chapter 4

Salt and Waterlogging: Effects on Plants

Overview

Types of plant response to salt

Plants can be broadly divided into three major groups: *halophytes* ('salt plants' — these grow at high salt concentrations), *salt-tolerant non-halophytes* (these grow at moderate salt concentrations), and *salt-sensitive non-halophytes* (these are sensitive to even low salt concentrations).

All crop plants are either salt-tolerant or salt-sensitive non-halophytes. About 150 agriculturally important species have been ranked for salt tolerance. However, these may be of only partial value for Pakistan because they do not take account of the problem of waterlogging in salt-affected soils.

Waterlogging in saline environments — effects on plant growth

All plants have developed ways to exclude salt from their shoots in order to survive. These mechanisms require energy. Waterlogging makes plant roots oxygen deficient, which decreases their production of energy. As a result, salt exclusion mechanisms break down and the roots become 'leaky' to salt. This causes increased uptake of salt into the shoot, which can decrease plant growth and yield, and affect survival.

Breeding for salt tolerance

It may be possible to breed agricultural plants for Pakistan's salt-affected land. However, such plants will need tolerance to both salinity and waterlogging.

4.1 Types of Plant Response to Salt

4.1.1 Halophytes and non-halophytes

Plants can be broadly divided into three groups on the basis of the effects of salt on their growth (Fig. 4.1).

- *Halophytes ('salt plants')*. Halophytes actually have increased growth at low salt concentrations (compared to no salt), with decreased growth at much higher concentrations. River saltbush (*Atriplex amnicola*) is typical: it has a 10% increase in growth at salinities (electrical conductivities) of 5 decisiemens per metre, a 50% decrease in growth at 40 decisiemens per metre, and is still alive at 75 decisiemens per metre. Other plants in this group include: quailbrush (*A. lentiformis*), *Suaeda fruticosa* and *Salicornia bigelovii*.
- *Salt-tolerant non-halophytes*. These plants maintain growth at low salt concentrations, but have decreased growth at higher concentrations. Cotton (*Gossipium hirsutum*) is typical: it has a 50% reduction in growth at salinities (electrical conductivities) of 17 decisiemens per metre. Other plants in this group include sugarbeet (50% decrease in growth at 15 decisiemens per metre), barley (50% decrease in growth at 18 decisiemens per metre) and date palm (50% decrease in growth at 18 decisiemens per metre) (calculated from Maas 1986).
- *Salt-sensitive non-halophytes*. The growth of these plants is sensitive to even low concentrations of salt. Beans (*Phaseolus vulgaris*) are typical: they have a 50% decrease in growth at salinities (electrical conductivities) of 3.6 decisiemens per metre. Other plants in this group include rice (50% decrease in growth at 7.2 decisiemens per metre), carrot (50%

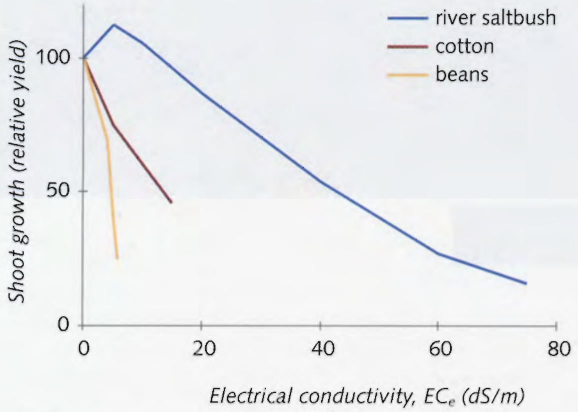

Figure 4.1. *The effect of salinity (electrical conductivity of the nutrient solution or EC_w) on plant growth in nutrient solution or irrigated sand culture. River saltbush is a typical halophyte (Aslam et al. 1986), cotton is a typical salt-tolerant non-halophyte (Eaton 1942), and beans are typical salt-sensitive non-halophytes (Eaton 1942; Lagerwerff and Eagle 1961).*

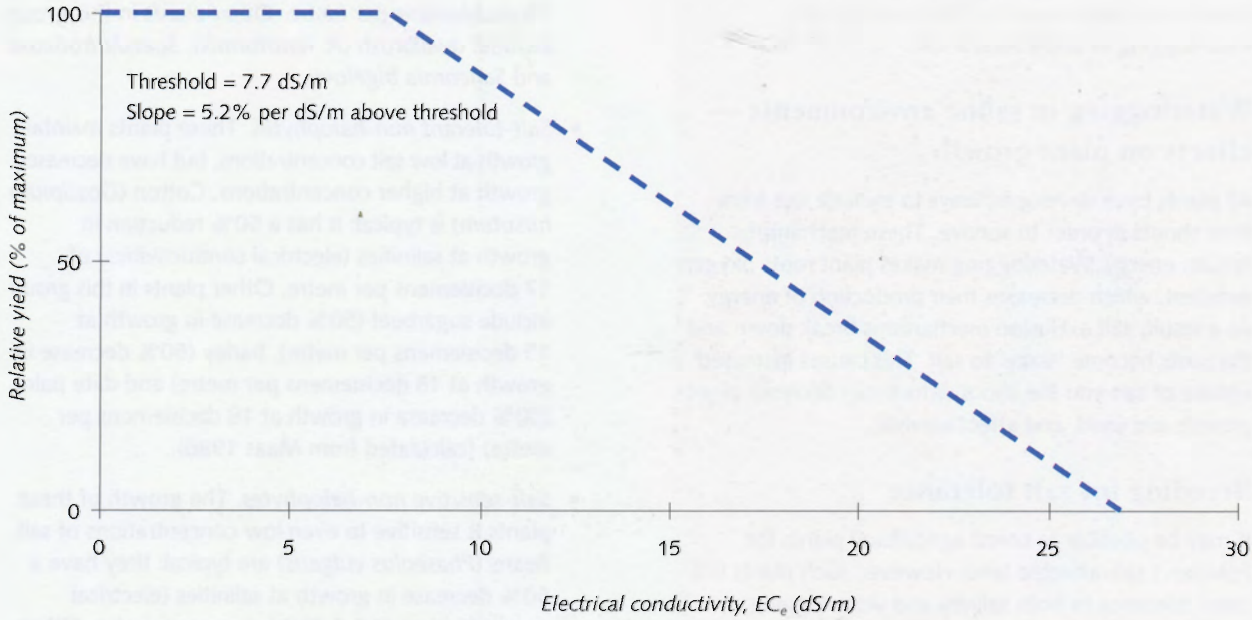

Figure 4.2. *Response of the relative yield of cotton to increasing soil salinity (electrical conductivity of the soil saturation extract or EC_e).*

decrease in growth at 4.6 decisiemens per metre), grapefruit (50% decrease in growth at 4.9 decisiemens per metre), and peach (50% decrease in growth at 4.1 decisiemens per metre) (calculated from Maas 1986).

4.1.2 Salt tolerance in crops — the Maas and Hoffman categories

The 1950s, 1960s and 1970s were a fruitful period for investigations of salt tolerance in the United States. Led by scientists at the US Salinity Laboratory at Riverside in California, attempts were made to determine the salt tolerance of most of America's major crop plants. In many of these experiments, the crops were grown in irrigated sand culture — that is, in deep columns of sand frequently irrigated with saline nutrient solutions. In this way, the researchers were able to precisely define the salt concentrations around the roots of the plants. However, it is important to note that in these investigations the plants were *not* waterlogged.

The results of this enormous body of work were summarised in a famous paper by Maas and Hoffman (1977)[1]. These two scientists suggested that the growth response of a plant species to increasing salinity could be summarised in terms of a 'bent stick' growth curve (Fig. 4.2). They suggested that:

1 The major themes of the paper were republished in Maas (1986). This second paper also included outcomes from more recent research.

- comparisons were easily made between species if growth was expressed as relative yield (i.e. yield as a percentage of what it would be with zero salt) rather than as absolute yield (tonnes per hectare);
- for most plants, there is no real change in relative yield as soil salinity increases until a critical salinity threshold is reached. Thereafter, relative yield decreases at a constant rate per unit increase in soil salinity; and
- the response of relative yield to salinity can be defined in terms of the 'threshold', and the 'slope' of the relative yield response to salinities higher than threshold.

In Figure 4.2, we have graphed the relationship between the relative yield of cotton and soil salinity (expressed here as the electrical conductivity of the soil saturation extract in decisiemens per metre). According to Maas and Hoffman, cotton has a threshold of 7.7 decisiemens per metre, and a slope of 5.2% per decisiemen per metre.

Using this kind of analysis, Maas and Hoffman defined categories of relative yield response curves (Fig. 4.3). Based on their relative yield response curves, plant species were categorised as being 'sensitive', 'moderately sensitive', 'moderately tolerant' or 'tolerant' to salinity. We can see that the curve for cotton (reproduced from Fig. 4.2) actually falls into the 'tolerant' region of Figure 4.3. Cotton was therefore classified by Maas and Hoffman as being 'tolerant' to salinity.

These categories of salt tolerance in crops can be compared with the soil salinity classes previously shown in Table 3.2. Figure 4.4 puts the information from the plant categories and soil classes into a single graph, which shows that:

- on *salt-free* soils, there may be some reductions in the growth of the most salt 'sensitive' crops but there is little inhibition in the growth of crops of greater tolerance;
- on *slightly saline* soils, there are substantial reductions in the growth of salt 'sensitive' crops, some reductions in the growth of 'moderately sensitive' crops, but little inhibition in the growth of crops of greater tolerance;
- on *moderately saline* soils there are substantial reductions in 'moderately tolerant' crops and some reductions in 'tolerant' crops; and
- on *strongly saline* soils there are substantial reductions in 'tolerant' crops.

Based on these analyses, Maas and Hoffman categorised the salt tolerance of over 150 different plant species of agricultural significance, some of which are listed in Table 4.1. However, it should be remembered that for saline soils in Pakistan, these assessments only indicate the maximum possible levels of relative growth in saline soils. Actual growth may be substantially decreased by the salt–waterlogging interaction (discussed below).

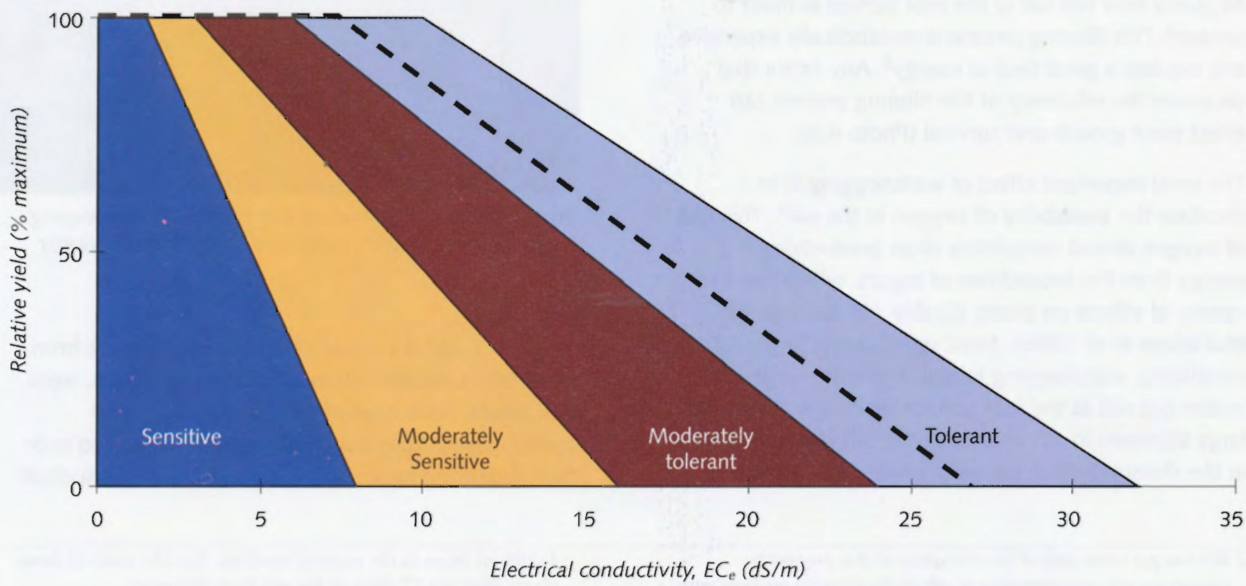

Figure 4.3. *Divisions for classifying crop tolerance to salinity (EC_e) along with the relative yield response curve for cotton (dotted line from Fig. 4.2) (Maas and Hoffman 1977).*

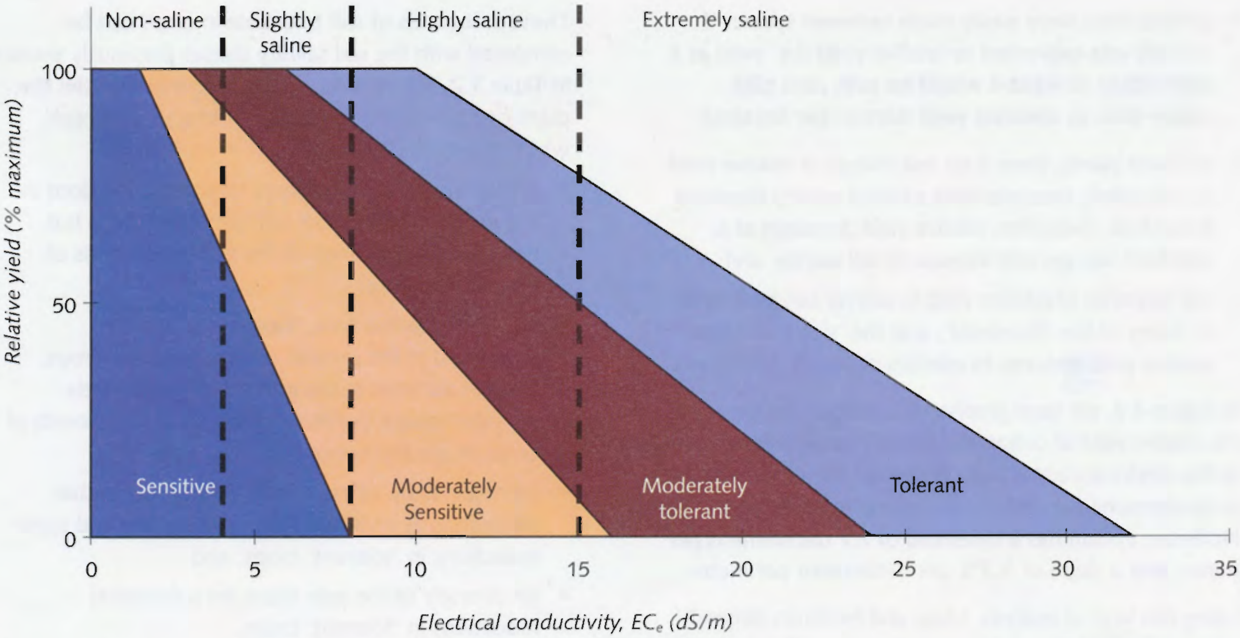

Figure 4.4. *Comparison of soil salinity categories (Table 3.2) with the crop tolerance categories of Maas and Hoffman (Fig. 4.3).*

4.2 Waterlogging in Saline Environments — Effects on Plant Growth

All plants filter out salt at the root surface in order to survive[2]. This filtering process is metabolically expensive and requires a great deal of energy[3]. Any factor that decreases the efficiency of this filtering process can affect plant growth and survival (Photo 4.1).

The most important effect of waterlogging is to decrease the availability of oxygen in the soil[4]. This lack of oxygen almost completely stops production of energy from the breakdown of sugars, which has a variety of effects on plants (Grable 1966; Drew 1983; McFarlane et al. 1989). Most significantly, under saline conditions, waterlogging inhibits the ability of roots to screen out salt at the root surface; there are therefore large increases in salt uptake and in salt concentrations in the shoots (Barrett-Lennard 1986).

Photo 4.1. *Mortality in wheat due to salt and waterlogging near Jaranwala. [PHOTOGRAPH: E. BARRETT-LENNARD]*

Tables 4.2 and 4.3 show a number of examples from the world scientific literature where crop plants, trees and shrubs have been grown under saline, and saline/waterlogged conditions. It is important to note that waterlogging increased concentrations of sodium

2 We can get some idea of the efficiency of this process by comparing the concentration of salt in the external medium with that in the xylem sap (the fluid which flows from the roots to the leaves) (see review by Munns et al. 1983). For plants without salt glands, the concentrations of chloride in the xylem sap are about 0.2–5% of the concentrations in the external medium; thus the roots of these plants filter out 95–99.8% of the salt from the water. For plants with salt-secreting glands on the surface of the leaves, the filtering process need not be quite as efficient. For these plants, the concentrations of chloride in the xylem are 4–28% of those in the external medium; thus the roots of these plants filter out 72–96% of the salt from the water.

3 Barrett-Lennard (1986) has calculated that the exclusion of sodium from the roots requires the expenditure of about 2.4% of the total amount of energy available to a root growing in drained soil. The exclusion of chloride probably requires as much energy again.

4 Oxygen diffuses about 10 000 times slower through water-filled than through gas-filled soil pores.

Table 4.1. Salt tolerance of selected plants of agricultural importance.[a]

Category/common name	Scientific name	Use
Tolerant		
Alkaligrass, Nuttall	*Puccinellia airoides*	forage grass
Asparagus	*Asparagus officinalis*	vegetable
Barley	*Hordeum vulgare*	grain
Bermuda grass	*Cynodon dactylon*	forage grass
Cotton	*Gossypium hirsutum*	fibre crop
Date palm	*Phoenix dactylifera*	fruit tree
Kallar grass	*Diplachne fusca*	forage grass
River red gum, seedlings[b]	*Eucalyptus camaldulensis*	fuelwood, timber
Saltgrass, desert	*Distichlis stricta*	forage grass
Sugarbeet	*Beta vulgaris*	tuber
Wheat, semidwarf	*Triticum aestivum*	grain
Wheatgrass, fairway crested	*Agropyron cristatum*	forage grass
Wheatgrass, tall	*Elytrigia elongata*	forage grass
Wildrye, Altai	*Leymus angustus*	forage grass
Moderately tolerant		
Barley, forage	*Hordeum vulgare*	forage crop
Beetroot	*Beta vulgaris*	vegetable
Fig	*Ficus carica*	fruit tree
Guar	*Cyamopsis tetragonoloba*	grain for gum, forage, green manure
Jujube	*Ziziphus jujuba*	fruit tree
Oats	*Avena sativa*	grain
Papaya	*Carica papaya*	fruit tree
Pomegranate	*Punica granatum*	fruit tree
Rape	*Brassica napus*	oil seed
Rhodes grass	*Chloris gayana*	forage grass
Rye	*Secale cereale*	grain
Safflower	*Carthamus tinctorius*	oil seed
Sorghum	*Sorghum bicolor*	forage, grain
Soybean	*Glycine max*	oil seed, pulse
Sudangrass	*Sorghum sudanense*	forage grass
Trefoil, broadleaf birdsfoot	*Lotus corniculatus arvenis*	forage
Trefoil, narrowleaf birdsfoot	*Lotus corniculatus tenuifolium*	forage
Wheat, forage	*Triticum aestivum*	forage crop
Wheatgrass, standard crested	*Agropyron sibiricum*	forage grass
Wildrye, beardless	*Elymus triticoides*	forage grass
Moderately sensitive		
Alfalfa, lucerne	*Medicago sativa*	forage legume
Broccoli	*Brassica oleracea botrytis*	vegetable
Cabbage	*Brassica oleracea capitata*	vegetable
Capsicum	*Capsicum annuum*	vegetable
Cauliflower	*Brassica oleracea botrytis*	vegetable
Celery	*Apium graveolens*	vegetable
Clover berseem	*Trifolium alexandrinum*	forage legume
Corn	*Zea mays*	vegetable, grain, forage
Cucumber	*Cucumis sativus*	vegetable

Table 4.1. Salt tolerance of selected plants of agricultural importance (continued).[a]

Category/common name	Scientific name	Use
Moderately sensitive (continued)		
Eggplant	*Solanum melongena esculentum*	vegetable
Grape	*Vitus* sp.	fruiting vine
Kale	*Brassica oleracea acephala*	vegetable, forage
Lettuce	*Lactuca sativa*	vegetable
Muskmelon	*Cucumis melo*	vegetable
Oats	*Avena sativa*	forage crop
Peanut	*Arachis hypogaca*	groundnut
Potato	*Solanum tuberosum*	tuber
Pumpkin	*Cucurbita pepo pepo*	vegetable
Radish	*Paphanus sativus*	vegetable
Rye, forage	*Secale cereale*	forage crop
Sesbania	*Sesbania exaltata*	forage crop
Shisham[c]	*Dalbergia sissoo*	timber tree
Spinach	*Spinacia oleracea*	vegetable
Sugarcane	*Saccharum officinarum*	grass crop
Sunflower	*Helianthus annuus*	oil seed
Sweet potato	*Ipomoea batatas*	tuber
Tomato	*Lycopersicon esculentum*	vegetable
Trefoil, big	*Lotus uliginosus*	forage
Turnip	*Brassica rapa*	tuber
Watermelon	*Citrullus lanatus*	vegetable
Sensitive		
Almond	*Prunis dulcis*	fruit tree
Apple	*Malus sylvestris*	fruit tree
Apricot	*Prunus armeniaca*	fruit tree
Bean	*Phaseolus vulgaris*	vegetable, pulse
Carrot	*Daucus carota*	vegetable
Cherry, sweet	*Prunus avium*	fruit tree
Grapefruit	*Citrus paradisi*	fruit tree
Lemon	*Citrus limon*	fruit tree
Lime	*Citrus aurantiifolia*	fruit tree
Loquat	*Eriobotrya japonica*	fruit tree
Mango	*Mangifera indica*	fruit tree
Okra	*Abelmoschus esculentus*	vegetable
Onion	*Allium cepa*	vegetable
Orange	*Citrus sinensis*	fruit tree
Pea	*Pisum sativum*	vegetable
Peach	*Prunus persica*	fruit tree
Pear	*Pyrus communis*	fruit tree
Persimmon	*Diospyros virginiana*	fruit tree
Plum	*Prunus domestica*	fruit tree
Rice	*Oryza sativa*	grain
Sesame	*Sesamum indicum*	oil seed

a Unless otherwise indicated, these classifications have been reproduced from Maas (1986), Tables 2 and 3

b We are aware of studies that suggest that *Eucalyptus camaldulensis* has substantially lower levels of salt tolerance in the field (e.g. Marcar et al. 1994). Growth in such cases may have been adversely affected by salt–waterlogging interactions. Our listing of the species as tolerant is based on the responses of seedlings under glasshouse conditions (Sands 1981)

c This assessment is for establishing trees (see Singh et al. 1996)

Table 4.2. Waterlogging under saline conditions and sodium chloride accumulation in the leaves or shoots — crop plants.

Common name/species	Tissue	Waterlogging (days)	EC_w[a] (dS/m)	Increase in concentration (%)		Source/notes
				Chloride	Sodium	
Barley (*Hordeum vulgare*)	Shoot	14	12.5	39	23	John et al. (1977)[b,c]
Bean (*Phaseolus vulgaris*)	Leaves	9	4	55	555	West and Taylor (1980a)[d,e]
Rice (*Oryza sativa*)	Shoot	17	8	26	17	John et al. (1977)[d,e]
Sunflower (*Helianthus annuus*)	Leaves	10	15	395	1045	Kriedemann and Sands (1984)[d,f]
Tobacco (*Nicotiana tabaccum*)	Leaves	10	9	101	435	West and Black (1978)[g,h]
Tomato (*Lycopersicon esculentum*)	Leaves	15	9	191	172	West and Taylor (1980b) Three different temperature regimes were reported in this paper. The data reported here are for 20°C[g, h]
Wheat (*Triticum aestivum*)						
cultivar Gamenya	Shoot	7	12	52	77	Barrett-Lennard (1986)[b,c]
cultivar Lyp-90	Leaves	42	11	53	230	Akhtar et al. (1994)[i,j]
cultivar SARC-1	Leaves	42	11	1	323	Akhtar et al. (1994)[i,j]
cultivar 7-Cerros	Leaves	42	11	40	577	Akhtar et al. (1994)[i,j]
cultivar Pato	Leaves	42	11	2	513	Akhtar et al. (1994)[i,j]
cultivar Pb-85	Leaves	42	11	18	380	Akhtar et al. (1994)[i,j]
cultivar Tchere	Leaves	42	11	41	482	Akhtar et al. (1994)[i,j]
cultivar Blue Silver	Leaves	42	11	57	436	Akhtar et al. (1994)[i,j]
cultivar LU-26S	Leaves	42	11	12	500	Akhtar et al. (1994)[i,j]
cultivar Chinese Spring	Leaves	42	11	−16	521	Akhtar et al. (1994)[i,j]

a Where appropriate, salt concentrations have been converted to electrical conductivities assuming that a solution of 10 mM NaCl has an EC of 1 decisiemen per metre (cf. Richards 1954)

b Plants were grown in sand cultures irrigated with nutrient solution

c Waterlogging was imposed by saturating the sand

d Plants were grown in air-bubbled nutrient solutions

e Waterlogging was simulated by bubbling solutions with nitrogen gas

f Waterlogging was simulated by allowing the solutions to become stagnant

g Plants were grown in soil irrigated with nutrient solution

h Waterlogging was imposed by saturating the soil for 12 in every 24 hours

i Plants were grown in vermiculite/gravel irrigated with nutrient solution

j Waterlogging was imposed by saturating the root medium

Table 4.3 Waterlogging under saline conditions and sodium chloride accumulation in the leaves or shoots — trees and shrubs.

Species[a]	Tissue	Waterlogging (days)	Salinity (dS/m)	Increase in concentration (%) Chloride	Sodium	Source/notes
Boorabbin mallee (*Eucalyptus platycorys*)	Leaves	77	42	186	135	Moezel et al. (1988) [b,c,d]
Comet Vale mallee (*Eucalyptus comitae-vallis*)	Leaves	77	42	236	157	Moezel et al. (1988) [b,c,d]
Forest red gum (*Eucalyptus tereticornis*)	Leaves	25	10	92	16	Marcar (1993) [b,c]
Goldfields blackbutt (*Eucalyptus lesouefii*)	Leaves	77	42	146	91	Moezel et al. (1988) [b,c,d]
Kondinin blackbutt (*Eucalyptus kondininensis*)	Leaves	77	42	177	106	Moezel et al. (1988) [b,c,d]
River red gum (*Eucalyptus camaldulensis*)	Leaves	25	10	100	119	Marcar (1993) [b,c]
	Leaves	77	42	590	853	Moezel et al. (1988) [b,c,d]
River saltbush (*Atriplex amnicola*)	Leaves	14	40	108	59	Galloway and Davidson (1993)[e,f]
Swamp mahogany (*Eucalyptus robusta*)	Leaves	25	10	83	115	Marcar (1993) [b,c]
Swamp mallet (*Eucalyptus spathulata*)	Leaves	77	42	75	133	Moezel et al. (1988) [b,c]
Swamp oak (*Casuarina glauca*)	Shoot	84	up to 56	167	289	Moezel et al. (1989) [b,c,g]
Tasmanian blue gum (*Eucalyptus globulus*)	Leaves	25	10	79	130	Marcar (1993) [b,c]
Swamp sheoak (*Casuarina obesa*)	Shoot	84	up to 56	243	404	Moezel et al. (1989) [b,c]
	Leaves	77	42	86	184	Moezel et al. (1988) [b,c,d]

a Common names of trees and shrubs have been adopted from REX-'96, the Revegetation Expert System devised by Agriculture Western Australia, Greening Western Australia and the Western Australian Department of Conservation and Land Management

b Plants were grown in sand irrigated with nutrient solution

c Waterlogging was imposed by saturating the sand

d Salt concentrations were increased by 7 decisiemens per metre per week for 6 weeks; leaves were harvested from the upper half of the stem

e Plants were grown in air-bubbled nutrient solutions

f Waterlogging was simulated by bubbling solutions with nitrogen gas

g Salt concentrations were increased as follows: weeks 0 to 6 — EC increases by 7 decisiemens per metre; weeks 7 to 10 — EC = 49 dS/m; weeks 11 to 12 — EC = 56 dS/m

Table 4.4. The effect of previous exposure of plants to waterlogging on their ability to exclude salt from the leaves during salt/waterlogging.[a]

Species	Previous exposure to waterlogging (days)	Increase in concentration due to salt/waterlogging (%)	
		Chloride	Sodium
Sunflower (*Helianthus annuus*)	none	395	1045
	13	–9	94
River red gum (*Eucalyptus camaldulensis*)	none	100	119
	21	30	31
Swamp mahogany (*Eucalyptus robusta*)	none	83	115
	21	4	9
Tasmanian blue gum (*Eucalyptus globulus*)	none	79	130
	21	–10	62

a In each case, salt/waterlogging stress was applied after the pretreatment. For sunflowers, the plants were grown in air-bubbled nutrient solutions. Salt/waterlogging stress was applied by increasing the salinity (electrical conductivity of the solution) to 15 decisiemens per metre and allowing the solutions to become stagnant for 10 days (Kriedemann and Sands 1984). For the three tree species, the plants were grown in sand cultures irrigated with nutrient solution. The salt/waterlogging stress was imposed by increasing the salt concentrations (electrical conductivities of the solutions) to 10 decisiemens per metre and saturating the sand to the surface for 25 days (Marcar 1993). Sodium and chloride concentrations were determined in the leaves.

or chloride in all plants tested. The plant with the lowest increase in concentrations in the leaves was the waterlogging-tolerant species, rice (*Oryza sativa*).

Previous exposure to waterlogging can improve the ability of plants to cope with salt–waterlogging interactions. Table 4.4 compares the effects of previous and no previous exposure to waterlogging on the increase in sodium and chloride concentrations in leaves after the start of salt/waterlogging. In each case, there is a smaller increase in sodium and chloride concentrations if the plants have been pretreated with waterlogging.

These kinds of results have encouraged researchers to suggest that plants have special mechanisms which improve their ability to cope with waterlogging. Previous waterlogging gives the plants a chance to 'switch on' these mechanisms before the salt/waterlogging starts.[5]

The increased salt concentrations in leaves due to salt/waterlogging interactions cause damage to leaves, which affects plant growth. Photo 4.2 shows the effects of salt–waterlogging interactions on wheat waterlogged at various salinities for 33 days. At all salinity (EC_w) values greater than 2 decisiemens per metre, waterlogging caused extensive leaf damage to plants and there was no growth (increase in shoot weight) after 33 days. This damage was not due to salinity alone, because when plants were grown under drained conditions, shoot growth continued even at EC_w values as high as 12 decisiemens per metre (Photo 4.2).

We believe that the growth of crop plants may be affected by waterlogging on saltland without farmers being aware of it. Figure 4.5 shows the average response to salinity of 17 wheat cultivars growing in a saline field in California (Richards et al. 1987) and the growth that would have been expected based on the studies of salinity response summarised by Maas and Hoffman (1977). There was a much greater depression in grain yield in the field than in the well-drained soils considered by Maas and Hoffman. These differences could have been due to low-level salt–waterlogging interactions occurring in the field[6].

5 One of the likely mechanisms is the formation of 'aerenchyma' in roots. Aerenchyma are unfilled spaces or channels in the root which enable oxygen to diffuse inside the root to the tip. Anatomical observations under the microscope confirmed that in one of the cases reported in Table 4.4 (sunflowers), previous exposure to waterlogging did stimulate aerenchyma formation (Kriedemann and Sands 1984).

6 We know that this site was subject to waterlogging as the authors used the presence of waterlogging to justify the discarding of some anomalous plant measurements (Richards et al. 1987, p. 280).

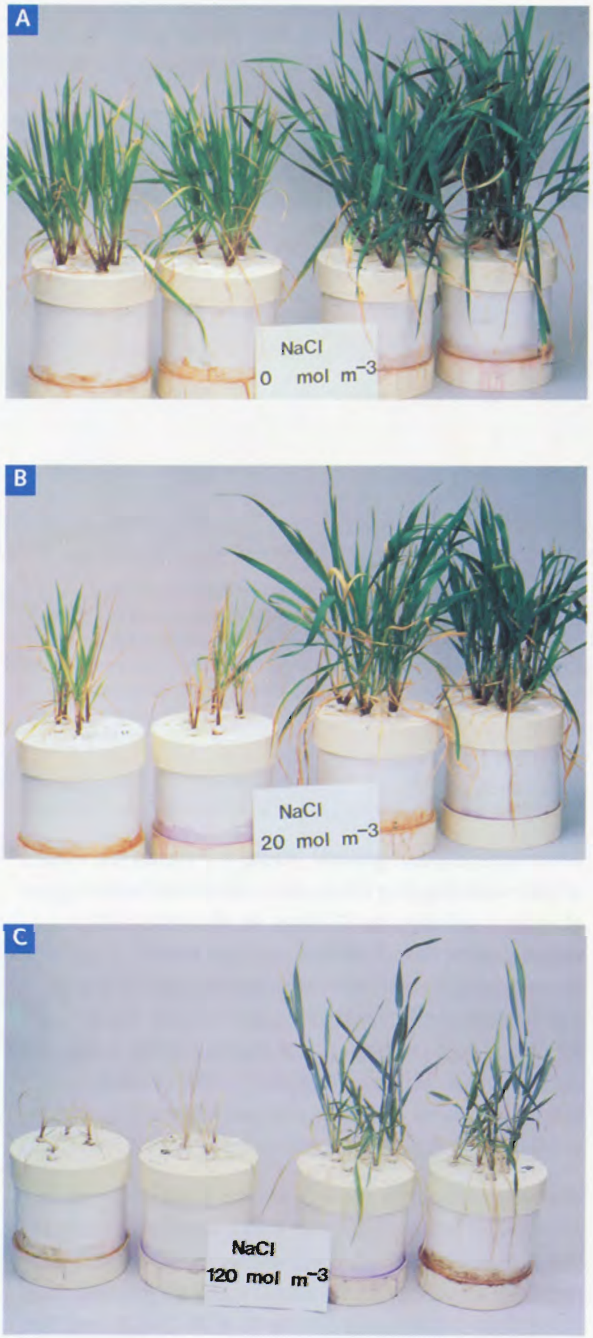

Photo 4.2. *Effects of salt and waterlogging on wheat grown in nutrient solutions. Pots on the left were 'waterlogged' for 33 days (simulated by bubbling solutions with nitrogen gas). Pots on the right were 'drained' (simulated by bubbling solutions with air). (A) Plants grown with no salt. (B) Plants grown with EC_w values of 2 decisiemens per metre. (C) Plants grown with EC_w values of 12 decisiemens per metre (Barrett-Lennard and Malcolm 1995, p. 12). [PHOTOGRAPHS: S. EYRES]*

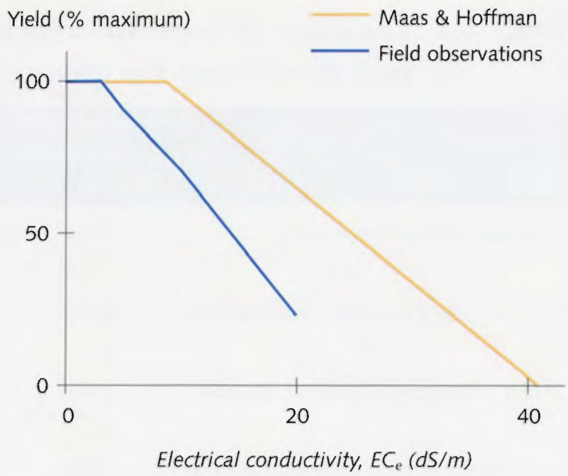

Figure 4.5. *Comparisons of the response of wheat to salinity (EC_e) in the field (where waterlogging did occur) and in the well-drained experiments summarised by Maas and Hoffman 1977 (median results of 17 cultivars).*

Salt–waterlogging interactions also affect plant survival. Figure 4.6 shows the effects of salt–waterlogging interactions on the survival of seven Australian tree species. All of these species had high percentages of survivors under conditions of salinity (EC_w values of 42 decisiemens per metre). However, there was much lower survival for all except one species (swamp oak) when the salinity treatment was imposed with 11 weeks of waterlogging.[7]

More than 70 Australian tree species have now been screened for tolerance to the combined stresses of salinity and waterlogging. The species with best survival under combined salinity and waterlogging are listed in Table 4.5.

4.3 Breeding for Salinity Tolerance

About two decades ago, one of the world's famous plant physiologists assembled a research team to breed cereals for salt tolerance[8]. The strategy was to: (a) screen a wide variety of cereal germplasm at high levels of salinity, (b) retain and bulk up seed of the survivors, and (c) grow that material out on a well-drained coastal

7 Similar variation has also been found within *Casuarina* species (Moezel et al. 1989).

8 We refer to Emanuel Epstein and a series of papers appearing from this group in the late 1970s and early 1980s (Epstein and Norlyn 1977; Epstein et al. 1980)