chapter 5

Crops and Grasses for Salt-Affected Land

Overview

In this chapter and the next two, we consider the botanical elements of saline agriculture (i.e. plant species with increased tolerance to salinity) in much greater detail. This chapter examines salt tolerance in crops and grasses; Chapters 6 and 7 focus on trees and saltbushes.

Salt-tolerant plants

There are more than 1500 salt-tolerant plant species in the world. Saline agricultural systems in Pakistan presently use less than 1% of this number.

General issues for growth of crops and grasses

Growth of good crops and grasses on saltland requires careful land preparation. It may also require the use of manure and soil amendments, and higher seeding rates than normal.

Growing crops on salt-affected land

Rice, wheat, cotton, and rapeseed are important annual food and cash crops that are currently cultivated on 3.5 million hectares of land in Pakistan, with patches of salinity covering 20% or more of the area. The relatively low crop yields on this land are of great concern and have serious economic impacts at the national level. Selection of the most salt-tolerant varieties and the use of improved planting techniques and fertilisers are important factors for achieving improved yields. Barley and sugarcane are also crops for which there may be scope for selecting for increased salt tolerance.

Growing salt-tolerant grasses

The growth of perennial forage grasses is also an important use of salt-affected areas. Rhodes grass (*Chloris gayana*), tall wheatgrass (*Elytrigia elongata*), kallar grass (*Leptochloa fusca*) and some other grass species have been shown to have some tolerance to salt and waterlogging. An increased understanding of the adaptation, propagation and management of these species will allow increased productivity in saline conditions.

5.1 Salt-Tolerant Plants

This chapter focuses on the growth of crops and salt-tolerant grasses on salt-affected land. We can begin this more detailed consideration of salt tolerance by asking the question: 'How many salt-tolerant plant species are there that would be of value to saline agriculture in Pakistan?'

World bibliographies list more than 1500 species with high levels of salt tolerance.[1] In these three chapters, we focus on less than 1% of these. We are therefore sure that this book omits many salt-tolerant species that will be found in the future to be highly suited to Pakistan. However, the field of saline agriculture is in its infancy; most species with potential have not yet been tested. Despite this lack of knowledge, we believe that the material presented here forms a sound basis for starting to build saline agricultural systems in Pakistan. As our understanding develops, further species will be added to these lists.

Figure 5.1 shows the relative salt tolerance of 19 of the species profiled in the next three chapters. Preparing this figure has been difficult because for some of the species of interest, there are few or no published data under conditions of controlled salinity. We have therefore done our best with data collected from the more variable environment of the field. Compiling this figure was also complicated because agricultural scientists often use differing methods for measuring: growth[2], and soil salinity.[3] Nevertheless, the figure suggests that only two of the listed species (mesquite and river saltbush) are capable of rapid growth in soil salinity at electrical conductivity of the saturation extract (EC_e) values of greater than 30 decisiemens per metre. However, there are a further five species (salt wattle *Acacia ampliceps*, kallar grass *Leptochloa fusca*, frash *Tamarix aphylla*, vilaitai kikar *Parkinsonia aculeata* and jangli saru *Casuarina equisetifolia*) that are capable of rapid growth at EC_e values between 20 and 30 decisiemens per metre. In contrast, three crops (cotton, wheat and rice) would have had little or no growth at EC_e values of 15 decisiemens per metre.

5.2 General Issues for Growth of Crops and Grasses

A number of agricultural factors, including seeding rate and use of fertilisers, are required for the successful growth of crops and salt-tolerant grasses.

5.2.1 Land preparation

Before cropping, fields should be deep ploughed with a chisel plough to break any hardpan. They should then be levelled to facilitate irrigation and ensure that irrigation does not cause waterlogging in low-lying areas.

5.2.2 Use of manure and soil amendments

Crop yields on marginal land are affected by fertility and soil structure. Fertility can be improved by the application and ploughing in of well-rotted farmyard manure at a rate of about 20–25 tonnes per hectare.

Soil structure of the salt-affected areas can be improved by the application of gypsum. Areas of sodicity are first identified from visual observation or measurement. Gypsum can then be added to the affected areas at a rate of 7–8 tonnes per hectare, and to the remaining land at the rate of 2–3 tonnes per hectare.

1 To gain some idea of the potential number of plant species that might be useful in building saline agricultural systems, the reader is referred to the bibliographies compiled by Mudie (1974) and Aronson (1989). The work by Mudie listed 550 highly salt-tolerant species, from 220 genera and 75 families. The more recent work by Aronson listed over 1560 species from 550 genera and 117 families.

2 Plant scientists have variously discussed the effects of salinity on plant growth in terms of: (a) differences in shoot dry weights (or yields) at one point in time, or (b) differences in relative growth rates over a period of time. It is important to realise that these measurements are not comparable. Relative growth rates assume exponential growth. Small differences in relative growth rate can give very large differences in harvestable dry weight. The comparisons in Figure 5.1 are based on differences in shoot dry weight or yield at single points in time. Such comparisons are useful provided that the time at which they are taken is consistent with that required for the harvest of a commercial product from the species concerned.

3 In preparing the figure, we have used salt tolerance data based on critical values of EC_w or EC_e interchangeably. This requires some justification. For freely draining medium to fine-textured soils, the EC of the soil solution in moist soils is about two times higher than the EC_e (cf. Richards 1954, p. 8). However, for plants growing in saline medium to fine-textured soils, the EC of the soil solution in the bulk of the soil is only about 50% of the EC of the soil solution immediately adjacent to the root (Sinha and Singh 1974, 1976). These two factors therefore roughly cancel each other out.

5.2.3 Seeding rates

In general, in salt-affected soils we expect the germination of seed and the survival of young plants to be substantially decreased. Therefore, the final plant density can be less than optimum. To maintain plant density, we recommend that 20–30% more seed should be used when sowing salt-affected compared with non-affected soils.

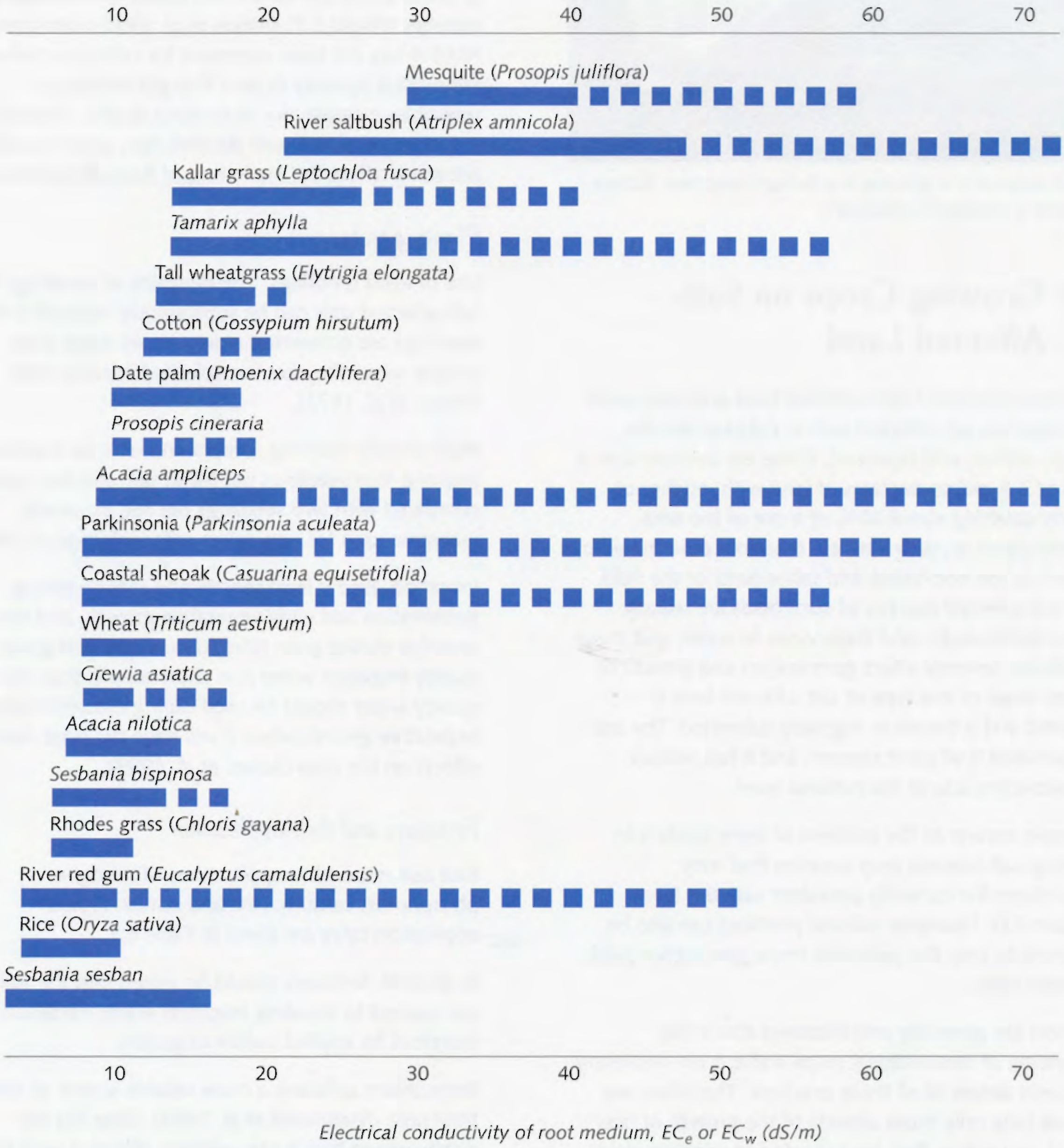


Figure 5.1. *Relative tolerance of plant species to salinity (EC_e or EC_w). The salt concentrations over which we expect 25–50% reductions in shoot growth or commercial yield are indicated by the solid line. More extreme growth reductions are indicated by the broken line. (The published sources used to build this figure are referred to under the detailed notes for each species in Chapters 5, 6 and 7). Preparing this figure has been difficult because for some of the species of interest, there are few or no published data under conditions of controlled salinity. We have therefore had to do our best with data collected from the more variable environment in the field.*

Photo 5.1. *Salt-tolerant rice growing in a farmer's field near Satiana. [PHOTOGRAPH: E. BARRETT-LENNARD]*

5.3 Growing Crops on Salt-Affected Land

The most important conventional food and cash crops cultivated on salt-affected soils in Pakistan are rice, wheat, cotton, and rapeseed. These are cultivated on a total of 3.5 million hectares of land with patches of salinity covering about 20% or more of the area. Overall yields on such land are therefore determined by growth in the non-saline and saline parts of the field. The salt-affected patches of such fields are usually highly saline–sodic, and impervious to water, and these conditions severely affect germination and growth of plants. Most of this type of salt-affected land is irrigated and is therefore regularly cultivated. The use of such land is of great concern and it has serious economic impacts at the national level.

A simple answer to the problem of these lands is to develop salt-tolerant crop varieties that may outperform the currently prevalent varieties (see Section 4.3). However, cultural practices can also be modified to help the particular crops give higher yields in saline fields.

Farmers are generally well informed about the agronomy of conventional crops and it is not necessary to repeat details of all these practices. Therefore, we discuss here only those aspects of the growth of rice, wheat and cotton that are expected to improve yield compared with the normal practice.

5.3.1. Rice

Varieties

Rice is a moderately salt-tolerant species, although there are differences between cultivars. On moderately salt-affected soils, the cultivars KS-282 and NIAB-6 produce about 30–35% more paddy than ordinary varieties (Photo 5.1) (Aslam et al. 1993). Unfortunately, NIAB-6 has not been approved for cultivation because, although it appears to be a fine-grained rice, it resembles a coarse rice in cooking quality. It could therefore be mixed with Basmati rice, which would adversely affect the marketing of Basmati varieties.

Planting techniques

Use of aged seedlings. The mortality of seedlings in salt-affected soils can be substantially reduced if the seedlings are somewhat older (40–45 days) than normal when they are transplanted into the field (Akbar et al. 1972).

High-density planting. Crop stands can be improved by planting four seedlings per hill in salt-affected soils, compared with two seedlings per hill, as usually recommended for non-saline soils (Aslam et al. 1990).

Irrigation. Rice is least sensitive to salinity during germination and early vegetative growth, and more sensitive during grain filling (Maas 1986). If good-quality irrigation water is in short supply, then the poor-quality water should be used during establishment and vegetative growth when it will have the least damaging effects on the crop (Aslam et al. 1993).

Fertilisers and their application

Rice can respond to applications of nitrogen, phosphorus, calcium, zinc and boron. Typical application rates are given in Table 5.1.

In general, fertilisers should be mixed into the soil and not applied to standing irrigation water. Fertilisers must therefore be applied before irrigation.

Ammonium sulfate is a more reliable source of nitrogen than urea (Mahmood et al. 1993). Urea has the disadvantage that it can volatilise (break down) to release nitrogen in the form of ammonia into the atmosphere. However, these losses can be minimised if the urea is applied early in the morning while temperatures are still relatively low, and the fertiliser is incorporated into the soil.

Table 5.1. Annual fertiliser application rates for rice.

Nutrient	Rate	Typical increase in crop growth (%)
Phosphorus	Apply superphosphate at 44 kilograms P per hectare	35 – 64[a]
Nitrogen	Apply urea at 100–150 kilograms N per hectare	120 – 220[b]
Calcium	Apply gypsum according to the sodicity of the soil at 50% of the gypsum requirement[c]	100 – 200[d]
Zinc	Apply zinc sulfate at 10–20 kilograms per hectare	100 – 175[e]
Boron	Apply boric acid at 1.5 kilograms per hectare every second year	120 – 130[f]

a Response found in glasshouse trial with two soils (Nawan Lahore, Awagat) (Aslam et al. 1996)

b Response found in glasshouse trial with two soils (Nawan Lahore, Awagat) (Aslam et al. 1992; Muhammad et al. in press)

c Gypsum requirement calculated according to Richards (1954)

d Aslam (in press)

e Mahmood et al. (in press)

f Aslam (in press)

Care needs to be taken with the application of phosphorus, zinc and boron, as over-application can lead to toxicity, which retards growth and reduces yield. In this respect, the reader is specifically referred to the need to apply boron only about once every 2 years (Table 5.1).

The beneficial effects of fertilisers can be increased if they are applied as split applications. For example with nitrogen, better results may be expected if one-third of the fertiliser is applied 8–10 days after transplantation, a further third is applied 20–25 days after transplantation, and the final third is applied before panicle initiation at 40–45 days after transplantation (Aslam et al. 1992).

Zinc can also be supplied to rice seedlings before they are transplanted into the field by dipping them into a 1% zinc oxide or zinc sulfate solution for 30–60 minutes.

5.3.2 Wheat

Varieties

Varieties selected for high salt tolerance do not always perform better than recommended varieties in salt-affected soils. This is because the extent and degree of salinity varies a great deal under field conditions. Moreover, climatic factors and cultural practices also affect performance. Nevertheless, we expect that salt-tolerant varieties will have 'an edge' over non-tolerant varieties under most saline field conditions. A lot of effort has gone into selecting salt-tolerant varieties of wheat by the Saline Agriculture Research Cell at the University of Agriculture Faisalabad. Selections that have performed well under field conditions include SARC-I, SARC-II, SARC-III and SARC-IV. Seed of SARC-I has been multiplied and distributed among farmers within the area of the Joint Satiana Pilot Project. These farmers have generally reported favourably on its performance in salt-affected fields. A new line (234-I) has recently been identified as being highly waterlogging tolerant, but trials in farmers' fields are not yet complete.

Other well-known salt-tolerant wheat varieties are Blue Silver, LU-26S and Kharchia-65. Unfortunately, Kharchia-65 is highly susceptible to rust and lodging, and LU-26S and Blue Silver also have susceptibility to rust.

Planting techniques

The choice of method for planting wheat depends on the soil texture and its permeability characteristics as detailed below.

Freely draining soils. For freely draining soils, the land should be well prepared. Seed should be sown into almost dry soil, which is then heavily irrigated to leach salts into the subsoil. (This method is called *dry sowing.*) Subsequent irrigation is given soon after the crop has established (i.e. 7–15 days after germination). Nitrogen and phosphorus fertilisers should be applied at this stage.

Poorly drained soil. Soils that are clayey, low-lying, sodic and/or used for rice generally have drainage problems, and after irrigation or rain, water can stand on the soil surface for a long time, causing waterlogging. In this situation dry sowing is hazardous. Instead, the land should be prepared in the form of raised beds, about 75–100 centimetres wide, and 20–30 centimetres high, separated by irrigation channels. After a heavy soaking irrigation and the addition of the first dose of the nitrogen and phosphorus fertilisers, the crop is sown in the beds in rows about 15 centimetres apart.[4]

Fertilisers and their application

The fertiliser requirements of wheat are documented in Table 5.2. The reader will notice that in cases where wheat is sown after rice, zinc and boron only need to be added once a year (in the rice phase). Our general comments (see Section 5.3.1) on the need to incorporate fertilisers after application, and the benefits of split fertiliser applications, also apply for wheat.

5.3.3 Cotton

Cotton is a relatively salt-tolerant crop (Table 4.1). However, there can be problems with emergence in sodic soils resulting in a lower plant density than required. Furthermore, waterlogging can seriously affect its growth.

Varieties

Of the various varieties tested, NIAB-78 and MNH-93 are more salt tolerant. In recent years, Pakistan's cotton crop has been very adversely affected by infestations of cotton leaf curl virus (CLCV). The newly developed varieties with tolerance to CLCV urgently need to be tested for salt tolerance.

Planting and managing the crop

Cotton is a summer (*kharif*) crop. It should be planted on ridges or raised beds about 30 centimetres high and 75 centimetres wide. These beds should be 75 centimetres apart. The sequence of events in building these beds is as follows.

Cultivate the soil and then apply gypsum. Use a bedding plough to construct the furrows and raised beds. These beds will be 75 centimetres wide, alternating with irrigation furrows 75 centimetres wide.

Table 5.2 Annual fertiliser application rates for wheat.

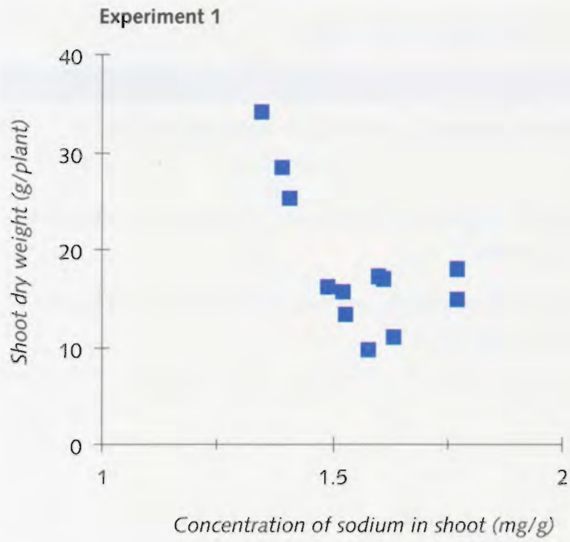
Nutrient	Form and rate	Typical increase in crop growth (%)
Phosphorus	Apply superphosphate at 35 kilograms P per hectare	100–200[a]
Nitrogen	Apply urea at 160 kilograms N per hectare	120–220[b]
Calcium	Apply gypsum according to the sodicity of the soil at 10–20% of gypsum requirement [c]	
Zinc	No requirement if applied in rice phase	
Boron	No requirement if applied in rice phase	

a M. Aslam (pers. comm. 1996)

b Response found in glasshouse trial with artificially salinised (EC_e = 11.8 decisiemens per metre) soil (Nadeem et al. 1995)

c It is common practice for gypsum to be applied only in the rice phase. However there are likely to be some benefits from the addition of small amounts of gypsum in the wheat phase, hence this recommendation. Gypsum requirement is calculated according to Richards (1954).

4 There were clear benefits of raised beds on the yield of wheat in an experiment on a saline (EC_e 8.3 decisiemens per metre) sodic (SAR 23, pH 8.9) loamy clay at Sadhoke. Wheat grown with conventional cultivation yielded 0.60 tonnes per hectare. However, wheat grown on 15-centimetre high beds 30, 45 or 60 centimetres wide had yields of 1.07, 1.06 and 1.20 tonnes per hectare (Qureshi and Aslam 1988).



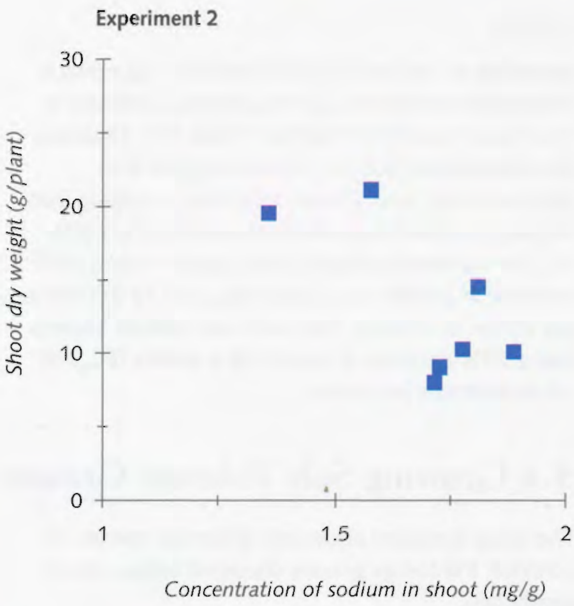


Figure 5.2. *For a range of barley cultivars, relationship between shoot dry weight after 20 weeks (EC_w 10 decisiemens per metre) and sodium concentration in the shoots. Experiments 1 and 2 are from Niazi et al. (1987 and 1992 respectively).*

Plant seeds in rows on either side of the beds. Instead of evenly spacing the seeds, there is improved emergence of broad-leaved crops like cotton through crusting soils by planting three to four seeds in a clump, with about 15 centimetres between clumps. Seedlings in these clumps can then be thinned about 45 days after sowing when the plants are about 15–20 centimetres high.

Apply fertiliser, in the irrigation furrows, 1 week after the first irrigation water has been applied. Incorporate the fertiliser into the soil (and control weeds) by reforming the bed/furrow surface with the bedding plough. It is possible to split the application of fertiliser into a number of applications after several irrigations; however the fertilising program should be complete by 60 days after sowing, otherwise the crop will finish too late to allow for the planting of wheat in the *rabi* season.

Apply plant hormone growth regulator (Pix — an antigibberellin) to the crop at the rate of 247 millilitres per hectare) at four periods during growth (40–45, 55–60, 70–75 and 85– 90 days after sowing).

Fertiliser requirement

Fertilisers are incorporated into the beds as described above. Cotton requires 23 kilograms per acre phosphate (applied as diammonium phosphate) and 69 kilograms per acre nitrogen (applied as diammonium phosphate and urea).

5.3.4 Salt-tolerant varieties of other crops

Some data are available on the responses of a range of other crops to salinity. However, it needs to be stressed that no consideration was given in these experiments to determining plant response to salinity *under conditions of waterlogging.* The results may therefore be of limited relevance to the field, where salinity and waterlogging often occur together (see Section 4.2).

Barley

Although barley has a reputation as a salt-tolerant cereal (Table 4.1), there is large variation within the species in response to salinity. In irrigated gravel

Table 5.3. Barley cultivars with some promise for salt-affected soils.

Cultivar	Reason for recommendation
Antares	In comparison with six other cultivars, this had the smallest percentage decrease in shoot weight (37%) at EC_w 30 decisiemens per metre after 44 days.[a]
PK-30163 PK-30172 PK-30139	In comparison with nine other cultivars, these had greatest shoot weights and lowest concentrations of sodium in the shoots at EC_w 10 decisiemens per metre after 20 weeks.[b]
PK-30157 PK-30121	In comparison with five other cultivars, these had greatest shoot weights and lowest concentrations of sodium in the shoots at EC_w 10 decisiemens per metre after 20 weeks.[c]

a From study of Qureshi et al. (1981–82). This cultivar was received from the Plant Genetic Resources Institute, National Agriculture Research Centre, Islamabad.

b Niazi et al. (1987)

c Niazi et al. (1992)

culture, a salinity (EC_w) of 20 decisiemens per metre decreased shoot dry weights (measured after 20 weeks) by between 40 and 75% (calculated from Niazi et al. 1987, 1992). Clearly for this species there is scope for selecting for increased salt tolerance.

Comparisons of the salt tolerance of barley cultivars have been made in three experiments in Pakistan in irrigated gravel culture. In two of these, a range of cultivars were grown for 20 weeks at a salinity (EC_w) of 10 decisiemens per metre. Cultivars with the highest growth had the lowest concentrations of sodium in the shoots (Fig. 5.2).

The most promising of the barley cultivars tested in Pakistan are listed in Table 5.3. These cannot be recommended for the field as they have not been screened for tolerance to salinity under waterlogged conditions.

Sugarcane

Sugarcane is moderately sensitive to salinity (Table 4.1). Glasshouse data suggest that there is less scope for selecting cultivars for increased salt tolerance within this species than there is in barley. In a comparison of the salt tolerance of nine different cultivars grown in irrigated gravel culture, a salinity (EC_w) of 10 decisiemens per metre decreased shoot dry weights by between 31 and 39%.[5]

Oilseeds

According to the international literature, rapeseed is moderately tolerant to salinity whereas sunflower is moderately sensitive to salinity (Table 4.1). However the outcomes of pot experiments suggest that sunflower may have greater tolerance to salinity than rapeseed. In two experiments summarised in Figure 5.3, the rapeseed cultivar Gobhi Sassoon had a 50% decrease in growth at a salinity (EC_w) of 12 decisiemens per metre. In contrast, the sunflower cultivar Shamas had a 50% decrease in growth at a salinity (EC_w) of 19 decisiemens per metre.

5.4 Growing Salt-Tolerant Grasses

The crops discussed above are all annual species. In contrast, the forage grasses discussed below are all perennials.

5.4.1 *Chloris gayana* Kunth[6]

Description

Chloris gayana Kunth is from the Poaceae family, and is commonly known as Rhodes grass. It is a perennial, leafy, tuft-forming stoloniferous grass that grows to a height of about 1 metre and is very aggressive once established. It produces long stout stolons, which produce leaves at every node. The seed head is palm-like and is made of 10–20 spikes. It is an excellent seed producer.

5 Calculated from unpublished data (N.A. Nasir and R.H. Qureshi, University of Agriculture Faisalabad). In this experiment, shoot fresh weights were measured after about 12 weeks.

6 These notes were primarily adapted from Quraishi et al. (1993) p. 85; and National Academy of Sciences (1990) p. 80.

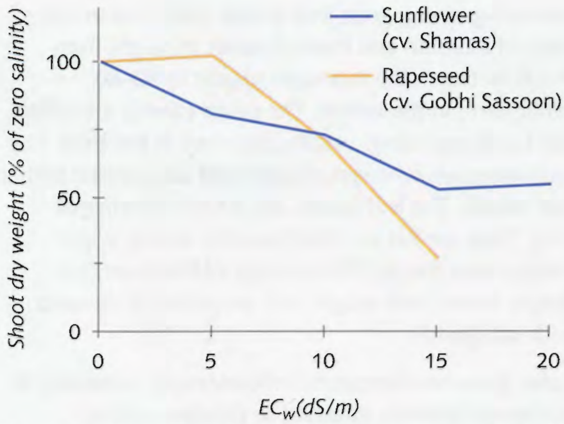


Figure 5.3. *Comparison of the growth response to salinity of rapeseed and sunflower. Results for two separate trials from Qureshi et al. (1982–83). In each case the salinity was increased over an 8-day period, and the plants were harvested after a further 28 days.*

Tolerance to salt and waterlogging

Rhodes grass is moderately tolerant/tolerant to salinity[7] and withstands high alkalinity. In the United Arab Emirates good growth of established Rhodes grass has been reported with irrigation water with a salinity of 15 000 parts per million (National Academy of Sciences 1990).

Other comments on adaptation

Rhodes grass is frequently found in Australia, Pakistan and India. It is widely adapted to tropical, subtropical and temperate areas with annual rainfall of 600–1200 millimetres and altitudes of up to 1500 metres; it is not winter hardy. It grows on heavy to medium textured soils, and on sandy soils if fertilised regularly with nitrogen. It prefers moist soil but continues to grow during drought.

Uses

This grass is an excellent species for grasslands in the tropics and subtropics. It is very palatable, withstands heavy grazing and trampling, makes good hay, and provides good cover for erosion control. As it becomes old its digestibility is reduced. It is extensively used as a hay grass in Oman where it is grown on sandy soils using moderately saline water through sprinklers.

Propagation and management

Rhodes grass is easily propagated through direct seeding. There are more than three million seeds per kilogram. Root stumps can also be used for quick establishment. Seed is sown at a rate of 6 kilograms per hectare in February–April. It is either broadcast or drilled to a depth of 1.25 centimetres. To ensure an even rate of spread when drilling, the seed should be mixed with rice husk or sawdust.

Rhodes grass responds well to nitrogen fertilisation and phosphorus fertilisers where necessary. Rotational grazing and proper fertilisation are necessary for good yields.

Productivity

In Pakistan, dry matter yields of 7.5 tonnes per hectare have been reported (Quraishi et al. 1993). In trials of the performance of a range of summer grasses on saline soils in Saudi Arabia, Rhodes grass yielded 8.9 tonnes of dry matter per hectare in 188 days; this was more than double the yield of any other tested species (Farnworth 1974, cited by Fisher and Skerman 1986).

5.4.2 *Elytrigia elongata* (Host) Nevski[8]

Description

This species has been variously referred to as *Agropyron elongatum*, *Elytrigia pontica*, *E. elongata* and *Thinopyrum elongatum*. It is from the Poaceae family and is commonly known as tall wheatgrass. It is a tufted, tussocky, cool season perennial grass with culms (stems) of up to 1 metre high or more. The leaves are greyish green, rough to touch, up to 30 centimetres long and 4–8 millimetres wide. The seed head is a spike 10–30 centimetres long. The spikelets are side-on to the rachis, which is recessed opposite the spikelet. Mature spikes shatter easily.

Tolerance to salt and waterlogging

Tall wheatgrass occurs in marshy situations, seashores and areas subject to inundation by sea water. It is well adapted to poorly drained and moderately saline and alkaline soils. No decrease in growth is expected at EC_e values up to 6–7.5 decisiemens per metre, while a yield decrease of 50% is expected at EC_e values of 13–19 decisiemens per metre (Moxley et al. 1978; Maas

7 The degree of salt tolerance in Rhodes grass is not completely clear. Maas and Hoffman ranked the species as being moderately tolerant (Table 4.1). However, there are reports that Rhodes grass has a 50% decrease in growth at EC_e values of 23.2 decisiemens per metre and a 100% decrease in growth at EC_e values of about 29 decisiemens per metre (Russell 1976). Under these conditions, the species should fall into the tolerant category (see Fig. 4.3). Salt tolerance in *Chloris gayana* is facilitated by the presence of salt glands in the leaves (Lipschitz et al. 1974).

8 These notes were adapted from Halpern (1976); Register of Australian Herbage Plant Cultivars (1982); National Academy of Sciences (1990) p. 81; Barrett-Lennard and Malcolm (1995) pp. 30–31.

1986). Wide differences in salt tolerance have been reported between different strains of the species (Shannon 1978).[9]

Other comments on adaptation

This species is native to the Balkans, Asia Minor and southern Russia. It is resistant to cold, tolerant to drought, and grows at altitudes of 1500–2000 metres.

Uses

Tall wheatgrass is a maintenance fodder for grazing animals (Warren and Casson 1992)[10] and its quality can be improved if it is cut and animals graze the fresh regrowth. It can be cut for hay before flowering. It is a summer pasture grass that grows between September and July. It is good for soil conservation and the control of erosion (particularly wind erosion). It has been successfully grown on sand dunes in Mastung Valley from seed and transplanted tufts.

Propagation and management

Tall wheatgrass has 150–200 000 seeds per kilogram. It germinates well but is slow to establish. The seed must be planted at a shallow depth (less than 1 centimetre). In semiarid areas, it should be sown in spring on subirrigated soils at a rate of 20 kilograms per hectare, in rows 15 centimetres apart. Alternatively, it can be sown into summer fallow in autumn at a rate of 10 kilograms per hectare, in rows 30 centimetres apart.

Productivity

Forage productivity is highly dependent on levels of nitrogen fertilisation. Once plants develop a crown of stems near ground level, they can withstand moderate grazing. Grazing should be done in rotation, but not in the first year.

5.4.3 *Leptochloa fusca* L. Kunth[11]

Description

Leptochloa fusca L. Kunth, also referred to as *Diplachne fusca*, is from the Poaceae family and is also known as kallar grass. Local names include *kallar ghas*, *kallar mar ghas*, *Australian ghas*. It is a perennial summer-growing grass that is now cultivated in many parts of Pakistan and India. It varies in height from 1–1.5 metres in the monsoon season to 40–80 centimetres in the winter. The culms (stems) are tufted, erect and ascending, usually branched at the base. The internodes are of varying length and are covered with a leaf sheath. The leaf blades are 20–50 centimetres long. They are flat or rolled inwardly on the upper surface near the tip. The surfaces of the leaves are deeply veined and rough, and are profusely covered with salt glands.

Kallar grass has compound inflorescences consisting of numerous spikelets attached to racemes, with a number of racemes joining on a rachis to form a panicle of flowers. There are 15–20 spikelets on shorter (6 centimetre) racemes and 20–25 spikelets on longer racemes. The rachis has finely toothed ridges on its surface.

The spikelets are 6–10 millimetres long and about 1 millimetre broad, and each contain 4–10 florets. The florets are attached to the raceme by a short stalk called the rachilla.

The grains produced by florets are brownish in colour, and about 1.8 millimetres long and 0.75 millimetres broad. The germination of grains is poor.

Tolerance to salt and waterlogging

Maas and Hoffman (1977) ranked kallar grass as tolerant (Table 4.1).[12] It is well adapted to waterlogged conditions and has well developed aerenchyma in the roots.

Other comments on adaptation

The species is native to many salt marshes of the world, but its use as a fodder crop in salt-affected and waterlogged soils is quite new. About 30 years ago the Punjab Department of Agriculture imported this grass from Australia; it is therefore also called Australian grass.

There is a misunderstanding among farmers that kallar grass only grows well in salt-affected land and that it disappears if salinity recedes. In fact kallar grass also grows on good land, but it is not recommended, as other crops give more profit, and on good land, other weeds compete with kallar grass so that it does not flourish.

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9 A survey of 32 different accessions found seven tall wheatgrass lines that survived a salinity of 382 mM NaCl + 191 mM $CaCl_2$, but two lines were unable to survive half this concentration.

10 Warren and Casson report that sheep lost 7% of their body weight over 56 days when grazing old tall wheatgrass pastures containing 10 tonnes per hectare dry matter. This poor performance was attributed to the highly fibrous nature and low digestibility (46%) of the forage.

11 These notes were adapted from Aslam et al. (1979); Sandhu et al. (1981); Qureshi et al. (1982); Booth (1983); Malik et al. (1986); and Sandhu and Qureshi (1986).

12 There was a 50% reduction in growth of kallar grass at EC_e values of 22.3 decisiemens per metre (Sandhu et al. 1981) and SAR values of 150 (Hussain and Hussain 1970).

Photo 5.2. *Kallar grass being cut for sale on a saline–sodic site in Lahore. [PHOTOGRAPH: E. BARRETT-LENNARD]*

Photo 5.3. *Buffalo grazing kallar grass on an irrigated saline soil near Jhang. [PHOTOGRAPH: E. BARRETT-LENNARD]*

Uses

Summer grown kallar grass is suitable for feeding cattle, buffalos, sheep and goats. It can be cut and sold (Photo 5.2), fed to stalled animals, or animals can directly graze on the grass in the field (Photo 5.3). It contains almost all the elements and sufficient salt for animal requirements.

Kallar grass is very effective as a biological reclamation agent on saline and saline–sodic soils with structural problems.[13] It can be profitably cultivated in areas where the underground water is of poor quality or is near the surface.

New uses are still being developed for kallar grass straw. The University of Agriculture Faisalabad has tested its use as a substrate for the growth of mushrooms, and the Nuclear Institute for Agriculture and Biology has investigated the use of kallar grass in the production of methane (bio-gas) and ethanol (Malik et al. 1986).

Propagation and management

Kallar grass can be sown from February up to October, but the best time is during the monsoon season when there is a lot of rainwater available. It establishes best under humid conditions.

Kallar grass can be grown from seed, root stumps or stem cuttings. However, the preferred method for establishment on sodic soils is to evenly spread 15 to 30-centimetre long stem cuttings of a 3–4 month old crop over a well prepared soil and irrigate it immediately. The crop from 1/16 of a hectare is sufficient to establish kallar grass on 1 hectare. The grass is widely found throughout Pakistan; farmers will therefore have little trouble in finding local sources of material for the establishment of new stands.

Kallar grass needs more water than most other crops. If the soil is slightly saline then the fields should have continuously standing water (as for a rice crop). However, if the soil is highly saline–sodic, then irrigation should be given at intervals so the soil has some chance to dry.[14]

The fertiliser requirements of kallar grass are lower than for other crops, partly because kallar grass is able to fix nitrogen in the root-zone.[15] Nevertheless, for good biomass production we recommend the application of 60 kilograms per hectare of urea after each cutting, and 150–200 kilograms of single superphosphate annually.

Productivity

Kallar grass can be grown successfully on waterlogged and salt-affected land where profitable cultivation of other crops is impossible; 35–50 tonnes per hectare of green fodder can be harvested annually. It also has

13 This use is widely recommended by the Department of Agriculture and the Directorate of Land Reclamation. For references on this see Section 2.2.

14 This recommendation is based on the experiments of Qureshi and Abdullah (reviewed by Qureshi et al. 1982) who studied the effects of continuous flooding or normal irrigation on the growth of kallar grass. Under conditions of low salinity (4–10 decisiemens per metre, flooded plants had 32–48% higher yields (fresh weight basis) than plants grown with normal irrigation. However, at high salinity (40 decisiemens per metre), flooded plants had 30% lower yields (fresh weight basis) than plants grown with normal irrigation.

15 Kallar grass appears to be able to fix 90–120 kilograms of nitrogen per hectare per year through the action of rhizosphere bacteria. The evidence for this is discussed more fully by Malik et al. (1986).

Table 5.4. Grass species cultivated experimentally in saline conditions.

Local/common name (Botanical name)	Occurrence	Salinity tolerance
Khabbal ghas/Bermuda grass (*Cynodon dactylon*)	Weed	Moderate[a]. Common in salt-affected soils of Pakistan and an early volunteer during the reclamation process[b]
Maddal (*Elusine coracana*)	Weed in rice fields	Tolerates high salinity and waterlogging[c]
Japani millet/ Dhidan (*Echinochloa crus-galli*)	Weed in rice fields	Tolerates high salinity and waterlogging[d]
Puccinellia (*Puccinellia ciliata*).	Cultivated pastures on saltland in Australia	Tolerant of salt and winter waterlogging Grows in winter, but dormant in summer[e]
Distichlis (coastal salt grass) (*Distichlis spicata*)	Grown on 20 000-ha salt flats near Mexico City	Highly salt and drought-tolerant[f]

a Fisher and Skerman (1986)

b The Saline Agricultural Research Cell of the University of Agriculture Faisalabad has, through the courtesy of Mr Takumi Izuno of USAID (Mart Project), acquired an ecotype which is reputed to be more productive, salt tolerant and of better fodder value than the ecotyve commonly found in Pakistan

c Rizwan (1988) reported that maddal had a 50% reduction in yield in solution culture at an EC_w of 13.5 decisiemens per metre. It also had higher biomass yields than janter (*Sesbania sesban*), dhancha (*Sesbania aculeata*) and sordan (intragenus cross of sorghum and sudangrass) at moderate to high salinities

d Has a 50% reduction in yield at EC_w values of 15.9 decisiemens per metre (Aslam et al. 1987)

e It is used for establishing saltland pastures in southern Australia, where it has yielded more than 7 tonnes per hectare per annum with appropriate nitrogen fertilisation (Barrett-Lennard and Malcolm 1995, pp. 29, 70)

f N.P. Yensen (NyPa Inc., Tucson, Arizona) has patented superior varieties for the production of grain, turf and fodder

value in decreasing the severity of soil salinity and sodicity. On one private farm near Jhang, the grazing of buffalos on kallar grass on an area of 40 hectares of dense saline–sodic soil was valued at 2000 Pakistan rupees (PKR) per hectare per year in 1976 (Sandhu and Qureshi 1986).

5.4.4 Other grasses with potential for saline agriculture in Pakistan

A number of grass species have been cultivated on an experimental scale in highly saline fields. No detailed information is yet available on their growth, productivity or management. However, these species may have potential for the utilisation of salt-affected land in Pakistan. The names of these species are shown in Table 5.4.