarina verticillata* seedlings grown in soil-filled pots was markedly affected by soil moisture content, N supply and salinity (rapid loss of activity above EC_e 2.3 dS/m).

House, S., Nester, M., Taylor, D., King, J. and Hinchley, D. (1998). Queensland Forest Research Institute, Gympie, Queensland. Selecting trees for the rehabilitation of saline sites in south-east Queensland. Queensland Department of Primary Industries, Brisbane, Australia. Technical Paper No. 52. 77 p.

This book provides a comprehensive account of results of recent tree species evaluation trials on saline sites in southern Queensland, recommendations for species choice, details (including growth characteristics, soils, climate and uses) of 39 species and insect pests. A basic reference for soil salinity processes as well as a practical guide to measuring soil salinity and tree planting techniques are also provided.

Hoy, N.T., Gale, M.J. and Walsh, K.B. (1994). University of Central Queensalnd, Department of Biology, Rockhampton, Queensland 4072, Australia. Revegetation of a scalded saline discharge zone in central Queensland. I. Selection of tree species and evaluation of an establishment technique. Australian Journal of Experimental Agriculture, 34:765–776.

> Reports on the performance of 38 Australian tree species on saline, waterlogged land (watertable within about 1 m of soil surface and with EC of about 30 dS/m, surface soil (0–0.1 m) $EC_{1:5}$ about 10 dS/m) in coastal central Queensland. *Casuarina glauca and C. obesa* had best survival and growth, while *Eucalyptus camaldulensis* and *C. cunninghamiana* had good initial survival only. Application of mulch greatly improved tree survival and growth, and reduced surface soil salinity. Plastic mulch was recommended over hay or bagasse mulch. The use of a double-ridged mound improved growth but not survival. Soil amelioration with lime, gypsum, or dolomite at 3.0 t/ha did not improve plant growth. The benefits of combined use of plastic mulch and a double-ridged mound were confirmed at another saline site.

Hughes, T.D., Butler, J.D. and Sanks, G.D. (1975). Department of Horticulture, Illinois Agriculture Experimental Station, Illinois, USA. Salt tolerance and suitability of various grasses for saline roadsides. Journal of Environmental Quality, 4:65–68.

> Two glasshouse experiments using soil culture are reported. In one experiment, forage yields of *Agropyron cristatum*, *A. smithii*, *Lolium perenne*, *Poa pratensis and Puccinellia distans* were determined, with NaCl additions of 0 to 20 000 ppm. *P. distans* was most tolerant with 23% yield reduction at 20 000 ppm. In the second experiment, addition of 30 000 ppm NaCl completely inhibited seedling survival of *A. cristatum, A. smithii*, *Elymus triticoides*, *P. distans, Puccinellia lemmoni* and *Sporobolus airoides*. There was no relationship between salt tolerance and leaf Na concentrations.

Hussain, A., Arshad, M. and Hussain, A. (1987). Department of Soil Science, University of Agriculture, Faisalabad, Pakistan. Effect of ascorbic acid and sucrose on seed germination of *Sesbania bispinosa* at different salinity levels. Nitrogen Fixing Tree Research Reports, 5:61–62.

> Reports on the effects of ascorbic acid (1 000 ppm) and sucrose (5%) on seed germination, and root and shoot length of seedlings under salinity.

Hussain, A., Arshad, M., Ranjha, A.M., Hussain, A. and Ali, F. (1986). Department of Soil Science, University of Agriculture, Faisalabad, Pakistan. Role of choline chloride in salt tolerance of *Sesbania bispinosa*. Nitrogen Fixing Tree Research Reports, 4:34–35.

Germination of *S. bispinosa* seeds in soil-filled pots at higher salt concentation (20 and 30 mol/m^3) was improved by 2.5 mol/m^3 choline chloride, and seedling dry matter, determined after 80 days, was increased by choline chlorides at all salt levels.

Hussain, A. and Gul, P. (1991). Pakistan Forest Institute, Peshawar, Pakistan. Selection of suitable tree species for saline and waterlogged areas. Pakistan Journal of Forestry, 41:34–43.

This paper reports on the survival and growth of 35 species in small plots on slightly saline, alkaline, seasonally waterlogged soil near Peshawar, Pakistan at 6 and 16 months. Local species, such as *Tamarix aphylla*, *Acacia modesta* and *A. nilotica*, as well as exotic species including *A. stenophylla*, *A. ampliceps*, *Casuarina obesa*, *Eucalyptus camaldulensis*, *Prosopis chilensis*, *P. siliquestrum* and *P. alba* had very good survival. *E. camaldulensis* had best height growth overall.

Hussain, G. and Helweg, O.J. (1994). King Abdul Aziz City of Science and Technology, PO Box 6006, Riyadh 114421, Saudi Arabia. Effect of saline irrigation water on tree growth. Journal of Irrigation and Drainage Engineering, 120:970–978.

Seedlings, established in large pots, of three common windbreak species (*Prosopis juliflora*, *Eucalyptus camaldulensis* and *Casuarina equisetifolia*) were compared in three soil types (sandy, loam and sandy clay) and five irrigation water salinities (total dissolved solids (TDS) 1360 to 15 864 ppm). *P. juliflora* was the most salt tolerant; it survived, though did not grow well, with water up to 8600 ppm TDS. The most suitable soil for irrigation with saline water was species-dependent.

Hussey, A. and Long, S.P. (1982). Department of Biology, University of Essex, Wivenhoe Park, Colchester CO4 3SQ, UK. Seasonal changes in weight of above- and below-ground vegetation and dead plant material in a salt marsh at Colne Point, Essex. Journal of Ecology, 70 :757–771.

Monthly changes in dry and ash-free dry weights per unit area of both above and below ground organs of the higher plants of an intertidal salt marsh were determined in an area of a marsh dominated by *Puccinellia*

maritima and *Halimione portulacoides*. Live vegetation and litter constituted a large potential source of energy and reduced carbon for other trophic levels, both in the salt marsh and adjacent coastal ecosystems.

Huvenne, P., Lust, N., Speleers, L. and De-Vos, B. (1997). Laboratoire de Sylviculture, Universite de Gand, Geraardsbergsesteenweg 267, B-9090 Melle, Belgium. Afforestation on dredged sludge deposits. Revue Forestiere Francaise, 49:115–130.

Reports on experiments into afforestation of dredge sludge deposits at two sites in Belgium with several tree species. The effects of salt in addition to heavy metal pollutants were evaluated at one site and here *Populus alba*, *Alnus glutinosa* and *Acer pseudoplatanus* performed best. (In French.)

Hyder, S.Z. (1981). Ministry of Agriculture and Water, Regional Agriculture and Water Research Center, PO Box 8784, Riyadh, Saudi Arabia. Preliminary observations on the performance of some exotic species of *Atriplex* in Saudi Arabia. Journal of Range Management, 34:208–210.

Reports on performance of seven different *Atriplex* species (four from the United States of America and three from Australia) in the field at Riyadh, Saudi Arabia. Data were obtained on vegetative growth, flowering, seed production, seed germination, and chemical composition of the plants.

Hyder, S.Z., Akil, B. and Yaeesh, F. (1987). Crop Production and Protection Section, Regional Agriculture and Water Research Centre, Ministry of Agriculture and Water, PO Box 17284, Saudi Arabia 11484. Establishment of exotic *Atriplex* species under irrigated and non-irrigated conditions in Central Saudi Arabia. Pakistan Journal of Agricultural Research, 8:184–190.

The performance of four exotic species of *Atriplex* was evaluated under irrigated and non-irrigated conditions in the field at Al-Kharj in Central Saudi Arabia. *A. rhagodioides, A. Amnicola* and *A. canescens* were superior to *A. undulata* and *A. lentiformis* both under irrigated and non-irrigated conditions. Good performance of *A. rhagodioides* in non-irrigated conditions is related to development of fine fibrous roots at one metre depth.

Islam, M.N., Wilson, C.A. and Watkins, T.R. (1982). Department of Food Science and Human Nutrition, University of Delaware, Newark, Delaware 19711, USA. Nutritional evaluation of seashore mallow seed, *Kosteletzkya virginica*. Journal of Agriculture and Food Chemistry, 30:1195–1198.

Seeds of seashore mallow (*Kosteletzkya virginica*), a highly salt-tolerant plant, were shown to have potential for use as food or feed. Hulled seed contained 32% protein and 22% fat. Valine was the limiting amino acid. Data for protein score and protein efficiency ratio are provided. Both whole and hulled seeds were low in Na and high in Ca and K. Cyclopropenoid fatty acids were detected, but gossypol was not.

Ismail, S., Ahmad, R. and Davidson, N.J. (1991). Department of Botany, University of Karachi, Karachi, Pakistan. Design and analysis of provenance trials in Pakistan. In: Productive use of saline land (Davidson, N. and Galloway, R., ed.), 38–44. Proceedings of a workshop held at Perth, Western Australia, 1–14 May 1991. ACIAR Proceedings No. 42.

This paper reports on a network of provenance trials ('ADAPT') to identify highly productive genotypes of halophytic shrubs on salt-affected soils in Pakistan. Details on trial design and pro forma for routine measurements are described, in conjunction with a spreadsheet for data analysis.

Itai, C. (1978). Department of Biology, Ben Gurion University, Beer Sheva, Israel. Response of *Eucalyptus occidentalis* to water stress induced by NaCl. Physiologia Plantarum, 43:377–379.

Describes changes in cytokinin, abscisic acid and ^{14}C leucine levels in *Eucalyptus occidentalis* plants exposed to NaCl in solution culture.

Jaenicke, H., Lips, H.S. and Ullrich, W.R. (1996). Institut für Botanik, Technische Hochschule, Schnittspahnstr 10, D-64 287 Darmstat, Germany. Growth, ion distribution, potassium and nitrate uptake of *Leucaena leucocephala*, and effects of NaCl. Plant Physiology and Biochemistry, 34:743–751.

Non-nodulated plants of *Leucaena leucocephala* 'K8' grown in solution culture were tolerant to NaCl up to 50 mol/m^3 NaCl. Data on Na, Cl and K, as well as nitrate concentrations in plant parts are provided. In N-supplied plants, salt treatment stimulated nitrate reductase activity particularly in the roots.

Jain, B.L. and Dass, H.C. (1988). Central Arid Zone Research Institute, Jodhpur, Rajasthan 342 003, India. Effect of saline water on performance of saplings of jujube (*Ziziphus mauritiana*), Indian cherry (*Cordia dichotoma* var. *wallichii*) and pomegranate (*Punica granatum*) at nursery stage. Indian Journal of Agricultural Sciences, 58:420–421.

Water with EC 0.5–6.5 dS/m was used to irrigate tree saplings in nursery beds (non-saline, sandy clay-loam soil). Jujube and pomegranate ('Khog') showed good survival at all salt levels but pomegranate ('Jalore Seedless') and *Cordia* could tolerate salinity only up to 4.5 dS/m, after 10 months.

Jain, B.L., Muthana, K.D. and Goyal, R.S. (1985). Central Arid Zone Research Institute, Pali, Rajasthan, India. Performance of tree species in salt-affected soils in arid regions. Journal of Indian Society of Soil Science, 33:221–224.

This paper reports the performance of six tree species considered suitable for arid and semi-arid zones in India. *Prosopis juliflora* and *Tamarix articulata* performed well at high salinity [EC_e (presumably) 20–40 dS/m]. *Acacia tortilis, Azadirachta indica* and *Eucalyptus camaldulensis* showed better performance on moderately saline conditions. *Albizia lebbeck* was most sensitive to salinity.

Jarrell, W.M. and Virginia, R.A. (1990). Environmental Science and Engineering, Oregon Graduate Institute of Science and Technology, Beaverton, OR 97006-1999, USA. Response of mesquite to nitrate and salinity in a simulated phreatic environment: water use, dry matter and mineral nutrient accumulation. Plant and Soil, 125:185–196.

This paper reports on a glasshouse experiment in which mesquite (*Prosopis glandulosa* var. *torreyana*) plants were grown in 2 m long columns and provided with a constant height of watertable (containing 0, 1 or 5 mol/m^3 nitrate, or a mixed salt solution—1.4, 2.8, or 5.6 dS/m), 10 cm above the sealed base of the column. Water uptake was reduced when soil salinity, measured by salinity probes 30 cm above column base, was approximately 28 dS/m. Data on growth, water use efficiency and ion concentrations, including P, are provided. Most fine roots were located in a zone about 25 cm above the ground water surface where water content and aeration appeared optimal for root growth. (Refer also Bachelet et al. 1986.)

Jefferies, R.L. (1981). Department of Botany, University of Toronto, Toronto, Ontario M5S 1A1, Canada. Osmotic adjustment and the response of halophytic plants to salinity. Bioscience, 31: 42–46.

This paper reviews physiological mechanisms of halophytes compared with non-halophyte crop plants and the potential for economic utilisation of halophytes (for example on soils of high salinity and low in Ca) versus the quest for further improving salt tolerance of current crop plants.

Jefferies, R.L., Davy, A.J. and Rudmik, T. (1979). Department of Botany, University of Toronto, Toronto, Ontario M5S 1A1, Canada. The growth strategies of coastal halophytes. In: Ecological processes in coastal environments (Jefferies, R.L. and Davy, A.J., ed.), 243–268. Blackwell Scientific Publications.

This paper reports on population differentiation, the phenology of plants and the allocation of resources to maintenance, growth and reproduction in relation to environmental heterogeneity within a salt marsh at Stiffkey, Norfolk. The impact of N nutrition on plant growth and organic N compounds is detailed.

Jefferies, R.L., Davy, A.J. and Rudmik, T. (1981). Department of Botany, University of Toronto, Toronto, Ontario M5S 1A1, Canada. Population biology of the salt marsh annual *Salicornia europaea* agg. Journal of Ecology, 69:17–31.

Reports on the biology of two populations of *Salicornia europaea*, from the upper and lower levels of Stiffkey salt marsh on the north Norfolk coast. Aspects considered include seed germination, phenology of growth and demography. A model is given which described the population dynamics of *Salicornia* in terms of density-dependent regulation of seed number and density-independent mortality. The reasons for the prevailing densities are discussed.

Jefferies, R.L. and Pitman, M.G. (1986). Department of Botany, University of Toronto, Toronto, Ontario M5S 1A1, Canada. Perspectives of the biology of halophytes in natural habitats in relation to forage production. Reclamation and Revegetation Research, 5:227–243.

Reviews measurements of net primary production by halophytic communities and discusses aspects of their commercial management. Issues considered include establishment/germination, N-fixation, grazing and forage quality.

Jefferies, R.L. and Rudmik, T. (1984). Department of Botany, University of Toronto, Toronto, Ontario M5S 1A1, Canada. The responses of halophytes to salinity: an ecological perspective. In: Salinity tolerance in plants: strategies for crop improvement (Staples, R.C. and Toenniessen, G.H., ed.), 213–227. Proceedings of the International Conference, Bellagio, Italy. John Wiley & Sons, New York, USA.

The genetic variation in populations of halophytes, variations in physiological traits in individuals of different species in relation to salt tolerance, and the growth and productivity of plants under saline conditions are discussed. It is argued that salt tolerance traits are under polygenic control and that halophytes exhibit a high level of plasticity for these traits.

Jefferies, R.L., Rudmik, T. and Dillon, E.M. (1979). Department of Botany, University of Toronto, Toronto, Ontario M59 1A1, Canada. Responses of halophytes to high salinities and low water potentials. Plant Physiology, 64:989–994.

For the halophytes (*Plantago maritima, Triglochin maritima, Limonium vulgare, Halimione portulacoides*) investigated, the accumulation of organic solutes (compatible osmotica) in tissues was primarily correlated with a decrease in the osmotic potential of culture solutions, induced by polyethylene glycol (PEG-6000) or seawater dilutions. Species differences were found in the concentrations of particular solutes (sorbitol, proline, reducing sugars, quaternary ammonium compounds, α-amino nitrogen and inorganic ions), particularly at higher salinities and PEG concentrations.

Jeschke, W.D. (1984). Lehrstuhl Botanik, Universitat Wurzburg, Wurzburg, Federal Republic of Germany. K–Na exchange at cellular membranes, intracellular compartmentation of cations and salt tolerance. In: Salinity tolerance in plants:strategies for crop improvement (Staples, R.C. and Toenniessen, G.H., ed.), 37–66. Proceedings of the International Conference, Bellagio, Italy. John Wiley & Sons, New York, USA.

The processes and mechanisms of univalent cation selectivity and their implication for salt tolerance are reviewed. Particular attention is given to the interrelationships between these processes in their importance for salt tolerance of the plant as a whole.

Jeschke, W.D., Aslam, Z. and Greenway, H. (1986). School of Agriculture, University of Western Australia, Nedlands, WA 6009, Australia. Effects of NaCl on ion relations and carbohydrate status of roots and on osmotic regulation of roots and shoots of *Atriplex amnicola*. Plant, Cell and Environment, 9:559–569.

Data are provided on Na, K and Mg concentrations in root tissues at different stages of development for *Atriplex amnicola* grown in 25, 200 or 400 mol/m^3 NaCl. Over this NaCl concentration range, the total Na+K

concentration in the cytoplasm was maintained at 180–200 mol/m^3, 170–420 mol/m^3 in the vacuole. Soluble sugar and starch concentration in expanding root tissues decreased between dusk and dawn, and increased with increasing external NaCl concentration; it is suggested that the limited supply of such solutes may restrict cell expansion because of inadequate osmotic adjustment.

Jeschke, W.D.and Stelter, W. (1983). Wurzburg University, Federal German Republic. Ionic relations of garden orache, *Atriplex hortensis* L.:growth and ion distribution at moderate salinity and the function of bladder hairs. Journal of Experimental Botany, 34:795–810.

Height, biomass and leaf size of *Atriplex hortensis* plants increased at 10 to 50 mol/m^3 NaCl or Na_2SO_4 with 1.0 mol/m^3 K added. Omission of K led to a substantial decrease in biomass and the authors suggest that increased growth in solutions with Na salts is due to a K-sparing effect of Na rather than to salinity per se. Data on K and Na partitioning in plant parts (roots, leaves and bladders) are provided.

Jolly, I.D. and Walker, G.R. (1996). CSIRO Divison of Water Resources, PMB 2, Glen Osmond, SA 5064, Australia. Is the field water use of *Eucalyptus largiflorens* F. Muell. affected by short-term flooding? Australian Journal of Ecology, 21:173–183.

Reports on transpiration of and water sources for *Eucalyptus largiflorens* trees at three sites (two flooded), underlain by saline ground water, on a semiarid floodplain of the lower River Murray in southern Australia during the course of a flood. Transpiration was not reduced during flood events. By using the naturally occurring stable isotopes of water and measurements of soil water suction, it was shown that trees could use ground water when soil water derived from rainfall or flooding became limiting.

Jolly, I.D. Walker,G.R. and Thorburn, P.J. (1993). CSIRO Division of Water Resources and Centre for Groundwater Studies, PMB No. 2, Glen Osmond, SA 5064, Australia. Salt accumulation in semiarid floodplain soils with implications for forest health. Journal of Hydrology (Amsterdam), 150:589–614.

This paper reports on a study to determine how ground water discharge varies with watertable depth, the relative importance of watertable depth and flood frequency in determining the salinisation of floodplain soils, and the time scale for salt accumulation in the soil profile as related to dieback of native *Eucalyptus largiflorens* forests along the River Murray, southern Australia. A field-based relationship between *E. largiflorens*' health and the factors that determined the critical depth is presented. The results suggest that complete salinisation of a soil profile and resultant tree death can occur in less than 20 years and that the critical watertable depth needed to be increased by 14–55% (more in clay soils) to prevent salt accumulation.

Joly, C.A. (1996). Departamento de Botanica, Instituto de Biologia, Universidade de Campinas, C.P. 6109-13081-970 Campinas, Brazil. The role of oxygen diffusion to the root system on the flooding tolerance of tropical trees. Revista Brasileira de Biologia, 56:375–382.

Reports on oxygen diffusion in flooded root systems in six tropical trees (*Sebastiania klotzchiana, Schizolobium parahybum, Peltophorum dubium, Hymenaea courbaril* var. *stilbocarpa, Chorisia speciosa* and *Enterolobium contortisiliquum*) in relation to morphological changes (e.g. hypertrophic lenticels). It is concluded that the distribution of these species along river margins is strongly dependent on the strategy evolved to tolerate soil waterlogging.

Jones, K. (1974). Department of Biological Sciences, University of Lancaster, Lancaster LAl 4YQ, UK. Nitrogen fixation in a salt marsh. Journal of Ecology, 62:553–565.

Data on N_2 fixation by bacteria and their importance to plant growth are presented; N_2 fixation is stimulated in the rhizosphere of *Puccinellia maritima*.

Jones, R. (1975). Biology Department, Trent University, Peterborough, Ontario K9J 7B8, Canada. Comparative studies of plant growth and distribution in relation to waterlogging. VIII. The uptake of phosphorus by dune and dune slack plants. Journal of Ecology, 63:109–116.

This paper reports on the uptake of P from waterlogged dune and slack soils by *Agrostis stolonifera, Festuca rubra, Carex flacca* and *Carex nigra* in a glasshouse pot experiment and examines the possibility that reduced growth of the grasses is due to P immobilisation by high concentrations of Fe in the root. (One of a series of papers.)

Jonsson, H.A. and Nilsson, C. (1977). Weibulls Grassektion, 261 20 Landskrona 1, Sweden. Tolerance in red fescue to high salt concentration. Weibulls Gras Tips, 20:29–31.

Data on germination responses of 16 *Festuca rubra* cultivars and selections to $CaCl_2$ alone, a weak NPK nutrient solution + NaCl, or NaCl + nutrients, are presented and related to impact of de-icing salts. (In Swedish, English summary.)

Joshi, A.J. (1982). Department of Botany, Sir P.P. Institute of Science, Bhavnagar University, Bhavnagar 364 002, India. Ecophysiological aspects of some tropical and salt marsh halophytes. In: Contributions to the ecology of halophytes (Sen, D.N. and Rajpurohit, K., ed.), Tasks for Vegetation Science, Vol. 2, 189–195. Dr. W. Junk Publishers, The Hague.

This chapter deals with: (i) the biology and biogeography of halophyte species and salinity-controlled ecosystems—based on data from Egypt, India and other places; (ii) ecological and physiological problems including mangrove species zonation, distribution, environmental control and growth form of *Spartina alternifolia,* germination ecology of halophytes, salinity and water relations of Australian chenopods, eco-physiology of salt marsh halophytes, salt secretion and glandular structures as a way of adaptation to saline environment, and role of bladders in removing salts from *Atriplex* species; and (iii) the economic importance of *Juncus*.

Joshi, A.J. and Anjaiah, N. (1987). Department of Life Sciences, Bhavnagar University, Bhavnagar 364 002, India. Seasonal changes in proteins and free amino acids in *Atriplex griffithii* Moq. under semi-arid saline conditions. Indian Journal of Plant Physiology, 30:194–198.

This paper reports on the impact of season on changes in concentrations of several amino acids in different plant parts of *Atriplex griffithii*. Concentration of soluble proteins was 21% (DM basis) and there was a greater concentration of free amino acids in leaves than in stems or roots.

Joshi A.J. and Bhoite A.S. (1988). Department of Life Sciences, Bhavnagar University, Bhavnagar 364002, Gujarat, India. Fluctuations of mineral ions in saline soils and halophytic grass *Aeluropus lagopoides* L. Annals of Arid Zone, 27:191–196

Reports on seasonal variation in mineral ion content (Na, Cl, K, Mg and Ca) of three coastal saline soils ($EC_{1:2}$ varying between 10.5 and 34.2 dS/m) and leaves, stems and roots of *Aeluropus lagopoides* growing on these soils.

Joshi, A.J. and Iyengar, E.R.R. (1982). Department of Botany, Sir P.P. Institute of Science, Bhavnagar University, Bhavnagar 364 002, India. Effect of salinity on the germination of *Salicornia brachiata* Roxb. Indian Journal of Plant Physiology, 25:65–70.

Seeds of *Salicornia brachiata*, a tropical salt marsh halophyte, germinated even in 36 000 ppm sea water, with maximum germination under NaCl in iso-osmotic solutions of 0.45 MPa. Concentration of some free amino acids (glutamic acid, alanine and serine) decreased whereas concentrations of aspartic acid and glycine increased in salinised seedlings.

Joshi, A.J. and Iyengar, E.R.R. (1982). Department of Botany, Sir P.P. Institute of Science, Bhavnagar University, Bhavnagar 364 002, India. Physico-chemical characteristics of soils inhabited by halophytes, *Suaeda nudiflora* Moq. and *Salicornia brachiata* Roxb. in Gujarat. Indian Journal of Marine Science, 11:199–200.

Soil characteristics (including texture, pH, EC, exchangeable Na and SAR) are provided for *Suaeda nudiflora* and the data suggest that *Salicornia brachiata* withstands high salt concentrations at all growth stages.

Joshi, A.J., Iyengar, E.R.R. and Bhatt, D.C. (1980). Department of Botany, Sir P.P. Institute of Science, Bhavnagar University, Bhavnagar 364 002, India. Effects of salinity on structure and frequency of stomata in salt marsh halophytes. Geobios, 7:210–213.

Data are provided for *Salicornia brachiata, Suaeda nudiflora* and *Sesuvium portulacastrum*.

Kalir, A. and Poijakoff-Mayber, A. (1976). Department of Botany, The Hebrew University of Jerusalem, Jerusalem, Israel. Effect of salinity on respiratory pathways in root tips of *Tamarix tetragyna*. Plant Physiology, 57:167–170.

This paper reports on the effects of NaCl on respiration, glucose uptake and utilisation, and oxidative phosphorylation in *Tamarix tetragyna* roots, collected from cuttings grown in solution culture and salinised in stepwise fashion to 480 mol/m^3 NaCl, in an attempt to better understand the physiological basis for survival and continued growth at high salinities.

Kanani, S.S. and Torres, F. (1986). International Council for Research in Agroforestry, PO Box 30677, Nairobi, Kenya. The extent of salinization and use of salt-tolerant plants in Kenya. Reclamation and Revegetation Research, 5:97–103.

Reports on uses of plants growing on salt-affected land (15% of land in Kenya) and concludes that little research is being conducted into the propagation, management and better utilisation of forage plants which occur on salt land.

Kaplan, A. and Gale, J. (1972). Department of Botany, The Hebrew University of Jerusalem, Jerusalem, Israel. Effect of sodium chloride salinity on the water balance of *Atriplex halimus*. Australian Journal of Biological Science, 25:895–903.

NaCl (0.3 – 1/0 MPa osmotic potential) was found to improve the water balance (as determined by potential turgor and saturation percentage) of solution-cultured *Atriplex halimus* plants under conditions of high evaporative demand, However, a constant water potential gradient was maintained between the culture solution and the leaf only at < 0.5 MPa. Root hydraulic conductivity appeared to have been impaired by salinity. Improved water balance was related to reduced transpiration, due to increased stomatal and mesophyll resistance.

Karimi, S.H. and Ungar, I.A. (1983). Department of Botany, Ohio University, Athens, Ohio 45701, USA. Effect of aeration, shading and salinity on oxalate accumulation of *Atriplex triangularis* Willd. American Journal of Botany, 70:86–87.

In solution-cultured seedlings of *Atriplex triangularis*, grown at low and high light intensities, plus or minus aeration and 0 to 3% NaCl, lack of aeration and increased salinity produced low total oxalate concentrations in leaves (max. under control conditions 12% of DW). Under salinity, there was an increase in the water-soluble form of oxalate and a decrease in the acid-soluble form. The significance of these findings in relation to the osmotic adjustment of plants and the balancing effect of oxalate in the presence of excess cations is discussed.

Karimi, S.H. and Ungar, I.A. (1984). Department of Botany, Ohio University, Athens, OH 45701, USA. The effect of salinity on the ionic content and water relation of *Atriplex triangularis* Willd. In: USDA Department of Agriculture, forest service general technical report INT-172. 124–132. Proceedings—Symposium on the Biology of *Atriplex* and related chenopods. Provo, Utah, USA. May 1983.

Reports on physiological and anatomical strategies used by *Atriplex triangularis* to cope with high salinity. These were found to include (i) regulation of ion influx into the plant in higher salinities by the root;

(ii) abscission of very old leaves to facilitate removal of ions; (iii) removal of salts by salt hairs in young leaves; and (iv) increased succulence as a principal mechanism for osmoregulation in mature leaves.

Karimi, S.H. and Ungar, I.A. (1986). Department of Botany, Ohio University, Athens, Ohio 45701-2979, USA. Oxalate and inorganic ion concentrations in *Atriplex triangularis* Willd. organs in response to salinity, light level and aeration. Botanical Gazette, 147:65–70.

Reports on inorganic ion and oxalate concentrations of *Atriplex triangularis* organs for both field and laboratory grown plants. Field-grown plants had lower water-soluble oxalate content than did laboratory-grown plants at comparable salinity. (Refer also Karimi and Ungar 1983.)

Karimi, S.H. and Ungar, I.A. (1989). Department of Botany, Ohio University, Athens, OH 45701, USA. Development of epidermal salt hairs in *Atriplex triangularis* Willd. in response to salinity, light intensity, and aeration. Botanic Gazettee, 150:68–71.

Describes changes in the abundance and size of leaf epidermal trichomes (salt hairs) in *Atriplex triangularis* in response to salinity, light intensity, and aeration. Plants exposed to 0.5 and 3% NaCl had reduced salt hair density and larger bladder cells. Reduced light intensity and waterlogging generally reduced salt hair density. Interactions between aeration and salinity were observed. The ecological significance of epidermal salt hairs in relation to salt tolerance is discussed.

Karschon, R. (1956). Division of Forestry, Agricultural Research Organization, The Volcani Center, Israel. The growth of *E. rostrata* on calcareous saline soils. Document, Working party on Eucalypts, FAO Joint Subcommission, Mediterranean Forest Problems, Nice, No. FAO/SCM/EU/7-A, 5 p.

Reports that *E. camaldulensis* spp. *rostrata* survived on highly calcareous soil and tolerated a Cl content of 0.51% and a total salinity (chlorides and sulphates) of 1.25%.

Karschon, R. (1958). Division of Forestry, Agricultural Research Organization, The Volcani Center, Israel. Leaf absorption of wind-borne salt and leaf scorch in *Eucalyptus camaldulensis* Dehn. (*E. rostrata*). Ilanoth, No. 4.

Reports on the effect of salt-laden winds on symptoms and Na, K and Cl concentrations in leaves of *E. camaldulensis* spp. *rostrata* in plantations on the coastal plain of Israel.

Karschon, R. and Zohar, Y. (1975). Division of Forestry, Agricultural Research Organization, The Volcani Center, Israel. Effects of flooding and of irrigation water salinity on *Eucalyptus camaldulensis* Dehn. from three seed sources. Paper presented at the Physiological Genetics Conference, Edinburgh, July 13–21, 1975. Division of Forestry, Agricultural Research Organisation, Israel, Leaflet No. 54, 8 p.

This report describes the effects of flooding with tap-water (alone or containing 1500–4500 ppm (approx. 25–77 mol/m^3) NaCl) on the growth in a nursery in Israel of *Eucalyptus camaldulensis* seedlings from three sources in Australia, and relates results to ecological conditions of the seed source.

Kaul, A. and Shankar, V. (1988). Centre for Arid Zone Research Institute, Jodhpur, Rajasthan 342003, India. Ecology of seed germination of the chenopod shrub *Haloxylon salicornicum*. Tropical Ecology, 29:110–115.

Effects of temperature, light, moisture and salinity on seed germination of *Haloxylon salicornicum* were studied. Increase in moisture stress and salinity (up to 48 dS/m) reduced germination rate and percentage. $MgSO_4$ and $NaHCO_3$ reduced germination more than NaCl, $CaCl_2$ or Na_2SO_4.

Keating, B.A., Strickland, R.J. and Fisher, M.J. (1986). Division of Tropical Crops and Pastures, CSIRO, 306 Carmody Road, St Lucia, Queensland 4067, Australia. Salt tolerance of some tropical pasture legumes with potential adaptation to cracking clay soils. Australian Journal of Experimental Agriculture, 26:181–186.

The comparative salt tolerance of some tropical pasture legumes was studied in soil-filled pots with NaCl added (EC_e achieved 2.0 to 20.0 dS/m). Based on EC_e at 50% of maximum growth (in parentheses), *Macroptilium atropurpureum* cv. Siratro (10.6) was the most tolerant and *Rhynchosia minima* (5.1) the least tolerant. The grass *Panicum coloratum* cv. Bambatsi was markedly more tolerant than any of the legumes studied, with 50% yield at an EC_e of 16.4 dS/m. Patterns of Na and Cl uptake with increasing level of salt were not related to species differences in tolerance.

Kelley, D.B., Goodin, J.R. and Miller, D.R. (1982). Department of Biological Sciences, Texas Technical University, Lubbock, Texas 79409, USA. Biology of *Atriplex*. In: Contributions to the ecology of halophytes (Sen, D.N., and Rajpurohit, K.S., ed.), Tasks for Vegetation Science, Vol. 2, 79–107. Dr. W. Junk Publishers, The Hague.

This paper discusses the tremendous genetic diversity and special features for adaptation to stress situations, including halophytism, within the genus *Atriplex* (which includes approximately 200 species) and opportunities for managing them for productive purposes.

Kenkel, N.C., McIlraith, A.L., Burchill, C.A. and Jones, G. (1991). Department of Botany, University of Manitoba, Winnipeg, Manitoba 3RT 2N2, Canada. Competition and response of three plant species to a salinity gradient. Canadian Journal of Botany, 69:2497–2502.

In controlled environment experiments, *Poa pratensis*, *Hordeum jubatum* and *Puccinellia nuttalliana* (*P. airoides*) were grown alone or in mixtures with gradual increases in NaCl (0 to 14 g/L). In monoculture, all species grew best with no salt. In the presence of NaCl, species differences were apparent. At 14 g/L, total biomass decreased by 72, 50 and 30% for *P. pratensis*, *H. jubatum* and *P. nuttalliana*, respectively. In mixtures, interspecific competition resulted in *P. pratensis* being suppressed in all but the lowest salinities. *H. jubatum* was more competitive at intermediate salinities, while *P. nuttalliana* was more competitive at high salinities.

Kernick, M.D. (1986). FAO, Grassland and Pasture Crops Group, AGPC, Via delle Terme di Caracalla, 00100 Rome, Italy. Forage plants for salt affected areas in developing countries. Reclamation and Revegetation Research, 5:451–459.

This paper reports on outcomes of selected projects in Algeria, Iran, Iraq, Libya, Pakistan and Tunisia in which emphasis was given to planting forage crops on farmers' fields and to revegetating demonstration areas on degraded rangeland close to villages. Problems associated with the introduction of improved forage plants into farming practice are discussed.

Khalique, A. and Beg, A.R. (1976). Pakistan Forest Institute, Peshawar, Pakistan. Effect of soil salinity on the ectomycorrhizal nodules in *Eucalyptus camaldulensis* Dehn. The Pakistan Journal of Forestry, 26:177–180.

In seedlings of *Eucalyptus camaldulensis*, grown in soil-filled pots and treated with combined NaCl and $CaCl_2$ (0.3–1.5% DW of soil), white ectomycorrhizal nodules were only present at the lowest (0.3%) salinity after 14 months. (Little data provided.)

Khan, D., Ahmad, R. and Ismail, S. (1986). Department of Botany, University of Karachi, Karachi-75270, Pakistan. Case history of *Prosopis juliflora* plantation at Makran coast raised through saline water irrigation. In: Prospects for biosaline research (Ahmad, R. and San Pietro, A., ed.), 559–585. Proceedings of the US–Pakistan Biosaline Research Workshop, 22–26 September 1985. Department of Botany, University of Karachi, Karachi, Pakistan.

> Reports on growth and productivity of plantations of mesquite (*Prosopis juliflora*) used to stop sand drift in coastal areas of Pishukan, Gwadar and Pasni, when irrigated with highly saline underground water (7–21 dS/m at variable depth). More than 300 ha of man-made *Prosopis* plantation along the coastal belt have been established by irrigating mature seedlings planted at 2 × 2.5 m spacing with 10–12 L of water (weekly in summer, fortnightly in winter) for two years. Within 10 years, the plants reached a height of 6.5 m and stem diameter of 18.7 cm. The quality of wood was similar between trees growing under saline and non-saline conditions.

Khan, D., Ahmad, R. and Ismail, S. (1987). Department of Botany, University of Karachi, Karachi-75270, Pakistan. Germination, growth and in *Prosopis juliflora* (Swartz) DC. under saline conditions. Pakistan Journal of Botany, 19:131–138.

> Reports that *Prosopis juliflora* had high salt tolerance at germination as well as during growth, with 50% reduction in plant biomass at applied irrigation water EC of 21.3 dS/m. Data on K, Na, Ca and Mg concentrations in plant parts are given.

Khan, D., Ahmad, R. and Ismail, S. (1989). Department of Botany, University of Karachi, Karachi-75270, Pakistan. Structure, composition and above ground standing phytomass of some grazable grass-dominated communities of Pakistan coast. Pakistan Journal of Botany, 21:88–106.

> Reports that biomass production from plant communities along Pakistan's coastline during the monsoon period varied with the species dominating the community (*Pennisetum divisum* > *Halopyrum mucronatum* > *Desmostachya bipinnata* > *Cenchrus pennisetiformis* > *Panicum turgidum* > *Dichanthium annulatum* > *Sporobolus arabicus*), but was generally low (about 90 to 412 g/m^2). The legume *Indigofera oblongifolia* produced substantial biomass in three communities of which two (*Sporobolus* and *Desmostachya* dominated) were on saline soils.

Khan, D., Ismail, S. and Ahmad, R. (1989). Department of Botany, University of Karachi, Karachi-75270, Pakistan. Field trial of *Azadirachta indica* (L.) A. Juss. under highly saline water irrigation at arid sandy coastal region of Pakistan. Pakistan Journal of Botany, 21:59–67.

Reports on height and stem growth reduction and foliar water and inorganic and organic ion content of *Azadirachta indica* in a field trial on sandy arid coastal land at Bhawani irrigated with saline (EC 10.0–15.3 dS/m) and sodic (SAR: approx. 28) underground water. Saline irrigation substantially increased soil EC and SAR, whereas rainfall (approx. 100 mm) during April leached the salts thus reducing the salt content to the same level as that in the virgin soil.

Khan, M.A. (1987). Department of Botany, University of Karachi, Karachi 75270, Pakistan. Salinity and density effects on demography of *Atriplex triangularis* Willd. Pakistan Journal of Botany, 19:123–130.

Reports on interactions between salinity and plant density on total biomass production and seed production of *Atriplex triangularis*.

Khan, M.A. and Rizvi, Y. (1994). Department of Botany, University of Karachi, Karachi 75270, Pakistan. Effect of salinity, temperature, and growth regulators on the germination and early seedling growth of *Atriplex griffithii* var. *stocksii*. Canadian Journal of Botany, 72:475–479.

Seed germination of *Atriplex griffithii* var. *stocksii* from a saline desert habitat in Karachi, Pakistan, was inhibited under high NaCl (516 mol/m^3), and early growth responses to salinity were similar to those of germination. Both GA_3 and kinetin alleviated salinity-induced germination inhibition.

Khan, M.A. and Ungar, I.A. (1984). Department of Botany, Ohio University, Athens, Ohio 45701, USA. Seed polymorphism and germination responses to salinity stress in *Atriplex triangularis* Willd. Botanical Gazette, 145:487–494.

Reports that larger seeds of *Atriplex triangularis* were more salt tolerant during germination than smaller seeds. Seeds from all size classes (range of 1.0 to 2.8 mm, 1.78 to 2.44 mg per seed) that were initially treated with 2%–5% NaCl had from 85% to 100% germination after being immersed in distilled water for six days, indicating a transitory adverse effect of salt stress on germination. The amount of water absorbed by all seeds was affected by NaCl concentrations but not by hormonal treatments. Small seeds had higher Na and Cl concentrations than medium and large seeds. GA_3 alleviated some of the dormancy in seeds induced by high NaCL concentrations.

Khan, M.A. and Ungar, I.A. (1984). Department of Botany, Ohio University, Athens, Ohio 45701, USA. The effect of salinity and temperature on the germination of polymorphic seeds and growth of *Atriplex triangularis* Willd. American Journal of Botany, 71:481–489.

Germination and early seedling growth of variably-sized seeds of *Atriplex triangularis* were evaluated at various temperatures (5–15°C, 5–25°C, 10–20°C, 20–30°C) and salinity regimes (0 to 1.5% NaCl). Larger seeds generally had a better germination under salinity.

Khan, M.A. and Ungar, I.A. (1985). Department of Botany, Ohio University, Athens, Ohio 45701, USA. The role of hormones in regulating the germination of polymorphic seeds and early seedling growth of *Atriplex triangularis* under saline conditions. Physiologia Plantarum, 63:109–113.

Gibberlic acid, GA_3 (2.9 mol/m^3), promoted germination and seedling growth of *Atriplex triangularis* at high NaCl concentrations (345 mol/m^3), kinetin (4.7 µM) stimulated germination at all salinities and seed sizes tested, and GA_3 and kinetin generally increased seedling growth at all NaCl concentrations.

Khan, M.A. and Ungar, I.A. (1986). Department of Botany, Ohio University, Athens, Ohio 45701, USA. Life history and population dynamics of *Atriplex triangularis*. Vegetatio, 66:17–25.

Reports on the effect of salinity and rainfall on survival, growth, and reproduction of the annual halophyte, *Atriplex triangularis*, in an inland salt marsh at Rittman, Ohio. Populations responded differently to salinity. Salinity, separately, and in combination with high temperature and darkness, inhibited the germination of small seeds more than large seeds.

Khan, M.A. and Ungar, I.A. (1997). Department of Environmental and Plant Biology, Ohio University, Athens, Ohio 45701-2979, USA. Effects of thermoperiod on recovery of seed germination of halophytes from saline conditions. American Journal of Botany, 84: 279–283.

This paper reports on the recovery of seed germination from NaCl salinity of several desert shrubs under various temperatures, when transferred to distilled water. *Zygophyllum simplex* had little recovery from all NaCl concentrations at all temperatures, whereas marked recovery was found for *Suaeda fruticosa*, *Triglochin maritima* and *Haloxylon recurvum* (in decreasing order). There was little temperature effect on the percentage recovery of *S. fruticosa*, except in the higher salinity treatment at higher temperatures.

Khan, M.A. and Weber, D.J. (1986). Department of Botany and Range Science, Brigham Young University, Provo, Utah 84602, USA. Factors influencing seed germination in *Salicornia pacifica* var. *utahensis*. American Journal of Botany, 73:1163–1167.

This paper reports on the effects of salinity, temperature, and growth regulators on seed germination in the halophyte *Salicornia pacifica* var. *utahensis* which produces seed when grown under high soil salinity, and deposits its seed on saline soil. Interactions between salinity and temperature were found: at 30/20°C (day/night), no germination occurred at 3, 4 and 5% NaCl, but 30% germination did occur at 5% at 15/5°C. In addition, GA_3 partially alleviated the inhibitory effect of NaCl and darkness (50% germination without NaCL), but kinetin did not promote germination.

Khan, M.A., Weber, D.J. and Hess, W.M. (1985). Department of Botany andRange Science, Brigham Young University, Provo, Utah 84602, USA. Elemental distribution in seeds of the halophytes *Salicornia pacifica* var. *utahensis* and *Atriplex canescens*. American Journal of Botany, 72:1672–1675.

Presents information on the distribution of ions in seed coat, endosperm and embryo of seeds of two halophytes, *Salicornia pacifica* var. *utahensis* and *Atriplex canescens* from different environments using energy dispersive X-ray micro-analysis. The seed coats of *S. pacifica* contained the highest counts of Na, Cl, K, and Ca, whereas the embryo and endosperm were both high in P. Most of the P was contained in the embryo and K was high in both the seed coat and the embryo in *A. canescens*.

Khan, M.A., Weber, D.J. and Hess, W.M. (1986). Department of Botany, University of Karachi, Karachi 32, Pakistan. Elemental distribution in shoots of *Salicornia pacifica* var. *utahensis* as determined by energy-dispersive X-ray microanalysis using a cryochamber. Botanical Gazette, 147:16–19.

Reports on cellular concentrations of Na, Mg, Al, Si, Cl, K and Ca in different regions of the stem of *Salicornia pacifica* var. *utahensis* using energy-dispersive X-ray microanalysis at liquid nitrogen temperature (in a cryochamber). The highest concentration of elements was in the cortex.

Khanduja, S.D. and Goel, V.L. (1986). Biomass Research Centre, National Botanical Research Instiutute, Lucknow, Uttar Pradesh, India. Pattern of variability in some fuel wood trees grown on sodic soils. Indian Forester, 112: 118–123.

> This paper reports on the survival and growth of 12 fast-growing, multipurpose fuel-wood tree species grown in alkali soils at Banthra, India. Marked tree-to-tree variation in growth of surviving trees is reported and it is suggest that this will be useful for selection and propagation. Best growth was achieved by *Prosopis juliflora* followed by *Eucalyptus* hybrid.

Khanzada, A.N., Morris, J.D., Ansari, R., Slavich, P.G., Collopy, J.J. (1998). Atomic Energy Agricultural Research Centre, Tando Jam, Pakistan. Groundwater uptake and sustainability of *Acacia* and *Prosopis* plantations in southern Pakistan. Agriculture and Water Management, 36:121–139.

> This paper reports on water use (determined by heat pulse) over two years in two small tree plantations (three species—*Acacia nilotica*, *A. ampliceps* and *Prosopis pallida*) with contrasting soil and ground water salinity at Tando Jam, Sindh province, Pakistan. Annual water use by three to five year old *A. nilotica* was 1248 mm and 2225 mm on the severely and slightly saline site, respectively. Water use by the other species was less than 25% of these rates, mainly due to their lower sapwood area per hectare. Since water use by *A. nilotica* was considerably greater than annual rainfall, uptake of ground water was inferred and was confirmed by water table measurements and Cl balance modelling. The authors suggest that occasional leaching and other salt-removing processes are required for sustainable growth of plantations using saline ground water.

Kik, C. (1989). Department of Plant Ecology, State University of Groningen, Biological Centre, PO Box 14, 9750 AA Haren (Gn), The Netherlands. Ecological genetics of salt resistance in the clonal perennial, *Agrostis stolonifera* L. New Phytologist, 113:453–458.

> Reports large differences in root length of tillers of four ecologically contrasting populations with known genotypic compositions to applied NaCl (max. 1000 mol/m^3) in a glasshouse. An inland meadow population had significantly lower salt tolerance than maritime populations and significant genetic variation for salt tolerance was found in this population. A transplant experiment in a natural salt marsh showed that relative root growth was a reasonable indicator of salt tolerance.

Kim, C.S. (1990). College of Agriculture, Chungnam National University, Taejon 302-764, Korea Republic. Photosynthesis and respiration of forage plants under saline stress. Korean Journal of Crop Science, 35:362–369.

> Reports on effects of irrigation with sea water and high (22–24°C) or low (11–16°C) temperature on photosynthesis, root respiration, transpiration and visual symptoms in pot-grown seedlings of orchard grass (*Dactylis glomerata* 'Nordstern'), tall fescue (*Festuca arundinacea* 'Alta'), lucerne (*Medicago sativa*) and white clover (*Trifolium repens* 'New Zealand White'). (In Korean, English summary.)

Kim, J.G. and Han, M.S. (1990). Livestock Experiment Station, RDA, Suweon 440-350, Korea Republic. Effects of sand mulching on forage production in newly reclaimed tidal lands. II. Studies on growth, dry matter accumulation and nutrient quality of selected forage crops grown on saline soils. Journal of Korean Society of Grassland Science, 10:77–83.

> Reports on yield and nutrient composition of orchard grass (*Dactylis glomerata*), tall fescue (*Festuca arundinacea*), tall wheatgrass (*Elymus elongatus, [Agropyron elongatum]*), Italian ryegrass (*Lolium multiflorum*), reed canarygrass (*Phalaris arundinacea*), alfalfa (*Medicago sativa*), red clover (*Trifolium pratense*), Ladino clover (*Trifolium repens*), birdsfoot trefoil (*Lotus corniculatus*), sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum americanum*) in field trials on newly reclaimed tidal saline soils. (In Korean, English summary.)

Kirby, J.M. (1972). Department of Geography, University of Guyana, PO Box 841, Georgetown, Guyana. Chile's tamarugal project. World Crops (November–December), 296–298.

> Describes Chile's tamarugal project in the experimental phase of a livestock-raising program aimed at exploiting the leaf and seed production of *Prosopsis tamarugo*, a leguminous tree adapted to the rigorous environment of the Atacama salt flats and which can support sheep at stocking rates comparable to those on high quality pasture.

Koheil, M.A.H., Hilal, S.H., El-Alfy, J.S. and Leistner, E. (1992). Faculty of Pharmacognosy, Cairo University, Cairo, Eygpt. Quaternary ammonium compounds in intact plants and cell suspension cultures of *Atriplex semibaccata* and *A. halimus* during osmotic stress. Phytochemistry, 31:2003–2008.

Reports that both cell suspension cultures raised from *Atriplex halimus* and *A. semibaccata* plants and intact plants exhibited enhanced growth under moderate NaCl concentrations, did not accumulate proline in response to osmotic stress, but did produce quaternary ammonium compounds.

Kok, B., George, P.R. and Stretch, J. (1987). Rangeland Management Branch, Department of Agriculture, Carnarvon, WA 6701, Australia. Saltland revegetation with salt-tolerant shrubs. Reclamation and Revegetation Research, 6:25–31.

The establishment and subsequent survival of seven halophytic shrubs seeded into bare saline soil (< 0.05% Cl surface, >1% Cl at 1 m), near Karratha, north western Western Australia, with a special niche seeder, was assessed. *Atriplex lentiformis, A. nummularia* and *A. cinerea* had the highest percentage establishment and greatest survival after two years. The former two species have an erect habit and are reasonably ornamental. *A. cinerea* though less attractive has a low, spreading habit and provides excellent ground cover. The cultivation and water harvesting caused by the seeding operation stimulated volunteering of other salt-tolerant shrubs and grasses, including *Salsola kali* and *Chloris* spp.

Kozlowski, T.T. (1985). Department of Forestry, University of Wisconsin, Madison, WI, USA. Soil aeration, flooding, and tree growth. Journal of Arboriculture, 11:85–96.

A review dealing with physiological, morphological and anotomical responses to flooding and waterlogging with particular reference to ornamental and urban trees.

Kozlowski, T.T. (1997). Department of Environmental Science, Policy and Management, College of Natural Resources, University of California-Berkley, Berkley, CA 94720, USA. Responses of woody plants to flooding and salinity. Tree Physiology Monograph 1, 1–17.

This monograph reviews a number of issues related to flooding and salt tolerance in woody plants. Topics covered are: (i) flooding—effects of flooding on soils, variation in responses to flooding, physiological responses and adaptations to flooding, and (ii) salinity—variation in salt tolerance, plant responses to salinity, physiological responses, mechanisms of growth inhibition and adaptations to salinity.

Kraiem, H. (1986). United Nations Sudano-Sahelian Office (UNSO), Post Office Box 366, Ouagadougou, Upper Volta, Chad. Vegetation of salt-affected land in Chad and Senegal. Reclamation and Revegetation Research, 5:31–39.

> This paper provides information on the potential for growth of fodder and fuel in the polders and wadis adjacent to Lake Chad and in the 'tanns' of the Sine Saloum region of Senegal.

Kretinin, V.M. and Dubovskaya, L.V. (1984). All Union Institute for Agricultural and Forest Melioration, USSR. Reaction of trees to soil alkalinity and salinity. Forest Soil Science, 16:52–58.

> Results of a pot experiment with tree seedlings showed the order of decreasing resistance to alkalinity was: English oak > box elder = common honey locust = green ash > Siberian elm > black locust and to Cl salinity was: black locust > Siberian elm > green ash > English oak.

Krupenikov, I.A. (1951). *Tamarix* and its salt resistance. Priroda, Moskva, 40:65–66.

> *Tamarix gracilis* is highly salt- and drought-tolerant and tolerates periodic flooding and deep snowfalls. *T. karelinii* is also salt-tolerant whereas *T. laxa* and *T. ramosissima* occur on less saline soils. (In Russian.)

Kuhnberger, R. and Mahn, E.G. (1976). Martin Luther Universitat, Halle Wittenberg, German Democratic Republic. Studies on the influence of magnesium chloride solution on *Puccinellia distans* and *Lolium perenne*. Arch. Naturschutz und Landschaftforsch, 16:71–82.

> Reports on greenhouse and field trials which show that $MgCl_2$ solutions, applied to streets in the winter, affect the development of *Puccinellia distans* and *Lolium perenne* growing along the verges. (In German, English summary.)

Kumar, A. (1985). Central Soil Salinity Research Institute, Karnal 132 001, India. Karnal grass for reclaiming alkali soils. In: Better farming in salt affected soils (Abrol, I.P. and Parshad, R., ed.), No. 5, 10 p., CSSRI, Karnal, India.

> The agronomic, economic and reclamation benefits of Karnal grass (*Leptochloa fusca*) for use in vast areas of alkali lands located in the states of Haryana, Punjab and Uttar Pradesh are discussed. It is suggested that Karnal grass is a good alternative for poor farmers who are unable to afford gypsum.

Kumar, A. (1988). Central Soil Salinity Research Institute, Karnal 132 001, India. Long-term forage yields of five tropical grasses on an extremely sodic soil and the resultant soil amelioration. Experimental Agriculture, 24:89–96.

In a field trial near Karnal (Haryana), 0, 5.2 or 10.4 t/gypsum/ha was applied to *Diplachne* [*Leptochloa*] *fusca, Panicum laevifolium, P. antidotale, Chloris gayana* and *Cynodon maritimus* on a highly sodic soil with an initial pH of 10.6 and an ESP of 94. Data on fresh forage yields over seven years are provided for each species. Yields of all species were improved with gympsum application except for *D. fusca.* Increase in gypsum rate decreased soil pH and ESP and increased Ca, Mg and organic C content and soil infiltration rate.

Kumar, A. (1988). Central Soil SalinityResearch Institute, Karnal 132 001, India. Performance of forage grasses in saline soils. Indian Journal of Agronomy, 33:26–30.

This paper reports on the results of two trials conducted between 1983 and 1986 on a saline site with a shallow watertable, to determine the impact of irrigation with canal (good quality) and tubewell (saline) water on DM production of several forage grasses. *Brachiaria mutica, Panicum maximum, Leptochloa fusca* and *P. antidotale* were considerably more productive and salt-tolerant than *Chloris gayana* and *Cynodon dactylon.* Data on shoot Ca, Mg, Na and K as well as crude protein concentrations are given.

Kumar, A. (1990). Central Soil Salinity Research Institute, Karnal 132 001, India. Effect of gypsum compared with that of grasses on the yield of forage crops on a highly sodic soil. Experimental Agriculture, 26:185–188.

Reports on a field experiment conducted near Karnal (Haryana), to compare amelioration of a highly sodic soil (ESP approx. 95, pH approx. 10.5) by the application of gypsum compared with that achieved by growing Karnal grass (*Leptochloa fusca*) or Para grass (*Brachiaria mutica*) for between one and three years. The application of gypsum increased green forage yields of all crops grown subsequently. In some grass treatments, yields similar to those achieved with gypsum were observed, however, following three years of grasses, yields were reduced.

Kumar, A. and Abrol, I.P. (1979). Central Soil Salinity Research Institute, Karnal, Haryana 132 001, India. Performance of five perennial forage grasses as influenced by gypsum levels in a highly sodic soil. Indian Journal of Agricultural Science, 49:473–477.

This paper reports on the green forage yield of five perennial grasses—para grass (*Brachiaria mutica*), Bermuda grass (*Cynodon dactylon*), Setaria grass (*Setaria sphacelata*), 'NB 21' hybrid Napier (*Pennisetum purpureum* × *P. typhoides*) and guinea grass. Bermuda grass and para grass were rated as tolerant of sodicity with little growth reduction up to ESP about 50, whilst guinea grass had severe reduction at ESP 40.

Kumar, A. and Abrol, I.P. (1979). Central Soil Salinity Research Institute, Karnal, Haryana, 132 001, India. Dry matter, crude protein and chemical composition of five perennial forage grasses as influenced by gypsum levels in a highly sodic soil. Indian Journal of Agricultural Science, 49:535–541.

In a field experiment conducted on a highly sodic soil (refer previous reference), DM and crude protein (CP) of grasses increased with increasing rate of gypsum application up to 12.50 t/ha (up to 6.25 t/ha for Bermuda grass). With each increase in the rate of gypsum application there was an increase in the percentage of CP, ash, Ca, Mg, K and P and a decrease in Na in cut forage. Leaves generally contained a higher percentage of CP than stems. The percentage of acid-detergent fibre of all the grass species declined at higher gypsum levels. Data on species differences in DM, CP and ion composition are provided.

Kumar, A. and Abrol, I.P. (1984). Central Soil Salinity Research Institute, Karnal, Haryana 132 001, India. Studies on the reclaiming effect of Karnal-grass and para-grass grown in a highly sodic soil. Indian Journal of Agricultural Science, 54:189–193.

In a four-year field experiment conducted on barren sodic land in Haryana, growing para grass (*Brachiaria mutica*) and Karnal grass (*Diplachne* [*Leptochloa*] *fusca*) resulted in gradual improvement in soil pH and EC with good yields of rice and wheat within 1–2 years.

Ladiges, P.Y., Foord, P.C. and Willis, R.J. (1981). Botany Department, University of Melbourne, Parkville, Victoria 3052, Australia. Salinity and waterlogging tolerance of some populations of *Melaleuca ericifolia*. Australian Journal of Ecology, 6:203–215.

Reports on germination and seedling (soil-filled pots) responses in populations of *Melaleuca ericifolia* (swamp paperbark) from near coastal saltmarsh and inland freshwater locations, to waterlogging and salinity (sea salt). Seedling growth was increased by waterlogging but the degree of response differed between populations. Waterlogging stimulated root growth and new roots were thick and aerenchymatous. In the field, root

systems are shallow, apparently restricted by clay at depth. Response to salinity was similar between populations; growth was reduced at >13% sea salt, and was severely restricted at 21%, although no seedlings died after 48 days at this concentration.

Ladiges, P.Y. and Kelso, A. (1977). School of Botany, University of Melbourne, Parkville, Victoria 3052, Australia. The comparative effects of waterlogging on two populations of *Eucalyptus viminalis* Labill. and one population of *E. ovata* Labill. Australian Journal of Botany, 25:159–169.

In a glasshouse experiment, height growth of two populations of *Eucalyptus viminalis* was reduced more in response to waterlogging than for *E. ovata*. Both species developed adventitious roots and stem hypertrophy, and exhibited leaf abscission under waterlogging. *E. ovata* had smaller increases in leaf Fe and Mn concentrations than *E. viminalis*. The two populations of *E. viminalis* derived from a well-drained sandy soil and a heavier solodic soil responded differently to waterlogging.

Langdale, G.W. and Thomas, J.R. (1971). Soil and Water Conservation Research Division, ARS, USDA, Weslaco, Texas 78596, USA. Soil salinity effects on absorption of nitrogen, phosphorus, and protein synthesis by coastal Bermuda grass. Agronomy Journal, 63:708–711

Reports on the DM to protein responses to salinity (irrigation water with EC of 0 to 14.4 dS/m) and N (0 to 200 mg/kg) and P (0 to 60 mg/kg) fertilisation of seedlings of Bermuda grass (*Cynodon dactylon*) grown in soil-filled pots under glasshouse conditions. N fertilisation offset the effects of salinity up to 9.6 dS/m, above which DM production and protein synthesis were significantly reduced even for N-fertilised plants. No response was obtained from P fertilisation.

Läuchli, A. (1984). Department of Land, Air and Water Resources, University of California, Davis, California, USA. Salt exclusion: an adaptation of legumes for crops and pastures under saline conditions. In: Salinity tolerance in plants: strategies for crop improvement (Staples, R.C. and Toenniessen, G.H., ed.), 171–187, Proceedings of the International Conference, Bellagio, Italy, John Wiley & Sons, New York, USA.

This chapter discusses the various mechanisms of salt exclusion found in rice, the regulation of salt concentration in leaves of salt excluders, and recent progress that has been made in the performance of legumes under saline conditions.

Lay, B. (1979). Department of Agriculture and Fisheries, GPO Box 1671, Adelaide, SA 5001, Australia. Shrub population dynamics under grazing: a long term study. In: Studies of the australian arid zone. IV. Chenopod shrublands (Graetz, R.D. and Howes, K.M.W., ed.), 107–124, Proceedings of Symposium, Deniliquin, NSW, Australia.

The method and some results from a re-evaluation, after 22 years, of a quantitative chenopod shrub density survey in the north western pastoral district of South Australia are described.

Le Houérou, H.N. (1979). International Livestock Centre for Africa, B.P. 60, Bamako, Mali. Resources and potential of the native flora for fodder and sown pasture production in the arid and semi-arid zones of North Africa. In: Arid plant resources (Goodin, J.R. and Northington, D.K., ed.), 384–400. Proceedings of the International Arid Lands Conference on Plant Resources, Texas Technical University, Texas, USA.

This paper discusses the potential of lesser-known and other local flora of the North African arid zone as potential forage species and/or for range reseeding.

Le Houérou, H.N. (1986). Caesar Kleberg Wildlife Research Institute, College of Agriculture, Texas A and I University, Kingsville, TX 78363, USA. Salt tolerant plants of economic value in the Mediterranean Basin. Reclamation and Revegetation Research, 5:319–341.

This paper reviews the ecology, productivity, management requirements and economic value of tree, shrub, grass and legume species used in large-scale plantations on farm and rangeland, parks and watershed areas. Emphasis given to the productivity and utilisation of *Atriplex* species and their integration into animal production or mixed farming systems. Economic and technical aspects of large-scale revegetation programs are described.

Le Roux, P. J. (1974). Department of Forestry, PO Box 333, Grootfontein, South-West Africa. Establishing vegetation in saline soil to stabilise aeolian sand at Walvis Bay, South-West Africa. Forestry in South Africa, 15:43–46.

This paper reports on trial plantings of many woody and non-woody species on sand dunes and highly saline wet silt where major constraints include strong winds, high salinity and lack of good irrigation water. On the saline silt (ground water EC of 35 dS/m), *Acacia* spp. and *Casuarina equisetifolia* were among the species that failed, but several *Atriplex* spp.

survived. On dune sand irrigated with sea water, *Atriplex* spp. grew adequately but *C. equisetifolia, Eucalyptus camaldulensis, Prosopis juliflora* and other species failed. *C. equisetifolia, E. camaldulensis, Acacia cyanophylla [A. saligna]* and *A. cyclops* were among the species that grew well under irrigation with sewage water.

Leigh, J.H. (1986). CSIRO, Division of Plant Industry, GPO Box 1600, Canberra ACT 2601, Australia. Forage value and utilization of chenopod dominated shrubland. Reclamation and Revegetation Research, 5:387–402.

This paper presents results from a number of grazing trials conducted to assess the forage value of natural communities of *Atriplex nummularia, Atriplex vesicaria* and *Maireana aphylla*. Results from pen-feeding trials are also presented.

Leonardi, S. and Fluckiger, W. (1986). Institute for Applied Plant Biology, Sangrubenstrafe 25, CH-4124 Schonenbuch, Switzerland. The influence of NaCl on leaf water relations and the proportions of K, Na, Ca, Mg and Cl in epidermal cells of *Fraxinus excelsior* L. Tree Physiology, 2:115–121

This paper reports on changes in leaf water potentials and stomatal diffusive resistances in response to NaCl (0.3 MPa) in 3–4-year-old potted *Fraxinus excelsior* L. trees. It is suggested that ncreased Ca and Mg contents in the epidermal cells, as determined by X-ray analysis, may be associated with malfunction of the stomatal apparatus.

Lerner, H.R., Reinhold, L., Guy, R., Braun, Y., Hasidim, M. and Poljakoff-Mayber, A. (1983). Department of Botany, Hebrew University of Jerusalem, 91904 Jerusalem, Israel. Salt activation and inhibition of membrane ATPase from roots of the halophyte *Atriplex nummularia*. Plant, Cell and Environment, 6:501–506.

Salt-stimulated ATPase activity in membrane preparations obtained from roots of *Atriplex nummularia* at pH 5 was unaffected by KCl or NaCl up to 450 mol/m^3, and showed a broad peak of activity between 150 and 300 mol/m^3, whereas at pH 8, stimulation occurred at 50 mol/m^3 but concentrations higher than 100 mol/m^3 depressed activity below the level of the MgATPase activity. By contrast, preparations from pea roots were much more sensitive to salt. This study relates to effects of salt on ion transport through roots via ATPase activity.

Letey, J. and Knapp, K.C. (1995). Department of Soil and Environmental Sciences, University of California, Riverside, CA 92521, USA. Simulating saline water management strategies with application to arid-region agroforestry. Journal of Environmental Quality, 24:934–940.

This paper describes the output of transient and steady-state models used to simulate the consequences of applying saline drainage water to *Eucalyptus camaldulensis* plantations under conditions typical to the San Joaquin Valley of California, USA, with respect to evaporation, tree growth, infiltration rate, changes in soil properties and sustainability. (Refer Tanji and Kerajeh 1993.)

Lewty, M.J. (1990). Department of Botany, University of Queensland, St Lucia, Queensland 4067, Australia. Effects of waterlogging on the growth and water relations of three *Pinus* taxa. Forest Ecology and Management, 30:189–201.

Reports that responses of Caribbean pine (*Pinus caribaea* var. *hondurensis*), slash pine (*Pinus elliottii* var. *elliottii*) and their Fl hybrid in soil-filled pots under glasshouse conditions were influenced by both season (autumn versus summer), duration of flooding (3 to 9 months) and by soil type (lateritic versus gleyed podzolic). Data on stem diameter, height, shoot and root growth, stomatal conductance and needle potential are provided. Slash pine was more tolerant of flooding than Caribbean pine, overall, and the F1 hybrid was intermediate.

Lipschitz, N. and Waisel, Y. (1982). Department of Botany, Tel-Aviv University, Tel-Aviv, Israel. Adaptation of plants to saline environments: salt excretion and glandular structure. In: Contributions to the ecology of halophytes (Sen, D.N. and Rajpurohit, K., ed.), Tasks for Vegetation Science, Vol. 2, 197–214, Dr. W. Junk Publishers, The Hague.

Detailed discussion on the role of salt glands and salt excretion in halophyte adaptation to salinity.

Liu, C.H., Suan, J.K. and Huang, W.H. (1992). Institute of Animal Science, Academy of Agricultural Sciences, Beijing, China. Study on the salt tolerance of grass forage cultivars. Grassland of China, 6:22.

Reports on the NaCl tolerance at germination (0–2.0%) and seedling (0.3–1.0%) stages of 18 cultivars and species of forage grass [canary grass (*Phalaris arundinacea*), tall wheatgrass (*Elymus elongatus*), tall fescue (*Festuca arundinacea*), smooth bromegrass (*Bromus inermis*), prairie brome grass (*Bromus catharticus*), smooth bromegrass, Russian wildrye

(*Psathyrostachys juncea*), crested wheatgrass (*Agropyron desertorum*), orchard grass (*Dactylis glomerata*), intermediate wheatgrass (*Elymus hispidus*) and meadow fescue (*Festuca pratensis*)]. (In Chinese, English summary.)

Lo, H.C. (1997). Department of Forestry, National Taiwan University, Taiwan. Salt tolerance of calli in *Casuarina equisetifolia* Forest. Quarterly Journal of the Experimental Forest of National Taiwan University, 11:1–11.

Describes changes in the salt tolerance of callus originated from four individuals of *Casuarina equisetifolia* through subculturing phases with increasing NaCl; calli derived from individual trees were significantly different in salt tolerance.

Long, S.P. and Baker, N.R. (1986). Department of Biology, Essex University, Colchester CO4 3SQ, UK. In: Saline terrestrial environments .Photosynthesis in contrasting environments (Baker, N.R. and Long S.P. ed.), 63–102, Elsevier. Amsterdam, Netherlands.

This review deals with the effects of salinity on higher plant photosynthesis in terrestrial environments. Issues considered include: physiological effects (water potential, ion relations), productivity in relation to photosynthesis, leaf CO_2 exchange, ionic relations of the chloroplast, thylakoid photochemical activities and C metabolism. Amongst the plants considered, experimental work is reported for several halophytes including *Avicennia* and *Atriplex* spp.

Loveland, D.G. and Ungar, I.A. (1983). Department of Botany, Ohio University, Athens 45701, USA. The effect of nitrogen fertilisation on the production of halophytes in an inland salt marsh. The American Midland Naturalist, 109:346–354.

Reports on growth responses and N concentration of three halophytes, *Salicornia europaea*, *Hordeum jubatum* and *Atriplex triangularis*, to N fertilisation in an Ohio salt marsh.

Luangjame, J. (1990). The Royal Forest Department, Division of Silviculture, Bangkhen, Bangkok 10900, Thailand. Salinity effects in *Eucalyptus camaldulensis* and *Combretum quadrangulare*: ecophysiological and morphological studies. Acta Forestry Fennica, 214:7–105.

Results from a glasshouse experiment (NaCl; 0 to 2.0%) were compared with those of a field study on non-saline and saline soils in north-eastern Thailand for *Combretum quadrangulare* and *Eucalyptus camaldulensis*. Shoot

height and diameter, shoot internode length, root length/biomass, leaf width and length, leaf area, number and biomass, and shoot:root and leaf:root ratios decreased with salinity, while leaf thickness increased. Photosynthesis, stomatal conductance and water potential decreased with salinity, while CO_2 compensation point increased. Transpiration, dark respiration and photorespiration increased at low salinity but decreased at high salinity. In the field, stomatal properties between trees were similar on saline and non-saline soils. In terms of ecophysiological and morphological responses, *E. camaldulensis* was more salt tolerant than *C. quadrangulare* in both studies.

Luangjame, J. and Bunbhakdee, L. (1987). The Royal Forest Department, Division of Silviculture, Bangkhen, Bangkok 10900, Thailand. Comparing salt tolerance of *Eucalyptus camaldulensis* with other fast-growing trees. Thai Journal of Forestry, 6:347–36

A comparison of the tolerance of five tree species, *Leucaena leucoceplala, Acacia auriculiformis, Anacardium occidentale, Azadirachta indica* and *Eucalyptus camaldulensis*, to NaCl (0–2%). Plants were grown as seedlings in bottles filled with vermiculite. In general, roots grew slowly and new leaves that appeared were thick and short.

Luard, E.J. and El-Lakany, M.H. (1984). Department of Forestry, The Australian National University, PO Box 4, Canberra ACT 2600, Australia. Effects on *Casuarina* and *Allocasuarina* species of increasing sodium chloride concentrations in solution culture. Australian Journal of Plant Physiology, 11:471–481.

Ten species of *Casuarina* and *Allocasuarina* were exposed to increasing levels of NaCl (maximum 550 mol/m^3) in solution culture over a period of five months. More salt-tolerant species had lower concentrations of Na and Cl in both shoots and roots and lower Na:K ratios than the more sensitive species. It is suggested that osmotic adjustment was principally accounted for by inorganic ions, and that inhibition of height growth by NaCl was probably due to high cellular ion concentrations.

Lumis, G.P., Hofstra, G. and Hall, R. (1973). University of Guelph, Guelph, Ontario, Canada. Sensitivity of roadside trees and shrubs to aerial drift of deicing salts. Horticultural Science, 8:475–477.

This paper reports on observations of specific injury symptoms to, and provides sensitivity ratings for, 75 deciduous and coniferous species along roadsides exposed to aerial drift of deicing salts. Trees with resinous buds, submerged buds and needle cuticular wax seemed resistant to damage.

Lunt, O.R., Youngner, V.B. and Oertli, J.J. (1961). University of California, Los Angeles, USA. Salinity tolerance of five turfgrass varieties. Agronomy Journal, 53:247–249.

The order of salt (mixed NaCl and $CaCl_2$) tolerance of five species was found to be: *Puccinellia distans* > *Agrostis palustris* 'Seaside' and *Festuca arundinacea* > *Poa pratensis* and *Agrostis tenuis* (colonial bentgrass) 'Highlands'. *F. arundinacea* and *A. palustris* germinated better than *P. pratensis* and *A. tenuis* under moderately saline field conditions.

Lüttge, U. (1971). Botanisches Institut der Technischen Hochschule, Darmstadt, Germany. Structure and function of plant glands. Annual Review of Plant Physiology, 22:23–44.

Provides a detailed account of gland physiology, structure and function with respect to their cytoplasm and transport mechanisms. Topics covered are: (i) the role of cytological properties of gland cells in gland activities, and (ii) models of transport in integrated systems of gland complexes and supporting tissues.

Lüttge, U. and Smith, J.A.C. (1984). Institut für Botanik, Technische Hochschule Darmstadt, Darmstadt, Federal Republic of Germany. Structural, biophysical, and biochemical aspects of leaves in plant adaptation to salinity and water stress. In: Salinity tolerance in plants: strategies for crop improvement (Staples, R.C. and Toenniessen, G.H., ed.), 125–150, Proceedings of the International Conference, Bellagio, Italy, John Wiley & Sons, New York, USA.

The biochemical and biophysical characteristics of succulent leaves are discussed with emphasis on the properties of the cells and tissues. The relationship between these characteristics and plant performance on saline and arid environments is then considered.

Ma, H.-C., Fung, L., Wang, S.-S, Altman, A., and Huttermann, A. (1997). Experimental Center of Forest Biology, Beijing Forestry University, Beijing 100083, China. Photosynthetic response of *Populus euphratica* to salt stress. Forest Ecology and Management, 93:55–61.

Reports on photosynthetic responses of seedlings of *Populus euphratica* and the hybrid *P. talassica* [*P. euphratica* × *Salix alba*] in response to 50 and 200 mol/m^3 NaCl. CO_2 compensation and saturation points increased at 200 mol/m^3 for both the hybrid and *P. euphratica* while light saturation point decreased. Changes in net photosynthesis, chlorophyll a, b, carotenoid contents and chlorophyll fluorescence are described in response to salinity and with time. The authors conclude that reduction of photosynthesis under high salinity was not due to damage of the photosynthetic apparatus, but more likely to inhibition of the dark reaction.

Maas, E.V. (1986). US Salinity Laboratory, USDA, Agricultural Research Service, 4500 Glenwood Drive, Riverside, CA 92501, USA. Salt tolerance of plants. Applied Agricultural Research, 1:12–16.

Summarised salt-tolerance data for 74 crops (expressed in terms of root-zone EC_e), qualitative ratings for 84 additional crops, and data for 49 ornamental species (expressed as the maximum permissible EC_e without foliar injury or excessive stunting) are provided, based on a database analysis. B tolerances of 59 crops and 40 ornamentals are expressed as the maximum permissible B concentration in the soil water that does not cause a yield reduction.

Maas, E.V. (1986). US Salinity Laboratory, USDA, Agricultural Research Service, 4500 Glenwood Drive, Riverside, CA 92501, USA. Crop tolerance to saline soil and water. In: Prospects for biosaline research (Ahmad, R. and San Pietro, A., ed.), 205–219, Proceedings of the US-Pakistan Biosaline Research Workshop, Department of Botany, University of Karachi, Karachi, Pakistan.

A list of 15 plant species for fibre, seed and sugar crops; 27 species of grasses and forage crops; 19 vegetable species; and 11 species of fruit trees in reference to their threshold salinity values and percentage inhibition in growth with each increasing salinity (dS/m) is given. After giving a brief description of environmental factors affecting salt tolerance, salinity threshold values of some crops with reference to salinity impinging on the leaves has been elaborated. Woody species, in particular, show specific ion toxicity (Cl or Na), whereas most of the herbaceous crops respond primarily to the osmotic potential of soil solution.

Maas, E.V. and Nieman, R.H. (1978). US Salinity Laboratory, USDA, Agricultural Research Service, 4500 Glenwood Drive, Riverside, CA 92501, USA. Physiology of plant tolerance to salinity. In: Crop tolerance to suboptimal land conditions (Jung, G.A., ed.), 277–299. American Society of Agronomy. Special Publication.

An extensive review with examples from non-halophytes and halophyes. Major sections are (i) mechanisms of growth reduction, (ii) mechanisms of salt tolerance, and (iii) selection and breeding for salt tolerance (small section only).

Macke, A.J. and Ungar, I.A. (1971). Department of Botany, Ohio University, Athens, Ohio, USA. The effects of salinity on germination and early growth of *Puccinellia nuttaliana*. Canadian Journal of Botany 49:515–520.

Germination of *Puccinellia nuttaliana* was markedly reduced at –1.2 MPa (ethylene glycol most inhibitory) and completely inhibited at –2.4 MPa, when seeds were germinated in solutions of either NaCl, $NaHCO_3$, Na_2SO_4 or ethylene glycol. Growth stimulation of seedlings was observed at –0.4 MPa and significant reduction at –1.6 MPa.

Maddaloni, J. (1986). Instituto Nacional de Tecnologia Agropecuaria, Estacion Experimental Regional Agropecuaria Pergamino, Casilla de Coreo No. 31, Pergamino (Buenos Aires), Argentina. Forage production on saline and alkaline soils in the humid region of Argentina. Reclamation Revegetation Research, 5:11–16.

Reports on the salinity/alkalinity problem in Argentina and provides information on a range of grasses and legumes tested on problem areas. Species of *Agropyron* and *Melilotus* species have given the best results.

Mahall, B.E. and Park, R.B. (1973). Department of Botany, University of California, Berkeley, CA 94720, USA. The ecotone between *Spartina foliosa* Trin. and *Salicornia virginica* L. in salt marshes of northern San Francisco Bay. Journal of Ecology, 61:793–809.

This paper describes aspects of the zonation between *Spartina foliosa* and *Salicornia virginica* communities in a salt marsh. Soil and above/below-ground biomass measurements show that *Salicornia* occupies a habitat with considerably higher apparent soil salinity than that of *Spartina* during the growing season. In hydroponic experiments, *S. foliosa* plants were less tolerant of rapid salinity changes, and their growth was much more inhibited by higher salinities than that of *S. virginica* plants. *S. foliosa* was

relatively ineffective at excluding salt ions and its water-use efficiency declined markedly with increasing salinity while that of *S. virginica* increased slightly.

Mahmood, K. and Malik, K.A. (1986). Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan. Studies on salt tolerance of *Atriplex undulata*. In: Prospects for biosaline research (Ahmad, R. and San Pietro, A., ed.), 149–155. Proceedings of the US-Pakistan Biosaline Research Workshop, 22–26 September 1985. Department of Botany, University of Karachi, Karachi, Pakistan.

In a gravel culture experiment, the effects of different salt levels (3–30 dS/m) on seed germination, plant growth and cation composition of *Atriplex undulata* were studied. Final germination percentage was lower at all salinities. Growth was stimulated up to 15 dS/m and 50% reduction in yield occurred at greater than 25 dS/m. Na concentrations in roots, stems and leaves increased, whereas those of K decreased with increasing salinity. All plant parts had higher K:Na ratios than the external solution, and this ratio decreased from stems to roots to leaves indicating retention of some Na in the roots. It is suggested that selective K uptake, retention of Na in roots and partitioning of excess salts in leaves contribute to higher salt tolerance of this species.

Mahmood, K. and Malik, K.A. (1987). Soil Biology Division, Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan. Salt tolerance studies on *Atriplex rhagodioides* F. Muell. Environmental and Experimental Botany, 27:119–125.

The effects of salinity on seed germination, plant growth and chemical composition of *Atriplex rhagodioides [A. amnicola]* were studied in gravel culture experiments. Biomass was stimulated up to applied EC of 15 dS/m, and plants survived at EC as high as 50 dS/m. Na and Cl concentrations in plant parts increased, and those of K and Ca decreased with increasing culture solution salinity. The K:Na ratio decreased from roots to stem to leaves. It is suggested that accumulation of ions against a concentration gradient, selective K uptake, and partitioning of excess salts in the leaf contribute to the high salt tolerance of this species.

Mahmood, K., Malik, K.A., Lodhi, M.A.K. and Sheikh, K.H. (1994). Nuclear Institute for Agriculture and Biology (NIAB), PO Box 128, Faisalabad, Pakistan. Soil-plant relationships in saline wastelands: vegetation, soils, and successional changes, during biological amelioration. Environmental Conservation, 21:236–241

This paper reports results of ecological studies of an undisturbed, salt-affected site in Punjab province, Pakistan. *Suaeda fruticosa* was dominant on highly-sodic soil, *Cynodon dactylon* on slightly saline and moderately sodic soil and the distribution of *Desmostachya bipinnata* appeared to be independent of salinity or sodicity. *Atriplex crassifolia* was restricted to marginally saline–sodic soils and *Eleusine flagellifera* to non-saline soil. Within *Leptochloa fusca* (Kallar grass) plots, weed colonisation occurred as soil conditions (pH, EC, SAR) improved. It is concluded that growing kallar grass would be a useful precursor to the cultivation of less salt-tolerant crops and pastures.

Mahmood, S.T. and Ahmed, M. (1989). Department of Botany, University of Karachi, Karachi-75270, Pakistan. Effect of sea water salinity on nodulation and nitrogen fixation in *Prosopis juliflora* (Swartz.) DC. Pakistan Journal of Botany, 21:68–73.

This paper reports on morphology of nodules, root:shoot ratio and total N content in root and shoot of *Prosopis juliflora* seedlings treated with 40 to 80% dilutions of sea water for one month.

Makwana, M.T., Patolia, J.S. and Iyengar, E.R.R. (1988). Centre for Salt and Marine Chemistry Research Institute, Bhavnagar 364 002, India. Salvadora plant species suitable for saline coastal wasteland. Transactions, Indian Society of Desert Technology, 2:121–131.

Salvadora persica and *S. oleoides* are highly salt-tolerant and grow in coastal regions and on inland saline soils. Their seeds are potential sources of oil for the soap and detergent industries. The salinity tolerance of *Salvadora* at germination, early and late stages of growth is described and yields from a natural *S. persica* community tabulated.

Malcolm, C.V. (1974). Resource Management Division, Department of Agriculture, South Perth, WA 6151, Australia. Forage production from shrubs on saline land. Journal of Agriculture, Western Australia, 15:68–73.

Efforts for producing shrubs on saline land are documented for various regions of Australia. Seed collections have been made from native saltland of Australia as well as other arid/saline parts of other countries. Seeds have been tested for germination, seedling growth in greenhouse and in field conditions. Experiments on their establishment, regeneration from cuttings and different management practices are also reported. Recommendations are made on choice of saltbush species for different saline conditions.

Malcolm, C.V. (1986). Department of Agriculture, Jarrah Road, South Perth, WA 6151, Australia. Rainfed halophyte forage production on salt affected soils. In: Prospects for biosaline research (Ahmad, R. and San Pietro, A., ed.), 541–551. Proceeding of the US-Pakistan Biosaline Research Workshop, 22–26 September 1985. Department of Botany, University of Karachi, Karachi, Pakistan.

> This paper advocates field screening of useful halophytic species, which include *Paspalum vaginatum*, *Puccinellia ciliata*, *Maireana brevifolia*, *Atriplex* spp. and *Halosarcia* spp., on representative field sites under partial agronomic conditions. The advantages of the niche seeding technique for direct seeding establishment of halophyte shrubs to reduce the impact of salinity, temperature and waterlogging are discussed. Data summarised from grazing experiments and farmer experience show that halophyte shrub pastures provide a useful feed during the autumn/winter feed supply gap.

Malcolm, C.V. (1986). Division of Resource Management, Department of Agriculture, South Perth, WA 6151, Australia. Production from salt affected soils. Reclamation Revegetation Research, 5:343–361.

> Advocates that growing halophytes on highly saline land is better than trying to breed for increased salt tolerance in non-halophytes, since even then growth is likely to be poor under these conditions. Appropriate evaluation methods are discussed. Important characteristics for determining suitable species for forage production include ability to establish, survive, reproduce, provide a suitable quantity and quality of biomass, and persist under utilisation. Economic considerations and environmental benefits (e.g. lowering of watertable) are discussed.

Malcolm, C.V. (1989). Resource Management Division, Department of Agriculture, South Perth, WA 6151, Australia. Forage shrub production on salt-affected soils. In: The biology and utilization of shrubs (McKell, C.M., ed.), 553–574. Academic Press, Inc.

> This paper focuses on direct seeding innovations (including land preparation to intercept and store water, and precise placement of seed) that aim to overcome several limitations to successful establishment of halophytic shrubs on saline land. These limitations include sensitivity to salt at germination, germination inhibitors, special temperature requirements, and interactions between temperature, salinity, matric potential and inhibition. Use of mulches, covering sprays and other treatments may be cost effective if applied at spot treatments.

Malcolm, C.V. (1989). Resource Management Division, Department of Agriculture, South Perth, WA 6151, Australia. Saltland management-revegetation. Farmnote, No. 44/86, 4 p.

Management practices for establishing halophyte fodder on saltland are recommended. Promising results have been obtained from the introduction of bluebush, saltbush, samphire and *Puccinellia* without any grazing for 22 months. Barren saltland revegetated with these species and protected from grazing have become productive after five years.

Malcolm, C.V. and Allen, R.J. (1981). Department of Agriculture, Jarrah Road, South Perth, WA 6151, Australia. The Mallen niche seeder for plant establishment on difficult sites. Australian Rangeland Journal, 3:106–109.

Describes the operation and use of the Mallen niche seeder, designed for establishing salt-tolerant forage shrubs on saline soils in Western Australia. In one operation the seeder makes a furrow and bank, presses a V-shaped niche on the bank and deposits seeds covered with mulch and/or sprayed with latex or bitumen emulsion at intervals in the niche.

Malcolm, C.V., Clarke, A.J., D'antuono, M.F. and Swaan, T.C. (1988). Resource Management Division, Department of Agriculture, South Perth, WA 6151, Australia. Effects of plant spacing and soil conditions on the growth of five *Atriplex* species. Agricultural Ecosystems and Environment, 21:265–279.

Differences in yield between five *Atriplex* species at 20 months on an agricultural soil were significant at wider spacings (up to 3 × 3 m) but not at close spacing (1 × 1 m). *A. amnicola* produced the largest bushes (1.6 t/ha DM yield at spacing of 2 × 1, 2 × 2, 2 × 3 and 3 × 3 m) and *A. vesicaria* had smallest bushes with progressively higher yields per hectare as spacing was decreased. Yield was poorly correlated with soil and ground water salinity and ground water depth. There were significant differences in salt concentration of leaves and twigs and the ratio of leaf to twig between species. Salinity increased in the top 2 m of soil beneath most plots during the experiment (by up to 21.7 t/ha Cl) although up to 0.66 t/ha of ash was removed from plots during harvests.

Malcolm, C.V., Clarke, A.J. and Swaan, T.C. (1984). Department of Agriculture, South Perth, WA 6151, Australia. Plant collections for saltland revegetation and soil conservation. Technical Bulletin No. 65.

Reports on a halophytic shrub testing program in Western Australia, based on a large assembly of plant germplasm from many countries including Algeria, Argentina, Australia, Chile, England, Iran, Israel, Libya, Morocco, the Netherlands, Russia, South Africa, Spain, Tunisia and the USA. This Bulletin includes details of all plant collections from 1966 to December 1983. Some plants have been collected for their special suitability for revegetation of coastal dunes, road verges and mine spoil dumps.

Malcolm, C.V. and Cooper, G.J. (1974). Resource Management Division, Department of Agriculture, South Perth, WA 6151, Australia. Samphire for waterlogged salt land. Journal of Agriculture, Western Australia, 15:74–75.

Provides information on seed harvesting, germination and establishment and grazing and management of samphires (*Arthrocnemum* spp.).

Malcolm, C.V., Hillman, B.J., Swaan, T.C., Denby, C., Carlson, D. and Antuono, M.D. (1982). Department of Agriculture, Western Australia, South Perth, WA 6151, Australia. Black paint soil amendment and mulch effects on chenopod establishment in a saline soil. Journal of Arid Environment, 5:179–189.

Reports on establishment response of *Maireana brevifolia* (small leaved bluebush), *Atriplex undulata* (wavy leaf saltbush) and *Atriplex rhagodioides [A. amnicola]* (river saltbush) to treatments including soil amendments, seed coverings and spraying with black latex paint in the field using the niche-seeding technique. Best results were obtained with black latex paint, which was shown to raise the temperature of the top 1–2 mm of soil by about 5°C on a clear, still mid-winter day, and it is suggested that the response to black paint is at least partly a temperature effect for two of the species tested. (Refer Malcom and Allen 1981.)

Malcolm, C.V. and Smith, S.T. (1971). Salinity and Hydrology Research Branch, Department of Agriculture, South Perth, WA 6151, Australia. Growing plants with salty water. Journal Agriculture, Western Australia, 12:41–44.

This article provides a brief practical guide on how to reduce salt damage to plants when saline water must be used and includes a table of plants (including fruit trees and some ornamental trees) suitable for specified degrees of salinity.

Malcolm, C.V. and Swaan, T.C. (1985). Western Australian Deptartment of Agriculture, Jarrah Road, South Perth 6151, Western Australia. Soil mulches and sprayed coatings and seed washing to aid chenopod establishment on saline soil. Australian Rangeland Journal, 7:22–28.

In three field experiments on saline sites, black pigmented latex and bituminous emulsion coatings gave significant improvements in emergence and survival of *Atriplex* spp. and *Maireana brevifolia* seedlings over 10 months. Seed washing to remove germination inhibitors doubled emergence of *Atriplex amnicola* (river saltbush) if used in combination with a mulch. Vermiculite gave a marked increase in emergence and survival of seedlings of river saltbush and was significantly better than 'Compeat'.

Malcolm, C.V. and Swaan, T.C. (1989). Division of Resource Management, Department of Agriculture, South Perth, WA 6151, Australia. Screening shrubs for establishment and survival on salt-affected soils under natural rainfall in south-western Australia. Western Australian Deptartment of Agriculture, Technical Bulletin No. 81. 35 p.

Reports major differences in survival, growth habit, seedling regeneration, disease resistance and size of 15 shrub halophytes planted at 14 saline sites in the Western Australian wheat belt. Soil conditions were very variable between sites, with the top 90 cm of soil having EC_e from 12 to 61.3 dS/m, SAR in the saturation extract ranged from 11 to 112, and pH (1:5 soil:water suspension) ranged from 3.4 to 10.1. Most of the soils consisted of loamy sand up to 0.25 m deep overlying sandy clay subsoil. Most sites had ground water EC of 40–80 dS/m at about 0.9 to 1.5 m depth. Some species were waterlogging sensitive but survival did not appear to relate well to soil salinity. Early growth of species appeared to be reduced by increased soil EC_e at 0.3 to 0.6 m.

Malik, K.A. and Azam, F. (1978). Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan. Decomposition of *Diplachne fusca* (L.) Beauv and *Suaeda fruticosa* Forsk. in salt-affected soils. Pakistan Journal of Botany, 10:89–93.

Reports on the decomposition of *Diplachne* [*Leptochloa*] *fusca* (Kallar grass) and *Suaeda fruticosa* material in saline soil with resultant changes in cellulolytic mycoflora and soil chemical properties in beakers for 42 days (cellulase activity, soluble Na, Ca and Mg, organic matter and humic acid content).

Malik, M.N. and Sheikh, M.I. (1983). Forestry Research Division, Pakistan Forest Institute, Peshawar, Pakistan. Planting of trees in saline and water-logged area. I. Test planting at Azakhel. Pakistan Journal of Forestry, 33: 1–17.

> This paper reports on results of several small species evaluation trials, at Azakhel (near Peshawar), on saline–alkaline, silt–clay loam soil. Salt concentration varied with topography and susceptibility to waterlogging; salinity measurements are unclear but the site was densely covered with *Desmostachya bipinnata*. The most salt-tolerant species were *Tamarix aphylla, Eucalyptus camaldulensis, Prosopis juliflora* and *Casuarina equisetifolia*. Survival and growth were not improved by planting in trenches or with gypsum addition.

Maliwal, G.L. and Nadiadara, C.M. (1990). National Agricultural Research Project, Gujarat Agricultural University, Arnej, Gujarat, India. Suitability of *Salvadora persica* for saline coastal wasteland. Indian Forester, 116:969–973.

> This paper reports that *S. persica*—a non-edible oilseed producing salt-tolerant multipurpose tree, widely distributed in parts of coastal and inland India following its introduction—was shown to be more tolerant of sodicity (no growth reduction up to ESP 45) than salinity (significant growth reduction at EC 6 dS/m of irrigation water) in glasshouse studies with seedlings in soil-filled pots. Shoot and root Na, K, Ca and Mg concentration data are provided.

Marcar, N.E. (1986). School of Agriculture, La Trobe University, Bundoora, Victoria, 3083, Australia. Effect of calcium on the salinity tolerance of Wimmera ryegrass (*Lolium rigidum* Gaud., cv. Wimmera) during germination. Plant and Soil, 93:129–132.

> Pretreatment of seeds of Wimmera ryegrass with Ca had no significant effect on germination under NaCl or $MgCl_2$ salinity. Germination percentage was significantly increased by the addition of Ca (up to 10 mol/m^3 as $CaCL_2$) to the germination medium especially in the presence of $MgCl_2$. Shoot and root growth were also increased with Ca addition for youg solution-cultured seedlings treated with $MgCl_2$ but not NaCL at 300 mequiv/L.

Marcar, N.E. (1987). School of Agriculture, La Trobe University, Bundoora, Victoria, 3083, Australia. Salt tolerance in the genus *Lolium* (Ryegrass) during germination and growth. Australian Journal of Agricultural Research, 38:297–307.

Reports on two experiments to evaluate variation for salt tolerance within *Lolium* (ryegrass), and to compare the responses of Wimmera (*L. rigidum*), Italian (*L. multiflorum*) and perennial (*L. perenne*) ryegrass with those of two known salt-tolerant grasses, tall wheat grass (*Elytrigia pontica* [*Agropyron elongatum*]) and saltmarsh grass (*Puccinellia ciliata*), at germination (petri-dishes) and during growth (sand-filled pots) under controlled environment conditions. Significant variation was found for salt tolerance amongst and within *Lolium* species, particularly during germination; however, field-collected accessions from saline sites were no more tolerant to NaCL than other accessions. NaCl up to 200 mol/m^3 had little effect on germination, but higher concentrations were tolerated only by saltmarsh grass, tall wheat grass and Italian ryegrass. Only the former two grasses maintained their high tolerance during vegetative growth. Shoot concentrations of Na, Cl and K did not reflect the degree of salt tolerance.

Marcar, N.E. (1989). CSIRO Division of Forestry and Forest Products, PO Box 4008, Queen Victoria Terrace, Canberra ACT 2600, Australia. Salt tolerance of frost-resistant eucalypts. New Forests, 3:141–149.

Seedlings of 19 frost-resistant *Eucalyptus* species, established in sand-filled pots, were screened for salt tolerance in a glasshouse using stepwise increases in NaCl up to 500 mol/m^3, in order to determine the potential of these species for planting on dryland salt-affected sites in frost-prone areas of south eastern Australia. Data on survival, leaf damage and height growth were obtained. Species in the subgenus *Symphyomyrtus*, particularly those in section *Maidenaria*, series *Ovatae*, were moderately salt-tolerant (no mortality at 300 mol/m^3) whereas those in the subgenus *Monocalyptus* were very salt-sensitive (no survival at 300 mol/m^{3}l). *Eucalyptus camaldulensis*, *E. tereticornis* and *E. occidentalis* were the most salt-tolerant. Salt-sensitive species generally had highest shoot Na and Cl concentrations.

Marcar, N.E. (1993). CSIRO Division of Forestry and Forest Products, PO Box 4008, Queen Victoria Terrace, Canberra ACT 2600, Australia. Waterlogging modifes growth, water use and ion concentrations in seedlings of salt-treated *Eucalyptus camaldulensis*, *E. tereticronis*, *E. robusta* and *E. globulus*. Australian Journal of Plant Physiology, 20:1–13.

This paper reports on two experiments designed to evaluate the effect of waterlogging on growth response to NaCl (up to 150 mol/m^3) in *Eucalyptus camaldulensis*, *E. tereticornis*, *E. robusta* and *E. globulus* seedlings under glasshouse conditions. Combined salt and waterlogging (SW) had a

much greater effect than salt and waterlogging alone, and also significantly reduced stomatal conductance and whole-plant water use and increased leaf and stem Na and Cl concentrations. Pre-treatment with waterlogging significantly improved growth and reduced ion concentrations of SW-treated plants.

Marcar, N.E. (1996). CSIRO Division of Forestry and Forest Products, PO Box 4008, Queen Victoria Terrace, Canberra ACT 2600, Australia. Casuarinas for salt-affected land. In: Recent casuarina research and development. (Pinyopusarerk, K., Turnbull, J.W. and Midgley, S.J. ed.), 180–186. Proceedings of Third International Casuarina Workshop. Da Nang, Vietnam. 4–7 March, 1996.

This paper provides information on (i) growth of several *Casuarina* species and provenances on salt-affected soils, (ii) physiological mechanisms related to observed salt and waterlogging tolerance, (iii) progress with selection and propagation of improved salt-tolerant lines and (iv) interactions between salinity and waterlogging and N_2 fixation induced by inoculation with *Frankia*. In the process, information discussed is drawn from a variety of sources, including field trials conducted in Australia, Pakistan and Thailand.

Marcar, N.E. (1998). CSIRO Forestry and Forest Products, PO Box E4008, Kingston, Canberra ACT 2604, Australia. Fodder value of four salt-tolerant Australian acacias. In: Nitrogen fixing trees for fodder production (Daniel, J.N. and Roshetko, J.M. ed.) 92–101. Proceedings of International Workshop, BAIF, Pune, India. March 20–25, 1995. Forest, Farm and Community Research Reports (Special Issue).

Several Australian *Acacia* species have performed well on salt-affected land in Pakistan, Thailand and Australia in recent trials. This paper highlights attributes of *A. stenophylla*, *A. salicina*, *A. ampliceps* and *A. saligna* and discusses their role in saline land utilisation. The current knowledge of their fodder value is indicated and suggestions made for future research.

Marcar, N.E. and Crawford, D. (1996). CSIRO Forestry and Forest Products, PO Box E4008, Kingston, Canberra ACT 2604, Australia. Tree-growing strategies for the productive use of saline land. Australian Journal of Soil and Water Conservation, 9:34–40.

This paper reviews opportunities for tree growing on saline land in dryland and irrigation areas of Australia. Tree-growing systems include wide-spaced agroforestry (including alley farming), woodlots and plantations, with opportunities for commercial cultivation, watertable control and use of saline water. The current state of knowledge related to species choice, breeding and management options is presented. Examples of selection programs are given.

Marcar, N.E., Crawford, D., Aswath, N. and Thomson, L.A.J. (1994). CSIRO Forestry and Forest Products, PO Box E4008, Kingston, Canberra ACT 2604, Australia. Salt and waterlogging tolerance of subtropical and tropical trees: a review. In: Current developments in salinity and drought tolerance of plants (Naqvi, S.S.M.N., Ansari, R., Flowers, T.J. and Azmi, R, ed.). Proceedings of an International Symposium. Tando Jam, Pakistan. January 7–11, 1990.

The extent and nature of salt and waterlogging tolerance of subtropical and tropical species in the Australian genera *Acacia* and *Sesbania* is reviewed. Salt tolerance is clearly linked with the ability to maintain low salt ion concentrations in shoot tissues.

Marcar, N.E., Crawford, D.F., Leppert, P.M., Jovanovic, T., Floyd, R. and Farrow, R. (1995). CSIRO Forestry and Forest Products, PO Box E4008, Kingston, Canberra ACT 2604, Australia. Trees for saltland: a guide to selecting native species for Australia. CSIRO Australia. 72 p.

This very useful book provides descriptions (attributes, description, salt and waterlogging tolerance, soil adaptations) of 60 Australian tree species (30 in detail) as well as information on tree response to salinity, insect attack and establishment procedures for salt-affected land.

Marcar, N.E., Dart, P. and Sweeney, C. (1991). CSIRO Forestry and Forest Products, PO Box E4008, Kingston, Canberra ACT 2604, Australia. Effect of root-zone salinity on growth and chemical composition of *Acacia ampliceps* B.R. Maslin, *A. auriculiformis* A. Cunn. Ex Benth. and *A. mangium* Willd. at two nitrogen levels. New Phytologist, 119:567–573.

Ranking of species, based on growth of pot-grown seedlings treated with 100, 200 and 400 mol/m^3 NaCl in a glasshouse experiment, was *Acacia ampliceps* > *A. auriculiformis* > *A. mangium*. The greater salt tolerance of *A. ampliceps* was associated with relatively low shoot Na and Cl concentrations and high phyllode succulence. Plants treated with

5 mol/m^3 N (high N) were larger than those treated with 1 mol/m^3 (low N) and inoculated with *Rhizobium* at each NaCl level. At higher NaCl, high N-plants had lower Na and Cl concentrations than low-N plants.

Marcar, N.E., and Ganesan, S.K. (1991). CSIRO Division of Forestry and Forest products, PO Box 4008, Queen Victoria Terrace, Canberra ACT 2600, Australia. Genetic variation for salt and waterlogging tolerance of *Acacia auriculiformis*. In: Advances in tropical *acacia* research (Turnbull, J.W., ed.), 82–86. ACIAR Proceedings No. 35, Canberra, Australia.

In a glasshouse study, large variation was found between seedlings of 30 provenances (salt tolerance) and 16 provenances (waterlogging tolerance) of *Acacia auriculiformis*. Increasing NaCl concentrations were applied weekly up to 750 mol/m^3; provenances were ranked on the basis of relative height growth rate and salt damage (index derived from number of phyllodes shed and final height).

Marcar, N.E. and Hossain, A.K.M.A. (ed.) (1999). CSIRO Forestry and Forest Products, PO Box E4008, Kingston, ACT 2604, Australia. Managing saltland into the 21st century: dollars and sense from salt. Proceedings of the 5th National Conference on the Productive Use and Rehabilitation of Saline Land, Tamworth, NSW, Australia, 9–13 March, 1998. 202 p.

This proceedings contains some papers dealing with (i) perennial grasses, saltbush and trees for saline land in a various parts of Australia, (ii) updates on the extent and future trends of salinity throughout Australia and (iii) various papers dealing with irrigation, catchment scale processes, socioeconomic considerations and urban salinity.

Marcar, N.E., Hussain, R.W., Arunin, S. and Beetson, T. (1991). CSIRO Division of Forestry and Forest products, PO Box 4008, Queen Victoria Terrace, Canberra ACT 2600, Australia. Trials with Australian and other *Acacia* species on salt-affected land in Pakistan, Thailand and Australia. In: Advances in tropical *Acacia* research (Turnbull, J.W., ed.), 229–232. ACIAR Proceedings No. 35, Canberra, Australia.

Some preliminary results are reported of species and provenance trials with Australian and other *Acacia* species conducted in Pakistan (12 species), Thailand (4 species) and Australia (Queensland, 7 species). Preliminary results are also given from a trial in Thailand dealing with the effect of various preplanting techniques (e.g. mulching, soil amendments, fertiliser treatment) on the survival and growth of *Acacia ampliceps*.

Marcar, N.E. and Khanna, P.K. (1997). CSIRO Forestry and Forest Products, PO Box E4008, Kingston, Canberra ACT 2604, Australia. Reforestation of salt-affected and acid soils In: Management of soil, nutrients and water in tropical plantation forests (Nambiar, E.K.S. and Brown, A.G. ed.), 481–524. ACIAR Monograph 43, Canberra, Australia.

> This chapter deals with reforestation of salt-affected and acid soils. It is argued that when suitable tree species are used and appropriate land management practices are employed, these soils can afford opportunities for sustainable plantation and farm forestry. Considerably more effort is required to increase the sustainable productivity of salt-affected than acid soils. Critical soil, plant and management factors that have a strong influence on reforestation strategies are discussed, with a particular focus on tropical and sub-tropical regions.

Marcar, N.E., Naqvi, M., Iqbal, S., Crawford, D.F., Arnold, R., Mahmood, K. and Hossain, A. (1998). Results from an *Acacia ampliceps* Maslin provenance–family trial on saltland in Pakistan. In: Recent developments in acacia planting (Turnbull, J.W., Crompton, H.R. and Pinyopusarek, K., ed.), 161–166. ACIAR Proceedings No. 82, Canberra, Australia.

> In several recent trials in Pakistan, *Acacia ampliceps* has proven to be one of the best performing woody species on saltland, with the potential to supply fuelwood and fodder. This paper reports that significant differences in growth at 28 months have been found between families and provenances in a seedling seed orchard established on saline–sodic land near Faisalabad, Pakistan. Good agreement was found between these results and those from a glasshouse study.

Marcar, N.E. and Termaat, A. (1990). CSIRO Division of Forestry and Forest products, PO Box 4008, Queen Victoria Terrace, Canberra ACT 2600, Australia. Effects of root-zone solutes on *Eucalyptus camaldulensis* and *Eucalyptus bicostata* seedlings: responses to Na, Mg and Cl. Plant and Soil, 125:245–254.

> This paper reports on a study designed to determine whether osmotic or salt-specific effects predominated seedlings of *Eucalyptus camaldulensis* (more salt-tolerant) and *E. globulus* ssp. *bicostata* (less tolerant), treated with either NaCl or $MgCl_2$, or with nutrient solutions rich in Na, Mg and Cl, at osmotic potentials of approx. –0.52 MPa. In general, salt-induced growth reductions were greater for *E. camaldulensis* than for *E. bicostata*, although *E. camaldulensis* had lower shoot Na, Mg and Cl concentrations. Treatment differences are described. Shoot and root growth was reduced

more for *E. biocostata* seedlings treated with high Cl concentrations in the presence of Mg and concentrated cations than those exposed to other salts. A specific effect for Cl (extensive leaf damage for Cl salt treatments) is suggested. Root growth was considerably less for plants treated with Mg salts and this effect was associated with low root Ca concentrations.

Marcum, K.B. and Murdoch, C.L. (1990). Department of Horticulture, University of Hawaii, Honolulu, HI 96822, USA. Growth responses, ion relations, and osmotic adaptations of eleven C_4 turfgrasses to salinity. Agronomy Journal, 82:892–896.

Shoot and root growth of C_4 turfgrasses were evaluated in solution culture in a glasshouse, with NaCl added to achieve salinities of 0.7, 10, 20 and 30 dS/m (0, 99, 198 and 298 mol/m^3). Tolerant grasses included a Hawaiian selection of seashore paspalum (*Paspalum vaginatum*), two St Augustine grasses (*Stenotaphrum secundatum*), and manilagrass (*Zoysia matrella*), whilst Bermuda grasses (*Cynodon* spp.) tested were generally less tolerant. Data on shoot and root Na, Cl and K concentrations, shoot water content and leaf osmolality are provided. Shoot and root Na and Cl concentrations were highest in St Augustine grasses, and lowest in manilagrass and Bermuda grasses. Seashore paspalum maintained higher shoot and root K concentrations under high salinity than did other grasses. All grasses adjusted osmotically using different degrees of ion uptake and tissue dehydration.

Marshall, J.K. (1979). CSIRO, Division of Land Resources Management, Private Bag, PO, Wembley, WA 6014, Australia. Plant weight to density relationships in chenopod shrublands. In: Studies of the Australian arid zone. IV. Chenopod shrublands (Graetz, R.D. and Howes, K.M.W., ed.), 75–82. Proceeding of Symposium, Denilquin, NSW, Australia.

Results from semiarid shrub communities dominated by *Atriplex nummularia, A. vesicaria, Maireana pyramidata* and *M. sedifolia* were used to examine the relationship between average shrub weight and density.

Marshall, J.K., Morgan, A.L., Akilan, K., Farrell, R.C.C. and Bell, D.T. (1997). CSIRO, Division of Land Resources Management, Private Bag, PO, Wembley, WA 6014, Australia. Water uptake by two river red gum (*Eucalyptus camaldulensis*) clones in a discharge site plantation in the Western Australian wheatbelt. Journal of Hydrology, 200:136–148

Reports on water use by nine-year-old trees of two clones (M80 and M66) of *E. camaldulensis*, determined by the heat pulse technique, on a saline discharge site near Wubin, Western Australia. Water use was similar to rainfall during the wetter months but exceeded rainfall as the dry season progressed. The two clones had different water use rates in spring and summer.

Martin, D.W. and Young, D.R. (1997). Department of Biology, Virginia Commonwealth University, Richmond, VA 23284, USA. Small-scale distribution and salinity response of *Juniperus virginiana* on an Atlantic Coast barrier island. Canadian Journal of Botany, 75:77–85.

Reports on field measurements and laboratory/growth chamber experiments to determine whether the small-scale distribution pattern of *Juniperus virginiana* on a Virginia barrier island was related to soil salinity patterns and plant responses to salinity. Data for ground water depth and salinity are provided. Since the median Cl concentration in the root zone of *J. virginiana* was 54 µg/g but germination and growth were significantly affected only at 1000 and 1400 µg/g. It was suggested that salinity was not the only factor regulating distribution. Data for tissue Cl concentrations, stomatal conductance and water potential are given.

Maryam, H., Ismail, S., Ala, F. and Ahmad, R. (1995). Department of Botany, University of Karachi, Karachi, Pakistan. Studies on growth and salt regulation in some halophytes as influenced by edaphic and climatic conditions. Pakistan Journal of Botany, 27:151–163.

Soil moisture content and salinity (EC) significantly affected growth of both *Suaeda fruticosa* and *Tamarix indica* on saline land at Karachi University, whereas growth of *T. indica* was also influenced by soil Na concentration. *T. indica* had higher organic matter and lower ash content than *S. fruticosa*. Soil Cl concentrations under *T. indica* were unaffected and maximum salt accumulation was observed under *S. fruticosa* (EC_e of 110–130 dS/m at 0–5 cm depth).

Mathur, N.K. and Sharma, U. (1984). Forest Research Institute and College, Dehra Dun, Uttar Pradesh, India. *Eucalyptus* in reclamation of saline and alkaline soils in India. Indian Forester, 110:9–15.

This paper reports on some outcomes of trials with eucalypts on saline and alkaline soils of Uttar Pradesh, Haryana, Tamil Nadu and other states. *Eucalyptus* 'hybrid' could be successfully grown on 'usar' (alkaline) soils with good drainage and pH up to 8.5 by planting in pits. Soils with pH

8–11.0, usually associated with poor drainage and a 'kankar' pan, can be afforested by planting in deep pits filled with other soils. Suggestions are made for suitable species for drier conditions, sandy and calcareous soils.

Matoh, T., Watanabe, J. and Takahashi, E. (1986). Department of Agricultural Chemistry, Kyoto University, Kyoto 606, Japan. Effects of sodium and potassium salts on the growth of a halophyte *Atriplex gmelini*. Soil Science and Plant Nutrition, 32:451–459.

Shoot DW of solution-cultured *Atriplex gmelinii* seedlings was stimulated at 50 mol/m^3 NaCl, 50 mol/m^3 KCl, 25 mol/m^3 Na_2SO_4 or 25 mol/m^3 K_2SO_4 to the same extent. However, higher concentration of K salts, reduced growth more than Na salts. At 250 mol/m^3, plant Na + K concentrations under KCl were higher than under NaCl, and this was ascribed to an inability to maintain internal K concentration, on the basis of results of time-course experiments.

Matoh, T., Watanabe, J. and Takahashi, E. (1987). Department of Agricultural Chemistry, Kyoto University, Kyoto 606, Japan. Sodium, potassium, chloride, and betaine concentrations in isolated vacuoles from salt-grown *Atriplex gmelini* leaves. Plant Physiology, 84:173–177.

Vacuoles isolated via protoplasts from the leaves of the halophyte *Atriplex gmelini* grown in culture solution with 250 mol/m^3 NaCl contained almost the same concentrations of Na (569 mol/m^3) and Cl (260 mol/m^3) as recorded in protoplasts. Betaine concentration in the protoplasts was about 16 mol/m^3, while that in vacuoles was only about 0.24 mol/m^3. It is suggested that vacuoles are a major site for Na and Cl accumulation in leaves and that betaine accumulates in the cytoplasm.

Maynard, D.G., Mallett, K.I. and Myrtholm, C.L. (1997). Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, 5320 122 St., Edmonton, Alberta T6H 3S5, Canada. Sodium carbonate inhibits emergence and growth of greenhouse-grown white spruce. Canadian Journal of Soil Science, 77:99–105.

Emergence was reduced by about 8% and growth at 12 weeks by 50% at 0.5 EC dS/m (sodium carbonate (Na_2CO_3) was the principal salt) for glasshouse-grown seedlings of white spruce (*Picea glauca*), a salt-sensitive species, in peat–perlite soil. Each treatment with successively higher EC resulted in a further decrease in emergence and growth. Data on leaf and root Na and Ca concentrations are provided.

McElgunn, J.D. and Lawrence, T. (1973). Research Station, Canada Department of Agriculture, Swift Current, Saskatchewan, Canada. Salinity tolerance of Altai wild ryegrass and other forage grasses. Canadian Journal of Plant Science, 53:303–307.

Reports on growth-chamber experiments in which *Elymus angustus, E. junceus, Agropyron elongatum, A. trachycaulum, Bromus inermis* and *Phalaris arundinacea* were grown in soil mixtures artificially salinised to produce EC_e levels of 4–40 dS/m. In terms of herbage yield, *A. elongatum* and *E. angustus* were most salt-tolerant, but root yields of *E. angustus* were greater than those of other grasses at all levels of soil EC, and at 6–14 dS/m its root yield exceeded that on the low-saline control soil.

McFarland, M.L., Ueckert, D.N., Hartmann, S. and Hons, F.M. (1990). University Lands Surface Interests,The University of Texas System, Midland, TX 79702, USA. Transplanting shrubs for revegetation of salt-affected soils. Landscape and Urban Planning, 19:377–381.

Reports on the establishment and growth of transplanted fourwing saltbush (*Atriplex canescens*) seedlings and rooted stem cuttings, and seedlings of oldman saltbush (*Atriplex nummularia*), winterfat (*Ceratoides lanata*) and prostrate kochia (*Kochia prostrata*) on three saline–sodic (EC_e ranging from 23 to 93 dS/m, ESP from 13 to 46%) oil-well reserve pits in Texas, USA, over a three-year period. Best survival of fourwing saltbush was for seedlings or stem cuttings from an accession adapted to saline soil. Survival and growth of winterfat and prostrate kochia transplants were acceptable, but oldman saltbush died from sub-freezing temperatures during the first winter.

McKee, K.L. (1996). Wetland Biogeochemistry Institute, Center for Coastal, Energy and Environmental Resources, Louisiana State University, Baton Rouge, LA 70803-7511, USA. Growth and physiological responses of neotropical mangrove seedlings to root-zone hypoxia. Tree Physiology, 16:883–889.

Reports on a growth chamber experiment, to investigate relative tolerance of seedlings of *Rhizophora mangle, Avicennia germinans* and *Laguncularia racemosa* to hypoxia (low oxygen) in nutrient culture and tolerance mechanisms, over 12 weeks. Root extension and morphology were least affected for *R. mangle*, and this was related to maintenance of root oxygen concentrations and root respiration rates

McKell, C.M. (1986). NPI, 417 Wakara Way, Salt Lake City, Utah 84108, USA. Propagation and establishment of plants on arid saline land. Reclamation and Revegetation Research, 5:363–375.

This paper deals with field studies on the reclamation of processed oil shale (a saline medium). Reclamation involved transplanting container-grown salt-tolerant species, water harvesting techniques and the placement of topsoil in a trench in the shale.

McKinnell, F.H. and Harisetijono (1991). Department of Conservation and Land management, PO Box 104, Como, WA 6152, Australia. Testing *Acacia* species on alkaline soils in West Timor. In: Advances in tropical *Acacia* research (Turnbull, J.W., ed.), 183–188. ACIAR Proceedings No. 35, Canberra, Australia.

This paper reports that *Acacia ampliceps, A. holosericea, A. auriculiformis* and the native species of *A. leucophloia* performed best on highly alkaline soils in tree species screening trials on five sites in West Timor (Indonesia) after 1.6 or 2.6 years of planting, and some species, such as *A. torulosa* and *A. shirleyi*, appeared to be tolerant of alkaline soils.

McLeod, M.N. (1973). CSIRO, Division of Tropical Pastures, The Cunningham Laboratory, St Lucia, Queensland 4067, Australia. The digestibility and the nitrogen, phosphorus and ash contents of the leaves of some Australian trees and shrubs. Australian Journal of Experimental Agricultural and Animal Husbandry, 13:245–250.

This paper reports on the dry matter digestibility measured in vitro and the levels of N, P and ash determined on the leaves from mature trees of 21 species growing in two arboreta in south eastern Queensland and known to be grazed by animals.

Mehanni, A.H. and Chalmers, D.J. (1986). Institute for Irrigation and Salinity Research, Department of Agriculture and Rural Affairs, Tatura, Victoria 3616, Australia. Effect of irrigation with saline water on soil properties and salinization of perennial pasture soils. Australian Journal of Experimental Agriculture, 26:173–179.

Reports changes in soil salinity and Na concentrations in pasture grown on a loam soil (red-brown earth), irrigated with saline water of about 100, 300, 700, 1500 and 3000 mg/L total soluble salt, with variable leaching depending on the extent of winter rainfall.

Mehanni, A.H. and Repsys, A.P. (1986). Institute for Irrigation and Salinity Research, Department of Agriculture and Rural Affairs, Tatura, Victoria 3616, Australia. Perennial pasture production after irrigation with saline groundwater in the Goulburn Valley, Victoria. Australian Journal of Experimental Agriculture, 26:319–324.

Reports on the application of irrigation water with nominal salinities of 100 to 3000 mg/L (see above reference) and superimposed over a yearly gypsum treatment (5 t/ha) on established white clover, ryegrass and paspalum pasture grown on a red-brown earth soil type. Pasture DM production was initially reduced at all salinities, predominantly because of a decline in white clover growth, however, after strawberry clover was added to the sward, pasture yield was reduced less at all salinities. Soil salinities had largely reached equilibrium after four years and relative pasture yields remained relatively stable from then on.

Mendelssohn, I.A. and McKee, K.L. (1988). Laboratory for Wetland Soils and Sediments, Centre for Wetland Resources, Louisiana State University, Baton Rouge, Louisiana 70803, USA. *Spartina alterniflora* die-back in Louisiana: time-course investigation of soil waterlogging effects. Journal of Ecology, 76:509–521.

Results of transplantation trials with streamside and inland *Spartina alterniflora* swards showed that soil salinity and pH were not significant factors in causing reduced growth but that sulphide toxicity, in combination with extended periods of anaerobic metabolism in the roots were, and may be a cause of dieback in inland marshes.

Mensforth, L.J., Thorburn, P.J., Tyerman, S.D. and Walker, G.R. (1994). CSIRO Division of Water Resources, Centre for Groundwater Studies, PMB 2, Glen Osmond, SA 5064, Australia. Sources of water used by riparian *Eucalyptus camaldulensis* overlying highly saline groundwater. Oecologia, 100:21–28.

Reports on a study to determine the water sources of woodland *Eucalyptus camaldulensis* trees on a semiarid floodplain in south eastern Australia growing at a distance of 0.5 to 40 m from a stream (with EC 0.8 dS/m) and over ground water with EC ranging from 10 to 50 dS/m. Data on naturally occurring isotypes and soil/plant water relations were obtained. Trees located more than about 15 m from the stream used no stream water. The trees used groundwater during summer and both groundwater and rain-derived water in surface (0.05–0.15 m depth) soils during winter. Data on plant water potential and stomatal conductance

suggest that trees were water-stressed when using groundwater of ECs higher than about 40 dS/m (equivalent to approximately −1.4 MPa); however this did not prevent trees from using groundwater.

Mensforth, L.J. and Walker, G.R. (1996). CSIRO Division of Water Resources, PMB 2, Glen Osmond, SA 5064, Australia. Root dynamics of *Melaleuca halmaturorum* in response to fluctuating saline groundwater. Plant and Soil, 184:75–84.

This paper reports on sources of water used by stands of *Melaleuca halmaturorum*, a salt- and waterlogging-tolerant tree, in different seasons during which soil salinity and ground water depth and salinity (64 dS/m; 0.3–1.2 m deep) varied in a swamp forest on Duck Island, South Australia, over a 15-month period. Through the use of naturally occurring stable isotopes of water, it was found that *M. halmaturorum* actively took up ground water at most times and combined this with a shallower soil water source replenished by rainfall in winter, and this was reflected in the appearance of new root tips examined at the window of a root observation chamber. Changes in leaf water potential reflected fluctuations in surface soil (10 cm depth) water potential at all times.These observations are related to the survival of *M. halmaturorum* in this saline swamp.

Mergen, F. (1988). Yale School of Forestry and Environmental Studies, New Haven, Connecticut, USA. Using multipurpose trees and shrubs to reclaim arid lands. In: Arid lands: today and tomorrow (Whitehead, E.E., Hutchinson, C.F., Timmermann, B. and Varady, R.G., ed.), 857–864. Proceedings of International Research Development Conference, Tucson, Arizona, Westview Press, Colorado, USA.

This paper reviews the attributes of a variety of trees and shrubs which can assist in the reclamation of arid and semiarid land. The variety of functions that these plants provide can make a significant difference in the social and economic lives of the inhabitants of arid lands. Successful schemes are reviewed on a worldwide basis to illustrate these approaches.

Mesleard, F., Ham, L.T., Boy, V., van Wijck, C., Grillas, P. and van Wijck, C. (1993). Station Biologique de la Tour du Valat, Le Sambuc, Arles 13200, France. Competition between an introduced and an indigenous species: the case of *Paspalum paspalodes* (Michx) *Schribner* and *Aeluropus littoralis* (Gouan) in the Camargue (southern France). Oecologia (Berlin), 94:204–209.

Cuttings of *Paspalum paspalodes* and *Aeluropus littoralis* were grown outdoors in a replacement series with five combinations (0/100, 25/75, 50/50, 75/25 and 100/0) and four salinities (0, 2, 4, and 6 g Cl^{-} L^{-1}). It was found that *P. distichum* was very competitive without salt but that the reverse was true with salt, and there was no significant effect of salinity on mean above- and below-ground growth for *A. littoralis* but a marked decrease for *P. distichum*. Similar results were found under high temperatures in a glasshouse.

Meyer, M.J., Smith, M.A.L. and Knight, S.L. (1989). Department of Horticulture, University of Illinois, Urbana, IL 61801, USA. Salinity effects on St Augustine grass: a novel system to quantify stress response. Journal of Plant Nutrition, 12:893–908

Reports on growth response of St Augustine grass (*Stenotaphrum secundatum*) cultivars 'Seville' (salt-tolerant) and 'Floratam' (salt-sensitive) to NaCl (EC levels of 2.4, 12.4, 22.4, and 32.4 dS/m) in vessels containing individual grass plugs growing in nutrient solutions.

Midgley, S.J., Turnbull, J.W. and Hartney, V.J. (1986). CSIRO, Division of Forest Research, PO Box 4008, Queen Victoria Terrace, Canberra ACT 2600, Australia. Fuel-wood species for salt affected sites. Reclamation and Revegetation Research, 5:285–303.

Fuel-wood shortages in many countries will necessitate the use of degraded land, including salt-affected wasteland. This paper reviews progress in the selection and improvement of trees for salt-affected sites. Characteristics of several species, especially with fuel-wood uses, and including *Eucalyptus camaldulensis, Acacia auriculiformis, Rhizophora* spp., *Prosopis tamarugo, Casuarina equisetifolia* and *Melaleuca quinquenervia*, are presented.

Migunova, E.S. (1966). Ukraine Instit Les. Khoz. Agrolesome, USSR. The root systems of woody species on saline soils in the South Ukraine. Lesovedenie, 6:27–36.

Field studies show that *Tamarix ramosissima* and *T. tetragyna* are able to root successfully in soil horizons that contain up to 6% salts including over 3% SO_4 and 1% Cl. Other species (*Robinia pseudoacacia, Ulmus pinnata-ramosissima, Gleditsia triacanthos, Fraxinus viridis* and *Populus alba*) were less tolerant. (In Russian.)

Mikhiel, G.S., Meyer, S.E. and Pendleton, R.L. (1992). Forage Section, Nubaria Research Station, Agricultural Research Centre, Egypt. Variation in germination response to temperature and salinity in shrubby *Atriplex* species. Journal of Arid Environments, 22:39–49.

This paper reports that significant between and within variation in germination response to temperature and salinity (0–400 mol/m^3 NaCl) was found for 13 seed accessions of *Atriplex canescens, A. confertifolia, A. lentiformis, A. linearis* and *A. polycarpa* collected from the Mojave Desert in Nevada and California.

Miller, T.R. and Chapman, S.R. (1978). Department of Plant and Soil Science, Montana State University, Bozeman, USA. Germination responses of three forage grasses to different concentrations of six salts. Journal of Range Management, 31:123–124.

This paper reports species differences in germination with respect to salt concentrations but not to salt composition.

Milthorpe, P.L. and Newman, J.C. (1979). Department of Soil Conservation, Sydney, Australia. Gypsum assists reclamation of scalded sodic clay soils near Condobolin. Journal of Soil Conservation Service, New South Wales, 35:149–155.

The application of gypsum (up to 2.5 t/ha) to scalded sodic clay soils, together with cultivation, changed the physical characteristics of the soil and allowed increased crop and pasture production through better establishment of desirable species.

Minhas, P.S., Singh, Y.P., Tomar, O.S., Gupta, R.K. and Gupta, Raj K. (1997). Central Soil Salinity Research Institute, Karnal 132 001, India. Saline-water irrigation for the establishment of furrow-planted trees in northwestern India. Agroforestry Systems, 35:177–186.

The growth of *Acacia nilotica* and *Dalbergia sissoo* planted in irrigation furrows near Hissar, Haryana was not reduced when irrigated with saline water of EC 10.5 dS/m. *A. nilotica* grew better than *D. sissoo*. Increasing the period of irrigation from first-year dry season only (recommended) to three years improved tree survival, growth and biomass (two-to-threefold) and water use efficiency (two-to-fourfold). Most of the salts added with saline irrigation were accumulated below the irrigation channels and were pushed laterally during the monsoon season. Water balance and soil salinity (EC_e) data are included.

Minhas, P.S., Singh, Y.P., Tomar, O.S., Gupta, R.K. and Gupta, Raj K. (1997). Central Soil Salinity Research Institute, Karnal 132001, India. Effect of saline irrigation and its schedules on growth, biomass production and water use by *Acacia nilotica* and *Dalbergia sissoo* in a highly calcareous soil. Journal of Arid Environments, 36:181–192.

This paper reports on a study near Hissar, Haryana, with factorial combinations of irrigation water quality (canal water and saline ground water with EC of 10.5 dS/m) and irrigation level [irrigating the furrows at 10 to 20% of cumulative open pan evaporation with standard furrows, or 20% with wider furrows] on growth of *Acacia nilotica* and *Dalbergia sissoo* planted in auger holes filled with the original soil mixed with fertilisers. Saline irrigation reduced biomass growth of *A. nilotica* by 16% and *D. sissoo* by 57%. Data on water use efficiency (derived from expotranspiration estimates and yield) and salt leaching are provided.

Mirbahar, M.B. and Yaseen, S.M. (1996). Drainage and Reclamation Institute, Tando Jam, Pakistan. Disposal of saline drainage water in agro-forestry systems. Proceedings of 6th drainage workshop on drainage and the environment, Ljubljana, Slovenia, April 21–29, 1996. 497–504.

This paper reports the results of using drainage effluent from Pakistan's Left Bank Outfall Drain for growing nine forest tree species on saline–sodic soils. Four species, *Conocarpus lancifolius*, *Eucalyptus camaldulensis*, *Casuarina equisetifolia* and *Prosopis juliflora* had good survival. However, soil salinity and sodicity increased in all the field plots and the watertable rose also in the experimental area due to poor natural drainage.

Misra, C.M. and Singh, S.L. (1981). Forest Research Laboratory, Kanpur, Uttar Pradesh 208024, India. Seed germination studies on three predominant tree species of southern Uttar Pradesh. Annals of Arid Zone, 20:193–198.

Germination of of *Acacia arabica [A. nilotica]*, *Acacia catechu* and *Albizia lebbeck* in mixed salt solutions ($NaCl + Na_2SO_4 + CaCl_2$) was little affected at ECs up to 12, 8 and 12 dS/m, respectively.

Misra, C.M. and Singh, S.L. (1985). Forest Research Laboratory, Kanpur, UP 208024, India. Salt stress studies upon germination of *Sesbania grandiflora*. Nitrogen Fixing Tree Research Reports, 3:2.

Laboratory tests showed that germination was little affected at salt concentrations of 0–8 dS/m, but was sharply reduced at 12 and 15 dS/m.

Misra, C.M. and Singh, S.L. (1987). Forest Research Laboratory, Kanpur, Uttar Pradesh 208024, India. Ecological evaluation of certain leguminous trees for agro-forestry. Nitrogen Fixing Tree Research Reports, 5:5.

This paper reports on the lateral spread of root systems of eight leguminous tree species in an 18-year-old mixed plantation on saline/alkaline soil in south central Uttar Pradesh. Greatest root spread was for *Pongamia pinnata* (9.10 m) and least in *Prosopis juliflora* (1.10 m).

Misra, C.M., Singh, S.L. and Behal, S. (1988). Forest Research Laboratory, Kanpur, Uttar Pradesh 208024, India. Germination of tropical leguminous tree species under high pH. Nitrogen Fixing Tree Research Reports, 6:13.

Germination of presoaked seeds of *Leucaena diversifolia, Prosopis juliflora, Pongamia pinnata* and *Albizia lebbeck* (*A. lebbek*) at pH 9, 10 and 11 (NaOH solutions) was generally good and similar.

Miyamoto, S., Glenn, E.P. and Olsen, M.W. (1996). Texas AandM University Research Center, El Paso, Texas, USA. Growth, water use and salt uptake of four halophytes irrigated with highly saline water. Journal of Arid Environments, 32:141–159.

Reports on lysimeter studies in the coastal desert of Sonora, Mexico on salt tolerance, salt uptake and water use of four halophytes—*Atriplex nummularia, Distichlis palmeri, Batis maritima* and *Suada esteroa*—using saline irrigation water (diluted or concentrated seawater with salt concentrations of 1.2 to 60 g/L). Results indicate that halophytes can be productively grown when irrigation water salinity is < 10 g/L and the leaching fraction is 0.3 or less, but that frequent irrigation at higher leaching fractions may be required at higher salinities.

Moore, J.A., Swingle, R.S., O'Leary, J.W., Glenn, E.P. and Colvin, L.B. (1982). University of Arizona, Tucson, USA. *In vitro* organic matter digestibility of salt-tolerant plants (halophytes). Journal of Animal Science, (Suppl. 1), Abstract 96, p. 520.

This paper reports on two experiments [one under non-saline and the other under saline (0–20 000 pm) conditions] conducted to determine in vitro organic matter disappearance (IVOMD) of halophyte species with potential for domestic crops for use as livestock feeds. Results suggest that growth in saline environments may not have a detrimental effect on the digestibility of halophytes.

Moore, R.T., Breckle, S.W. and Caldwell, M.M. (1972). Department of Range Science and the Ecology Center, Utah State University, Logan, Utah, USA. Mineral ion composition and osmotic relations of *Atriplex confertifolia* and *Eurotia lanata*. Oecologia (Berlin), 11:67–78.

This paper reports on changes in osmotic potential, water content, and concentration of Na, K, soluble Ca, Cl, and SO_4 ions of *Atriplex confertifolia* and *Eurotia lanata* leaf tissue throughout the growing season. *A. confertifolia* accumulated Na, while *E. lanata* accumulated more K. Tissue moisture content and osmotic potential during the season varied more for *Atriplex* than for *Eurotia*, possibly as a result of greater NaCl accumulation by *Atriplex* compared to *Eurotia*.

Morabito, D., Jolivet, Y., Prat, D. and Dizengremel, P. (1996). Laboratoire de Physiologie Vegetale et Forestiere, Universite de Nancy I, BP 239, 54506 Vandoeuvre les Nancy Cedex, France. Differences in the physiological responses of two clones of *Eucalyptus microtheca* selected for their salt tolerance. Plant Science Limerick 1996, 114:129–139.

Cuttings of two *Eucalyptus microtheca* clones were treated in a glasshouse for two months with and without 200 mol/m^3 NaCl. The more salt-tolerant clone had higher root Na concentrations, lower K and Ca concentrations and higher proline content than the less-tolerant clone. Salt-induced synthesis of one predominant polypeptide with an apparent molecular weight of 18 kDa is described.

Morabito, D., Mills, D., Prat, D. and Dizengremel, P. (1994). Laboratoire de Physiologie Vegetale et Forestiere, Universite de Nancy I, BP 239, 54506 Vandoeuvre les Nancy Cedex, France. Response of clones of *Eucalyptus microtheca* to NaCl *in vitro*. Tree Physiology, 14:201–210.

This paper reports on the survival, shoot and root growth, and ion relations of small nodal segments from three *E. microtheca* clones treated with 0–140 mol/m^3 NaCl in a tissue culture system. These three clones had previously been shown to respond differently to high NaCl. Accumulation of Na and Cl and decreased K:Na ratio was correlated with inhibition of growth due to NaCl. (Response of in vitro cultures is not compared to whole plants; refer also Prat and Fathi-Eltai 1990.)

Morris, J., Bickford, R. and Collopy, J. (1994). Centre for Forest Tree Technology, Department of Natural Resources and Environment, Heidelberg, Victoria, Australia. Tree and shrub performance and soil conditions in a plantation irrigated with saline groundwater. Research Report 357, Department of Conservation and Natural Resources, Kew, Victoria, Australia. 41 p.

Reports on field trials established between 1980–2 (including trial described by Morris 1984) and conducted over 10 years in which 22 Australian tree and shrub species (mainly eucalypts) were irrigated with saline water (EC 6.5–13.3 dS/m) on highly saline, sodic soil near Kerang in the irrigation region of northern Victoria. Data on survival, height and foliar Cl are presented and relationships developed with soil salinity. Root distribution of *Eucalyptus camaldulensis* with soil depth (up to 30 cm) and distance from tree is given. Species performance is related to glasshouse responses.

Morris, J., Mann, L. and Collopy, J. (1998). Centre for Forest Tree Technology, Heidelberg, Victoria 3084, Australia. Transpiration and canopy conductance in a eucalypt plantation using shallow saline groundwater. Tree Physiology, 18:547–555.

This paper reports that a 20-year-old *Eucalyptus grandis* and *E. camaldulensis* plantation at Kyabram, Victoria, Australia, known to be using shallow saline ground water, had approximately 300 mm annual water use for both species (on the basis of heat pulse measurements), with a winter minimum and a weak maximum in spring. Data on calculated canopy conductance, vapour pressure deficit response, and the decoupling coefficient (ω) are provided. Resistance to water movement to the roots increased as the soil in the vicinity of the active roots dried as a result of water uptake during the day; the authors conclude that effectiveness of plantations to control rising watertables and salinity as water users will be reduced as the watertable is drawn down in soils of low hydraulic conductivity.

Morris, J.D. (1981). Forest Commission of Victoria, 1 Macarthur Street, Melbourne, Victoria 3002, Australia. Factors affecting the salt tolerance of eucalypts. In: Eucalypt dieback in forests and woodlands (Old, K.M., Kile, G.A. and Ohmart, C.P., ed.), 190–204. Proceedings Conference, CSIRO Division of Forest Research, Canberra, Australia.

A review of current knowledge of salt tolerance and its physiological basis in eucalypts. Includes the author's experimental information on germination (petri dishes) and seedling (glasshouse) response to salinity for several eucalypt species and changes in proline, Na and K concentrations for *Eucalyptus leucoxylon* and *E. globulus*.

Morris, J.D. (1984). Department of Conservation, Forest and Lands, GPO Box 4018, Melbourne, Victoria 3001, Australia. Establishment of trees and shrubs on a saline site using drip irrigation. Australian Forestry, 47:210–217.

This paper reports on a trial with 20 species near Kerang, north central Victoria, Australia, on a saline–sodic clay soil overlying highly saline ground water within 2 m of the surface. High mortality occurred in the first and second years after planting as a result of salinity, frost and other site factors. *Eucalyptus camaldulensis* had best survival and height growth, but *E. astringens, E. brockwayi, E. largiflorens, E. leucoxylon, E. occidentalis, Leptospermum lanigerum* and *Melaleuca lanceolata* also grew satisfactorily. During the first two years an improvement in site conditions (including decreased surface and upper profile salinity and an increase in exchangeable Ca content to 25 cm depth) was found but these effects were attributed to the site treatments rather than the trees.

Morris, J.D. (1995). Centre for Forest Tree Technology, Department of Natural Resources and Environment, Heidelberg, Victoria, Australia. Clonal red gums for Victorian planting. Trees and Natural Resources, 37:26–28.

Reports on the performance of several *Eucalyptus camaldulensis* (river red gum) clones on saline sites in Victoria, Australia.

Morris, J.D. and Collopy, J.J. (1999). Centre for Forest Tree Technology, Department of Natural Resources and Environment, Heidelberg, Victoria, Australia. Water use and salt accumulation by a plantation of *Eucalyptus camaldulensis* and *Casuarina cunninghamiana* with shallow saline groundwater. Agricultural Water Management, 39:205-227.

This paper reports on growth and water use of *Eucalyptus camaldulensis* and *Casuarina cunninghamiana* trees within plots in a 5–8-year-old plantation in northern Victoria. Average single tree water use determined by the heat pulse method varied from less than 10 L/day in winter to over 30 L/day in summer. Mean daily water use was similar for the two species. Modelled results indicated that more than half the tree water uptake (170 to 220 mm/year) was drawn from ground water. Salinity was slight to moderate at depth with a maximum of EC_e of 8 dS/m at around 200 cm. Salt was found to accumulate over 32 months of monitoring even though there was substantial fluctuation in concentrations of salt in the soil solution between 100 and 400 cm.

Morris, J.D. and Thomson, L.A.J. (1983). Research Branch, Forests Commission, Victoria, Australia. The role of trees in dryland salinity control. Proceedings of the Royal Society of Victoria, 95:123–131.

The effects of trees on recharge and discharge control are discussed and selection criteria for choice tree species (mainly *Eucalyptus* and *Pinus*) are considered.

Morton, A. and Marcar, N.E. (1990). Department of Conservation and Land Management, Walpole, WA 6938, Australia. Effect of salinity on frost tolerance of *Eucalyptus camaldulensis*. In: Management of soil salinity in south east Australia (Humphreys, E., Muirhead, W.A. and van der Lelij, A., ed.), 371–372. Proceeding Symposium, Albury, New South Wales, Australia.

This paper reports that 200 mol/m^3 NaCl decreased the frost tolerance of four provenances of both hardened and unhardened *Eucalyptus camaldulensis* seedlings, grown in sand/perlite-filled pots, in a glasshouse, on the basis of conductivity of leaf extracts, and that 100 mol/m^3 increased tolerance to severe freezing temperatures of unhardened seedlings.

Mount, J.H. and Schuppan, D.L. (1978). Department of Agriculture, Kerang, Victoria, Australia. The effects of saline irrigation water and gypsum on perennial pasture grown on a sodic, clay soil at Kerang, Victoria. Australian Journal of Experimental Agriculture and Animal Husbandry, 18:533–538.

Saline effluents [100 to 6000 mg/L total soluble salt (TSS)] were used to irrigate perennial pasture grown on a heavy clay, sodic soil for five consecutive irrigation seasons at Kerang, Victoria. Pasture yields were generally unaffected by salinities up to 1600 TSS, but were reduced above this amount. DM response to gypsum was variable with season. There were no significant interactions between saline irrigations and gypsum applications. *Medicago sativa* (lucerne) and *Lolium perenne* (perennial ryegrass) proved valuable species under saline and sodic conditions. The percentage of *Agropyron elongatum* (tall wheat grass) increased with salinity whereas the clover content decreased.

Moxley, M.G., Berg, W.A. and Barrau, E.M. (1978). Wyoming Department of Environmental Quality, Lander, Wyoming, USA. Salt tolerance of five varieties of wheatgrass during seedling growth. Journal of Range Management, 31:54–55.

Agropyron dasystachyum was shown to be more salt-tolerant than *A. smithii* 'Arriba', 'Barton' and 'Rosana', but not as tolerant as *A. elongatum* 'Jose', in a 6-week glasshouse study at salinities ranging from 0–20 dS/m.

Mudie, P.J. (1974). Foundation for Ocean Research, Scripps Institute of Oceanography, La Jolla, CA 92037, USA. The potential economic uses of halophytes. In: Ecology of halophytes (Reimold, R.J. and Queen, W.H., ed.), 565–597. Academic Press.

This paper describes the potential direct and indirect uses of about 550 halophytic species belonging to 220 genera in 75 different families and includes a table of species that were of potential value when the paper was published in 1974. Since then, extensive studies have been done on some of the genera including *Mesembryanthemum*, *Avicennia*, *Atriplex*, *Salicornia*, *Aster*, *Pluchea*, *Distichlis*, *Tamarix* and many of the species of these genera are now widely used as economic halophytes. The paper also compares relative and absolute growth of cultivated and salt marsh species; since then, however, advances in selection and breeding have improved yields for some species.

Munoz, G.E., Barlow, P. and Pring, R (1997). Laboratorio de Biologia Molecular en Plantas, Instituto de Biologia, Universidad Catolica de Valparaiso, Casilla 4059, Valparaiso, Chile. Effect of free phosphotyrosine on *Prosopis alba* seedlings growing in sea water. Phyton Buenos Aires, 60:83–92.

This paper reports that addition of phosphotyrosine into the medium of solution-cultured seedlings of *Prosopis alba* improved the tolerance (root length) to sea water. It is concluded that this was due to an increase in root tip phosphate and tyrosine both of which are necessary for plant development.

Muthana, K.D. and Jain, B.L. (1984). Central Arid Zone Research Institut, Regional Research Station, Pali, Rajasthan, India. Use of saline water for raising tree seedlings. Indian Farming, 34:37–38.

This paper reports on survival and growth of seedlings of *Prosopis juliflora*, *Eucalyptus* 'hybrid' (*E. tereticornis*), *Cassia siamea*, *Leucaena leucocephala*, *Dichostachys glomerata*, *Colophospermum mopane* and *Acacia aneura* in soil-filled polyethylene bags in a nursery and irrigated with water of salinity 0.6, 2.7, 6.0 or 9.0 dS/m.

Myers, B.J., Benyon, R.G., Theiveyanathan, S., Criddle, R.S., Smith, C.J. and Falkiner, R.A. (1998). CSIRO Forestry and Forest Products, PO Box E4008, Kingston, Canberra ACT 2604, Australia. Response of effluent-irrigated *Eucalyptus grandis* and *Pinus radiata* to salinity and vapour pressure deficits. Tree Physiology, 18:565–573.

This paper reports on an experiment to differentiate between effects of high vapour pressure deficit (VPD) and root-zone salinisation on growth and physiology of *Pinus radiata* and *Eucalyptus grandis* in a five-year-old plantation by irrigating plots with salt-enhanced effluent (EC 2.2 dS/m) or fresh water (0.2 dS/m) for 14 weeks in spring and summer, and then rapidly leaching by over-irrigation with low-salinity effluent. Maximum EC_e in the root zone was 5.8 and 6.8 dS/m in the eucalypt and pine plots, respectively. *E. grandis* was much more sensitive to salinity than *P. radiata*, both with respect to water relations (pre-dawn water potential) and leaf and stem diameter growth. Differences in leaf biomass and Na, K and Cl concentrations, and water use between eucalypts and pines are presented. Salinised eucalypts had a 50% reduction in respiration efficiency, as determined by microcalorimetry (Refer Criddle et al. 1989).

Nahal, I. (1989). Faculte d'Agronomie, Universite d'Alep, Syria. *Eucalyptus* and ecological conditions in the Mediterranean region. Foret Mediterraneenne, 11:3–8.

Includes information on tolerance to high soil pH and salinity of *Eucalyptus* spp. from trials in Syria, Lebanon, Libya, Tunisia, Algeria and Morocco, in 11 different Mediterranean climatic zones. (In French, English summary.)

Naidu, B.P., Jones, G.P., Paleg, L.G. and Poljakoff-Mayber, A. (1987). Department of Plant Physiology, Waite Agricultural Research Institute, University of Adelaide, Glen Osmond, SA 5064, Australia. Proline analogues in *Melaleuca* species: response of *Melaleuca lanceolata* and *M. uncinata* to water stress and salinity. Australian Journal of Plant Physiology, 14:669–677.

This paper reports on accumulation of nitrogen-containing compatible solutes (proline and proline derivatives) in field sampled *Melaleuca* and *Callistemon* species, and in *M. lanceolata* seedlings subjected to water stress or NaCl (200 and 500 mol/m^3) and *M. uncinata* to water stress under growth cabinet conditions. Salinised *M. lanceolata* plants showed considerable osmotic adjustment and maintained tugor potential comparable to that of control plants but had lower relative water content.

National Academy of Sciences (1990). Saline agriculture: salt-tolerant plants for developing countries. National Academy Press, Washington, 143 pp.

An excellent overview of the potential for the growth of salt tolerant plants in developing countries. With contributions from nine countries (USA, India, Pakistan, Israel, Tunisia, Sweden, France, Australia, and Egypt), this book has sections dealing with the production of food, fuel, fodder, fibre and other products.

Neales, T.F. and Sharkey, P.J. (1981). Botany School, University of Melbourne, Parkville, Victoria 3052, Australia. Effect of salinity on growth and on mineral and organic constituents of the halophyte *Disphyma australe* (Soland.) J.M. Black. Australian Journal of Plant Physiology, 8:165–179.

This paper reports that growth of the succulent halophyte *Disphyma australe* was stimulated by NaCl up to 200 mol/m^3 , largely due to changes in leaf number, inorganic ion concentration and water content, and reduced by 30% at 500 mol/m^3. At 500 mol/m^3 NaCl, the inorganic component was 55% of total leaf DM. The contribution of organic solutes to organic potential was small even though proline content was high.

Nema, A.G. and Khare, A.K. (1992). Department of Forestry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur 482 004, India. Effect of waterlogging on some forest plants. Journal of Tropical Forestry, 8:187–188.

This paper reports on apparent symptoms of oxygen deficit in 13 tree species (12–20 months old), waterlogged for two months, at a field site near Jabalpur, India.

Nerd, A. and Pasternak, D. (1992). Institutes for Applied Research, Ben-Gurion University of the Negev, Beer-Sheva, Israel. Growth, ion accumulation and nitrogen fractioning in *Atriplex barclayana* grown at various salinities. Journal of Range Management, 45:164–166.

> The relative growth rate of *Atriplex barclayana* shoots, in solution culture, at 400 mol/m^3 NaCl was less than half that at 50–200 mol/m^3. At high salinity, shoot K and Ca and total N concentrations were much lower than at low salinity. Na and Cl concentrations increased in response to increasing NaCL, particularly at low salinity (50–100 mol/m^3). It was concluded that *A. barclayana* is a highly salt-tolerant plant with leaves rich in N, but high salt concentrations in the leaves and stems even at low salinities markedly reduce its potential as a fodder plant.

Ng, B.H. (1987). Botany Department, University of Queensland, St Lucia, Queensland 4067, Australia. The effects of salinity on growth, nodulation and nitrogen fixation of *Casuarina equisetifolia*. Plant and Soil, 103:123–125.

> In a sand culture experiment, DW of nodules, shoots and roots, and N content of shoots of *Casuarina equisitifolia* increased at 50–100 mol/m^3 NaCl but were markedly lower at 500 mol/m^3. Up to 200 mol/m^3 had little effect on N_2-fixation rate, but the rate decreased to 40% of the control value at 500 mol/m^3.

Niazi, M.L.K., Haq, M.I. and Malik, K.A. (1985). Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan. Salt tolerance studies on ipil ipil (*Leucaena leucocephala* L.) cv. K-8. Pakistan Journal of Botany, 17:43–47.

> Growth of Ipil Ipil (*Leucaena leucocephela*) 'K-8' in pots containing gravel soaked in nutrient solution maintained at EC of 3–20 dS/m, was reduced by 50% at EC of 12.4 dS/m.

Nilsen, E.T., Virginia, R.A. and Jarrell, W.M. (1986). Biology Department, Virginia Polytechnique Institute and State University, Blacksburg, VA 24061, USA. Water relations and growth characteristics of *Prosopis glandulosa* var. *torreyana* in a simulated phreatophytic environment. American Journal of Botany, 73:427–433.

> Using a simulated phreatophytic regime under laboratory conditions, increased ground water salinity (1.4–5.6 dS/m, 2 m depth) resulted in lower plant water potentials and greater osmotic adjustment of *Prosopis glandulosa* var. *torreyana* seedlings without significant increases in leaf Na concentration. Increasing salinity was also associated with higher leaf conductance, reduced leaf size, reduced leaf area/plant and increased root

to shoot ratio. Increasing N availability (0–5 mol/m^3 NO_3) resulted in increased growth rates but did not influence water-use efficiency; net assimilation rate was also increased. Responses observed here were similar to those predicted by field measurements.

Noble, C.L. (1985). Irrigation Research Institute, Department of Agriculture, Tatura, Victoria 3616, Australia. Germination and growth of *Secale montanum* Guss. in the presence of sodium chloride. Australian Journal of Agricultural Research, 36:385–395.

In growth cabinet and glasshouse experiments, NaCl tolerance of *S. montanum* was lowest in terms of shoot DW reduction (64% at 200 mol/m^3 for seedlings in sand-filled pots), followed by emergence (50% reduction at 300 mol/m^3) and germination (50% reduction at 340 mol/m^3). During later plant growth, shoot DW declined at 20 mol/m^3, with 50% decline at about 90 mol/m^3. Osmotic adjustment was facilitated by decrease in tissue water content and accumulation of Na and Cl.

Noble, J.C. and Whalley, R.D.B. (1978). CSIRO, Division of Land Resources Management, Riverina Laboratory, Deniliquin,NSW 2710, Australia. The biology and autecology of *Nitraria L.* in Australia. II. Seed germination, seedling establishment and response to salinity. Australian Journal of Ecology, 3:165–177.

Nitraria billardieri is found in *Atriplex* communities on the Riverine Plain of south-western NSW, Australia. Glasshouse sand culture experiments indicated that both *Nitraria* and *Atriplex vesicaria* could survive at 900 mol/m^3 NaCl and increased DM production at relatively low salinity (300 mol/m^3 NaCl) although growth of *Nitraria* decreased more rapidly as salinity increased.

Nord, E.C., Hartless, P.F. and Nettleton, W.D. (1971). US Department of Agriculture, Riverside, California, California, USA. Effects of several factors on saltbush establishment in California. Journal of Range Management, 24:216–233.

This paper describes the effect of planting depth and date (temperature) on direct seedings of fourwing, allscale, and Gardner saltbushes.

Northington, D.K., Goodin, J.R. and Wangberg, J.K. (1979). Department of Biological Sciences, Texas Technical University, Lubbock, Texas 79409, USA. *Atriplex canescens* as a potential forage crop introduction into the Middle

East. In: Arid land plant resources (Goodin, J.R. and Northington, D.K., ed.), 426–429. Proceeding of International Arid Land Conference on Plant Resources, Texas Technical University, Texas, USA.

> The perfomance of *Atriplex canescens* is described on the basis of various criteria (including productivity, agronomy, usefulness as animal feed and degree of drought/salt tolerance) and its introduction in Egypt is also discussed.

Norton, B.E. (1986). Department of Range Science, Utah State University, Logan, Utah 84322, USA. Guidelines for determining stocking rates for saline shrubland. Reclamation and Revegetation Research, 5:403–422.

> This paper reviews conventional procedures for vegetation trend assessment and describes an alternative method based on analysis of plant population dynamics, and advocates that monitoring vegetation change is a better way to evaluate optimum stocking rate than animal-based methods.

Oertli, J.J. and Muller, D. (1985). Department of Crop Science, Swiss Federal Institute of Technology (ETH), Zurich, Switzerland. Competition between two grass species under salinity and alkalinity stress. Agrochimica, 29:445–458.

> In the Hungarian Puszta, *Festuca pseudovina* grows on elevated plateaus, on soils which are neutral to moderately acid and salt-free, whilst *Puccinellia limosa* grows on flat-bottomed basins on the exposed B-horizon which are salt-affected and highly alkaline. Results of a glasshouse experiment in which *P. limosa* and *F. pseudovina* were grown as monocultures and in mixtures with three NaCl (1, 10, or 100 mol/m^3) and pH levels (7, 8.5 or 10) treatments confirmed that *P. limosa* tolerated saline and alkaline conditions whereas *F. pseudovina* preferred neutral conditions without salt.

Okusanya, O.T. and Ungar, I.A. (1984). Department of Botany, Ohio University, Ohio, Athens, Ohio 45701, USA. The growth and mineral composition of three species of *Spergularia* as affected by salinity and nutrients at high salinity. American Journal of Botany, 71:439–447.

> This paper reports on the effects of salinity and nutrition on growth and mineral composition of *Spergularia marina*, *S. rupicola* and *S. rubra* in sand culture. Growth of *S. marina* and *S. rupicola* under high salinity increased with the addition of most nutrients, while growth of *S. rubra* was further reduced. High salinity resulted in a marked reduction in leaf Ca and K concentrations and an increase in Na and Cl concentrations.

O'Leary, J.W. (1979). Environmental Research Laboratory, University of Arizona, Tucson, Arizona 85721, USA. Yield potential of halophytes and xerophytes. In: Arid land plant resources (Goodin, J.R. and Northington, D.K., ed.), 574–581, Proceedings of International Arid Land Conference on Plant Resources, Texas Technical University, USA.

The paper describes the growth potential and aspects of physiology of halophytes under salt and water stress and also compares them with xerophytic plants. A particular focus of discussion is salt compartmentation in vacuoles to avoid toxicity to cells and the energy requirements for this.

O'Leary, J.W. (1984). Environmental Research Laboratory, University of Arizona, Tucson, Arizona 85706, USA. The role of halophytes in irrigated agriculture. In: Salinity tolerance in plants: strategies for crop improvement (Staples, R.C. and Toenniessen, G.H., ed.), 285–300. John Wiley & Sons, Inc., New York, USA.

This paper describes the potential of halophytes to meet energy requirements versus the limitations and drawbacks caused by saline water irrigation on long term bases along with economic aspects. It is suggested that (i) their value as animal feeds is restricted because of high salt contents, and that other uses (e.g. as seed crops, fuel crops, landscape plants etc.) are possible, (ii) reclamation is not possible because of limited net removal of salts from soil (with or without saline water irrigation), and (iii) strategies to overcome these and other drawbacks include screening of other wild halophytes for beneficial properties, increasing seed supply and genetic improvement. Aspects of saline water management for halophytic production including economic feasibility are discussed.

O'Leary, J.W. (1986). Environmental Research Laboratory, University of Arizona, Tucson, Arizona, USA. A critical analysis of the use of *Atriplex* species as crop plants for irrigation with highly saline water. In: Prospects for biosaline research (Ahmad, R. and San Pietro, A., ed.), 415–432. Proceedings of the US–Pakistan Biosaline Research Workshop, 22–26 September 1985, Department of Botany, University of Karachi, Karachi, Pakistan.

This paper reports on the growth, crude protein content and salt concentration of ten *Atriplex* species under irrigation with water of salt concentration of up to 40 000 ppm. DM production (17–23 t DM/ha for some species), crude protein (10–20%) and in vitro digestibility (50–87%) compared favourably with conventional forage crops such as lucerne. However, salt accumulation in the leaves was high, sometimes up to 30%

of the DW, and that imposes constraints on use as animal feed. In spite of the high amount of salt accumulated by halophytes, it is argued that they offer little promise for use as 'salt harvesters' in reclamation of salinised farmland because the amount of salt accumulated by the plants typically is far less than the amount of salt added in irrigation water.

O'Leary, J.W. (1988). Environmental Research Laboratory, University of Arizona, Tucson, Arizona, USA. Saline environments and halophytic crops. In: Arid lands: today and tomorrow (Whitehead, E.E., Hutchinson, C.F., Timmermann, B. and Varady, R.G., ed.), 773–790. Proceedings of the International Research Development Conference, Tucson, Arizona. Westview Press, Colorado, USA.

This paper reports on prospects for the use of halophytes as forage and seed crops. Since nutritional properties of halophyte seed compare favourably with present grain and oilseed crops, and forage tissue is often high in salt, it is suggested that the greater promise for halophytes is as seed crops.

O'Leary, J.W., Glenn, E.P. and Watson, M.C. (1985). Environmental Research Laboratory, University of Arizona, Tucson, AZ 85706, USA. Agricultural production of halophytes irrigated with seawater. Plant and Soil, 89:311–321.

This paper provides an update on development of halophytes as forage and fodder crops and suggests that since seeds of halophytes do not accumulate salt any more than do those of glycophytes, the greatest promise for seawater-irrigated halophytes probably will be as seed crops. The seeds of many halophytes have high protein and oil contents and compare favourably with traditional oilseed crops. It is predicted that operational-scale irrigation of halophytes for seed and biomass production will soon occur.

Oltman, D. (1994). Salting it away. California Farmer (January):10–22.

This article reviews efforts in California (USA) on reuse of saline drainage water to irrigate trees and salt-tolerant plants as one of the possible solutions for the San Joaquin Valley drainage problems.

Omran, T.A. (1986). Department of Forestry and Wood Technology, Alexandria University, Egypt. Salinity effects on growth and mineral content of some *Eucalyptus species*. Alexandria Journal of Agricultural Research, 31:449–459.

This paper reports that *Eucalyptus occidentalis* was the most salt-tolerant species tested in a pot study with 0–3% NaCl (w/w) involving *E. camaldulensi, E. brockwayi, E. gomphocephala, E. kondininensis, E. microtheca, E. occidentalis, E. rudis* and *E. sideroxylon*. Data on foliar Na, K, Ca and Mg are provided.

Omran, T.A., Badran, O.A. and El-Sayed, A.B. (1979). Department of Forestry and Wood Technology, Faculty of Agriculture, University of Alexandria, Egypt. Growth of some timber tree seedlings irrigated with saline water. Alexandria Journal of Agricultural Research, 27: 725-731.

This paper reports on a pot study with irrigation water (300–3000 ppm mixture of NaCl, $CaCl_2$ and $MgCl_2$ to give SAR of 10) using seedlings of *Casuarina cunninghamiana, Eucalyptus camaldulensis, Cupressus sempervirens* and *Taxodium distichum*.

Oram, R.N. (1982). Divison of Plant Industry, CSIRO, Canberra ACT 2601, Australia. *Agropyron elongatum* (Host.) Beauv. (tall wheat grass) cv. Tyrrel (Reg. No. A-18a-1). Journal of the Australian Institute Agricultural Science, 48:184–186.

Reports that cv. Tyrrel (PI368851), a moderately palatable Australian selection of Largo, has high salt tolerance and shows good growth and persistence on highly alkaline soils and saline seepage areas.

Osmond, C.B., Björkman, O. and Anderson, D.J. (1980). Research School of Biological Sciences, The Australian National University, PO Box 475, Canberra ACT 2601, Australia. Physiological processes in plant ecology: towards a synthesis with *Atriplex*. Springer-Verlag, Berlin. 467 p.

In the first part of this book, chapters are devoted to (i) habit and morphology, species geographical distribution and systematics, (ii) intra-specific variation morphological and physiological aspects of genecological differentiation, (iii) genetic and evolutionary relationships and (iv) studies of communities. The second part is related to the interactions between individual plants and the environment. Chapters are devoted to (i) germination and seedling establishment in relation to fruit, temperature, light, gas exchange and other factors, (ii) the absorption of ions and nutrients, responses to salinity (including discussions on the process of salt exclusion, salt accumulation and salinity tolerance, the selectivity of Na and K) and mineral recycling, (iii) growth in response to water transport and water stress, (iv) different aspects of photosynthesis, and (v) productivity in relation to such factors as light, temperature, mineral nutrition and salinity, water and plant communities.

Oxley, R.E. (1979). CSIRO, Division of Land Resources Management, Private Bag, PO, Deniliquin, NSW, 2710, Australia. The perennial chenopod pasture lands of Australia. In: Studies of the Australian arid zone. IV. Chenopod shrublands (Graetz, R.D. and Howes, K.M.W., ed.), 1–4. Proceeding of Symposium, Deniliquin, NSW, Australia.

The present extent of the perennial chenopod shrub communities within Australia is described and mapped. Species of *Atriplex, Maireana, Rhagodia* and *Chenopodium* are depicted according to their relative abundance, aerial extent and whether or not they occur as an understorey.

Panchaban, S., Katawatin, R. and Srisataporn, P. (1989). Department of Soil Science, Faculty of Agriculture, Khon Kaen University, Thailand. Effect of salinity on growth of fast growing trees. Kaen Kaset Khon Kaen Agricultural Journal, 17:91–99.

In an experiment in which seedlings in soil-filled pots were treated with 0–6% NaCl, the order of salt tolerance was: makam-tet (*Pithecellobium dulce*) ≅ tamarind (*Tamarindus indica*) > eucalyptus (*Eucalyptus camaldulensis*) > sadao (*Azadirachta indica*) ≊ giant leucaena (*Leucaena leucocephala* > cashew nut (*Anacardium occidentale*).

Parker, D.R., Page, A.L. and Thomason, D.N. (1991). Department of Soil and Environental Science, University of California, Riverside, CA 92521, USA. Salinity and boron tolerances of candidate plants for the removal of selenium from soils. Journal of Environmental Quality, 20:157–164.

Choosing Se-accumulating species is advantageous when planted to use saline agricultural drainage water from the west side of the San Joaquin Valley, California which is often contaminated with Se. A number of cultivars or lines of species from the genera *Austragalus, Leucaena, Medicago, Trifolium, Elymus, Elytrigia, Festuca, Leymus, Oryzopsis, Psathyrostachys, Puccinellia* and *Sporobolus* with Se accumulating ability were screened for tolerance to salinity and B in solution culture. EC_{50} (EC required to reduce germination by 50%) ranged from 50 to 30 dS/m. The five most salt-tolerant species—*Astragalus bisulcatus*, *A. racemosus*, *Elytrigia pontica* [*Agropyron elongatum*], *Puccinellia distans*, and *Sporobolus airoides*—had 50% yield reduction at >20 dS/m and were unaffected by B concentrations up to 4.0 mol/m^3 during seedling growth.

Parrondo, R.T., Gosselink, J.G. and Hopkinson, C.S. (1978). Department of Botany, Louisiana State University, Baton Rouge, Louisiana 70803, USA. Effects of salinity and drainage on the growth of three salt marsh grasses. Botanical Gazette, 139:102–107.

This paper reports on studies with seedlings of *Spartina alterniflora*, *S. cynosuroides*, and *Distichlis spicata* treated with NaCl in both solution culture and a 50–50 sediment–sand mixture under constantly flooded or drained conditions (*S. alterniflora* and *S. cynosuroides* only). Based on DW, *D. spicata* was the most salt-tolerant, with *S. alterniflora* and *S. cynosuroides* similar. In general, NaCl reduced shoot more than root growth. Roots of *S. alterniflora* grew better under flooded conditions, while overall growth of *S. cynosuroides* was much better under drained conditions. These findings are compared with field observations on the relative distribution of these species in the salt marsh.

Parsons, R.F. (1968). Botany School, University of Melbourne, Parkville, Victoria 6052, Australia. Effects of waterlogging and salinity on growth and distribution of three mallee species of *Eucalyptus*. Australian Journal of Botany, 16:101–108.

This paper reports on the responses of *Eucalyptus incrassata*, *E. diversifolia*, and *E. oleosa* to waterlogging and salinity (increasing NaCl concentrations) in pot experiments. Similar reductions in plant DW under waterlogging were found for these species, but *E. incrassata* had much better survival than *E. diversifolia* at high NaCl.

Passioura, J.B., Ball, M.C. and Knight, J.H. (1992). CSIRO, Division of Plant Industry, GPO Box 1600, Canberra 2601, Australia. Mangroves may salinise the soil and in so doing limit their transpiration rate. Functional Ecology, 6:476–481.

This paper provides a theoretical argument that salt will concentrate around roots of mangroves growing in poorly drained intertidal muds. It is concluded that salt is likely to become so concentrated that it will severely limit the rate of water uptake by the roots, and that the limiting rate corresponds to a transpiration rate of about 1 mm/day. It is proposed that mangroves may be adapted to low transpiration rates

despite their growing with an apparently unlimited water supply, and that they may be unable to sustain initially vigorous growth after colonising freshly deposited muds.

Pasternak, D., Danon, A. and Aronson, J.A. (1985). The Boyko Institute for Agricuture and Applied Biology, The Institutes for Applied Research, Ben-Gurion University of the Negev, Beer-Sheva, Israel. Developing the seawater agriculture concept. Plant and Soil, 89:337–348.

This paper reports on experiments conducted near the Mediterranean seashore on seawater irrigation of halophytic fodder plants. Of 125 species tested since 1982, 26 have performed at least as well under irrigation with 100% sea water as under irrigation with 15% sea water. Best species were *Atriplex lentiformis, A. barclayana, A. atacamensis, A. undulata* and an *Atriplex* species from Camarones in Argentina.Yield, ash content, crude protein and feeding trial data are given for *A. nummalaria* (50% yield decline at 100% of 15% sea water). The authors conclude that low feed intake is the main limiting factor in the development of seawater-irrigated fodder.

Pastridge, T.R. and Wilson, J.B. (1987). Department of Botany, University of Otago, PO Box 56, Dunedin, New Zealand. Salt tolerance of salt marsh plants of Otago, New Zealand. New Zealand Journal of Botany, 25:559–566.

Of 29 halophytic species from salt marshes of Otago examined in solution culture, most could not grow in sea water (3.5% NaCl), although a small number could grow in hypersaline conditions of up to 7.5% NaCl, and whilst some species required salt (highest 1.5% NaCl) for maximum growth, most grew best in fresh water. In general, the salt tolerance of species decreased from the lower to the upper marsh, which generally parallels salinity changes.

Patcharapreecha, P., Goto, I. and Ninaki, M. (1990). Khon Kaen University, Khon Kaen, Thailand. Salt-affected soils in northeast Thailand: their characterization and management. In: Transactions 14th International Congress Soil Science, Kyoto, Japan. Vol. VII, 192–197.

This paper deals mainly with soil characterisation and management, but some information is provided to indicate that lime and mulching improved yields of Rhodes grass (*Chloris gayana*) and *Stylosanthes hamata*, but that gypsum was not effective, on saline soils.

Patel, V.J. and Moulik, T.K. (1988). Fuel, fodder and food from wastelands through agroforestry. In: Food energy nexus and ecosystem (Moulik, T.K., ed.), 394–411, Proceedings of Second International Symposium, Food Energy Nexus and Ecosystem, New Delhi, India. Oxford and IBH Publishing Co. Pvt. Ltd.

This paper presents biological and socio-economic criteria for selecting tree species for saline soils, and suggests species for soils of varying salinity.

Pathak, P.S. and Gupta, S.K. (1986). Indian Grassland and Fodder Research Institute, Jhansi 284003, India. Preliminary evaluation of *Leucaena* populations on saline sodic wastelands. Leucaena Research Report, 7:66.

This paper provides data on survival and growth of seedlings of seven cultivars of *Leucaena leucocephala*, one of *L. diversifolia* and two hybrids between these species planted in saline–sodic soils of pH 9.5 with lime concretions over the surface.

Pearce-Pinto, G.V.N., van der Moezel, P.G. and Bell, D.T. (1990). Department of Botany, University of Western Australia, Nedlands, WA 6009, Australia. Seed germination under salinity stress in Western Australian species of *Eucalyptus*. Seed Science Technology, 18:113–118.

Seed of 17 *Eucalyptus* species was collected from several mother trees in areas thought to be affected by salinity. Most were relatively salt-sensitive during germination (with < 50% reduction at 50 mol/m^3 NaCl); *E. occidentalis*, *E. stenanthina*, *E. sargentii* and *E. loxophleba* were exceptions. Tolerance to salinity during germination and seedling growth were not related, nor between salt tolerance at seed germination and the salinity of the surface soil near the mother trees at the time of seed collection.

Pepper, R.G. and Craig, G.F. (1986). Department of Agriculture, Jarrah Road, South Perth, WA 6151, Australia. Resistance of selected *Eucalyptus* species to soil salinity in Western Australia. Journal of Applied Ecology, 23:977–987.

Twelve *Eucalyptus* species were assessed for their potential use in revegetation of salt affected land near Brookton, Western Australia (425 mm AAR). *E. occidentalis*, *E. sargentii* and *E. platypus* (var. *heterophylla*).performed best at high soil salinities: these species survived and grew well at EC_e >30 dS/m. *E. spathulata* and *E. diptera* were also very salt-tolerant species but they had very poor survival. *E. wandoo*,

E. salmonophloia, E. kondininensis and *E. loxophleba* were moderately salt-tolerant species, whilst *E. rudis, E. camaldulensis* and *E. robusta* were the most salt sensitive. Poor performance for the latter two species may have been partly due to use of inappropriate provenances.

Perry, L. and Williams, K. (1996). Department of Botany, University of Florida, Gainesville, FL 32611-8526, USA. Effects of salinity and flooding on seedlings of cabbage palm (*Sabal palmetto*). Oecologia (Berlin), 105: 428–434.

This paper describes field and greenhouse studies conducted to determine the effect of variation in tidal water salinity on regeneration failure of *Sabal palmetto* under tidal flooding along the coast of North Florida and Georgia, southern USA. Survival of field-grown seedlings was higher when flooded with low-salinity (3 000 ppm) compared with high-salinity (up to 23 000 ppm) water. Effect of increasing salinity and inundation on net CO_2 assimilation rates of glasshouse-grown seedlings related well with field performance.

Pezeshki, S.R. (1990). Laboratory for Wetland Soils and Sediments, Centre for Wetland Resources, Louisiana State University, Baton Rouge, Lousiiana 70803-7511, USA. A comparative study of the response of *Taxodium distichum* and *Nyssa aquatica* seedlings to soil anaerobiosis and salinity. Forest Ecology and Management, 33/34:531–541.

Seedlings of *Taxodium distichum* (baldcypress) and *Nyssa aquatica* (water tupelo), both highly flood-tolerant species of the Mississippi River delta, were treated with 51 mol/m^3 salt (synthetic sea salt) with and without flooding (redox potential −160 mV-anaerobic) under greenhouse and laboratory conditions. Although net photosynthesis was reduced more for *T. distichum* under flooding and salt plus flooding, both species were equally sensitive to combined stresses (about 55% reduction) in terms of height growth and it is expected that seedling survival and regeneration will be reduced with frequent saltwater intrusion.

Philipp, K.R. and Gallagher, J.L. (1985). University of Delaware, Newark, Delaware 19716, USA. Evapotranspiration from two potential halophytic crop species. In: Proceeding of National Conference on Advances in Evapotranspiration, Chicago, Illinios, USA. 4 p.

The paper describes the water-use efficiency (WUE) of two halophytic species, *Atriplex triangularis* and *Kosteletzkya virginica*, grown in lysimeters and irrigated with fresh and saline water. The WUE values decreased with increasing salinity in *K. virginica* and increased in *A. triangularis*, indicating different tolerance mechanisms in the two species.

Philipson, J.J. and Coutts, M.P. (1980). Forestry Commision, Northern Research Station, Roslin, Midlothian, UK. The tolerance of tree roots to waterlogging. 4. Oxygen transport in woody roots of Sitka spruce and Lodgepole pine. New Phytologist, 85:489–494.

This paper reports on the use of indigo-carmine solution to demonstrate internal oxygen transport in woody roots of both Sitka spruce and Lodgepole pine. Results are discussed in relation to the survival of tree roots when waterlogging of both primary and woody roots occurs. (One in a series of papers; refer also Coutts 1982.)

Philipupillai, J. and Ungar, I.A. (1984). Department of Botany, Ohio University, Athens, Ohio 45701, USA. The effect of seed dimorphism on the germination and survival of *Salicornia europaea* L. populations. American Journal of Botany, 71:542–549.

This paper includes information on germination and survival of *Salicornia europaea* in response to salinity in the field.

Phleger, C.F. (1971). Scripps Institution of Oceanography, University of California at San Diego, La Jolla, CA 92037, USA. Effect of salinity on growth of a salt marsh grass. Ecology, 52:908–911.

This paper provides data on growth, protein and lipid content and Na and K concentrations for the coastal salt marsh grass, *Spartina foliosa*, grown in nutrient solution at different salinities (0–125% sea water) for eight weeks.

Plaut, Z., Bachmann, E. and Oertli, J.J. (1991). Institut of Soils and Water, ARO, The Volcani Centre, Bet Dagan 50250, Israel. The effect of salinity on light and dark CO_2 fixation of salt-adapted and unadapted cell cultures of *Atriplex* and tomato. Journal of Experimental Botany, 42:531–535.

NaCl up to 400 mol/m^3 in cell cultures of *Atriplex portulacoides* and up to 50 mol/m^3 for tomato, enhanced the rate of light-induced CO_2 fixation in unadapted cells, but higher salt concentrations led to a marked decline in CO_2 fixation in both species. However, in salt-adapted *Atriplex* cells, no decline in the rate of light CO_2 fixation was seen even at 500 mol/m^3 NaCl. Dark CO_2 fixation was approximately 40% of light fixation without NaCL and enhanced with increasing salinity.

Poljakoff-Mayber, A. and Gale, J. (ed.) (1975). Department of Botany, The Hebrew University of Jerusalem, Jerusalem, Israel. Plants in saline environments. Springer-Verlag, Berlin. 213 p.

This book is divided into three parts. The first part deals with the distribution of saline areas and halophytic vegetation throughout the world, economic importance and possible uses of saline soils and of halophytes, severity of the salinity problem in modern agriculture, and possible practices which will enable the farmer to cope with and combat the damage caused by salinity. The second deals with various aspects of soil, water and salinity (soil salinity, salinity in water—especially in irrigation water—and factors influencing distribution of soluble salts in the natural environment and the redistribution which results from environmental disturbances). The third part discusses different responses of plants to salinity (including water uptake and water balance, gas exchange–transpiration, photosynthesis and respiration, optical properties of leaves, ion uptake, metabolic pathways, growth, morphology and anatomy of the plant and balance of hormones).

Prasad, R. (1992). State Forest Research Institute, Jabalpur, MP 482 008, India. Use of acacias in wastelands reforestation. Journal of Tropical Forestry, 8:3–17.

A review is presented of results obtained in India on the use of *Acacia* spp. (and other species) in reclamation of various types of mined areas and their overburden dumps, saline and alkaline soils, arid and semiarid areas, lateritic soils, and other wasteland areas.

Prat, D. and Fathi-Ettai, R.A. (1990). Lab. de Sciences Forestieres, ENGREF, 14, rue Girardet, 54042 Nancy, France. Variation in organic and mineral components in young *Eucalyptus* seedlings under saline stress. Physiologia Plantarum, 79:479–486.

This paper reports that Na, K, Ca and sugar contents of leaves and stems increased and water content decreased in glasshouse-grown seedlings of salt-sensitive *Eucalyptus alba* and salt-tolerant *E. camaldulensis* and *E. microtheca* treated for one month with NaCl (100 to 500 mol/m^3). Significant variation was found for five provenances of *E. microtheca* treated with 300 and 600 mol/m^3 NaCl, in terms of survival, leaf Cl and stem Ca concentrations, leaf amino acid and leaf proline contents.

Price, D.L., Donart, G.B. and Southward, G.M. (1989). Department of Animal and Range Sciences, New Mexico State University, Las Cruces 88003, USA. Growth dynamics of fourwing saltbush as affected by different grazing management systems. Journal of Range Management, 42:158–162.

This paper reports on growth responses of leaders of fourwing saltbush during a three-year study in a short duration grazing system, a four-year pasture rotation system, and in ungrazed exclosures.

Priebe, A. and Jager, H.J. (1978). Justus-Liebig University, 6300 Giessen, German Federal Republic. Influence of NaCl on growth and ion content of plants differing in salt tolerance. Angewandte Botanik, 52:331–341.

In a glasshouse experiment, ranking for salt tolerance was: *Atriplex halimus* > *A. calotheca* > *A. nitens* > *Vicia faba*. All species adjusted osmotically to soil salinity by uptake of Na and especially Cl. *Atriplex* species took up Na and Cl only at low salt levels and limited salt absorption at high salt levels, in contrast to *V. faba*. Data on K, Ca, Mg, SO_4 and N concentrations are provided. (In German, English abstract.)

Qadar, A. (1987). Central Soil Salinity Research Institute, Karnal 132 001, India. Effect of sodicity on growth and chemical composition of *Diplachne fusca* (Linn.) P. Beauv, an alkali halophyte. Indian Journal of Plant Physiology, 30:52–59.

This paper reports that *Diplachne [Leptochloa] fusca* is highly tolerant to sodicity, with DM increase up to pH 9.8. Younger laminae, leaf sheath and stem tissue had lower Na concentrations than older ones, with the reverse for K and P. The leaf sheath had higher concentrations of Na, K and P than laminae and stems.

Qadar, A. (1992). Central Soil Salinity Research Institute, Karnal 132001, India. Influence of cations on the growth of *Atriplex amnicola*. Indian Journal of Plant Physiology, 35:48–55.

This paper reports growth and ion concentration responses of solution-cultured, clonal *Atriplex amnicola* plants to treatment with different NaCl:KCl ratios at 75 mol/m^3.

Qadir, M., Qureshi, R.H., Ahmad, N. and Ilyas, M. (1996). Department of Soil Science, University of Agriculture, Faisalabad, Pakistan. Salt-tolerant forage cultivation on a saline-sodic field for biomass production and soil reclamation. Land Degradation and Development, 7:11–18.

This paper reports that the capacity of forage crops to reclaim saline–sodic soils is directly related to their biomass potential. Four salt- and/or sodicity-tolerant forage species, (sesbania (*Sesbania aculeata*), kallar grass (*Leptochloa fusca*), millet rice (*Echinochloa colona*) and finger millet (*Eleusine coracana*)), were planted on a calcareous saline–sodic site (EC_e = 9.6–11.0 dS/m, SAR = 59.4–72.4) with and without gypsum (equivalent to 100% of the gypsum requirement for a 15 cm soil layer). Capacity for soil amelioration was in the order: *S. aculeata* + gypsum > *E. colona* > *E. coracana* > control (no gypsum or crop). *S. aculeata* produced 32.3 t forage/ha, followed by *L. fusca* (24.6 t/ha), *E. colona* (22.6 t/ha) and *E. coracana* (5.4 t/ha).

Qureshi, J.A., Zafar, Y. and Malik, K.A. (1988). Nuclear Institute for Agriculture and Biology, PO Box 128, Faisalabad, Pakistan. *Klebsiella* sp. NIAB-I: a new diazotroph, associated with roots of kallar grass from saline sodic soils. Plant and Soil, 110:219–224.

Reports on the isolation of an N-fixing organism containing a plasmid from the rhizosphere fraction of *Leptochloa fusca* (kallar grass) growing on saline soils in the Punjab, Pakistan. Maximum N_2 fixation in batch cultures occurred with 100 mol/m^3 NaCl at pH 8.0 and 35°C with subsequent decrease, and growth continued at 1000 mol/m^3 under aerobic conditions. On the basis of protein electrophoretic pattern, physiological characteristics, DNA-relatedness, and better growth in the presence of high NaCl concentration, the authors conclude that this strain is a new species of *Klebsiella*.

Qureshi, R.H. and Barrett-Lennard, E.G. (1998). Department of Soil Science, University of Agriculture, Faisalabad, Pakistan and Natural Resources Management Services, Agriculture Western Australia, South Perth, WA, Australia. Saline agriculture for irrigated land in Pakistan: a handbook. Australian Centre for International Agricultural Research, Canberra, Australia.

This book is a very useful account of important biophysical considerations involved in the productive use of salt-affected land in Pakistan, drawing on outcomes of recent research in Pakistan and Australia. Chapters deal with (i) Pakistan and its salinity problem, (ii) three approaches to managing saline, sodic and waterlogged soils, (iii) classification, sampling and analysis of salt-affected soils and water, (iv) salt and waterlogging—effects on plants, (v) crops and grasses for salt-affected land, (vi) trees for salt-affected land, (vii) saltbushes for highly salt-affected land, and (viii) building farming systems—integrating the elements.

Qureshi, R.H., Salim, M., Abdullah, M. and Pitman, M.G. (1982). Department of Soil Science, University of Agriculture, Faisalabad, Pakistan. *Diplachne fusca*: an Australian salt-tolerant grass used in Pakistani agriculture. The Journal of the Australian Institute of Agricultural Science, 48:195–199.

This article reviews aspects of the use of this salt-tolerant species in Pakistan and its tolerance to salinity, sodicity and waterlogging.

Raj, D. (1990). Tata Energy Research Institute, New Delhi 110 003, India. Experiences in waste land development: a case study. In: Renewable energy and environment (Mathur, A.N. and Rathore, N.S., ed.), 139–143. Proceedings of the National Solar Energy Convention, Udaipur, India.

This paper describes the success of planting several tree species onto saline–alkaline ('kalar') community land in Haryana (India). *Acacia nilotica* (kikar), *A. nilotica* var. *cupressiformis* (ramkanti babul), *Dalbergia sissoo* (shisham) and *Prosopis juliflora* (mesquite) were amongst the best performing species.

Rajput, P. and Sen, D.N. (1991). Department of Botany, University of Jodhpur, Jodhpur 342001, Rajasthan, India. Salt secretion in some exotic species of *Atriplex* in semi-arid zone of Rajasthan. Research Bulletin, Punjab University Science, 42:37–45.

This paper reports on distilled water leachable, retained and total salts in young and mature leaves of *Atriplex lentiformis*, *A. amnicola* and *A. halimus* collected during different seasons.

Ramakrishnan, P.S. and Krishnan, K. (1973). Department of Botany, Punjab University, Chandigarh 160014, India. Adaptation of *Cynodon dactylon* (L.) Pers. populations towards sodium salts. Tropical Ecology, 14:219–227.

This paper reports that *Cynodon dactylon* plants derived from alkaline soil differed from those from non-alkaline normal soil in growth response, rooting ability and succulence when treated with NaCl or $NaSO_4$ in sand-filled pots. Significant differences were found between populations from alkaline soils. In some cases, these differences could be related to local site conditions.

Ramani, S,, Joshua, D.C. and Shaikh, M.S. (1989). Nuclear Agriculture Division, Bhabha Atomic Research Centre, Trombay, Bombay 400085, India. Response of three *Sesbania* species to salinity when grown hydroponically. Journal of Plant Nutrition, 12:1447–1455

Shoot and root growth of *Sesbania rostrata*, *S. aculeata* and *S. speciosa* in solution culture was significantly reduced at 100 mol/m^3 NaCl, but *S. speciosa* was least salt-tolerant. Absorption and translocation of Na and Cl in 15-day-old seedlings were studied using ^{22}Na and ^{36}Cl-labelled NaCl. Differences in uptake and transport of Na and Cl are related to differences in salt tolerance of *S. rostrata* and *S. aculeata*.

Rana, R.S. and Parkash, V. (1987). Central Soil Salinity Research Institute, Karnal 132001, India. Floristic characterisation of alkali soils in northwestern India. Plant and Soil 99:447–451.

This paper reports on a detailed vegetation survey of 40 ha of alkali soil in north western India as well as a glasshouse experiment to determine response of eight halophytes to soil alkalinity (pH). It is concluded that *Sporobolus marginatus*, *S. coromandelianus*, *Diplachne [Leptochloa] fusca* and *Chloris barbata* are suitable indicators of highly alkaline soils.

Rao, D.L.N. (1985). Central Soil Salinity Research Institute, Karnal 132 001, India. Sesbania for green manuring. In: Better farming in salt affected soils (Abrol, I.P. and Parshad, R., ed.), No. 6, 7 p., CSSRI, Karnal, India.

This paper presents information on the long-term effects of green manuring on ameliorating alkali or saline soils with *Sesbania*.

Rao, D.L.N. and Gill, H.S. (1993). Central Soil Salinity Institute, Karnal 132 001, Haryana, India. Nitrogen fixation, biomass production, and nutrient uptake by annual *Sesbania* species in an alkaline soil. Biology and Fertility of Soils, 15:73–78.

This paper provides data on nodulation, N_2 fixation (acetylene reduction assay), DW of roots and shoots, woody biomass production, and nutrient concentrations of 17 accessions of annual *Sesbania* species from field trials on alkaline soil (mean pH 8.7 and $EC_{1:2}$ 0.25 dS/m). All accessions nodulated well and average plant N concentration was 5.2% with most N occurring in the stem. Best performance was by accessions of the *S. cannabina* complex. *S. rostrata* had poor root nodulation but exhibited excellent stem nodulation. Mean green matter production was 26.0 Mg (5.9 Mg DM) per ha and N uptake was 158 kg/ha, 54 days after sowing. Average woody biomass of six accessions at maturity, 200 days after sowing, was 19.9 Mg/ha.

Raper, G.P. (1998). Department of Agriculture, Baron Hay Court, South Perth, Western Australia 6151. Agroforestry water use in Mediterranean Regions of Australia. Water and salinity issues in agroforestry No. 2. Publication No. 98/63, Rural Industries Research and Development Corporation, Canberra, 71 pp.

This is a comprehensive review of tree water use in Mediterranean climates of southern Australia and the implications of tree water use on ground water.

Reddell, P., Foster, R.C. and Bowen, G.D. (1986). CSIRO Division of Soils, Private Bag 2, Glen Osmond, SA 5064, Australia. The effects of sodium chloride on growth and nitrogen fixation in *Casuarina obesa* Miq. New Phytologist, 102:397–408.

Field studies in Western Australia showed that nodulation in *Casuarina obesa*, a highly salt-tolerant species, was found in soils with salinity up to 28 mg Cl/g. In a glasshouse study, it was shown that *C. obesa* seedlings inoculated with *Frankia* (from a saline (*C. obesa* host) and non-saline (*C. cunninghamiana* host)) sources had reduced growth, N-fixation, and total nodule weight when NaCl added to soil-filled pots was above 0.15 mg Cl/g soil. Some growth still occurred with salinities up to 15 mg Cl/g soil. NaCl reduced the amount of N fixed per mg nodule more for the non-saline *Frankia* symbiosis. Data are given for concentrations of Cl in nodules and shoots, analysed using electron micrographs, and their subcellular localisation.

Reddy, M.P., Rao, U.S. and Iyengar, E.R.R. (1996). Central Salt and Marine Chemicals Research Institute, G.B. Merg, Bhavnagar 364 002, India. In vitro propagation and related biochemical changes in *Atriplex nummularia* Lindl. in saline conditions. Indian Journal of Plant Physiology, 1:10–13.

This paper reports that 0.5 mg/L benzylaminopurine [BAP, (benzyladenine)] was the best treatment for multiple shoot formation in nodal explants of *Atriplex nummularia*, and that roots were induced when shoots were placed on MS media supplemented with 5 mg indole butyric acid/L. Multiple shoot formation and shoot elongation in MS medium was not affected at 176 and 345 meq/L salinity (seawater dilution), but higher concentrations did. Na and Cl ion accumulation and ATPase activity increased with increasing salinity.

Rehman, S., Harris, P.J.C., Bourne,W.F. and Wilkin, J. (1997). School of Natural and Environmental Sciences, Coventry University, Priory Street, Coventry CV1 5FB, UK. The effect of sodium chloride on germination and the potassium and calcium contents of *Acacia* seeds. Seed Science and Technology, 25:45–57.

> *Acacia bivenosa, A. coriacea, A. elata, A. farnesiana, A. nilotica, A. salicina, A. saligna, A. senegal, A. tortilis* and *A. tumida* are ranked for germination response under NaCl and water uptake and ion concentrations determined for *A. coriacea* (salt-sensitive), *A. nilotica* (intermediate) and *A. tortilis* (salt-tolerant). There was no indication that selective uptake or exclusion of Na contributed to differences in salt tolerance. The authors conclude that species differences in tolerance to NaCl appear to result from internal osmotic or ion toxicity effects rather than from reduced imbibition.

Reimann, C. (1992). Abteilung Okologie, Fakultat fur Biologie, Universitat Bielefeld, 4800 Bielefeld, Germany. Sodium exclusion by *Chenopodium* species. Journal of Experimental Botany, 43:503–510.

> This paper reports on Na, K and Cl uptake by seedlings of several chenopod halophytes and Na-excluding non-halophytes (*Phaseolus aureus* and *Trifolium alexandrinum*) in sand-culture treated with 100 mol/m^3 of K, Na and Cl. In contrast to *Atriplex prostrata* and *Suaeda maritima* which had high Na and K uptake rates and preferential transport of Na to shoots, *Chenopodium albium* and *C. schraderianum* had low shoot Na concentrations and high K–Na selectivity.

Reinhold, L., Braun, Y., Hassidim, M. and Lerner, H.R. (1989). Department of Botany, Hebrew University of Jerusalem, Jerusalem, Israel. The possible role of various membrane transport mechanisms in adaptation to salinity. In: Environmental stress in plants: biochemical and physiological mechanisms (Cherry, J. H., ed.), 121–130. NATO ASI Series, Vol. G19. Springer-Verlag, Berlin.

> The possible role of proton pumps and other membrane mechanisms in plant adaptation to salinity is considered. Recent membrane performance studies on vesicles isolated from *Atriplex nummularia* and cotton roots are reviewed. Evidence for the existence of a Na–H antiporter in membrane preparations from higher plant cells is discussed.

Rhodes, D. and Felker, P. (1988). Center for Semi-Arid Forest Resources, Caesar Kleberg Wildlife Research Institute, Campus Box 218, Texas A&I University, Kingsville, TX 78363, USA. Mass screening of *Prosopis* (mesquite) seedlings for growth at seawater salinity concentrations. Forest Ecology and Management, 24:169–176.

This paper describes the results of screening seedlings of *Prosopis* species (one accession per species from highly saline environments of West Africa, Chile, Argentina, and the USA), previously identified high-biomass-producing *Prosopis* species and *Leucaena leucocephala*, in a hydroponic sand-culture system with increasing NaCl concentrations (from 0 to 3.3% sea water). Large differences in survival and shoot growth are reported, with *L. leucocephala* 'K67' and *P. pubescens* most sensitive (died at 1.2% NaCl) and *P. alba*, *P. alba/nigra*, *P. articulata*, *P. chilensis*, and *P. juliflora* most tolerant (some plants grew at 3.3% NaCl). (It appears that salt tolerance characteristics are not only present in species/populations from highly saline environments.)

Richardson, S.G. (1982). Department of Range Science, Texas A&M University, College Station, TX 77843, U.S.A. High and low sodium biotypes of fourwing saltbush: their responses to sodium and potassium in retorted oil shale. Journal of Range Management, 35:795–797.

Differences in leaf Na concentrations were shown by five populations of fourwing saltbush (*Atriplex canescens*) in the field and pot-grown plants in saline retorted oil shale. High Na plants grew better on retorted oil shale than low Na plants and growth low Na plants was enhanced by addition of K.

Richardson, S.G. and McKell, C.M. (1980). Institute for Land Rehabilitation, Utah State University, UMC 52, Logan, UT 84322, USA. Water relations of *Atriplex canescens* as affected by the salinity and moisture percentage of processed oil shale. Agronomy Journal, 72:946–950.

In a greenhouse study, fourwing saltbush (*Atriplex cancescens*) was treated with Na_2SO_4 and $MgSO_4$, the two major salts in processed oil shale. $MgSO_4$ was more detrimental to growth than was Na_2SO_4 when added at equal osmotic concentrations to leached processed oil shale. Data on osmotic and turgor potential, leaf diffusive resistance and leaf cation concentrations are presented and inferences drawn on reasons for the observed differences between the salts.

Richardson, S.G. and McKell, C.M. (1980). Institute of Land Rehabilitation, Utah State University, Logan, Utah 84322, USA. Salt tolerance in two saltbush species grown in processed oil shale. Journal of Range Management, 33:460–463.

This paper reports on the salt tolerance of fourwing saltbush (*Atriplex canescens*) and cuneate saltbush (*Atriplex cuneata*) in processed oil shale in a greenhouse experiment. Cuneate saltbush was more salt-tolerant than fourwing saltbush, but both species survived and grew at salinities as high as EC_e 38 dS/m.

Riehl, T.E. and Ungar, I.A. (1982). Department of Botany, Ohio University, Athens, Ohio 45701, USA. Growth and ion accumulation in *Salicornia europaea* under saline field conditions. Oecologia (Berlin), 54:193–199.

The relationship between the distribution and growth of *Salicornia europaea* and soil conditions was studied on an inland saline marsh. Soil salinity was the factor most highly correlated with plant growth, survival and ionic content of organs of *S. europaea*.

Riehl, T.E. and Ungar, I.A. (1983). Department of Botany, Ohio University, Athens, OH 45701, USA. Growth, water potential and ion accumulation in the inland halophyte *Atriplex triangularis* under saline field conditions. Acta Oecologica/Oecologia Plantarum, 4:27–39.

The effect of soil conditions on growth and distribution of *Atriplex triangularis* was studied in three communities within an inland salt marsh in Ohio, where salinity ($EC_{1:1}$) ranged from 6 to 90 dS/m. DM production at the most saline sites was <50% of that at less saline sites and all plants died by late summer (before flowering) in the most saline sites. Increases in salinity with season and site were reflected in higher shoot Na and Cl concentrations and more negative water potential in roots and shoots.

Ries, R.E. and Hoffman, L. (1983). Northern Great Plains Research Centre, USDA–ARS, PO Box 459, Mandan, North Dakota, 58554, USA. Effect of sodium and magnesium sulphate on forage seed germination. Journal of Range Management, 36:658–661.

This paper reports on germination responses of eight forage species to Na_2SO_4 and $MgSO_4$. After species-specific optimum incubation periods, germination of fourwing saltbush was improved by the Na_2SO_4 and $MgSO_4$, that of green needlegrass and red clover was depressed by all salt

treatments, and that of alkali sacaton, little bluestem and switchgrass germination was depressed by Na_2SO_4, whilst that of thickspike wheatgrass and Canby bluegrass was not affected by any treatments.

Ritson, P. and Pettit, N.E. (1992). Hydrology and Land Use Research Section, Water Authority of Western Australia, PO Box 100, Leederville, WA 6007, Australia. Double-ridge mounds improve tree establishment in saline seeps. Forest Ecology and Management, 48:89–98.

This paper reports on the effectiveness of different mound types and heights for establishment of *Eucalyptus camaldulensis* and *E. largiflorens* on five saline seepage (saline ground water discharge) sites with seasonal waterlogging in south-western Western Australia. Watertable heights fluctuated between 0–>0.5 m and ground water salinities varied from 1 000–20 000 ppm depending on the site. Survival was best (50% overall average) with double-ridge mounds (seedlings planted in a 0.5 to 0.9 m wide trough between the ridges) and was higher with increasing mound height (up to 1.0 m). There were no significant effects of mound type or mound height on tree growth after two years. *E. camaldulensis* was taller and had a bigger crown than *E. largiflorens* overall.

Robertson, K.P. and Wainwright, S.J. (1987). Department of Botany and Microbiology, University College of Swansea, Singleton Park, Swansea SA 2 8PP, UK. Photosynthetic responses to salinity in two clones of *Agrostis stolonifera*. Plant, Cell and Environment, 10:45–52.

Short-term (one week) response of photosynthesis, stomatal conductance and ion accumulation to salinity was examined in two clones of *Agrostis stolonifera,* one derived from a salt marsh (SM) and the other from an inland site (IL). Responses of older leaves were similar between clones, but whereas photosynthesis of young leaves of the IL clone was reduced by 20%, that of the SM clone was unaffected. This reduction for the IL clone was attributed to reduced stomatal conductance and photosythetic capacity of the mesophyll and to higher Na and Cl concentrations and lower K concentrations than in the SM clone.

Robinson, S.P. and Downton, W.J.S. (1985). Division of Horticultural Research, CSIRO, GPO Box 350, Adelaide, SA 5001, Australia. Potassium, sodium and chloride ion concentrations in leaves and isolated chloroplasts of the halophyte *Suaeda australis* R. Br. Australian Journal of Plant Physiology, 12:471–479.

This paper reports that best growth of *Suaeda australis* in solution culture occurred at 50–150 mol/m^3 NaCl, although the plants continued to grow even at 600 mol/m^3. Decreased osmotic potential of the leaf sap was mostly related to increased Na and Cl concentrations, whereas K concentrations decreased. Using mechanically isolated chloroplasts (purified on a two-step Percoll gradient) it was found that chloroplast Na and K is regulated (maximum conc. < 140 mol/m^3), with these ions being accumulated in the chloroplast at low leaf Na and Cl concentrations and excluded when leaf concentrations are high.

Rogers, A.L. (1985). Division of Groundwater Research, CSIRO, Private Bag, PO Wembley, WA 6014, Australia. Foliar salt in *Eucalyptus* species. Australian Forestry Research, 15:9–16.

Foliar salt concentrations of several *Eucalyptus* species grown on one non-saline site and four saline sites in the south-west of Western Australia were determined over a five-year period. Mean Na concentrations ranged from 0.15 mg/g DM in *E. melliodora* to 12.1 mg/g in *E. astringens*, and mean Cl concentrations from 3.3 mg/g in *E. rudis* to 18.1 mg/g in *E. astringens*. With some exceptions, Cl and Na concentrations were much higher on the saline sites than on the non-saline site; however, foliar analysis did not prove to be a reliable indicator of relative salt tolerance of species.

Rogers, J.A. and Davies, G.E. (1973). Hill Farming Research Organization, Edinburgh EH9 2JQ, UK. The growth and chemical composition of four grass species in relation to soil moisture and aeration factors. Journal of Ecology, 61:455–472.

In a field and pot experiment using clones of cocksfoot (*Dactylis glomerata*), timothy grass (*Phleum pratense*), perennial ryegrass (*Lolium perenne*) and tall fescue (*Festuca arundinacea*), cocksfoot was most sensitive to waterlogging and anaerobic conditions and tall fescue was most tolerant.

Roman, C.T. and Daiber, F.C. (1984). College of Marine Studies, University of Delaware, Newark, Delaware 19711, USA. Aboveground and belowground primary production dynamics of two Delaware Bay tidal marshes. Bulletin Torrey Botanical Club, 111:34–41.

Above-ground and below-ground net primary productivity (NPP) estimates of the dominant angiosperms from two tidal marshes along the Delaware Bay estuary are reported. Data are provided for tall and short *Spartina alterniflora*, *S. patens*, *Distichlis spicata* and *Phragmites australis*.

Roomi, D., Ghaffar, A., Ahmad, R. and Ismail, S. (1994). Department of Botany, University of Karachi, Karachi, Pakistan. Effect of salinity on growth of *Rhizobium* spp., nodulation and height of *Prosopis* species. Pakistan Journal of Botany, 26:253–258.

This paper reports on growth of *Rhizobium* spp., isolated from *Prosopis glandulosa* and *P. juliflora* from Pakistan, in vitro under NaCl (0.1–1.0%), as well as the effect of NaCl on plant height, number of nodules per plant and nodule size of inoculated seedlings.

Roundy, B.A., Young, J.A. and Evans, R.A. (1989). School of Renewable Natural Resources, University of Arizona, Tucson, AZ 85721, USA. Seedling growth of three Great Basin wildrye collections at reduced osmotic potential. Agriculture, Ecosystems and Environment, 25: 245-251.

In solution culture experiments, relative seedling growth of the improved cultivar 'Magnar' of salt-tolerant bunchgrass, *Leymus cinereus*, under saline (NaCl, $CaCl_2$ or NaCl + $CaCl_2$) and water stress (polyethylene glycol) conditions (up to –2.5 MPa osmotic potential), was similar to that of ecotypes from a saline soil in central Nevada, and slightly greater than ecotypes from non-saline soil.

Roux, E.R. (1965). Salt tolerance in four invasive exotic acacias of the Cape Peninsula. South African Journal of Science, 61:438.

In sand-and-nutrient solution cultures to which NaCl was gradually added, *Acacia melanoxylon* was least salt-tolerant, followed in ascending order by *A. longifolia*, *A. cyclops* and *A. cyanophylla* [*A. saligna*].

Rozema, J. (1975). Werkgroep Plantenoekologie, Biologisch Laboratorium, Vrije Universiteit, Amsterdam, The Netherlands. An eco-physiological investigation into the salt tolerance of *Glaux maritima* L. Acta Botanica Neerlandica, 24:407–416.

Glaux maritima, a highly salt-tolerant species, continued to grow at 300 mol/m^3 NaCl. Data on ion concentrations, salt secretion, succulence and chlorophyll content are provided. K made an important contribution to the total osmotic potential of expressed sap. Salinity stimulated salt secretion up to 150 mol/m^3.

Rozema, J. (1976). Department of Ecology, Biological Laboratory, Free University, Amsterdam, The Netherlands. An ecophysiological study on the response to salt of four halophytic and glycophytic *Juncus* species. Flora Bd., 105 S:197–209.

On the basis of growth reduction, *Juncus gerardii* appeared to be more salt-tolerant than *J. alpino-articulatus* ssp. *atricapillus* and the glypcophytic species *J. bufonius* ssp. *bufonius*. The slow-growing *J. maritimus* was only slightly affected by increasing salinity. K made an important contribution to the total osmotic potential of expressed sap, whereas soluble sugars, PO_4, Mg and Ca made a small contribution. Oxlate content did not increase at higher salinities.

Rozema, J., Arp, W., van Diggelen, J., Kok, E., Fanger, A. and Letschert, J. (1986). Department of Ecology and Ecotoxicology, Free University, PO Box 7161, 1007 MC Amsterdam, The Netherlands. Comparative ecophysiology of the water relations of salt resistant monocotyledonae and dicotyledonae. In: Prospects for biosaline research (Ahmad, R. and San Pietro, A., ed.), 101–114. Proceedings US–Pakistan Biosaline Research Workshop, 22–26 September 1985. Department of Botany, University of Karachi, Karachi, Pakistan.

Marked differences were found in the pattern of diurnal leaf growth and thickness changes of monocotyledonous and dicotyledonous species. Consequences of these morphological differences for water utilisation costs to maintain turgor and growth rate are discussed.

Rozema, J., Arp, W., van Diggelen, J., Kok, E. and Letschert, J. (1987). Department of Ecology and Ecotoxicology, Free University, PO Box 716l, 1007 MC Amsterdam, The Netherlands. An ecophysiological comparison of measurements of the diurnal rhythm of the leaf elongation and changes of the leaf thickness of salt-resistant dicotyledonae and monocotyledonae. Journal of Experimental Botany, 38:442–453.

This paper reports on continuous measurement of leaf elongation and thickness with the use of a rotation potentiometer to determine diurnal changes for several halophytes at 0 and 450 mol/m^3 NaCl. All dicotyledonous species (*Atriplex hastata*, *A. littoralis*, *A. tripolium*, *Suaeda maritima* and *Beta vulgaris*) had greater elongation at night, in contrast with monocotyledons (*Spartina anglica*, *Juncus gerardii*, *J. maritimus*, *Festuca rubra* ssp. *litoralis*, *Elymus pycnanthus*). Diurnal patterns are related to photosynthesis and transpiration responses to light and dark.

Rozema, J., Bijl, F., Dueck, T. and Wesselman, H. (1982). Department of Biology, Free University, Postbus 7161, 1007 MC Amsterdam, The Netherlands. Salt-spray stimulated growth in strand-line species. Physiologia Plantarum, 56:204–210.

This paper compares the response to salt spray and soil salinity of two sand dune strand-line species (*Cakile maritima* and *Salsola kali*) and two salt marsh strand-line species (*Atriplex hastata* and *Atriplex littoralis*) in sand-compost cultures. The growth of the salt-marsh species were unaffected, while the growth of *C. maritima* was markedly reduced by150 and 300 mol/m^3 NaCl in the root zone. All four species were resistant to airborne salinity. Data on foliar Na, K, Cl, Ca and Mg concentrations, shoot methylated quaternary ammonium compound content and turgor potential are provided, and relationships discussed.

Rozema, J., Dueck, T., Wesselman, H. and Bijl, F. (1983). Biological Laboratory, Vrije Universiteit, De Boelelaan 1087, 1007 MC Amsterdam, Netherlands. Nitrogen dependent growth stimulation by salt in strand-line species. Acta Oecologica/Oecologia Plantarum, 4:41–52.

This paper reports that growth of *Atriplex hastata* and *A. littoralis* was stimulated by 60 and 150 mol/m^3 NaCl in the presence of 3.5 mol/m^3 NO_3, but at 0.5 mol/m^3 NO_3 growth was reduced by these salt concentrations. Growth of the sand dune species *Cakile maritima* was strongly inhibited by 60 mol/m^3 NaCl. Possible physiological mechanisms related to these observed responses are discussed.

Rozema, J., Gude, H., Bijl, F. and Wesselman, H. (1981). Biologisch Laboratorium, Vrije Universiteit, 1081 HV Amsterdam, The Netherlands. Sodium concentration in xylem sap in relation to ion exclusion, accumulation and secretion in halophytes. Acta Botanica Neerlandica, 30:309–311.

This paper reports on salt secretion, salt accumulation and transpiration, measured simultaneously in salt-secreting and non-salt-secreting halophytes and glycophytes. Salt-secreting halophytes differed considerably in their Na secretion rates, but less in their Na exclusion capacity. Salt-sensitivity of the non-secreting species was related to a comparatively high Na xylem concentration (15.1 mol/m^3 Na).

Runciman, H.V. (1986). Department of Agriculture, Division of Resource Management, South Perth, WA 6151, Australia. Forage production from salt-affected wasteland in Australia. Reclamation and Revegetation Research, 5:17–29.

This paper describes the native vegetation of salt-affected land in Australia, the revegetation of this land with more productive salt-tolerant plants and the use of these plants as forage.

Russell, J.S. (1976). Division of Tropical Agronomy, CSIRO, Cunningham Laboratory, St. Lucia, Queensland, Australia. Comparative salt tolerance of some tropical and temperate legumes and tropical grasses. Australian Journal of Experimental Agriculture and Animal Husbandry, 16:103–109.

> Reports on growth response of 11 tropical legumes, 10 temperate legumes and 11 tropical grasses in soil-filled pots to NaCl. Grasses persisted better at high salt levels than legumes. The most tolerant grasses were *Chloris gayana*, *Panicum coloratum*, *Pennisetum clandestinum*, *Sorghum almum* and *Digitaria decumbens* with 50% DM yield reduction at EC_e approx. 1.5–2.3 dS/m. *Medicago sativa*, *Macroptilium lathyroides* and *M. atropurpureum* were the most tolerant legumes (50% yield reduction at EC_e approx. 1.0 dS/m). The least tolerant grass was *Setaria anceps* and the least tolerant tropical and temperate legumes were *Desmodium uncinatum* and *Trifolium semipilosum* respectively. No consistent relationship was found between plant salt tolerance and Na and Cl concentration.

Saad Eddin, R.S. and Doddema, H. (1986). Department of Biological Sciences, University of Jordan, Amman, Jordan. Effects of NaCl on the nitrogen metabolism of the halophyte *Arthrocnemum fruticosum* (L.) Moq. grown in a greenhouse. Plant and Soil, 92:373–385.

> In a glasshouse study, seedlings of *Arthrocnemum fruticosum*, a halophyte from the shore of the Dead Sea in Jordan, became more succulent, mainly due to an accumulation of Na (rather than Cl) and water with increasing NaCl (0–5%). Data on changes in plant ammonium, nitrate and nitrate reductase enzyme over time and in response to salinity are provided. High NaCl concentrations delayed flower initiation.

Sagi, M., Dovrat, A., Kipnis, T. and Lips, H. (1997). Ramat Negev Desert Agroresearch Center, D.N. Halutza 85515, Israel. Ionic balance, biomass production, and organic nitrogen as affected by salinity and nitrogen source in annual ryegrass. Journal of Plant Nutrition, 20: 1291–1316.

> This paper reports on changes in inorganic ions (cations, Cl, NO_3) and organic anion concentrations when *Lolium multiflorum* plants in sand culture were irrigated with nutrient solution containing 0.5–0.9 mol/m N as $NaNO_3$, NH_4NO_3 or $(NH_4)_2SO_4$ and having an EC of 2 or 11.2 dS/m.

Sagi M., Savidov N.A., L'vov N.P. and Lips S.H. (1997). Biostress Research Laboratory (J.Blaustein Institute for Desert Research), Ben Gurion Univ. of the Negev, Sede Boqer 84993, Israel. Nitrate reductase and molybdenum cofactor in annual ryegrass as affected by salinity and nitrogen source. Physiologia Plantarum, 99:546–553.

This paper reports on changes in shoot inorganic and organic N concentration, nitrate reductase and biomass of *Lolium multiflorum* 'Westerwoldicum' plants grown in sand culture in response to salinity (EC of 2 or 11.2 dS /m, ammomium and nitrate (0 or 4.5 mol/m^3).

Saini, M.L., Dahiya, I.S. and Singh, K. (1980). Haryana Agricultural University, Hissar, India. Salt transport and performance of some grass species under precipitation management in a highly saline sodic soil. In: Arid zone research and development (Mann, H.S., ed.), 323–330. Poceedings of International Symposium on Arid Zone Research and Development, Jodhpur, India. February 1978.

Five treatments (natural rainfall and rainfall that was collected and supplemented with extra water to provide four leaching fractions) were applied to field plots of Rhodes grass (*Chloris gayana*), guinea grass (*Panicum maximum*), para grass (*Brachiara mutica*) and *P. laevifolium* on highly saline, sodic site near Hansi, Haryana. Results indicated that adequate leaching can significantly assist with site reclamation (reduced EC_e and ESP).

Sala, A., Smith, S.D. and Devitt, D.A. (1996). Department of Biological Sciences, University of Nevada, Reno, Nevada 89154-4004, USA. Water use by *Tamarix ramosissima* and associated phreatophytes in a Mojave desert floodplain. Ecological Applications, 6: 888–898.

Reports on measurement of water use by introduced *Tamarix ramosissima* [*T. chinensis*] in a closed monospecific stand and of three native phreatophytes (*Pluchea sericea, Prosopis pubescens* and *Salix exigua*) in a mixed community in the lower Virgin River floodplain (moderate to high watertables), southern Nevada, using the stem heat balance method. Sap flow rates based on leaf area were comparable in the four species. Daily estimates of transpiration in dense *T. chinensis* stands (leaf area index up to 3.5) exceeded potential evapotranspiration by a factor ranging from 1.6 to 2.0.

Salama, R.B., Bartle, G.A. and Farrington, P. (1994). CSIRO Division of Water Resources, Private Bag Wembley, WA 6014, Australia. Water use of plantation *Eucalyptus camaldulensis* estimated by groundwater hydrograph separation techniques and heat pulse method. Journal of Hydrology (Amsterdam), 156:163–180.

> This paper reports on determination of long-term water use of a 10-year-old plantation of river red gum (*Eucalyptus camaldulensis*) near Perth, Western Australia, using a ground water hydrographic separation technique compared with transpiration rate estimated by sap flow measurements using the heat pulse method. The hydrograph separation technique allowed differences between rates of transpiration to be estimated. Results were similar using both methods.

Salim, M. (1989). School of Biological Sciences, University of Sydney, Sydney, NSW 2006, Australia. Effects of salinity and relative humidity on growth and ionic relations of plants. New Phytologist, 113:13–20.

> This paper reports on short-term growth and ionic relations of mung bean, sunflower, red kidney bean, tomato and *Atriplex spongiosa* seedlings, grown in solution culture, and treated with 0, 50 or 100 mol/m^3 NaCl. Increasing salinity did not affect transpiration rate, FW:DW ratio or shoot:root ratio, but increased shoot Na and Cl concentrations and decreased K concentrations in *A. spongiosa*. Higher rates of net ion transport from roots to shoots resulted in higher K, Na and Cl concentration in shoot tissue water when the relative humidity was decreased from 90 to 30%.

Samra, J.S., Stahel, W.A. and Kunsch, H. (1991). Central Soil and Water Conservation Research and Training Inst., Madhya Marg, Chandigarh 160019, India. Modelling tree growth sensitivity to soil sodicity with spatially correlated observations. Soil Science Society of America Journal, 55:851–856.

> Data on height growth of *Melia azedarach* at one, two and three years after planting and on soil variables (SAR, DTPA-ammonium acetate extractable Na, P and K and pH) at four depth intervals of 0.3 m to 1.2 m were collected from a site in the alluvial plains at Karnal, Haryana. Tree height after three years was related to soil sodicity. SAR was a better predictor of height growth than soil pH or extractable Na. Inclusion of extractable P or K in the model did not add extra information. Use of data from 0.0–0.6 m was as good as that for 0.0–1.2 m. (This and earlier manuscripts by Samra appear to be the only information available to relate growth to sodicity other than by the use of pH.)

San Pietro, A. (1982). Indiana University, Bloomington, Indiana, USA. Biosaline research: a look to the future. Proceedings of 2nd International Workshop on Biosaline Research, La Paz, Mexico, 578 p., Plenum Press, New York, USA.

The proceedings of the second workshop on biosalinity held in Mexico. The first section deals with regional reviews on work that has been done on different aspects of biosaline research. The second section deals with food and economic plants and includes papers on different plant species grown with saline water or sea water. The third section includes papers on potential uses of microalgae and deals with the use of *Dunaliella* and marine blue-green algae, and with processing methods of different byproducts. The next section deals with stress biology and includes work on biochemical, physiological and genetics of salt-tolerance. The fifth section deals with the present and future application of biosaline technology and touches on topics like biocatalytic conversions, saline silviculture, macroalgal mariculture, and pollutant and waste removal. The last section includes contributed papers on salt-tolerance of cultivated crops to wild species, nutritional values to biochemical aspects, physiological approaches to ecological ones.

Sanda, J.E. (1978). Institutt for Dendrologi og Planteskoledrift, Norges Landbrukshoegskole, 1432 As-NLH, Norway. Salt tolerance in grass. Forskning og Forsoek i Landbruket, 29:61–72.

This paper reports on the salt tolerance of 29 commercial species and cultivars of turfgrass, representing *Festuca rubra*, *F. arundinacea*, *F. ovina*, *Agrostis tenuis*, *A. canina*, *Lolium perenne*, *Phleum nodosum*, *P. pratense*, *Poa pratensis* and *Poa annua*, during germination and seedling growth. There was little relationship between tolerances expressed at these stages. (In Norwegian, English summary.)

Sanderson, M.A., Stair, D.W. and Hussey, M.A. (1997). Texas AandM University Agricultural Research and Extension Center, Stephenville, TX 76401, USA. Physiological and morphological responses of perennial forages to stress. Advances in Agronomy, 59: 171–224.

A comprehensive review is presented of literature concerning physiological and morphological responses of perennial forages to water stress, mechanical cutting, low-light levels, nutrient stress, low-temperature stress and salinity. Plant breeding for abiotic stress tolerance is discussed and recent research is highlighted.

Sanderson, P.L. and Armstrong, W. (1980). Department of Plant Biology, University of Hull, Hull HU6 7RX, UK. The responses of conifers to some of the adverse factors associated with waterlogged soils. New Phytologist, 85:351–362.

The effect of Fe, acetic and butyric acids and ethylene on rooted cuttings of Sitka spruce and Lodgepole pine were studied in solution culture and compared with effects of anoxia, using relative rate of root growth. The greater tolerance of Lodgepole pine is discussed in terms of gas transport.

Sandhu, G.R., Aslam, Z., Salim, M., Qureshi, R.H., Ahmad, N. and Wyn Jones, R.G. (1981). Nuclear Institute of Agriculture and Biology (NIAB), Faisalabad, Pakistan. The effect of salinity on the yield and composition of *Diplachne fusca* (Kallar grass). Plant, Cell and Environment, 4:177–181.

In pot trials, growth of kallar grass (*Diplachne [Leptochloa] fusca*) was reduced by 50% at EC_e of 22.3 dS/m. Data on shoot Na, K and Cl, and glycinebetaine concentrations are given. The authors conclude that osmotic adaptation was mainly brought about by tissue dehydration and not net salt accumulation, since most Na and Cl was secreted.

Sandhu, G.R. and Qureshi, R.H. (1986). National Agricultural Research Centre, Islamabad, Pakistan. Salt affected soils of Pakistan and their utilization. Reclamation and Revegetation Research, 5:105–113.

This paper outlines an approach for the utilisation of heavy saline/sodic soils in central Punjab, Pakistan, by introducing salt-tolerant trees, shrubs, crops and grasses with economic prospects. Reports that *Diplachne [Leptochloa] fusca* has been a primary coloniser of highly salt-affected soils, and that areas have been sown with this grass as a forage for buffaloes and cattle. Supply of fodder and the utilisation of salt-affected land during winter are highlighted as problems.

Sands, R. (1981). Division of Soils, CSIRO, Private Bag No. 2, Glen Osmond, SA 6064, Australia. Salt resistance in *Eucalyptus camaldulensis* Dehn. from three different seed sources. Australian Forestry Research, 11:93–100.

This paper reports that germination of *Eucalyptus camaldulensis* (Shepparton, Australia) was less than that from Lake Albacutya and Port Lincoln provenances (saline sites) under saline conditions. Salt damage was greatest and survival lowest in pot-grown seedings from Shepparton. Differences in salt tolerance could not be explained in terms of

differences in Na and Cl concentrations in leaves, stems, and roots or in differences in plant water potential. It is suggested that differences in salt tolerance may be due to differences in tissue tolerance to Na and/or Cl.

Sands, R. and Clarke, A. R. P. (1977). Division of Soils, CSIRO, Private Bag No. 2, Glen Osmond, SA 6064, Australia. Response of radiata pine to salt stress. I. water relations, osmotic, adjustment and salt uptake. Australian Journal of Plant Physiology, 4:637–646.

Radiata pine *(Pinus radiata)* seedlings were treated with stepwise increases in $CaCl_2$ or NaCl, or PEG 4000 (inert) in solution culture in two glasshouse experiments. $CaCl_2$ caused greater damage than iso-osmotic concentrations of NaCl, and the damage was associated with Cl excess and an induced P deficiency. Data on ion absorption by rapidly and slowly salinised seedlings are presented. Proline accumulated in needle sap under water stress and at high salinity, and its accumulation in relation to osmotic adjustment is discussed. It is concluded that radiata pine seedlings avoided rather than tolerated high ion concentrations.

Sarir, M.S., Marwat, K.B. and Khattak, J.K. (1984). Department of Soil Science, N.W.F.P. Agricultural University, Peshawar, Pakistan. Studies on some halophytes of Peshawar district. Pakistan Journal of Botany, 16:49–51.

Suaeda fruticosa, Desmostachya bipinnata, Cyperus laevigatus, Saccharum spontaneum and *Cynodon dactylon* have a wide ecological range and prefer saline and saline–sodic soils, while *Acacia jacquemontii, Capparis decidua* and *Tamarix aphylla* prefer saline–sodic soil and have a narrow ecological range.

Schrimer, U. and Breckle, S.W. (1982). Department of Ecology, University of Bielefeld, PO Box 8640, D-4800, Bielefeld, Federal Republic of Germany. The role of bladders for salt removal in some Chenopodiaceae (mainly *Atriplex* species). In: Contributions to the ecology of halophytes (Sen, D.N. and Rajpurohit, K.S., ed.), Tasks for Vegetation Science, Vol. 2, 215–231. Dr. W. Junk Publishers, The Hague.

Mechanisms for tolerating salts are described for salt excluder and salt absorber groups. The latter group consists of species that have high cellular ionic contents and face both osmotic and ionic stress. The process of forming bladders on the leaves of *Atriplex* species and their accumulation of salt (Na, and in some cases K) is reviewed in detail.

Schwarz, M. and Gale, J. (1981). Department of Botany, Hebrew University of Jerusalem, Jerusalem, Israel. Maintenance respiration and carbon balance of plants at low levels of sodium chloride salinity. Journal of Experimental Botany, 32:933–941.

This paper reports on the balance between respiration and photosynthesis in seedlings of C_3 *Phaseolus vulgaris* (salt-sensitive), *Xanthium strumarium* (salt-tolerant), and C_4 *Zea mays* (salt-sensitive) and *Atriplex halimus* (salt-tolerant) exposed to NaCl (up to 1.2 MPa) and varying daytime light intensities. In *Phaseolus*, *Xanthium* and *Atriplex*, maintenance respiration (R_M) rose with increasing NaCl, approximately up to those concentrations above which signs of toxicity appear. At higher levels of NaCl, R_M declined. NaCl did not affect the ratio of growth respiration to photosynthesis. The authors conclude that part of the growth reduction caused by low levels of salinity may be explained by diversion of assimilates from anabolic to catabolic processes. (There is some current debate about the justification for dividing respiration into growth and maintenance components.)

Schwarz, M. and Gale, J. (1984). Department of Botany, Hebrew Univeristy of Jerusalem, Jerusalem, Israel. Growth response to salinity at high levels of carbon dioxide. Botany, 35:193–196.

The study reports that, in a solution culture experiment, growth of two C_3 and two C_4 (including the C_4 halophyte *Atriplex halimus*) species under NaCl treatment was improved at elevated CO_2 levels. *A. halimus* seedlings in solution grew better at 170 mol/m^3 at c. 2500 compared with c. 320 ppm CO_2 ; this was especially true for roots.

Semushina, L.A., Bukhteeva, A.V. and Morozova, A. (1978). VIR, Leningrad, USSR. Comparative salt tolerance of *Agropyron* and *Elymus*. Bulletin Vsesoyuznogo Ordena Lenina i Ordena Druzhby Narodov Instituta Rasteni evodstva Imeni N. I. Vavilova, 86:65–68.

This paper provides information on the tolerance and DM yield of the most salt-tolerant material from 50 ecotypes of three *Agropyron* species, and 19 ecotypes of *Elymus junceus*. (In Russian.)

Sen, D.N., Jhamb, R.B. and Bhandari, D.C. (1988). Department of Botany, University of Jodhpur, Jodhpur, India. Biology and land reclamation in the Indian desert. In: Arid lands today and tomorrow (Whitehead, E.E.,

Hutchinson, C.F., Timmermann, B.N. and Varady, R.G., ed.), 791–800. Proceedings International Research and Development Conference, Tucson, Arizona, Westview Press, Colorado, USA.

The paper describes the biology of plant species in the Indian desert, the biology of halophytes and the reclamation of saline areas. Particular attention is given to germination of halophyte seeds in relation to time of shedding and soil salinity. The dominant species of the area were *Aeluropus lagopoides, Cressa cretica, Haloxylon recurvum, Salsola baryosma, Sporobolus helvolus, Suaeda fruticosa, Trianthema triquetra* and *Zygophyllum simplex*. Methods for reclamation of saline areas are described mainly in reference to irrigation, drainage and leaching practices. The role of biological improvement is also discussed.

Sen, D.N., Prakash, B.S.V. and Thomas, T.P. (1988). Botany Department, University of Jodhpur, Jodhpur, Rajasthan, India. Wasteland management with special reference to introduction of *Atriplex* spp. Advances Forestry Research India, 1:221–240.

This paper discusses various aspects of the management of the sandy and saline waste lands of western Rajasthan. Stabilisation methods for sand dunes and forage production on saline waste land are discussed, the latter with particular reference to the potential of *Atriplex* (facultative halophytes) as a forage crop. Some experimental data on growth under saline conditions and crude protein content of *Atriplex* species are included.

Sen, D.N. and Rajpurohit, K.S. (ed.) (1982). Department of Botany, University of Jodhpur, Jodhpur 342 001, India. Contributions to the ecology of halophytes. In: Tasks for vegetation science, Vol. 2, 271 p. Dr. W. Junk Publishers, The Hague, Netherlands.

The book is divided into three parts. The first deals with the biology and biogeography of halophytic species and salinity-controlled ecosystems, including halophytic vegetation of Egypt and India, estuarine ecosystems of India, biogeography of mangroves and biology of *Atriplex*. The second deals with ecological and ecophysiological problems, including productivity and growth form of *Spartina*, germination ecology of halophytes, water relations of Australian chenopods, senescence in mangroves, ecophysiological aspects of salt marsh halophytes, salt excretion and salt removal. The third deals with current and potential uses of halophytes. Overall the book provides interesting information about the growth behavior of halophytes and mangroves, the tolerance of different species to salinity and different mechanisms operating in them.

Sena Gomes, A.R. and Kozlowski, T.T. (1980). Department of Forestry, University of Wisconsin, Madison, Wisconsin 53706, USA. Effects of flooding on *Eucalyptus camaldulensis* and *Eucalyptus globulus* seedlings. Oecologia (Berlin), 46:139–142.

> When flooded for up to 40 days, morphological and growth responses differed between six-week-old *Eucalyptus camaldulensis* and *E. globulus* seedlings. Whilst both species produced many adventitious roots from near the tap root and original lateral roots, only *E. camaldulensis* produced these roots on submerged portions of the stem. Flooding induced leaf epinasty and reduced DW growth of both species, but especially in *E. globulus*. The greater adaptation to flooding in *E. camaldulensis* is related to formation of adventitious roots.

Shannon, M.C. (1978). US Salinity Laboratory, SEA, USDA, Riverside, CA 92501, USA. Testing salt tolerance variability among tall wheatgrass lines. Agronomy Journal, 70:719–722.

> In glasshouse experiments using sand culture, seven-week-old plants of 32 tall wheatgrass lines were treated with increasing salinity (1:1 mix of CaCL and $CaCL_2$) up to 765 meq/L or until leaves were severely damaged, and classified according to relative leaf damage and rate of recovery. Results were confirmed by repeating the procedure with seven of each of the most tolerant and sensitive lines. Tolerance was associated with relatively low shoot Na, Ca and Cl concentrations. Proline and soluble sugar concentrations increased at high salinities, but sensitive and tolerant lines did not differ in proline concentrations.

Sharma, M.L. (1976). CSIRO, Division of Land Resources Management, Wembley 6014, Western Australia. Soil water regimes and water extraction patterns under two semi-arid shrub (*Atriplex* spp.) communities. Australian Journal of Ecology, 1:249–258.

> This paper reports on soil water regimes and water extraction patterns over a period of two years for two plantation communities of semi-arid shrubs, *Atriplex vesicaria* and *A. nummularia*, growing on the same soil type near Deniliquin, NSW, Australia.

Sharma, M.L. (1982). Division of Land Resources Management, CSIRO, Wembley, WA 6014, Australia. Aspects of salinity and water relations of Australian chenopods. In: Contributions to the ecology of halophytes (Sen, D.N. and Rajpurohit, K.S., ed.), Tasks for vegetation science, Vol. 2, 155–172, Dr. W. Junk Publishers, The Hague, The Netherlands.

This paper discusses various aspects of plant physiology related to salt and drought tolerance of Australian chenopods, which are halophytic xerophytes (especially tolerant of salt and water stress during seedling and mature growth and most with a C_4 photosynthetic pathway). Salt accumulation into vesicles, succulence and ion accumulation are highlighted. High solute and oxalate concentrations are discussed in relation to their use as animal forage.

Sharma, M.L. and Tongway, D.J. (1973). Rangelands Research Unit, Riverina Laboratory, CSIRO, Deniliquin, NSW 2710, Australia. Plant induced soil salinity patterns in two saltbush (*Atriplex* spp.) communities. Journal of Range Management, 26:121–125.

This paper reports that salinity in the 0–15 cm soil horizon underneath bushes of *Atriplex vesicaria* and *A. nummularia* communities, established at regular spacings on two soil types, increased significantly, especially for *A. nummularia*. pH also increased, but only for the 0–7.5 cm layer. The authors propose that this accumulation of salt was due to decomposition of large quantities of salt-rich leaves and fruits.

Sharma, M.L., Tunny, J. and Tongway, D.J. (1972). Division of Plant Industry, CSIRO, Riverina Laboratory, PO Deniliquin, NSW 2710, Australia. Seasonal changes in sodium and chloride concentration of saltbush (*Atriplex* spp.) leaves as related to soil and plant water potential. Australian Journal of Agricultural Research, 23:1007–1019.

Mature leaf Na and Cl concentrations of *Atriplex nummularia* and *A. vesicaria,* growing on two clay soils, were strongly correlated with soil water content, osmotic potential and matric potential of soil water over a one-year period, but the correlation with leaf relative water content was significant only for *A. vesicaria*. Various factors which might be responsible for inducing seasonal variability in leaf salt concentration are discussed.

Sharma, S.K. and Gupta, R.K. (1971). Central Arid Zone Research Institute, Jodhpur, Rajasthan, India. Effect of salts on seed germination of some desert grasses. Annals of Arid Zone, 10:33–36.

When treated with NaCl, Na_2SO_4 or $CaCl_2$, each at concentrations of 1.7 to13.6 g/L, *Dactyloctenium aegyptium*, *Dichanthium annulatum* and *Chloris virgata* were more salt-tolerant than *Dactyloctenium sindicum*, *Digitaria adscendens*, *Lasiurus sindicus*, *Echinochloa colonum* and *Cenchrus setigerus*.

Sharma, T.P. and Sen, D.N. (1989). Botany Department, University of Jodhpur, Jodhpur 342 001, India. A new report on abnormally fast germinating seeds of *Haloxylon* spp.—an ecological adaptation to saline habitat. Current Science, 58:382–385.

> This paper reports that very rapid initiation of germination (within 40–180 min) found in *Haloxylon salicornicum* and *H. recurvum* may be an adaptation to saline habitats, so that seeds can germinate during brief periods of water availability.

Shaybany, B. and Kashirad, A. (1978). Department of Horticulture and Soils, Pahlavi University, Shiraz, Iran. Effect of NaCl on growth and mineral composition of *Acacia saligna* in sand culture. Journal of American Society of Horticultural Science, 103:823–826.

> In a glasshouse experiment, seedlings of *Acacia saligna*, grown in sand culture, were treated with 0 to 240 mol/m^3 NaCl for 90 days. Growth, chlorophyll content, photosynthesis and respiration were reduced with increasing NaCl. Concentrations of 96–144 mol/m^3 caused 50% growth reduction. The concentrations of Na and Cl increased and that of K decreased. Shoots contained less Na and more Cl than roots. NaCl treatment increased Zn and decreased Ca concentrations of both roots and shoots. Data on P, Mn, N, Fe and Mg concentrations in plants are also provided.

Sheikh, K.H. and Mahmood, K. (1986). Department of Botany, Punjab University, New Campus, Lahore, Pakistan. Some studies on field distribution and seed germination of *Suaeda fruticosa* and *Sporobolus arabicus* with reference to salinity and sodicity of the medium. Plant and Soil, 94:333–340.

> On the basis of vegetation and soil sampling from two wasteland sites near Dera Chahl (via Lahore), *Suaeda fruticosa* was found to be a dominant species on saline and sodic soil whereas soil under *Sporobolus arabicus* was saline and non-sodic. Seed germination studies also showed that *S. arabicus* is relatively more affected by Na-salinity than by Ca-salinity, and confirm that this species is rather sensitive to sodicity.

Sheikh, M.I. (1974). Pakistan Forest Institute, Peshawar, Pakistan. Afforestation in waterlogged and saline areas. Pakistan Journal of Forestry, 24:186–192.

> This paper reports on several tree species trials on three saline and waterlogged sites in Pakistan. (Little site information.)

Sheikh, M.I. (1984). Pakistan Forest Institute, Peshawar, Pakistan. Afforestation in waterlogged and saline areas. Technical Note No. 15, 32–34.

The note describes some tree trials conducted in different parts of Pakistan over 25 years. Trials included species of *Ailantes, Acacia, Albizia, Eucalyptus, Populus* and *Salix*. No data of the salinity and waterlogging extent in these areas are provided. pH varied from 8–10.

Shrivastava, M.B., Tewart, K.N. and Shrivastava, M. (1988). Department of Zoology, Lucknow University, Lucknow, India. Afforestation on salt affected soils in India. Indian Journal of Forestry, 11:1–12.

This paper reviews literature related to afforestation problems and growing techniques for salt-affected soils of India, and includes a list of suitable species of economic importance. The ameliorating effect of trees are also discussed.

Singh, B. and Brar, S.P.S. (1988). Department of Soils, Punjab Agricultural University, Ludhiana 141004, India. Suitability of soils with respect to salinity and alkalinity for *Eucalyptus* plantations in Punjab. Journal of Tropical Forestry, 4:140–142.

In experiments with seedlings of *Eucalyptus* hybrid (*E. tereticornis*) planted in 23 soils with pH ranging from 8.6 to 10.4 (and EC approx. 0.18–2.70 dS/m), collected from various sites in the Indian Punjab, growth was substantially reduced at pH >9.8 and >0.6 dS/m.

Singh, G. (1996). Central Soil Salinity Research Institute, Karnal 132 001, India. Effect of site preparation techniques on *Prosopis juliflora* in an alkali soil. Forest Ecology and Management, 80:267–278.

This paper reports that establishment and growth, pod production, litter yield of *Prosopis juliflora* plantations and nutrient additions to the site on a highly alkali soil (initial soil pH 10.3) near Karnal was best up to 8 years after planting with the use of auger holes (15 cm diam. and 90 cm deep). In trench (30 cm deep and 30 cm wide) and pit (30 × 30 × 30 cm) planting, most of the roots were confined to surface layers (0–60 cm), whereas in auger hole planting the roots were able to pierce the hard $CaCO_3$ layer and were nearly 2.5 m deep two years after planting. Improvements in soil pH, EC, organic C and available N status of soil due to *P. juliflora* growth were not significantly affected by site preparation methods.

Singh, G., Abrol, I.P. and Cheema, S.S. (1989). Central Soil Salinity Research Institute, Karnal 132001, India. Effects of gypsum application on mesquite (Prosopis juliflora) and soil properties in an abandoned sodic soil. Forest Ecology and Management, 29:1–14.

> Gypsum application (7.5 and 15 t/ha) markedly improved survival and height and diameter of mesquite on a sodic soil (pH 10.4, ESP 90) after two years, and also improved soil physical (e.g. inflitration rate) and chemical (e.g. reduced pH and EC) conditions.

Singh G., Dagar, J.C. and Singh, N.T. (1997). Central Soil Salinity Research Institute, Karnal 132 001, India. Growing fruit trees in highly alkali soils—a case study. Land Degradation and Development, 8:257–268.

> This paper reports on the performance of pomegranate (*Punica granatum*), guava (*Psidium guajava*), sapote (*Achras sapota*), baelpather (*Aegle marmelos*), amla (*Emblica officinalis*), ber (*Ziziphus mauritiana*), karaunda (*Carissa carandas*), date palm (*Phoenix dactyleform*), jamun (*Syzygium cumini*), and imli (*Tamarindus indica*) in response to site preparation (auger holes and pits) and amendments (gypsum, FYM, or sand) in a highly alkali soil (pH 10.5) near Karnal, India.

Singh, G., Gill, H.S., Abrol, I.P. and Cheema, S.S. (1991). Central Soil Salinity Research Institute, Karnal 132001, India. Forage yield, mineral composition, nutrient cycling and ameliorating effects of Karnal grass (*Leptochloa fusca*) grown with mesquite (*Prosopis juliflora*) in a highly alkaline soil. Field Crops Research, 26:45–55.

> This paper deals with a field trial to examine the forage production, mineral composition, nutrient cycling and reclaiming effects of Karnal grass (*Leptochloa fusca*) grown in association with mesquite (*Prosopis juliflora*) in an agroforestry system on a highly sodic (pH 10.4, ESP 90) soil in the Karnal district. Karnal grass was very productive (47 t green forage/ha in 15 cuttings without any amendment) and a nutritionally valuable fodder. After 52 months, pH and EC were reduced and organic C, available N and water infiltration capacity improved. Moderately salt-tolerant crops such as *Trifolium resupinatum*, *T. alexandrinum* and *Melilotus denticulata* were grown successfully after incorporation of Karnal grass with soil.

Singh, K. and Jha, M.N. (1993). Division of Forest Soils and Land Reclamation, Forest Research Institute, Dehra Dun, India. Trees, shrubs and grasses on saline soils of Indo-Gangetic plains. Indian Forester, 119:630–647.

This paper reports on a soil–vegetation survey and trials in western Uttar Pradesh to evaluate site suitability and tolerance limits for selected trees, shrubs and grasses. Detailed soil properties are given for different sites. There was virtually no vegetation on two of the most highly saline sites (pH >8.8; EC_e >40 dS/m and $CaCO_3$ >12%; compact impervious kankar pan). *Prosopis juliflora* in association with shrubs (*Tamarix* spp., *Salvadora oleoides*, *Capparis decidua* and *Acacia leucophloia*) grew on soils with pH 7.7–8.2, EC_e <40 dS/m and $CaCO_3$ <12%. *Acacia nilotica* and natural *Crateva adansonii*, *Anthocephalus indicus* [*A. chinensis*], *Diplachne [Leptochloa] fusca*, *Cynodon dactylon* and *Sporobolus marginatus* grew on soils with pH < 7.9, EC_e <27 dS/m and $CaCO_3$ <5%. Other species like *Dalbergia sissoo*, *Pongamia pinnata*, *Holoptelea integrifolia*, *Eucalyptus tereticornis*, *Cassia siamea* and natural *Cryptostegia grandiflora*, *Prosopis cineraria*, *Capparis zeylanica* and *Saccharum spontaneum* grew in various soils with pH approximately 8.5, EC_e <19 dS/m and $CaCO_3$ <5% and no kankar layer.

Singh, K. and Yadav, J.S.P. (1985). Forest Research Institute and College, Dehra Dun, Uttar Pradesh, India. Growth response and cationic uptake of *Eucalyptus* hybrid at varying levels of soil salinity and sodicity. Indian Forester, 111:1125–1137.

This paper reports on growth response and Na, K, Ca, and Mg concentrations and their ratios in nine-month-old seedlings of *Eucalyptus* hybrid in soil-filled pots treated with salt (EC_e 0.7 to 32.5 dS/m) or $NaHCO_3$ (ESP 1.1 to 88.7%. Plants did not grow at EC_e >16.3 dS/m or ESP >30.6%.

Singh, K., Yadav, J.S.P. and Sharma, S.K. (1990). Forest Research Institute, Dehra Dun, India. Performance of shisham (*Dalbergia sissoo*) in salt affected soils. Indian Forester, 116:154–162.

The performance of shisham (*Dalbergia sissoo*) and several other tree species on five salt-affected sites in Uttar Pradesh, is reported. Data on watertable depth, drainage and soil morphology, and soil chemical/physical properties are provided. It is recommended that *D. sissoo* is planted on saline soils with values of EC_e < 18.5 dS and pH <8.8 in the root zone, and sodic soils with values of ESP 30 and pH 9.0. Data are also interpreted in terms of site quality classes. *Prosopsis juliflora*, *Acacia nilotica*, *Eucalyptus tereticornis* and *Salvadora oleoides* all performed better than *D. sissoo* in both saline and sodic soils.

Singh, K., Yadav, J.S.P. and Singh, B. (1986). Division of Ecology and Conservation, Forest Research Institute, Dehradun, Uttar Pradesh 248 006, India. Performance of *Acacia nilotica* on salt affected soils. Indian Journal of Forestry, 9:296–303.

> This paper reports on the performance of *Acacia nilotica* and *Prosopis juliflora* on salt-affected sites where other species failed to grow in western Uttar Pradesh. *A. nilotica* grew well on moderately calcareous sodic soil (fine loams) with maximum pH 9.5, ESP 50, EC_e 4 dS/m, soluble salts dominated by Na carbonates and bicarbonates, and the absence of a compact and indurated horizon of $CaCO_3$ (kankar). *A. nilotica* also grew on saline soils (coarse loams) with maximum pH 8.8, EC_e 15 dS/m and a predominance of neutral Na salts of Cl and SO_4. Good growth was also associated with better drainage and a deep ground watertable. *P. juliflora* performed better than *A. nilotica* at higher sodicities, and was also less affected by the presence of a kankar horizon and by $CaCO_3$ >10% throughout the soil profile.

Singh, K., Yadav, J.S.P and Singh, V. (1991). Division of Ecology and Conservation, Forest Research Institute, Dehradun, Uttar Pradesh 248 006, India. Tolerance of trees to soil salinity. Journal of the Indian Society of Soil Science, 39:549–556.

> This paper reports on growth and ionic composition of seedlings of six tree species, grown in soil-filled pots, in response to salinity (chloride:sulfate:bicarbonate in the ratio 6:3:1). *Casuarina equisetifolia* grew at an EC_e of 32.5 dS/m, *Acacia nilotica*, *Eucalyptus* hybrid (*E. tereticornis*) and *Pongamia pinnata* grew well at EC_e 16.3 dS/m and *Dalbergia sissoo* and *Araucaria cunninghamii* grew well at EC_e 8.1 dS/m.

Singh, R.P., Yadav, J.S.P., Gupta, I.C. and Singh, U. (1988). Bishen Singh Mahendra Pal Singh, PO Box 137, Dehra Dun 248001, India. Utilisation of salt affected soils and saline waters for trees and grasses (world literature—1950–82). 204 p.

> This bibliography provides 453 references including abstracts and contains many references from eastern Europe, including Russia.

Singh, S. and Thompson, F.B. (1992). Oxford Forestry Institute, South Parks Road, Oxford 0X1 3RB, UK. Salt tolerance in some tropical tree species. Bois et Forets des Tropiques, 234:61–67.

In a glasshouse experiment, in which sand-cultured seedlings were treated with mixed salts, *Acacia nilotica* and *Prosopis juliflora* were more salt-tolerant than *Dalbergia sissoo*. Data for Na and K concentrations in leaves, stems and roots are provided. *A. nilotica*, the most tolerant species, maintained higher K:Na ratios in its leaves with increasing salinity.

Sinha, A., Gupta, S.R. and Rana, R.S (1985). Department of Biosciences, Maharshi University, Rohtak 124 100, India. Effect of clipping on growth and total non-structural carbohydrates of *Diplachne fusca* in saline and alkali soils. Proceedings of Indian National Science Academy, B51, No. 1:123–127.

In experiments conducted under controlled conditions in pots using alkali soils (pH 9.3 and 9.8), saline soils (EC_e 6 and 12 dS/m) and normal soil (EC_e 0.5 dS/m; pH 7.5), total non-structural carbohydrate (TNC) content of *Diplachne [Leptochloa] fusca* in above-ground and below-ground parts of the plants was influenced by clipping strategies and regrowth of plants was related to TNC reserves of residual plant tissues after clipping.

Sissay, B. (1986). Ministry of Agriculture, Animal Resources Department, PO Box 661, Addis Ababa, Ethiopia. Salt affected wastelands in Ethiopia; potential for production of forage and fuel. Reclamation and Revegetation Research, 5:59–64.

Since about 16% of the total area of Ethiopia is salt-affected and much vegetation has been exploited, it is suggested that high priority be given to research to revegetate salt-affected wasteland for fodder, forage and fuel wood production.

Skirde, W. (1979). Investigations into the salt tolerance of grasses based on pot and field experiments. Zeitschrift für Vegetationstechnik im Landschafts und Sportstattenbau:107–113.

Reports on the NaCl tolerance of 78 cutivars of *Festuca ovina, F. rubra, Agrostis stolonifera, A. canina, A. tenuis, Lolium perenne* and *Poa pratensis* grown in soil-filled pots under glasshouse conditions. (In German.)

Slavich, P.G., Smith, K.S., Tyerman, S.D. and Walker, G.R. (1996). CSIRO Land and Water, Private Bag 2, Glen Osmond, SA 5064, Australia. Water use of *Atriplex nummularia* above saline watertables. In: Productive use and rehabilitation of saline lands. Proceedings Fourth National Conference and Workshop, Albany, Western Australia (Promaco Conventions Pty Ltd. Canning Bridge, WA), 255–261.

The water use characteristics of regularly grazed saltbush (*Atriplex nummularia*) plantations established over shallow (1–2 m) watertables are examined. Transpiration rate (determined by heat pulse) was very low (<0.2 mm/day) over the monitoring period (summer–winter); this was associated with low leaf area index (0.35), low stomatal conductances and low xylem water potentials. At most times of the year, plants used shallow water sources derived mainly from rainfall (determined from natural isotope studies), however up to half the transpiration rate in late summer (driest period) was derived from ground water.

Smart, R.M. (1982). Environmental Laboratory, USAE, Waterways Experiment Station, Vicksburg, MS 39180, USA. Distribution and environmental control of productivity and growth form of *Spartina alterniflora* (Loisel.). In: Contributions to the ecology of halophytes (Sen, D.N. and Rajpurohit, K., ed.), Tasks for Vegetation Science, Vol. 2, 127–142. Dr. W. Junk Publishers, The Hague, The Netherlands.

The paper presents a review of the environmental factors controlling distribution of *Spartina alterniflora* and its physiological adaptation to the intertidal zone. Possibilities of physiological adaptations with reference to colonisation ability, anaerobiosis, salinity tolerance and water conservation are discussed.

Smit, B., Stachowiak, M. and Volkenburgh, E. (1989). Center for Urban Horticulture, University of Washington, Seattle, Washington 98195, USA. Cellular processes limiting leaf growth in plants under hypoxic root stress. Journal of Experimental Botany, 40:89–94.

In a short-term solution culture experiment, it was concluded that leaf growth of hypoxia-stressed clonal plants of a *Populus trichocarpa* × *P. deltoides* hybrid was limited by cell wall extensibility. Data are provided for leaf expansion, leaf size, epidermal size and number, water potential and cell wall extensibility.

Solanki, K.R., Jindal, S.K., Kachkar, N.L. and Jain, B.L. (1985). Central Arid Zone Research Institute, Jodhpur 324 003, India. Performance of *Leucaena leucocephala* (Lam.) de Wit. varieties using saline water for irrigation. Leucaena Research Reports, 6:54–55.

The perfomance at 15 months of 20 varieties of *Leucaena leucocephalla* on a slightly saline site, underlain by a calcareous hardpan (15–22 cm) in Pali (India) is presented. Variety 'Cunningham' gave the highest yield of fresh leaves and stem weight.

Somers, G.F. (1979). School of Life and Health Sciences and College of Marine Studies, University of Delaware, Newark, DE, USA. Natural halophytes as a potential resource for new salt-tolerant crops: some progress and prospects. In: The biosaline concept: an approach to the utilization of underexploited resources (Hollaender, A., Aller, J.C., Epstein, E., San Pietro, A. and Zabrosky, O.R., ed.), 101–115. Plenum Press, New York, USA.

The paper describes the significance and approaches for naturally growing coastal and inland halophytes to be grown for food, forage/fodder and fuel, etc. Important characteristics for successful utilisation and their economic feasibility, in addition to salt tolerance, include yield, characteristics and quality of edible protein, and potential for adapting to commercial production. Specific examples are given.

Somers, G.F. (1979). University of Delaware, Newark, Delaware, USA. Production of food plants in areas supplied with highly saline water: problems and prospects. In: Stress physiology in crop plants (Mussell. H. and Staples, R.C., ed.), 107–125. John Wiley & Sons.

This paper briefly describes the progress and prospects for 235 selections of halophytes belonging to 65 different plant species. The most prominent species described is *Spartina alterniflora,* which can be grown under flooded conditions with highly saline water (25–32%). The paper also mentions growth of: *Atriplex patula* with 20–25% saline water and having 14% protein (DW); *Chenopodium album,* with seeds having 10–12% protein (DW); *Kosteletzkya virginica* having 33% protein (DW) in seeds. Other halophytic species reported include *Spartina patens, Distichlis spicata, Elymus virginicus* and *Elymus mollis.*

Somers, G.F. (1982). University of Delaware, Newark, DE 19711, USA. Food and economical plants: general review. In: Biosaline research: a look to the future (San Pietro, A., ed.), 127–148. Proceedings of 2nd International Workshop on Biosaline Research, La Paz, Mexico, Plenum Press, New York, USA.

A general review of the work done in the last 10–15 years on (i) the culture of crop plants with saline water (including both glycophtes and halophytes), (ii) selection criteria for salt tolerance and (iii) discussion of physiological processes involved in salt tolerance. The paper also discusses the potential for increasing salt tolerance in conventional crop species as well as various wild plants for saline areas. Emphasis is given to potential of wild plant species including *Chenopodium* spp., *Cressa truxellensis, Simmondsia chilensis, Prosopis* spp., *Salicornia* spp. and *Kosteletzkya virginica* for use as crops.

Somers, G.F., Fontes, M. and Grant, D.A. (1979). School of Life and Health Sciences, University of Delaware, Newark, USA. Halophytes from coastal salt marshes: a potential source of crop plants for arid lands. In: Arid land plant resources (Goodin, J.R. and Northington, D.K., ed.), 402–417. Proceedings of the International Arid Land Conference on Plant Resources, Texas Technical University, Texas, USA.

> The potential of different halophytic species to be irrigated with very high salinity water is discussed. Species belonging to the family Poaceae (including *Spartina alterniflora, S. patens, S. foliosa* and *Distichlis spicata*), Chenopodiaceae (including *Atriplex patula, Chenopodium album* and *Salicornia* spp.) and Batidaceae (including *Batis maritima*) have been studied in respect of germination, growth, yield and quality of fruits.

Soufi, S.M. and Wallace, A. (1982). The Laboratory of Biomedical and Environmental Sciences, University of California, Los Angeles, CA 90024, USA. Sodium relations in desert plants. 8. Differential effects of sodium chloride and sodium sulphate on growth and composition of *Atriplex hymenelytra* (desert holly). Soil Science, 134:69–70.

> This paper reports that maximum growth over a period of three months of *Atriplex hymenelytra* (desert holly) cuttings in solution culture was obtained at 50 mol/m^3 NaCl (maximum level imposed). Data on macro- and micro-nutrient concentrations in leaves, stems, and roots are presented.

Squella, F. (1986). Estacion Experimental La Platina, Instituto de Investigaciones Agropecuarias (INIA), PO Box 5427, Santiago, Chile. Forage and fuel production from salt affected wastelands in Chile. Reclamation and Revegetation Research, 5:41–48.

> This paper provides information on current uses of plants for forage and fuel, particularly *Prosopis tamarugo* and *P. chilensis*, and research programs to develop potentially new salt-tolerant sources of forage and fuel, in Chile.

Squires, V.R. (1993). National Key Centre for Dryland Agriculture and Land Use Systems, Roseworthy Campus, University of Adelaide, Roseworth 5371, Australia. Australian experiences with high salinity diets for sheep. In: Towards the rational use of high salinity tolerant plants (Lieth, H. and Al-Masoom, A., ed.), Vol. 1, 449–457. Proceedings of the ASWAS Conference Al-Ain, United Arab Emirates.

Australian research into the behaviour, productivity and physiology of sheep on salty diets is reviewed.

Staples, R.C. and Toenniessen, G.H. (ed.) (1984). Boyce Thompson Institute, Cornell University, Ithaca, USA. Salinity tolerance in plants: strategies for crop improvement. Proceedings of International Conference, Bellagio, Italy, 434 p. John Wiley & Sons, New York, USA.

This book comprises papers dealing with the review of the current state of knowledge concerning the physiological and biochemical mechanisms used by plants to adapt to high salinity. The book has 22 chapters divided into three parts. Part 1 (Mechanisms of salt tolerance) deals with cytology and phsyiology. Part 2 (Crop selection and improvement) reviews the successes and difficulties that plant breeders and cell biologists have encountered in trying to select for and use salt-tolerant plants in breeding programs. Chapters are also included on the potential use of halophytic plants and on genetic engineering and cell culture as promising future plant improvement technologies. Part 3 (Controlled environments and economic analyses) has a chapter that considers the use of controlled environment agriculture as an alternative strategy for using saline waters. Two other chapters present an economic analysis of plant improvement strategies, and a review of the world food situation including the role of salt-tolerant plants.

Stelzer, R. (1981). Botanishes Institut der Tieraztlichen Hochschule Hannover, Butenweg 17d, D-3000, Hannover 71, Federal Republic of Germany. Ion localization in the leaves of *Puccinellia peisonis*. Z. Pflanzenphysiologie, Bd., 103.S.:27–36.

Using energy dispersive X-ray microprobe analyses, the authors showed that vacuoles of bundle sheath cells in leaves of *Puccinellia peisonis* provide an important salt-tolerance mechanism since they contain higher amounts of Na than the mesophyll cells at 9 and 80 mol/m^3 NaCl, but from 80 to 320 mol/m^3 vacuoles of the mesophyll cell also contain Na, although the concentration is always lower than in the bundle sheath cells.

Stelzer, R. and Läuchli, A. (1977). Botanisches Institut der Tierarztlichen Hochschule Hannover, Bunteweg 17d, D-3000 Hannover-Kirchrode, BRD. Salt- and flooding-tolerance of *Puccinellia peisonis*. I. The effect of NaCl- and KCl-salinity on growth at varied oxygen supply to the root. Zeitschrift für Pflanzenphysiologie Bd., 83.S.:35–42.

This paper reports that growth of *Puccinellia peisonis*, endemic in the eastern area of the Neusidedler See (Austria) and tolerant to high salinity and flooding was improved under poor aeration both in the presence and absence of NaCl in solution culture. Under well aerated conditions, plants continued to grow up to 250 mol/m^3 KCl, but at low O2 concentrations (40–50% of control) plants grew up to 300 mol/m^3 NaCL and KCL, over a six-month period. DM yield under aerated conditions (without salt) was only 30% of that without aeration.

Stelzer, R. and Läuchli, A. (1977). Institut fur Botanik der Technischen Hochschule Darmstadt, Federal Republic of Germany. Salt- and flooding-tolerance of *Puccinellia peisonis*. II. Structural differentiation of the root in relation to function. Zeitschrift für Pflanzenphysiologie, 84.S.:95–108.

This paper provides a detailed account of root anatomy in relation to gas exchange (under flooding) and solute movement (under salinity) in *Puccinellia peisonis*. A well-developed aerenchyma, continuous from the apical to the proximal region of the root, contributes to flood tolerance. Development of suberisation of the endodermis, and the inner cortical cells to secondary endodermis is highlighted, amongst other anatomical features, in relation to physiological barriers to the transport of solutes into the stele.

Stelzer, R. and Läuchli, A. (1978). Botanisches Institut der Tierarztlichen Hochschule Hannover, D-3000, Hannover 71, Federal Republic of Germany. Salt- and flooding-tolerance of *Puccinellia peisonis*. III. Distribution and localization of ions in the plant. Zeitschrift für Pflanzenphysiologie Bd., 88.S.:437–448.

This paper provides evidence that Na transported through roots of *Puccinellia peisonis* is restricted in contrast with K. X-ray microanalyses of unfixed, frozen roots show a decreasing gradient of Na and an increasing gradient of K from the outer cortex through the endodermis to the stele, leading to a high K/Na selectivity in transport to the xylem. Two possible pathways of Cl transport across the endodermis to the xylem are suggested on the basis of data from the Ag precipitation technique: (i) the symplasmic pathway, which would involve the endoplasmic reticulum and plasmodesmata; and (ii) from outer to inner plasmalemma transport through the passage cells into the apoplast of the stele.

Stelzer, R. and Läuchli, A. (1980). Botanisches Institut der Tierarztlichen Hochschule Hannover, D-3000, Hannover 71, Federal Republic of Germany. Salt- and flooding-tolerance of *Puccinellia peisonis*. IV. Root respiration and the role of aeranchyma in providing atmospheric oxygen to the roots. Zeitschrift für Pflanzenphysiologie, 97.S.:171–178.

This paper reports increased respiration rate in *Puccinellia peisonis* roots under O_2-deficient conditions at 100 mol/m^3 NaCl but no stimulation with added KCl. Root respiration of plants under these conditions is supported by atmospheric O_2 from the aerenchyma, with diffusion of O_2 from the shoot of only minor importance.

Stewart, G.R. and Lee, J.A. (1974). Department of Botany, The University, Manchester M13 9PL, UK. The role of proline accumulation in halophytes. Planta (Berl.), 120:279–289.

This paper reports that proline is the major component of the amino acid pool in most field-grown higher plant halophytes. For example, in *Triglochin maritima*, free proline can represent 10–20% of the shoot DW. Proline levels increase with increasing salinity and an osmotic adjustment role is suggested. Comparisons of inland and coastal populations of *Armeria maritima* suggest that the capacity to accumulate proline is correlated with salt tolerance.

Stirzaker, R.J., Cook, F.J., and Knight, J.H. (1997). CSIRO Land and Water, GPO Box 1666, Canberra, ACT 2601. How to space trees in a paddock for control of dryland salinity: a first approximation. In: Proceedings of workshop on agroforestry for sustainable land-use: fundamental research and modelling, temperate and Mediterranean applications, pp. 169–173. Montepellier, 23–29 June.

This paper gives simple rules and analytical expressions to optimise the number and location of trees required to control rising watertables on relatively flat cropping or pasture lands. With reference to salinity, the paper describes situations where belts of trees with alleys between them (up to than 100 m apart for most cases when the saturated conductivity of the subsoil exceeds 5 mm/day) can be used to access water from the watertable, but where the possibility of salt build up in the capillary fringe above a watertable means that the salinity of the ground water needs to be relatively low (less than 5 dS/m), or uptake rate from the watertable low (less than 200 mm/year), unless the root zone is leached once or

twice a decade. It is concluded that the planting of tree belts to manage perched watertables will be of limited value unless slope exceeds 5 degrees.

Stolte, W.J., McFarlane, D.J. and George, R.J. (1997). University of Saskatchewan, Seskatoon, Seskatchewan S7N 5A9, Canada. Flow systems, tree plantations and salinisation in a Western Australian catchment. Australian Journal of Soil Research, 35:1213–1229.

This paper reports that although watertables were successfully lowered, root-zone salinity and watertable salinity increased in a 15-year-old agroforestry planting of eucalypts on a saline discharge site in the wheatbelt of Western Australia. The authors conclude that such biological interventions are short- to medium-term solutions to managing salinity.

Storey, R. and Wyn Jones, R.G. (1979). Department of Biochemistry and Soil Science, University College of North Wales, Bangor, Gwynedd, Wales, UK. Response of *Atriplex spongiosa* and *Suaeda monoica* to salinity. Plant Physiology, 63:156–162.

This paper reports on the growth and tissue water (succulence), K, Na, Cl, proline and glycinebetaine contents of the shoots and roots of *Atriplex spongiosa* and *Suaeda monoica* over a range of external NaCl salinities. An association between high leaf Na accumulation, high osmotic potential, succulence, and a positive growth response at low salinities was found for both species. Increased proline and glycinebetaine contents were closely correlated with sap osmotic potential and it is suggested that glycine-betaine is the major cytoplasmic osmoticum (with K salts) at high salinities whereas Na salts may be preferentially used as vacuolar osmotica.

Stumpf, D.K. and O'Leary, J.W. (1985). Environmental Research Laboratory, University of Arizona, Tucson International Airport, Tucson, AZ. 85706, U.S.A. The distribution of Na^+, K^+ and glycinebetaine in *Salicornia bigelovii*. Journal of Experimental Botany, 36:550–555.

This paper reports on the chlorophyll, ash (salt), protein and glycinebetaine content of vascular, spongy mesophyll and palisade tissue of stems of young, actively growing *Salicornia bigelovii*.

Stumpf, D.K., Prisco, J.T., Weeks, J.R. Lindley, V.A. and O'Leary, J.W. (1986). Environmental Research Laboratory, University of Arizona, Tucson International Airport, Tucson, AZ. 85706, USA. Salinity and *Salicornia bigelovii* Torr. seedling establishment. Water relations. Journal of Experimental Botany, 37:160–169.

> Seedling establishment of *Salicornia bigelovii* was inhibited when seeds were sown in vermiculite watered with 0 ppm NaCl (T1) while 10 000 (approx. 170 mol/m^3; T2) or 30 000 (T3) ppm had no inhibitory effect. This was related to increased water movement into cotyledons and embryos under NaCl, due to ion uptake, compared with control conditions.

Suehiro, K. and Ogawa, H. (1980). Biological Institute, Faculty of Education, Kagawa University, Takamatsu 760, Japan. Competition between two annual herbs, *Atriplex gmelini* C.A. Mey and *Chenopodium album* L., in mixed cultures irrigated with seawater of various concentrations. Oecologia (Berl.), 45:167–177.

> This paper reports that the relative dominance of *Atriplex gmelini* and *Chenopodium album* in a mixed stand was strongly affected not only by total plant density and density ratio between the two species but also by concentration of sea water used for irrigation.

Sugimoto, K., Uchiyama, Y., Takeuchi, Y and Toyama, M. (1988). Sand Dune Research Institute, Tottori University, Tottori 680, Japan. Studies on the growth of saltbush. II. Effect of saline water concentration on the yield of *Atriplex nummularia* in sandy soil. Japanese Journal of Tropical Agriculture, 32:129–139.

> This paper reports on glasshouse trials in which *Atriplex nummularia* was irrigated daily with saline water. Saline irrigation increased plant FW, DW, leaf:stem ratio and water content/unit leaf area, and decreased percentage DM. Yields were increased by 7–43% with 0.7–1.4% NaCl, 48–61% with 25 and 50% sea water and 54–79% with compound salt water (mixture of $CaCl_2$, $MgSO_4$ and $NaHCO_3$). Yields were decreased by 10% and 40% with 75% sea water and 2.7% NaCl, respectively. Data on changes in ion concentrations are provided. (In Japanese, English summary.)

Suhayda, C.G., Yin-Lijuang, Redmann, R.E., Li-Jiandong, Yin, L.J. and Li, J.D. (1997). Department of Crop Science and Plant Ecology, University of Saskatchewan, Saskatoon, Saskatchewan S7N 5A8, Canada. Gypsum amendment improves native grass establishment on saline-alkali soils in northeast China. Soil Use and Management, 13:43–47.

This paper reports that survival and growth of three grass species—*Aneurolepidium chinense*, *Puccinellia tenuiflora* and *Hordeum brevisubulatum*—transplanted into saline–alkali soils in the field (Jilin Province, China) were increased by the application of gypsum.

Sun, D. and Dickinson, G.R. (1993). Queensland Forest Research Institute, Department of Primary Industries, PO Box 210, Atherton, Queensland 4883, Australia. Responses to salt stress of 16 *Eucalyptus* species, *Grevillea robusta*, *Lophostemon confertus* and *Pinus caribaea* var. *hondurensis*. Forest Ecology and Management, 60:1–14.

Seedlings of 16 *Eucalyptus* species, *Grevillea robusta*, *Lophostemon confertus* and *Pinus caribaea* var. *hondurensis* in sand-filled pots were treated with NaCl (0–200 mol/m^3) in a glasshouse experiment. Based on overall performance (plant height, leaf length, width, thickness, and number of leaves), *Eucalyptus depanophylla*, *E. argophloia*, *E. camaldulensis* and *E. robusta* were most tolerant to NaCl while *E. cloeziana* and *E. pilularis* were least tolerant.

Sun, D. and Dickinson, G.R. (1995). Bureau of Resource Sciences, PO Box E11, Parkes, Canberra ACT 2600, Australia. Survival and growth responses of a number of Australian tree species planted on a saline site in tropical north Australia. Journal of Applied Ecology, 32:817–826.

Results of the survival and growth (diameter at breast height, tree crown size, branch number per tree, growth form, fork numbers per tree, and leaf length, width and thickness) at three (survival and height only) and 24 months of 15 species and provenances of Australian trees planted on a saline site in dry tropical northern Australia are presented. Survival and growth varied with salinity and species. *Casuarina cunninghamiana*, *C. glauca* and *Eucalyptus camaldulensis* achieved the highest survival, fastest growth rate and best form. *Acacia aulacocarpa* had the poorest performance.

Sun, D. and Dickinson, G.R. (1995). Queensland Forest Research Institute, Department of Primary Industries, PO Box 210, Atherton, Queensland. 4883, Australia. Salinity effects on tree growth, root distribution and transpiration of *Casuarina cunninghamiana* and *Eucalyptus camaldulensis* planted on a saline site in tropical north Australia. Forest Ecology and Management, 77:127–138.

This paper reports on survival, height and diameter at breast height (DBH), as well as root growth (by excavation), transpiration rate (with the heat pulse technique) and chemical composition at ages 24 and 36 months for *Casuarina cunninghamiana* and *E. camaldulensis* planted on mounds on a tropical saline site in Queensland, N. Australia was evaluated. Both species had high survival. *E. camaldulensis* trees were taller with greater DBH at both low (<0.6 dS/m), and moderate (0.6–1.1 dS/m) salinity, and transpired more water in both summer and winter, but at high (1.1 dS/m) salinity, *C. cunninghamiana* performed better. *C. cunninghamiana* had a shallow root system with most of the lateral roots in the upper 12 cm of soil, while *E. camaldulensis* had most lateral roots in the upper 28 cm.

Sun, D. and Dickinson, G.R. (1997). Bureau of Resource Sciences, PO Box E11, Parkes, Canberra ACT 2600, Australia. A screening trial of 28 species conducted on non-saline and saline soils in dry tropical northeast Australia. Journal of Sustainable Forestry, 3/4:1–13.

In a trial with 28 tree species on a moderately saline ($EC_{1:5}$ approx. 0.9 dS/m) near Ayr, Queensland, in dry tropical Australia, *Eucalyptus camaldulensis, E. drepanophylla, E. mollucana, E. raveretiana* performed best after 24 months. Data for a non-saline site are also provided. *E. camaldulensis* was highly recommended for both saline and non-saline conditions.

Sun, D., Dickinson, G.R. and Bragg, A.L. (1994). Queensland Forest Research Institute, Department of Primary Industries, PO Box 210, Atherton, Queensland 4883, Australia. The establishment of *Eucalyptus camaldulensis* on a tropical saline site in north Queensland, Australia. Agriculture, Ecosystems and Environment, 48:1–8.

This paper reports on an experiment located on a saline site in northern Queensland in which plants of *Eucalyptus camaldulensis* were provided either tree shelter, plastic mulch, organic mulch and no treatment. Trees with organic mulch and tree shelter treatments had a greater survival (at three, six and nine months) than trees with plastic mulch and control treatments, particularly when salinity was higher. Fifty percent height reduction occurred at $EC_{1:5}$ approx. 0.7 dS/m.

Sweeney, S.M. and Stevens, R.M. (1997). Lenswood Centre, Primary Industries South Autralia, Swamp Rd, Lenswood, SA 5240, Australia. Growth and water-use of eucalypt trees irrigated with saline drainage water. Irrigation Science 17: 173–181.

Growth, water use and leaf chemical composition of *Eucalyptus camaldulensis* (Lake Albacutya provenance) are reported for the fourth year of a field experiment designed to investigate response to irrigation water salinity (0.5 to 10 dS/m; combinations of river, drainage and ground water) and nutrition (annual additions of 200 kg N and 100 kg P per hectare or no addition of nutrients). Growth was not decreased even at 10 dS m^{-1}, however the soil was well drained which enabled soil water salinities to remain at about 10 dS m^{-1}. Tree size and water use were well correlated.

Sykes, M.T. and Wilson, J.B. (1988). Department of Botany, University of Otago, PO Box 56, Dunedin, New Zealand. An experimental investigation into the response of some New Zealand sand dune species to salt spray. Annals of Botany, 62:159–166.

This paper reports on the tolerance of 29 species, mainly from New Zealand sand dunes, to overhead salt spray in a glasshouse. Tolerant species included *Scirpoides nodosa, Elymus faretus and Desmoschoenus spiralis*. There was little correlation between tolerance to salt spray and tolerance to root-zone salinity. Salt spray tolerance correlated well with field distribution only for some species.

Szwarcbaum, I. and Waisel, Y. (1973). Department of Botany, Tel Aviv University, Tel Aviv, Israel. Inter-relationships between halophytes and glycophytes grown on saline and non-saline media. Journal of Ecology, 61:775–786.

Growth of the halophytes *Hordeum marimum* and *Chloris gayana* and of the non-halophyte *Triticum vulgare* was investigated in pure and in mixed cultures. Using the Michaelis–Menten equation, it was shown that, under non-saline conditions, growth of both halophytes was competitively inhibited by the non-halophyte, but this was not observed under saline conditions.

Taha, F.K., Omar, S.A. and Nassef, A.A. (1990). Aridland Agriculture Department, Food Resources Division, Kuwait Institute for Scientific Research, Safat, Kuwait. Forage trials under Kuwait's conditions. In: Advances in range management in arid lands (Halwagy, R., Taha, F.K. and Omar, S.A., ed.), 135–153. Proceedings of the First International Conference on Range Management in the Arabian Region.

Included in information presented here is the suggestion that saline water of 5 000 ppm can be used for seedling establishment of *Atriplex* species. Saline water was applied following plant germination and was continued

for 12–15 weeks without adverse effects. It was concluded that *A. halimus* could establish with sewage, brackish water and diluted sea-water (1:1 to 1:15 sea water:fresh water) and that 1:7 to 1:15 were the best seawater dilutions.

Talbot, R.J., Etherington, J.R. and Bryant, J.A. (1987). Department of Plant Science, University College, Cardiff CF1 IXL, UK. Comparative studies of plant growth and distribution in relation to waterlogging. XII. Growth, photosynthetic capacity and metal ion uptake in *Salix caprae* and *S. cinerea* ssp. *oleifolia*. New Phytologist, 105:563–574.

This paper reports that growth of rooted cuttings of *Salix caprea* was reduced more by intermittent, partial and complete soil waterlogging than that of *S. cinerea* ssp. *oleifolia*. Data are provided on leaf turgidity, Fe concentration, chlorophyll, Mg concentration and photosynthesis and related to species differences in growth. *S. cinerea* produced adventitious roots at the surface of flooded soil and when immersed in water whereas *S. caprea* did not. These observations are related to the ecology of the two species; *S. caprea* normally inhabits better drained soils than *S. cinerea*.

Tanji, K.K. and Karajeh, F.F. (1993). Department of Land, Air and Water Resources, University of California, Davis, CA 95616-8628, USA. Saline drain water reuse in agroforestry systems. Journal of Irrigation Drainage Engineering, 119:170–180.

The potential of agroforestry systems to lower high watertables and to reuse poor-quality subsurface drainwater was investigated in a eucalypt (*Eucalyptus camaldulensis*) and saltbush (*Atriplex* spp.) plantation in the San Joaquin Valley, California, USA. Saline subsurface drainwater (EC of 10 dS/m, 12 ppm B, 400 ppb Se and an SAR of 11) from nearby croplands were used to irrigate the eucalypts. The tree plantation reduced the watertable depth from 0.6 m to 2.3 m. After several years of drain-water reuse, salinity and B levels increased in the soil profile and trees were unable to extract the available soil water fully; hence it was necessary to increase the leaching fraction (16%) to prevent further soil salinisation.

Tarrad, A.M., Younis, A.A., Nasr, M.A. and Kasseh, T. (1991). Evaluation of drought and salinity resistance of some *Atriplex* species in the northwestern Egyptian coast. In: Desert development. Part 1: desert agriculture, ecology and biology (Bishay, A. and Dregne, H., ed.), 367–376. Proceedings Second International Desert Development Conference, Cairo, Egypt. Hardwood Academic Publishers, GmbH, Chur, Switzerland.

This paper provides data on biomass of leaves and plants as well as leaf diffusive resistance and transpiration for *Atriplex nummularia*, *A. halimus*, *A. vesicaria*, *A. lentiformis* and *A. canescens* at a field site near El-Kasr, Matrouh where the soil salinity was 7 932 ppm. It was concluded that *A. nummularia* was most suitable of those tested for the north western Egyptian coastal region.

Teas, H.J. (1979). Biology Department, University of Miami, Coral Gables, Florida 33124, USA. Silviculture with saline water, In: The biosaline concept: an approach to the utilization of underexploited resources (Hollaender, A., Aller, J.C., Epstein, E., San Pietro, A. and Zaborsky, O.R., ed.), 117–161. Plenum Press, New York, USA.

A detailed review of various aspects of mangrove ecology, uses, physiology, soils and improvement.

Thind, S.S., Chhibba, I.M. and Hothi, B.S. (1984). Punjab Agricultural University, Ludhiana, India. Reclamation of alkali land in village Jainpur. Indian Farming, 33:13–17.

This paper describes the strategies used to reclaim alkali land. The main processes were land levelling, construction of bunds around each field, gypsum application followed by two to three leachings and sowing of *Sesbania aculeata* followed by sowing rice and wheat.

Thompson, J.R. and Rutter, A.J. (1986). Department of Pure and Applied Biology, Imperial College, Silwood Park, Ascot, Berkshire SL5 7PY, UK. The salinity of motorway soils. IV. Effects of sodium chloride on some native British shrub species, and the possibility of establishing shrubs on the central reserves of motorways. Journal of Applied Ecology, 23:299–315.

This paper reports on the effects of either periodically spraying plants, or adding NaCl to the soil (2500 μg Na/g and 1500 μg Cl/g at the start of the growing season) on container-grown plants of 11 native British shrub species through two successive winters. In general, soil-applied NaCl had greater effects than spraying.

Thomson, L.A.J. (1987). CSIRO, Tree Seed Centre, Division of Forest Research, PO Box 4008, Canberra ACT, Australia. Australian acacias for saline, alkaline soils in the hot, dry subtropics and tropics. In: Australian acacias in developing countries (Turnbull, J.W., ed.), 66–69. ACIAR Proceedings No. 16, Canberra, Australia.

The most promising species for these conditions, with high salt tolerance, a moderate to fast growth rate and a moderate to high coppicing ability, are *Acacia ampliceps*, *A. cuspidifolia*, *A. ligulata*, *A. maconochieana*, *A. salicina*, *A. sclerosperma*, *A. stenophylla* and *A. victoriae*. A table is presented showing the characteristics and potential uses of these and 18 other species.

Thomson, L.A.J., Morris, J.D. and Halloran, G.M. (1987). CSIRO Forestry and Forest Products, PO Box E4008, Kingston, ACT, 2604, Australia. Salt tolerance in eucalypts. In: Afforestation of salt-affected soils (Rana, R.S. (ed.)), Proceedings International Symposium, Karnal, India. Volume 3. 1–12.

This paper summarises genetic and physiological aspects of salt tolerance in several *Eucalyptus* species from controlled environment and field trials. Species in the section *Exsertaria* (red gums) were particularly salt tolerant. In some species, intra-specific variation for survival under saline conditions was high. This variation provides breeders with some scope for selecting more tolerant genotypes. The principal mechanism associated with increased salt tolerance appears to be maintenance of lower foliar levels of ions, especially Cl and Mg. Field trials in Victoria, Australia, indicate that red gums can be grown successfully on moderately saline soils provided prolonged waterlogging does not occur.

Thomson, W.W. (1975). Department of Biology, University of California, Riverside, California, USA. The structure and function of salt glands. In: Plants in saline environments (Poljakoff-Mayber, A. and Gale, J., ed.), 118–146. Springer-Verlag, Berlin.

This detailed review covers the following topics: (i) an introduction to where salt glands are located and what they contain, (ii) the general structure and ultrastructure of salt glands, and (iii) their function in terms of pathways for solute movement, selectivity and ionic and osmotic concentrations of the secreted fluid, active versus passive processes, physiological role, light dependency, lag period prior to secretion and mechanisms of secretion.

Thorburn, P.J. (1996). Department of Primary Industries, Indooroopilly, Queensland, Australia. Can shallow water tables be controlled by the revegetation of saline lands? Australian Journal of Soil and Water Conservation, 9:45–49.

This review concludes that ground water uptake by plants is often no more than would be expected by discharge from bare soil alone. Uptake of ground water continually increases root zone salinity which, in turn,

limits water uptake. Results of model simulations (which can account for interacting effects of watertable depth and salinity, plant salt tolerance and soil hydraulic properties) and field studies indicate that ground water uptake by plants is most likely to be higher than discharge from bare soils where watertables are relatively deep (>3 m) and of low salinity (EC < 10 dS/m), and soils are of fine texture. The long term survival of plants in saline discharge areas is determined by the balance between salt accumulation during ground water uptake and leaching of the salts from the profile during wet seasons or floods.

Thorburn, P.J., Hatton, T.J. and Walker, G.R. (1993). CSIRO Division of Water Resources, Centre for Groundwater Studies, PMB No. 2, Glen Osmond, SA 5064, Australia. Combining measurements of transpiration and stable isotopes of water to determine groundwater discharge from forests Journal of Hydrology (Amsterdam), 150:563–587.

This paper reports on the combined use of transpiration flux and source of water use with naturally-occuring stable isotopes of water to estimate transpiration rate of *Eucalyptus largiflorens* (black box) and *E. camaldulensis* (river red gum) communities on a floodplain in South Australia. Ground water discharge fluxes were 40–100% of the transpirational fluxes.

Thorburn, P.J. and Walker, G.R. (1994). Centre for Groundwater Studies, CSIRO Division of Water Resources, Private Mail Bag No. 2, Glen Osmond, SA 5064, Australia. Variations in stream water uptake by *Eucalyptus camaldulensis* with increasing access to stream water. Oecologia (Berlin), 100:293–301.

This paper reports on the use of stable isotopes ^{2}H and ^{18}O to determine the water sources of *Eucalyptus camaldulensis* at three sites in South Australia, with varying exposure to stream water. All streams were underlain by moderately saline ground water. Water uptake patterns are shown to be a function of the long-term availability of surface water.

Thorburn, P.J., Walker, G.R. and Brunel, J.P. (1993). CSIRO Division of Water Resources, Centre for Groundwater Studies, PMB No. 2, Glen Osmond, SA 5064, Australia. Extraction of water from *Eucalyptus* trees for analysis of deuterium and oxygen-18: laboratory and field techniques. Plant, Cell and Environment, 16:269–277.

The paper reports on a method for sampling and extracting water from *Eucalyptus* spp. for analysis of stable isotopes of water with respect to understanding relative water use from soil and ground water. (Refers to related papers by Thorburn and Mensforth.)

Thorburn, P.J., Walker, G.R. and Jolly, I.D. (1995). Resource Management Institute, Queensland Department of Primary Industries, Meirs Road, Indooroopilly, Queensland, 4068, Australia. Uptake of saline groundwater by plants: an analytical model for semi-arid and arid areas. Plant and Soil, 175:1–11.

This paper reports on an analytical model for describing the uptake of saline ground water by plants in dry regions. Model predictions were close to data collected from several sites in a *Eucalyptus* forest on a floodplain in South Australia

Tiku, B.L. (1976). Department of Environmental Biology, University of Guelph, Guelph, Ontario, Canada. Effect of salinity on the photosynthesis of the halophytes *Salicornia rubra* and *Distichlis stricta*. Physiologia Plantarum, 37:23–28.

This paper reports on the interaction between light intensity and osmotic potential (0–3.2 MPa, using combinations of ethylene glycol (EG) and NaCl) on photosynthesis and biomass production in *Salicornia rubra* and *Distichlis stricta*. NaCl increased growth, succulence and CO_2 uptake of *S. rubra* but decreased that of *D. stricta* and this was associated with more rapid increases in tissue Na concentrations in *S. rubra*. NaCl increased chlorophyll concentrations in *S. rubra* but decreased that of *D. stricta*, with the resultant higher photosynthesis per unit chlorophyll concentration in *S. rubra*.

Tiku, B.L. and Snaydon, R.W. (1971). Department of Environmental Biology, University of Guelph, Guelph, Ontario, Canada. Salinity tolerance within the grass species *Agrostis stolonifera* L. Plant and Soil, 35:421–431.

NaCl applied to plants in solution and sand culture had less effect on DW yield of populations of *Agrostis stolonifera* from maritime, high Na soils than on inland populations from soils of low Na content. Irrespective of location, shoot Na concentration and Na:K ratio was higher for populations from low Na soils.

Tomar, O.S. (1997). Central Soil Salinity Research Institute, Karnal 132001, India. Technologies of afforestation of salt-affected soils. International Tree Crops Journal, 9:131–158.

> This paper reviews efforts to grow timber and fruit trees on a range of saline and sodic soils in India. Aspects covered include: (i) planting techniques, including the relative merits of preparing auger holes and use of amendments, such as FYM, (ii) classification of tree species according to their tolerance of saline and sodic conditions, and (iii) the potential for ameliorative effects.

Tomar, O.S. and Gupta, R.K. (1985). Central Soil Salinity Research Institute, Karnal 132001, India. Performance of some forest tree species in saline soils under shallow and saline water-table conditions. Plant and Soil, 87:329–335.

> This paper reports on a field and pot study to determine the influence of seasonal variations in salinity and soil moisture profiles due to a fluctuating watertable (EC of 2–46 dS/m^3; 10–140 cm from the surface) on the survival of 16 tree species. Survival of waterlogging-sensitive species (e.g. *Acacia auriculiformis*) was improved by planting on ridges. Species recommendations are provided.

Tomar, O.S., Gupta, R.K. and Dagar, J.C. (1998). Central Soil Salinity Research Institute, Karnal, India. Afforestation techniques and evaluation of different tree species for waterlogged saline soils in semiarid tropics. Arid Soil Research and Rehabilitation, 12:301–316.

> This paper presents results of trials which started in 1982 near Sampla (Haryana, India) with a view to defining species performance and appropriate establishment techniques (ridge-trench, subsurface and furrow) for afforestation of waterlogged saline soils in arid and semiarid regions of India. Initial soil EC_e was 36.4 dS/m (0–30 cm), watertable depth fluctuated between 0 and 1.5 m and irrigation water was saline (average EC 29.8 dS/m). Tree growth was best with the use of furrows (and is the most economical for such soils). *Prosopis juliflora*, *Tamarix* sp., *Casuarina glauca*, *Acacia farnesiana*, *A. nilotica*, *A. tortilis*, and *Parkinsonia aculeata* performed best; *C. glauca* and *Salvadora oleoides* survived prolonged flooding.

Tomar, O.S., Kumar, R.M., Gupta, R.K. and Minhas, P.S. (1997). Central Soil Salinity Research Institute, Karnal, Haryana, India. Raising nursery of *Acacia nilotica* var. *cupressiformis* with saline water. Indian Forester, 123:148–152.

This paper reports on an experiment with *Acacia nilotica* to evaluate treatments [combination of salinities of irrigation water, EC 0.4–12 dS/m; irrigation frequency, 2–6 days; leaching fraction; and ratio of depth of irrigation water to cumulative pan evaporation (0.85–1.30)] that minimise salt accumulation in soil-filled nursery bags when tree seedlings are irrigated with saline ground water under arid conditions when no canal water is available. There appeared to be some benefit in maintaining more frequent irrigation and it is concluded that seedlings can be successfully grown with irrigation water of EC up to 4 dS/m, applied every 2–4 days.

Tomar, O.S. and Yadav, J.S.P. (1980). Central Soil Salinity Research Institute, Karnal 132001, India. Effect of saline irrigation water of varying EC, SAR and RSC levels on germination and seedling growth of some forest species. Indian Journal of Forestry, 3:306–314.

This paper reports on the effects of irrigation with saline (EC of 2–10 dS/m and SAR of 5, 15 and 30) and sodic [EC of 2 and 4 dS/m and residual sodium carbonate (RSC) of 5, 10 and 15 meq/L] water artificially prepared from $CaCl_2$, $MgCl_2$, NaCl, Na_2SO_4 and $NaHCO_3$. Germination, shoot growth and root length of all species were reduced and mortality increased by increasing EC, SAR and RSC, with root length most affected. All species were sensitive to saline water with an EC >2 dS/m and an SAR >5 at the early stages of germination. It is concluded that water of EC 8–10 dS/m and SAR up to 30 can be used for *Acacia nilotica*, *Pongamia pinnata* and *Prosopis juliflora*, and water of EC 4–6 dS/m and SAR up to 15 can be used for *A. tortilis*, *Albizia lebbeck*, *Azadirachta indica*, *Lawsonia glauca* and *Parkinsonia aculeata*, and water of EC <2 dS/m for *Eucalyptus* hybrid [*E. tetricornis*].

Tomar, O.S. and Yadav, J.S.P. (1982). Central Soil Salinity Research Institute, Karnal 132001, India. Effect of irrigation with saline and sodic waters on the growth of *Albizia lebbeck* and soil properties. Indian Journal of Forestry, 5:290–297.

This paper reports that growth of *Albizia lebbeck* seedlings in soil-filled pots (undrained) was reduced by EC 5 and 10 dS/m irrigation treatments but was not affected by sodicity [residual sodium carbonate (RSC) values of 5, 10 and 15 meq/L] until 240 days after transplanting, especially at EC 4 dS/m. Gypsum application appeared to improve growth at EC 2 and 4 dS/m.

Torello, W.A. and Rice, L.A. (1986). Department of Plant and Soil Sciences, University of Massachusetts, Amherst, MA 01003, USA. Effects of NaCl stress on proline and cation accumulation in salt sensitive and tolerant turfgrasses. Plant and Soil, 93:241–247.

> In a glasshouse experiment in which plants were treated with 170 mol/m^3 NaCl, salt-tolerant 'Fults' alkaligrass and 'Dawson' red fescue had lower shoot Na concentrations than salt-sensitive Kentucky bluegrasses ('Adelphi' and 'Ram I') and 'Lamestown' red fescue. Although proline concentration increased rapidly after salt application, its concentration was considered to be too low and variable to have any significant osmoregulatory role.

Totey, N.G., Kulkarni, R., Bhowmik, A.K., Khatri, P.K., Dahia, V.K. and Prasad, A. (1987). Forest Soil Vegetation Survey, Western Region, Jabalpur, Madhya Pradesh, India. Afforestation of salt affected wasteland. I. Screening of forest tree species of Madhya Pradesh for salt tolerance. Indian Forester, 113:805–815.

> This paper reports on germination responses with NaCl [EC 0.5–18 dS/m (0.06–1.35% salt)]. Overall ranking was *Dendrocalamus strictus* (bamboo) > *Phyllanthus emblica* > *Acacia auriculiformis.*

Townsend, A.F. (1980). USDA Agricultural Research Service, Nursery Crops Research Laboratory, Delaware, OH 43015, USA. Response of selected tree species to sodium chloride. Journal of the American Society of Horticultural Science, 105:878–883.

> Flowering dogwood *(Cornus florida)* and American sycamore *(Platanus occidentalis)* had the most foliar injury followed by pin oak *(Quercus palustris)*, honeylocust *(Gleditsia triacanthios)*, eastern white pine *(Pinus strobus)*, and Japanese pagoda tree *(Sophora japonica)* when solution-cultured seedlings were treated with NaCl (over the range 0 to 7 000 ppm; about 0–120 mol/m^3). Height and DW of sycamore and dogwood, and DW of eastern white pine were significantly reduced by salt treatment, whilst DW of the other species were unaffected. Concentration of Cl in the stem was better correlated with species' sensitivity to salt than were Cl and Na in the leaves, or Na in the stem.

Townsend, A.F. (1984). USDA Agricultural Research Service, Nursery Crops Research Laboratory, Delaware, OH 43015, USA. Effect of sodium chloride on tree seedlings in two potting media. Environmental Pollution, 34:333–344.

Ginkgo (*Ginkgo biloba*), honeylocust (*Gleditsia triacanthos*) and Japanese pagoda tree (*Sophora japonica*) showed the least foliar injury followed by eastern white pine (*Pinus strobus*), while sycamore (*Platanus occidentalis*) and white flowering dogwood (*Cornus florida*) showed the most injury when sedlings were treated using NaCl in soil- and perlite-filled pots. Cl concentrations in stems correlated well with species' tolerance.

Townsend, A.M. (1989). United States National Arboretum, New York Avenue NE, Washington DC 20002, USA. The search for salt-tolerant trees. Arboricultural Journal, 13:67–73

A short review of information related to tree injury by deicing or sea salts in the soil or through exposure of above-ground tissue to salt spray and efforts to identify salt-tolerant trees. The importance of Cl exclusion as a mechanism controlling salt tolerance in tree species is emphasised.

Traver, L.D., Preston, R.L. and Goodin, J.R. (1983). Texas Technical University, Lubbock, TX 79409, USA. Digestibility of *Atriplex canescens* as affected by saline conditions during plant growth. Proceedings of the American Society of Animal Science, 34:201–202.

On the basis of in vitro digestibility analysis on shoot material of *Atriplex canescens* seedlings grown in solution culture with 0–400 mol/m^3 NaCl added, for 95 days, it is suggested that digestibility is improved with up to about 200 mol/m^3 NaCl.

Troughton, A. (1967). Welsh Plant Breeding Station, Aberystwyth, Wales, UK. Effect of sodium chloride on the growth of *Lolium perenne*. Plant and Soil, 27:148–150.

Based on several measured growth variates, the effects of NaCl are shown not be related to water stress in *Lolium perenne*.

Truman, R. and Lambert, M.J. (1978). Wood Technology and Forest Research Division, Forestry Commission of NSW, PO Box 100, Beecroft, NSW 2119, Australia. Salinity damage to Norfolk Island pines caused by surfactants. 1. The nature of the problem and effect of potassium, sodium and chloride concentration on uptake by roots. Australian Journal of Plant Physiology, 5:377–85.

This paper relates to an investigation into the deterioration of Norfolk Island pine, *Araucaria heterophylla*, on the coast of eastern Australia. Reports on changes in shoot and root Na, K and Cl concentrations and symptoms of damage over a wide range of Na:K ratios and NaCl concentrations (0.1–460 mol/m^3) in two solution culture experiments. It was concluded that soil Na and Cl concentrations beneath seaside trees were too low to account for their high concentrations in the shoots of affected trees. (Refer to Dowden et al. 1978 and Grieve and Pitman 1978.)

Turner, J. and Kelly, J. (1973). Division of Wood Technology, Forestry Commission of NSW, PO Box 100, Beecroft, NSW 2119, Australia. Foliar chloride levels in some eastern Australian plantation forests. Soil Science Society of America Proceedings, 37:443–445.

Decrease in mean foliar Cl concentration in plantation forests of New South Wales, Australia, was significantly correlated with increasing distance from the Pacific Ocean and its increase with increasing rainfall and/or number of wet days over a 12 month period. Cl concentrations were consistently different between species.

Uchiyama, Y. (1987). Tropical Agriculture Research Centre, Tsukuba, Ibaraki 305, Japan. Salt tolerance of *Atriplex nummularia*. Technical Bulletin of The Tropical Agricultural Research Center Japan, 22: 69.

Reports on tolerance of *Atriplex nummularia* to NaCl at seed germination, seedling establishment, and during later plant growth. Adult plants survived at 5% NaCl, with optimum growth at 1%. Growth under salt was stimulated with increased nutrition (N, P, K). Germination of seeds from high-salt treated plants was better than those from low-salt plants, when treated with NaCl. Data on forage value are provided. The impact of salt-excreting vesiculated hairs is discussed.

Uchiyama, Y. and Sugimura, Y. (1985). Tropical Agriculture Research Centre, Yatabe-machi, Ibaraki-ken 305, Japan. Salt excreting function of vesiculated hairs of *Atriplex nummularia*. Japanese Journal of Crop Science, 1:39–46.

The morphological structure of the surface of leaves and stems of *Atriplex nummularia*, grown in solution culture with or without 2% NaCl, under optical as well as cryo-scanning electron microscopy, are described in detail. Data are provided on the structure of vesiculated hairs and ionic contents of their bladder cells (100 to 200 μm in diameter), ionic contents of the epidermal, mesophyll and bundle sheath cells. A proposed mechanism for removal of Cl from leaf lamina, via bladder cells, is presented, and it is suggested that this process can also apply to stems.

Ungar, I.A. (1978). Department of Botany, Ohio University, Athens, Ohio 45701, USA. Halophyte seed germination. The Botanical Review, 44:233–264.

Topics dealt with in this review include: (i) specific versus osmotic effects, (ii) interactions between salinity and temperature, and (iii) salinity and hormonal effects.

Ungar, I.A. (1978). Department of Botany, Ohio University, Athens, Ohio 45701, USA. The effects of salinity and hormonal treatments on growth and ion uptake of *Salicornia europaea*. Society Botany Fr., Actualites Botaniques, 3/4:95–104.

In a solution culture experiment, growth of *Salicornia europaea* was improved at 170 and 340 mol/m^3 NaCl, but was inhibited at 510 mol/m^3. At 0.1 mol/m^3, gibberellic acid (GA_3) stimulated growth at all salinities tested, but kinetin was inhibitory to growth in all salinity treatments up to 340 mol/m^3 NaCl. Data on Na, Cl and K concentrations are provided.

Ungar, I.A. (1982). Department of Botany, Ohio University, Athens, Ohio 45701, USA. Germination ecology of halophytes. In: Contributions to the ecology of halophytes (Sen, D.N. and Rajpurohit, K., ed.), Tasks for vegetation science, Vol. 2, 143–154. Dr. W. Junk Publishers, The Hague, The Netherlands.

The following topics are discussed: (a) salt tolerance, (b) specific ion toxicity, (c) hormones, (d) protein and amino acids, (e) temperature–salinity interactions, (f) ecotypes, and (g) seed demorphism and polymorphism.

Ungar, I.A. (1984). Department of Botany, Ohio University, Athens, OH 45701, USA. Autecological studies with *Atriplex triangularis* Willdenow. In: Proceedings—symposium on the biology of *Atriplex* and related chenopods, 40–52. USDA Forest Service, Intermountain Range and Forest Experiment Station, Ogden, Utah, USA. General Technical Report INT-172.

The influence of biotic and abiotic factors on the seed ecology, growth and distribution of *Atriplex triangularis* was investigated in coastal marshes at Rittmann, Ohio. Seed germination and growth were strongly inhibited by >2% NaCl. Plants survived hypersaline conditions in the field by adjusting their water potentials, but soil water potentials between –2 and –5 MPa caused high mortality.

Ungar, I.A. (1987). Department of Botany, Ohio University, Athens, Ohio 45701, USA. Population ecology of halophyte seeds. The Botanical Review, 53:301–334.

A number of aspects of the population biology of halophytes, with particular reference to seed production and germination, are considered in this review.

Ustin, S.L. (1984). Department of Botany, University of California, Davis, USA. Contrasting salinity responses of two halophytes. California Agriculture, 38:27–28.

This paper describes salinity responses of alkali burlrush (*Scirpus paludosus*), a less salt-tolerant perennial tuberous sedge, and the more salt-tolerant pickleweed (*Salicornia virginica*). Best vegetative and reproductive growth for alkali burlrush was without salt, whereas picklewood growth increased with increase in salinity up to 30 dS/m, and inflorescence and seed formation were unaffected. Alkali burlrush accumulated sugars for osmotic adjustment, whereas pickleweed utilised inorganic salts.

van der Moezel, P.G. (1992). Allan Tingay and Associates, 35 Labouchere Road, South Perth, WA 6151, Australia. Growth of *Eucalyptus camaldulensis* clones at Boyanup Brook, Western Australia. Land and Water Research News, 13:19–23.

This article describes the growth at five years of several *E. camaldulensis* clones, derived from plants selected for salt tolerance in glasshouse screening trials, along a salinity gradient on a site south of Perth, Western Australia. Salinity levels were apparently not high enough to cause significant growth reductions.

van der Moezel, P.G. and Bell, D.T. (1987). Department of Botany, University of Western Australia, Nedlands, WA 6009, Australia. Comparative seedling salt tolerance of several *Eucalyptus* and *Melaleuca* species from Western Australia. Australian Forestry Research, 17:151–158.

In two glasshouse experiments, survival and growth of seedlings of *Eucalyptus halophila, E. occidentalis, E. leptocalyx, E. goniantha, E. uncinata, E. angulosa, Melaleuca cymbifolia, M. thyoides, M. calycina, M. cariophylla* and *M. subtrigona* were evaluated with increased salinity (to a maximum of 72 dS/m). *M. cymbifolia* and *M. thyoides* were the most salt-tolerant melaleucas, while *E. halophila* was the most salt-tolerant *Eucalyptus* species. The seedlings with the highest tolerance were those raised from seeds collected from trees growing near the edge of salt lakes.

van der Moezel, P.G. and Bell, D.T. (1987). Department of Botany, University of Western Australia, Nedlands, WA 6009, Australia. The effect of salinity on the germination of some Western Australian *Eucalyptus* and *Melaleuca* species. Seed Science Technology, 15:239–246.

The effects of NaCl at germination were evaluated for 11 *Eucalyptus* and 10 *Melaleuca* species from Western Australia. *E. occidentalis* and *M. cardiophylla* were the most tolerant species with LD_{50} (lethal dose, when germination percentage is reduced by 50%) values of 176 and 148 mol/m^3 NaCl, respectively. The most salt-sensitive species were *E. redunca* and *M. subtrigona*. The seed from a population of *M. thyoides* growing in saline soil was more salt-tolerant than the seed from three other *M. thyoides* populations growing on non-saline soil.

van der Moezel, P.G. and Bell, D.T. (1987). Department of Botany, University of Western Australia, Nedlands, WA 6009, Australia. Comparative water use in river red gum and swamp she-oak seedlings stressed with different salinities. Land and Water News, 12:19–22.

Growth and water use of *Eucalyptus camaldulensis* (river red gum) and *Casuarina obesa* (swamp she-oak) seedlings in response to increasing salinity (up to 300 mol/m^3 NaCl) were determined in a glasshouse experiment. Swamp she-oak seedlings had better growth and greater water use at higher salinities.

van der Moezel, P.G. and Bell, D.T. (1990). Department of Botany, University of Western Australia, Nedlands, WA 6009, Australia. Saltland reclamation: selection of superior Australian tree genotypes for discharge sites.

This paper provides a summary and discussion of glasshouse screening for salt and waterlogging tolerance of 101 Australian tree species from the genera *Acacia*, *Casuarina*, *Eucalyptus* and *Melaleuca* over several years, and associated micropropagation of over 400 selected plants.

van der Moezel, P.G., Bell, D.T., Bennett, I.J., Strawbridge, M. and McComb, J.A. (1990). Department of Botany, University of Western Australia, Nedlands, WA 6009, Australia. Development of salt-tolerant clonal trees in Australia. In: Proceedings of The International Plant Propagators' Society, 40:73–78.

This paper describes the stages of development (from initial screening, through tissue culture research to second generation screening of seedlings from a seed orchard) of species of *Acacia*, *Casuarina*, *Eucalyptus* and *Melaleuca* in a program to select salt-tolerant clones of Australian trees and shrubs. In addition, the philosophy of using clonal seed orchards is discussed.

van der Moezel, P.G., Pearce-Pinto, G.V.N. and Bell, D.T. (1991). Department of Botany, University of Western Australia, Nedlands, WA 6009, Australia. Screening for salt and waterlogging tolerance in *Eucalyptus* and *Melaleuca* species. Forest Ecology and Management, 40:27–37.

This paper reports on the comprehensive screening of seedlings of 40 Australian *Eucalyptus* and 20 *Melaleuca* species in three glasshouse experiments for their tolerance to individual and combined salinity (mixed salts) and waterlogging using step-wise increases in salinity. *Melaleuca* species were generally tolerant of waterlogging, but growth reduction occurred for most *Eucalyptus* species. Under freely-drained conditions, growth of all species was reduced by salinity, while survival remained high. Survival and growth for all species were reduced most under combined salt and waterlogging. A tolerance index combining percent survival and relative height growth was calcuated. Based on the first two experiments (maximum EC 35 dS/m), the most salt/waterlogging-tolerant eucalypts were *E. intertexta*, *E. microtheca*, *E. occidentalis*, *E. raveretiana*, *E. sargentii*, *E. spathulata*, *E. striaticalyx*, and *E. tereticornis*. In the third experiment (maximum of 63 dS/m), *M. lateriflora*, *Melaleuca* spp. aff. *lanceolata* and *M. thyoides* were most tolerant to both freely-drained and saline/waterlogged conditions. Marked provenance variation was found in response to treatments for most species.

van der Moezel, P.G., Walton, C.S., Pearce-Pinto, G.V.N. and Bell, D.T. (1989). Department of Botany, University of Western Australia, Nedlands, WA 6009, Australia. Screening for salinity and waterlogging tolerance in five *Casuarina* species. Landscape and Urban Planning, 17:331–337.

This paper reports on a glasshouse study in which seedlings were treated with increasing salinity (with and without waterlogging). *Casuarina obesa* and *C. glauca* were most tolerant of saline waterlogged conditions, whilst *C obesa* and *C. cristata* wre most tolerant of salinity alone. *C. cunninghamiana* was most sensitive to both conditions. *C. cunninghamiana* and *C. cristata* had higher Na and Cl concentrations under salt than other species. High waterlogging tolerance in all species was related to a large

proportion of aerenchyma in the roots. Shoot Na and Cl concentrations were highest and growth rate lowest under combined salt and waterlogging.

van der Moezel, P.G., Watson, L.E. and Bell, D.T. (1989). Department of Botany, University of Western Australia, Nedlands, WA 6009, Australia. Gas exchange responses of two *Eucalyptus* species to salinity and waterlogging. Tree Physiology, 5:251–257.

In this glasshouse study, seedlings of *Eucalyptus camaldulensis* and *E. lesouefii*, which have potential for planting on saline waterlogged sites in Western Australia, were treated with waterlogging, salinity (increasing weekly to 42 dS/m, held for six weeks) or both in sand-filled pots. Under non-saline conditions, stomates of both species closed in response to waterlogging. However, stomates in *E. camaldulensis* re-opened after five weeks, when adventitious roots were produced, and this was related to growth recovery, in contrast to the more waterlogging-sensitive *E. lesouefii*. Under freely drained conditions, high salinity reduced rates of growth, stomatal conductance and photosynthesis somewhat less in *E. lesouefii* than in *E. camaldulensis*. For both species, the above variates were lowest under conditions of combined salt and waterlogging.

van der Moezel, P.G., Watson, L.E., Pearce-Pinto, G.V.N. and Bell, D.T. (1988). Department of Botany, The University of Western Australia, Nedlands, WA 6009, Australia. The response of six *Eucalyptus* species and *Casuarina obesa* to the combined effect of salinity and waterlogging. Australian Journal of Plant Physiology, 15:465–474.

This paper reports on survival, growth, ion concentrations and root adaptations of sand-cultured seedlings of *Eucalyptus camaldulensis, E. comitae-vallis, E. kondininensis, E. lesouefii, E. platycorys, E. spathulata* and *Casuarina obesa* treated with increasing salinity, with and without waterlogging, in a glasshouse for three months. *E. camaldulensis* and *C. obesa* were most tolerant of non-saline waterlogged conditions, and this was related to production of specialised roots containing aerenchyma. Saline but freely drained conditions reduced seedling growth for all species but except for *E. kondininensis,* there was no effect on survival. *C. obesa* was most tolerant of saline waterlogged conditions, better exclusion of Na and CL (linked with probable improved aeration within roots).

van Epps, G.A., Barker, J.R. and McKell, C.M. (1980). Range Science Department, Utah State University, Logan, Utah 84322, USA. Energy biomass from large rangeland shrubs of the intermountain United States. Journal of Range Management, 35:22–25.

Reports on biomass burning qualities and other shrub physical characteristics plus site data for big sagebrush (*Artemisia tridentata*), fourwing saltbush (*Atriplex canescens*), big saltbush (*Atriplex lentiformis*), grease wood (*Sarcobatus vermiculatus*), rubber rabbitbrush (*Chrysothamnus nauseosus*), and spreading rabbitbrush (*Chrysothamnus linifolius*) in 34 locations.

Varshney, K.A. and Baijal, B.D. (1977). Department of Botany, Agra College, Agra 282 002, Uttar Pradesh, India. Effect of salt-stress on chlorophyll contents of some grasses. Indian Journal of Plant Physiology, 20:161–163.

Leaf chlorophyll *a*, chlorophyll *b* and total chlorophyll contents of *Panicum antidotale*, *Setaria sphacelata*, *Chloris gayana* and *Pennisetum pedicellatum* increased with increasing salinity (EC_e 4–16 dS/m). The ratio of chlorophyll *a:b* varied from 1.0 to 2.7.

Venables, A.V. and Wilkins, D.A. (1978). Worcester College of Higher Education and Department of Plant Biology, University of Birmingham, UK. Salt tolerance in pasture grasses. New Phytologist, 80:613–622.

In a study of six species, from a pasture salinised over 20 to 30 years, there was a high within-species correlation between rates of root growth in culture solutions containing varying concentrations of NaCl and the EC of water extracts of the soils of origin indicating strong selection for salt tolerance. In *Puccinellia distans*, selection for tolerance to reduced salt levels was evident. Salt tolerance was highly heritable in *Festuca rubra*.

Verma, D.P.S. (1987). Conservator of Forests (Planning), Community Forest Project, Vadodara, Gujarat, India. Wastelands development—a case for *Prosopis juliflora*. Indian Forester, 113:529–540.

It is argued that *Prosopis juliflora* is a highly suitable species for planting on hostile sites in arid and semiarid saline areas of India. The characteristics which make it a suitable choice of species are described and include tolerance to salinity and alkalinity.

Villafane, R. (1989). Faculty of Agronomy, University of Central Venezuela, Apdo. 4579, Maracay, 2101 Aragua, Venezuela. Evaluation of four forage grasses for the reclamation of a saline-sodic soil. Revista de la Facultad de Agronomia, Universidad Central de Venezuela, 15:173–184.

This paper reports on results of a glasshouse study undertaken to evaluate the tolerance of four grasses (*Echinochloa polystachya, Brachiaria mutica, Cynodon nlemfuensis* and *Leersi hexandra)* to salinity and sodicity using a saline–sodic soil (pH 9, EC_e 4.6 dS/m, SAR 44.9). (In Spanish, English summary.)

Vlahos, S., Nicholas, D. and Malcolm, C. (1991). Department of Agriculture, Baron Hay Court, South Perth, Western Australia 6151. Variable quality of saltbush seed influences establishment. Journal of Agriculture of Western Australia, 32:130–132.

Seed quality from naturally-occurring stands of *Atriplex* species can be highly variable in quality. This paper documents this variation in seed of river saltbush (*Atriplex amnicola*) and wavy leaf saltbush (*Atriplex undulata*). It is suggested that seed germinability needs to be tested prior to direct seeding to reduce the risk of failure. A simple method by which farmers can conduct their own tests is presented.

Waisel, Y. (1961). Department of Botany, Tel-Aviv University, Tel-Aviv, Israel. Ecological studies on *Tamarix aphylla* (L.) Karst. III. The salt economy. Plant and Soil, 13:356–364.

Growth of cuttings of tamarix established in sand-filled pots was reduced by 100 mol/m^3 NaCl. At 300 mol/m^3 growth ceased and at 700 mol/m^3 plants died. Content and composition of salts excreted by plants were studied in response to treatment with NaCl, KCl, $CaCl_2$ and $MgCl_2$ solutions.

Waisel, Y. (1972). Department of Botany, Tel-Aviv University, Tel-Aviv, Israel. Biology of halophytes. Academic Press Inc., New York, 395 p.

This book provides a basic knowledge of halophytes in relation to their environment. It describes the sources of salinity, and the development and nature of salt-affected soils. Classification of halophytes, their mutual relationships, distribution and sociology are then described briefly. Much of the book is related to physiological characteristics such as water relations, mineral nutrition, salt transport, salt secretion, reproduction, growth, metabolism and salt resistance. Autecological information on

some terrestrial halophytes is summarised in a separate chapter. This book also has a short discussion of the formative effects of salinity and ends with a short review of ecotypic differentiation in halophytes.

Waisel, Y. and Friedman, J. (1965). Department of Botany, Tel-Aviv University, Tel-Aviv, Israel. Selection of *Tamarix* trees for planting on exposed coasts. La Yaaran, 15:114–117.

> Describes tests with clones of *Tamarix gallica*, *T. aphylla* and *T. meyeri* to determine their suitability for growing on exposed coastal areas. (In Hebrew.)

Walker, C.D. and Sinclair, R. (1992). PO Yallingup, WA 6282, Australia. Salinity is correlated with a decline in ^{13}C discrimination of *Atriplex* species. Australian Journal of Ecology, 19:83–88.

> Increasing soil salinity of a dune–swale–dune transect in north eastern South Australia, surveyed as electromagnetic soil conductivity, correlated with a decrease in delta composition (discrimination against ^{13}C in CO_2) in the leaves of the C_4 *Atriplex vesicaria* and *A. stipitata*. The latter measurement is related to water use efficiency.

Wallace, A. and Kleinkopf, G.E. (1974). Laboratory of Nuclear Medicine and Radiation Biology, University of California Los Angeles, CA 90024, USA. Contribution of salts to the water potential of woody plants. Plant Science Letters, 3:251–257.

> This paper relates plant water potentials of various desert and non-desert species grown in a glasshouse to leaf cation concentrations.

Wallace, A., Mueller, R.T. and Romney, E.M. (1973). Laboratory of Nuclear Medicine and Radiation Biology, University of California Los Angeles, CA 90024, USA. Sodium relations in desert plants. 2. Distribution of cations in plant parts of three different species of *Atriplex*. Soil Science, 115:390–394.

> This paper reports the effects of salinity (at low concentrations) on growth and Na concentrations in three *Atriplex* species grown in soil-filled pots and in solution culture. Growth of *Atriplex hymenelytra* cuttings was not affected up to 1.7 g NaCl/kg soil, and in nutrient solution DM of roots, stems and leaves was unaffected to 200 mol/m^3 NaCl (maximum level imposed). Na and K concentrations were highest in leaves and lowest in roots, the extent being species- and experiment-dependent. When

A. *confertifolia* and A. *canescens* seedlings were grown in nutrient solutions with and without 5 mol/m^3 Na_2SO_4, DM yields and Na concentrations were increased.

Wallace, A., Romney, E.M. and Mueller, R.T. (1982). Laboratory of Biomedical and Environmental Sciences, University of California, Los Angeles, CA 90024, USA. Sodium relations in desert plants. 7. Effects of sodium chloride on *Atriplex polycarpa* and *Atriplex canescens*. Soil Science, 134:65–68.

In a glasshouse experiment, leaf and stem DM of soil-cultured plants of *Atriplex canescens* ssp. *canescens* and *Atriplex polycarpa* was not reduced by concentrations of NaCl and Na_2SO_4 equivalent to sea water. Yields were slightly higher with Cl, particularly with stems of *A. polycarpa.* Changes in concentrations of macro and micro nutrient concentrations of leaves and stems with treatment are presented.

Walsh, K.B., Gale, M.J. and Hoy, N.T. (1995). Department of Biology, University of Central Queensland, Rockhampton, Queensland 4702, Australia. Revegetation of a scalded saline discharge zone in central Queensland. 2. Water use by vegetation and watertable drawdown. Australian Journal of Experimental Agriculture, 35:1131–1139.

The hydrological effect (theorectical and measured) of a *Casuarina glauca* tree on a saltpan in East Barmoya, central Queensland, is described. Implications for lowering saline watertables with agroforestry plantings are discussed. (Refer also to Hoy et al. 1994.)

Warren, B., Casson, T. and Barrett-Lennard, E. (1995). Agriculture Western Australia, Albany, Australia. The value of saltbush questioned. WA Journal of Agriculture, 36:24–27.

This article provides data from Kattaning (Western Australia) to indicate that whilst saltbush is selected and eaten by sheep, its value for wool production is not high and it cannot act as a genuine supplement to dry pastures.

Watson, C.M., Banuelos, G.S., O'Leary, J.W. and Riley, J.J. (1994). School of Renewable Natural Resources, University of Arizona, Tucson, AZ 85721, USA. Trace element composition of *Atriplex* grown with saline drainage water. Agriculture, Ecosystems and Environment, 48:157–162.

Reports on Se, B, S, Fe, Zn, Mn and Cu concentrations in harvested shoot samples over the first 27 months growth from five *Atriplex* species established with fresh water and irrigated with saline drainage water (often containing elevated B and Se concentrations) in the San Joaquin Valley, California, USA. The mean tissue concentrations for all species were 129 and 0.6 mg/kg DW for B (above the maximum tolerable levels recommended for ruminants) and Se, respectively.

Watson, M.C. (1990). Environmental Research Laboratory, University of Arizona, Tucson, AZ 85706, USA. *Atriplex* species as irrigated forage crops. Agriculture, Ecosystems and Environment, 32: 107–118.

This paper reports that productivity, forage quality and agronomic characteristics of 18 accessions of both native and exotic *Atriplex* species, irrigated with saline drainage water (EC 10–13 dS/m), in field trials in the San Joaquin Valley, California, were promising, with total clipping harvest yields and overall nutritive values being highest for *A. barclayana*. It is concluded that if the perennial species are used as a multi-clipped forage crop, irrigation and harvest management practices need to be developed to provide optimum yields and quality forage. Average levels of ash, crude protein, acid detergent fibre, neutral detergent fibre, lignin and Se of harvested clippings were 297, 166, 240, 423, 92 g/kg and 1 mg/kg, respectively.

Watson, M.C., O'Leary, J.W. and Glenn, E.P. (1987). Environmental Research Laboratory, University of Arizona, Tucson, AZ 85706, USA. Evaluation of *Atriplex lentiformis* (Torr.) S. Wats. and *Atriplex nummularia* Lindl. as irrigated forage crops. Journal of Arid Environment, 13:293–303.

This paper reports on biomass yields and forage quality (with and without clipping to 15–20 cm height) of *Atriplex lentiformis* and *Atriplex nummularia* when irrigated with brackish water obtained from an artesian well seepage pond. Highest biomass yields of *A. lentiformis* and *A. nummularia* were estimated to be 14.7 and 12.3 t/ha, respectively, and these were generally higher than the sum of clipped regrowth harvests. Ash and protein contents decreased and neutral-detergent and acid-detergent fibre levels increased with time of harvest (cuttings), and Ca and P concentrations generally declined.

Weber, D.J. (1982). Department of Botany and Range Science, Brigham Young University, Provo, Utah 84602, USA. Mechanism of salt tolerance in *Salicornia pacifica* var. *utahensis*. In: Biosaline research: a look to the future (San Pietro, A., ed.), 555–558, Proceedings of 2nd International Workshop on Biosaline Research, La Paz, Mexico. Plenum Press, New York, USA.

This paper describes a general mechanism of salt tolerance in *Salicornia pacifica* var. *utahensis*. In general, salt tolerance has been attributed to a combination of compartmentalisation, active ion transport and selective death of independent internodes.

Weiler, G. and Gould, W.L. (1983). Department of Crop and Soil Sciences, New Mexico University, Las Cruces, NM 88003, USA. Establishment of blue grama and fourwing saltbush on coal mine spoils using saline ground water. Journal of Range Management, 36:712–717.

In a greenhouse experiment, blue grama (*Bouteloua gracilis*) and fourwing saltbush (*Atriplex canescens*) were irrigated with water having EC of 0.75–12.89 dS/m and SAR of 2–68 in columns containing 20 cm of sandy loam over alkaline spoil containing shale. Emergence and growth of blue grama were reduced as water salinity increased and no plants survived the most saline treatment. The most saline water reduced *A. canescens* emergence, but the plants grew well after the seedling stage.

Weimberg, R. (1986). US Salinity Laboratory, Agricultural Research Service, USDA, 4500 Glenwood Drive, Riverside, CA 92501, USA. Growth and solute accumulation in 3-week-old seedlings of *Agropyron elongatum* stressed with sodium and potassium salts. Physiologia Plantarum, 67:129–135.

Agropyron elongatum 'Arizona Glendale' was grown in solution culture salinised with either NaCl, KCl, or a 50:50 mixture of these two salts at osmotic potentials ranging from 0 to −1.6 MPa. Growth inhibition was approximately proportional to the osmotic potential of the solution and was independent of salt composition, whereas concentrations of Na + K and the ratio Na:K in leaves were mainly a function of salt composition. Proline started accumulating in leaves when the tissue concentration of Na + K exceeded 200 μmol/g FW.

Welch, B.L. (1978). Intermountain Forest and Range Experiment, Forest Service, US Department of Agriculture, Ogden, Utah 84401, USA. Relationships of soil salinity, ash, and crude protein in *Atriplex canescens*. Journal of Range Management, 31:132–133.

The relationships between soil salinity, ash and crude protein in seven natural populations of fourwing saltbush (*Atriplex canescens*) are presented. Ash content ranged from 11.9% to 18.7% and crude protein (CP) ranged from 8.9% to 22.4%. Significant differences in CP were found between populations.

West, D.W. (1986). Institute for Sustainable Agriculture, Tatura, Victoria, Australia. Stress physiology in trees—salinity. Acta Horticulturae, 175:321–332.

A review and discussion, with reference mainly to subtropical and temperate fruit trees, under the following headings: (i) factors influencing salinity stress, (ii) environmental factors, (iii) stage of plant growth, (iv) varieties and rootstocks, (v) specific solute (Cl) effects, (vi) ion localisation and distribution, (vii) selection of plants for salt tolerance, (viii) markers (chemical) in the roots, (ix) markers in shoots, (x) plasma membrane salt resistance, and (xi) chlorophyll fluorescence (as a marker).

Wiesner, L.E. and Johnson, W.J. (1977). Plant and Soil Science Department, Montana State University, Bozeman, Montana 59715, USA. Fourwing saltbush (*Atriplex canescens*). Propagation techniques. Journal of Range Management, 30:154–156.

This paper reports that the highest percentage of rooted cuttings was obtained when green succulent cuttings were soaked for 24 hours in a complete nutrient solution before being dipped in a woody species rooting compound and placed in a mist bench for five weeks. Rooted cuttings should be transplanted into flats containing 75% sand and 25% peat and watered every 4–5 days to obtain maximum growth.

Wiley, S.T., Swingle, R.S., Brown, W.H., Glenn, E.P., O'Leary, J.W. and Colvin, L.B. (1982). University of Arizona, Tucson, Arizona, USA. Evaluation of two *Atriplex* species grown with hypersaline water and the effect of water leaching on their digestibility by goats. Journal of Animal Science, 55 (Suppl. 1):486.

This paper reports on feeding experiments with goats using washed and unwashed sun-dried shoots of *Atriplex lentiformis* and *A. barclayana*, grown in Sonora, Mexico, using highly saline (40 000 ppm) waste water from a shrimp production facility. Twenty-five percent of this material was mixed with 75% lucerne and 10% molasses added to each diet. Data on water cosumption and apparent digestibilities for DM, OM and gross energy

(GE) are provided. A diet including 25% *A. lentiformis* was more digestible than lucerne hay. Water washing did not improve either acceptability or digestibility.

Williams, D.G. (1979). School of Applied Science, Canberra College of Advanced Education, Belconnen, Canberra ACT, Australia. The comparative ecology of two perennial chenopods. In: Studies of the Australian arid zone. IV. Chenopod shrublands (Graetz, R.D. and Howes, K.M.W., ed.), 29–40. Proceeding of Symposium, Denilquin, NSW, Australia.

A comparative review of the ecology of *Atriplex vesicaria* (a short-lived—about 25 years—dioecious shrub with long-lived seeds) and *Maireana pyramidata* (a much longer-lived shrub—greater than 50 years —with seeds of little dormancy and thus short-lived) is made with reference to their life cycles in the shrublands of south western New South Wales. Some reference to salinity.

Wilson, A.D. (1975). CSIRO, Division of Land Resources Management, Deniliquin, NSW 2710, Australia. Influence of water salinity on sheep performance while grazing on natural grassland and saltbush pastures. Australian Journal of Experimental Agriculture and Animal Husbandry, 15:760–765.

The effect of giving saline water (up to 2.0% (w/v) soluble salts, using a mix of NaCl and $MgSO_4$ to mimick ground water composition) on growth and wool production of Merino sheep grazing a semiarid natural grassland or saltbush (*Atriplex vesicaria*) is detailed. It was concluded that water salinities up to 1.2% on grassland and 0.8% on saltbush will not affect sheep productivity.

Wilson, A.D. (1977). Division of Land Resources Management, CSIRO, Riverina Laboratory, Deniliquin, NSW 2710, Australia. The digestibility and voluntary intake of the leaves of trees and shrubs by sheep and goats. Australian Journal of Agricultural Research, 28:501–508.

This paper reports on the in vitro and in vivo digestibility of dried leaves of four shrub species (*Atriplex vesicaria, A. nummularia, Maireana pyramidata* and *Bassia diacantha*) and four tree species (*Acacia pendula, Casuarina cristata, Geijera parviflora* and *Heterodendrum oleifolium*) that are common to western New South Wales, as fed to either sheep or goats.

Winter, E. (1988). Institut für Systematische Botanik und Pflanzengeographie der Freien Universitat, Berlin, West Germany. Salt-induced hypodermal transfer cells in roots of *Prosopis farcta* and ion distribution within young plants. Botanica Acta, 101:174–181.

This paper reports on Na, Cl and K uptake by solution-culture-grown plants of *Prosopis farcta* treated with 0.5, 10, 50, and 100 mol/m^3 NaCl. Below 10 mol/m^3, Na and Cl were preferentially absorbed, but at >10 mol/m^3, K selectivity was induced and rose exponentially with increasing salt stress. The possible role of transfer cells in the hypodermis at the zone of side root formation in the Na:K selectivity of the roots of *P. farcta* is discussed.

Woods, R.V (1955). Mt. Crawford Forest Reserve, South Australia, Australia. Salt deaths in *Pinus radiata* at Mount Crawford Forest Reserve, SA. Australian Forestry, 19:13–19.

This paper reports on deaths in *Pinus radiata* forests of the Adelaide Hills (South Australia) since 1952 in gullies, soaks, and flats mostly in very vigorous forest, related to salinity. Injury to needles (browning, death of top) was associated with Cl concentrations of 0.5% and affected trees covered a range of ages from 5 to 39 years over several geological formations. These deaths are associated with the rise of salt-laden ground water.

Wrona, A.F. and Epstein, E. (1982). Department of Land, Air and Water Resources, University of California, Davis, CA 95616, USA. Screening for salt tolerance in plants: an ecological approach. In: Biosaline research: a look to the future (San Pietro, A., ed.), 559–564. Proceedings of 2nd International Workshop on Biosaline Research, La Paz, Mexico. Plenum Press, New York, USA.

This paper describes the salt tolerance of a wild halophyte, *Distichlis spicata*, as it exists in diversified environments, and reports a screening trial on different ecotypes of this species. The ecotypes were collected from six different sites in northern California and grown in a greenhouse treated with 0.0, 0.8 and 2.0 times the salinity of sea water, using 'Rila mix' (synthetic sea salt mix). Results are discussed in reference to the concentration of ions in roots and shoots and indicates ecotypic differences in salt tolerance.

Wu, L. (1981). Department of Envionmental Horticulture, University of California, Davis, USA. The potential for evolution of salinity tolerance in *Agrostis stolonifera* L. and *Agrostis tenuis* Sibth. New Phytologist, 89:471–486.

A. stolonifera plants growing on a sandy seashore were more tolerant than those from an adjacent area with low salinity. It was possible to selection for increased salt tolerance between plants from the less tolerant population in a single generation. *A. tenuis* was not found on the shore (related to lack of tolerance to Mg) and even the most tolerant populations nearby were only comparable with the less tolerant population of *A. stolonifera*. However, the salt tolerance detected in *A. tenuis* from a copper mine site in the UK indicated that tolerance can develop.

Xu, Y.Q. and Long, W.B. (1983). Forestry Department, South China College of Agriculture, China. The adaptive character and species choice of main planting trees of farmland shelterbelt in the Pearl River delta. Scientia Silvae Sinicae, 19:225–234.

An extensive survey showed that the main species planted in the Pearl River delta (Guangdong) were *Taxodium distichum*, *T. ascendens*, *Casuarina equisetifolia* and *Glyptostrobus pensilis*. The main factors affecting tree growth were soil acidity, salt content and height of the watertable. Optimum pH for *Taxodium* spp. was 6.1, and for *C. equisetifolia* and *G. pensilis* 7.0–8.0. All four species were relatively salt-tolerant and still grew well on soils with a salt content of 0.38%; however, growth of *Taxodium* spp. was negatively correlated with soil total salt content. The waterlogging-tolerant species (*Taxodium* and *G. pensilis*) had best growth at shallow watertable sites. (In Chinese, English summary.)

Yadav, B.R. and Singh, A.K. (1981). Amelioration of salt affected soils through afforestation—an overview. In: Environmental assessment and management: social forestry in tribal regions (Trivedi, R.N., Sarma, P.K.S. and Singh, M.P., ed.), 69–75. Proceedings Third Conference, Mendelian Society of India, New Delhi, India. Today & Tomorrow's Printers & Publishers, New Delhi, India.

An account with reference to saline and sodic soils in India, covering planting techniques, suitable tree species, and economic feasibility.

Yadav, J.S.P. (1975). Central Soil Salinity Research Institute, Karnal, India. Improvement of saline alkali soils through biological methods. Indian Forester, 101: 385–395.

This paper discusses various biological approaches to reclamation and utilisation of saline alkali soils. The relative performance of various forest trees, grasses and agricultural crops is described and data on the changes

in the properties of saline alkali soils brought about as a result of the vegetative growth are presented. The role of green manuring, algal growth and addition of other organic materials in the improvement of saline alkali soils and the need for more research are discussed.

Yadav, J.S.P. (1977). Central Soil Salinity Research Instiutute, Karnal, India. Tree growth on salt-affected lands. Indian Farming, 26:43–45.

The paper describes the prospects for growing babul (*Acacia arabica [A. nilotica]*), dhak (*Butea monosperma*), neem (*Azadirachta indica*), jhau (*Tamarix articulta*), jal (*Salvadora oleoides*), ber (*Zizyphus* sp.), hus (*Capparis horrida*) and karil (*Capparis aphylla*) on various types of salt-affected land. Some similar work to that provided in Yadav (1980) is described.

Yadav, J.S.P. (1980). Central Soil Salinity Research Institute, Karnal, India. Salt affected soils and their afforestation. Indian Forester, 106:259–272.

This paper describes the extent and distribution of saline and sodic soils in different parts of India. The work done on the relative tolerance of important forest species for soil salinity and alkali conditions in India as well as in other countries is summarised. A detailed account is given of suitable planting techniques. Species including *Prosopis juliflora, Eucalyptus* hybrid and *Acacia nilotica* can be grown successfully by treating the soil of the planting pit with gypsum and FYM along with application of a small dose of N and P fertiliser.

Yadav, J.S.P. (1983). Central Soil Salinity Research Institute, Karnal, Haryana, India. Soil limitations for successful establishment and growth of *Casuarina* plantations. In: *Casuarina* ecology, management and utilization (Midgley, S.J., Turnbull, J.W. and Johnson, R.D. ed.), Proceedings of an International Workshop, Canberra, Australia, 138–157. CSIRO, Canberra, ACT, Australia.

Data are reviewed on the growth performance of *Casuarina equisetifolia* plantations in India under different conditions of soil, climate, topographical and other site factors. Some information on response to salinity of soil and groundwater is provided.

Yadav, J.S.P. (1988). Central Soil Salinity Research Institute, Karnal, Haryana, India. Management of saline and alkali soils for fodder and forage production. In: Rangelands resource and management (Singh. P. and Pathak, P.S., ed.), 384–394. Proceedings of National Rangeland Symposium, IGFRI, Jhansi, India.

This paper reviews the relative tolerances of grasses, including *Diplachne [Leptochloa] fusca, Chloris gayana, Cynodon dactylon, Brachiaria mutica, Panicum laevifolium, P. antidotale* and *P. maximum* to soil salinity and sodicity, and impact of fertilisers and gypsum to these, other forages and trees including *Acacia nilotica, Prosopis juliflora, Eucalyptus* hybrid, *Terminalia arjuna* and *Albizia lebbeck*.

Yadav, J.S.P. and Sharma, B.M. (1976). Central Soil Salinity Research Institute, Karnal, Haryana, India. Soil changes in differently treated planting pits under *Eucalyptus* hybrids in a saline sodic soil. Agrokemia es Talajtan, 25:327–338.

The impact of planting *Eucalyptus* hybrid in pits on a saline sodic soil, receiving various treatments (1. filling with original soil; 2. application of gypsum; 3. application of FYM; 4. application of gypsum + FYM; 5. filling with transported normal soil), on growth and soil properties (pH and EC), is discussed. Under treatment 1, the seedlings died a few months after transplanting but they continued to grow in other treatments. Plant height after four years was as good under treatment 4 as under 5 and was much better than that obtained under 2 and 3.

Yadav, J.S.P. and Singh, K. (1970). Forest Research Institute and Colleges, Dehra Dun, India. Tolerance of certain forest species to varying degree of salinity and alkali. Indian Forester, 96: 587–599.

In a survey of saline alkali soils in Uttar Pradesh, India, it was found that all tree species failed to grow on compact and indurated, highly calcareous (pH >10) soils with a cemented bed of kankar nodules and soluble salts >3.42% and >1.14% in the topsoil and subsoil, respectively. Details of soil characteristics tolerated by *Prospis juliflora, Acacia arabica, [A. nilotica], Azadirachta indica, Butea monosperma, Dalbergia sissoo, Pongamia pinnata, Terminalia arjuna, Albizia lebbeck* and *Ailanthus excelsa* are provided. The relative merits of the trench-ridge method and use of soil amendments are discussed.

Yensen, N.P. and Bedell, J.L. (1993). NyPa, Inc. Tucson, 727 North Ninth Avenue, Tucson, AZ 85705, USA. Considerations for the selection, adaptation, and application of halophyte crops to highly saline desert environments as exemplified by the long-term development of cereal and forage cultivars of *Distichlis* spp. (Poaceae). In: Towards the rational use of high salinity tolerant plants (Lieth, H. and Al-Masoom, A.A., ed.), Vol. 2., 305–313. Proceedings of the ASWAS Conference, Al Ain, United Arab Emirates. Kluwer Academic Publishers, The Netherlands.

The potential for, and constraints on, using halophytic crops on salt-affected land are considered with particular reference to *Distichlis*. Nearly 20 years of work with varieties of *Distichlis* spp. from around the world has resulted in a number of useful cultivars, most notably a grain crop trademarked WildWheat grain, a forage grass called NyPa Forage, a turf grass called NyPa Turf and a reclamation grass called NyPa Reclamation Saltgrass. These and other halophyte crops developed by NyPa and NyPa associates are being distributed to countries and peoples in desert environments confronted with salt problems.

Yeo, A.R. (1981). Plant Physiology Group, School of Biological Sciences, The University of Sussex, Brighton, BN1 9QG, UK. Salt tolerance in the halophyte *Suaeda maritima* L. Dum.: Intracellular compartmentation of ions. Journal of Experimental Botany, 32:487–497.

This paper reports data on the time-course of exchange of Na and K ions from root and leaf material of the halophyte *Suaeda maritima* with an analysis based on efflux and compartmentation (between vacuoles and cytoplasm).

Yeo, A.R. and Flowers, T.J. (1977). School of Biological Sciences, University of Sussex, Falmer, Brighton, Sussex, UK. Salt tolerance in the halophyte *Suaeda maritima* (L.) Dum.: interaction between aluminium and salinity. Annals of Botany, 41:331–339.

This paper reports that growth of *Suaeda maritima* was stimulated by low Al concentrations (but reduced at higher levels) in saline solution culture, with an increase in the number and extent of lateral roots, and relates this to reduced Al uptake compared with that under control conditions. The results are discussed in relation to proposed mechanisms of Al toxicity and the interaction between Al and salt toxicities.

Yeo, A.R. and Flowers, T.J. (1980). Plant Physiology Group, School of Biological Sciences, The University of Sussex, Brighton BN1 9QG, UK. Salt tolerance in the halophyte *Suaeda maritima* L. Dum.: evaluation of the effect of salinity upon growth. Journal of Experimental Botany, 31:1171–1183.

This paper reports on ion effects of the concentrations and species, applied in treatment solutions, on the growth of *Suaeda maritima,* a coastal halophyte. It is shown that plant growth is often optimal under highly saline conditions, but that this increase in growth is exaggerated because differing contributions of water and inorganic ions mean that organic DM production is lower than FW or DW increases suggest. Enhanced growth over long periods was attributed to increased cell size.

Yeo, A.R. and Flowers, T.J. (1986). School of Biological Sciences, The University of Sussex, Brighton BN1 900, UK. Ion transport in *Suaeda maritima:* its relation to growth and implications for the pathway of radial transport of ions across the root. Journal of Experimental Botany, 37:143–159.

This paper provides a detailed description of the ion relations of the halophyte *Suaeda maritima* under NaCl treatment, and includes data on osmotic potentials, ion concentrations, transport of Na, K, and Cl and membrane flux rates. The authors argue (i) that both symplasmic and xylem loading are likely to be passive processes mediated by ion channels rather than active carriers, (ii) that net ion transport at 340 mol/m^3 NaCl is close to the maximum which is physiologically sustainable and (iii) that growth of this halophyte is limited by NaCl supply from the root.

Young, J.A., Kay, B.L., George, H. and Evans, R.A. (1980). USDA–SEA/AR, Reno, NV 89512, USA. Germination of three species of *Atriplex*. Agronomy Journal, 72:705–709.

Trailing saltbush (*Atriplex semibaccata*), quailbush (*A. lentiformis*), and fat-hen (*A. patula* ssp. *hastata*) are adapted for growth in saline alkaline areas and provide valuable cover, browse, and/or feed for waterfowl. Data on the germination characteristics of these species which have potential as artifically seeded revegetation species are presented.

Youngner, V.B., Lunt, O.R. and Nudge, F. (1967). University of California, Riverside, California, USA. Salinity tolerance of seven varieties of creeping bentgrass, *Agrostis palustris* Huds. Agronomy Journal, 59:335–336.

On the basis of relative shoot yields under salinity in solution cultures, order of tolerance of bentgrass varieties was: Arlington, Seaside, Pennlu and Old Orchard > Congressional and Cohansey > Penncross.

Zaerr, J.B. (1983). School of Forestry, Oregon State University, Corvallis, Oregon 97331, USA. Short-term flooding and net photosynthesis in seedlings of three conifers. Forest Science, 29:71–78.

This paper reports on effects of flooding (up to 4 days) on photosynthesis, transpiration, water potential and shoot elongation of young seedlings of Scots pine, Douglas fir, and Norway spruce.

Zafar, Y. and Malik, K.A. (1984). Soil Biology Division, Nuclear Institute of Agriculture and Biology, Faisalabad, Pakistan. Photosynthetic system of *Leptochloa fusca* (L.) Kunth. Pakistan Journal of Botany, 16:109–116.

On the basis of a study of leaf anatomy, distribution of starch grains, measurement of CO_2-compensation point and ^{13}C:^{12}C ratios, the authors conclude that *Leptochloa fusca* has a C_4 pathway of photosynthesis.

Zahran, M.A. (1986). Department of Botany, Mansoura University, Mansoura, Egypt. Establishment of fiber producing halophytes in salt affected areas of Egypt. In: Prospects for biosaline research (Ahmad, R. and San Pietro, A., ed.), 235–251. Proceedings of the US–Pakistan Biosaline Research Workshop, 22–26 September 1985. Department of Botany, University of Karachi, Karachi, Pakistan.

This paper reports that two fibre-producing halophytes, *Juncus rigidus* and *Juncus acutus*, have agro-industrial potential on salt-affected lands of Egypt, where they can be grown as non-conventional fibre-producing crops.

Zahran, M.A. and Abdel Wahid, A.A. (1982). Botany Department, Faculty of Science, Mansoura University, Mansoura, Egypt. Halophytes and human welfare. In: Contributions to the ecology of halophytes (Sen, D.N. and Rajpurohit, K., ed.), Tasks for Vegetation Science, Vol. 2, 235–257. Dr. W. Junk Publishers, The Hague, The Netherlands.

Ecological and agronomic information is presented on: (a) *Juncus* spp. in the paper industry, (b) *Salsola tetrandra* in the drug industry, and (c) *Kochia* spp. as a prospective forage plant.

Zallar, S. and Mitchell, A. (1970). Soil Conservation Service, Victoria, Australia. Pasture species for non-irrigated salt-affected land. In: Proceedings of XI International Grasslands Congress. University of Queensland Press.

This paper reports on growth of *Puccinellia ciliata*, *Agropyron elongatum* and *Lolium rigidum* in field trials in Victoria on saline soils (0.3–1.0% Cl in 0–15 cm surface soil), with and without mulch application. Mulch application improved establishment on wet, saline soils.

Zawadzka, M. (1976). Instytut Przyrodniczych Podstaw Melioracji, Akademii Rolniczej, Warsaw, Poland. Salt tolerance of grasses and leguminous plants. Acta Agrobotanica, 29:85–98.

Reports on germination responses of 11 grass and 10 legume species using various dilutions of saline water [concentration not clear]. *Lolium perenne, L. multiflorum, Festuca pratensis, Arrhenatherum elatius, Trifolium resupinatum, T. incarnatum, T. repens, Melilotus albus, Festuca ovina, Agrostis alba, Lotus corniculatus, Medicago lupulina* and *Medicago sativa.* (In Russian.)

Zhao, K., Zhang, B., Lu Y. and Harris, P.J.C. (1990). Department of Biology, Shandong Teachers' University, Jinan, China. Growth of *Sesbania* species in saline soils of the Yellow River delta, China. Nitrogen Fixing Tree Research Reports, 8: 165–166.

Sesbania bispinosa, S. cannabina, S. formosa and *S. sesban* had good biomass production at high soil salinities (average 0.8–1.5%), shallow (0.8–2.4 m), saline watertables, low rainfall and cold winters. (Little data provided.)

Zid, E. and Boukhris, M. (1977). Institut de Recherches scientifiques et techniques, Faculte des Sciences de Tunis, Tunisia. Some aspects of salt tolerance in *Atriplex halimus.* Reproduction, growth, mineral composition. Oecologia Plantarum, 12:351–362.

Germination of *Atriplex halimus* is highly sensitive to salinity. Cuttings produce roots more easily in non-saline conditions, even though growth is better with salt (NaCl up to 20 g/L). NaCl increased plant Na and Cl concentrations, but decreased K, Ca, N (soluble and total). (In French, English abstract.)

Zohar, Y. (1982). Division of Forestry, Agricultural Research Organization, Ilanot, Israel. Growth of eucalypts on saline soils in the Wadi 'Arava. La Yaaran, 32:38–49.

Survival and growth of five *Eucalyptus occidentalis* provenances and of a single provenance each of *E. kondininensis, E. loxophleba, E. sargentii, E. spathulata,* and *E. wandoo were* studied (up to 3.5 years old) on playas in the Wadi 'Arava and (up to 2.5 years old) on saline sand on the Gulf of Elat coast (Israel). Except for one *E. occidentalis* provenance, the seeds were collected in saline habitats within the natural distribution of the species in Western Australia. The highest growth rate and tolerance to salinity (EC_e >30 dS/m), was shown by an *E. occidentalis* provenance collected north of Esperance, WA, and by *E. sargentii.* At lower salinities (20–30 dS/m), *E. spathulata, E. kondininensis* and *E. loxophleba* had rapid growth. Results are also presented for foliar analyses, soil salinity and chemistry, and xylem water potentials. (In Hebrew; English version p. 60–64.)

Zohar, Y., Karschon, R. and Waisel, Y. (1975. Division of Forestry, Agricultural Research Organization, Ilanot, Israel. The autecology of *Eucalyptus occidentalis* Endl. Israel Journal of Botany, 24:52.

Na and Cl concentrations were lower and growth better for *Eucalyptus occidentalis* grown on saline soils of higher lime content, possibly due to higher soil Ca.

Zou, N. Dart, P.J. and Marcar, N.E. (1995). Department of Agriculture, The University of Queensland, St Lucia, Queensland 4072, Australia. Interaction of salinity and rhizobial strain on growth and N_2-fixation by *Acacia ampliceps*. Soil Biology and Biochemistry, 27:409–413.

The growth, nodulation and N content of *Acacia ampliceps* inoculated with salt-tolerant *Rhizobium* PMA63/1 and salt-sensitive *Bradyrhizobium* PMA37 were compared at NaCl levels of 0, 100 and 200 mol/m^3 in sand culture. *A. ampliceps* inoculated with PMA63/1 was less affected in growth, nodule number and N content per plant by 200 mol/m^3 NaCl than plants inoculated with PMA37. Inoculation with a salt-tolerant *Rhizobium* strain may improve biological N_2-fixation under saline conditions.

ADDENDUM

Bennett, D.L. and George, R.J. (1996). Agriculture Western Australia, PO Box 1231, Bunbury, Western Australia. River red gums (*E. camaldulensis*) for farm forestry on saline and waterlogged land in south-western catchments of Western Australia. In: Productive use and rehabilitation of saline lands. Proceedings Fourth National Conference and Workshop, Albany, Western Australia (Promaco Conventions Pty Ltd., Canning Bridge, WA), 345–358.

Provides information on growth of *Eucalyptus camaldulensis* provenances and clones from several trials in south west Western Australia. Measurements with the EM 38 (refer Bennett and George 1995) indicate that volume growth is reduced above EC_a of 150 mS/m.

Odie, R.L.A. and McComb, J.A. (1996). Biological and Environmental Sciences, Murdoch University, Murdoch, Western Australia, 6150, Australia. *Eucalyptus camaldulensis* × *globulus* hybrids for saline land. In: Productive use and rehabilitation of saline lands. Proceedings Fourth National Conference and Workshop, Albany, Western Australia (Promaco Conventions Pty Ltd. Canning Bridge, WA), 345-358.

Provides results of survival and growth of sand-cultured *Eucalyptus camaldulensis* x *E. globulus* hybrid compared with parental populations when treated with NaCl up to 350 mol/m^3, and preliminary field trial data. Field trials are on-going.

Schulz, M.A. and Petterson, G. (1994). Productive use of saline lands: saline irrigation areas Proceedings Third National Workshop, Echuca, Victoria (Victorian Department of Agriculture, Tatura). 197 p.

This proceedings provides papers on trees, ground water use, irrigation, and utilisation, production and agronomy of grasses and halophytic shrubs in the Australian context. Biennial workshops have been held since 1990 (refer also Marcar and Hossain 1999.)

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