chapter 6

Trees for Salt-Affected Land

Overview

In this chapter, profiles of 18 different tree and shrub species with potential for growth on salt-affected land are presented.

Raising and planting trees

Farmers must be careful in specifying the tree *species* and *provenance* they wish to plant. A range of tree species and provenances may all have the same name in the local language.

Trees are generally raised in nurseries and transplanted into the field. Seedlings can either be raised in *polythene bag nurseries,* or in *field nurseries* as bare-rooted seedlings.

Field sites for planting out the trees and shrubs should be levelled, worked to break up hardpan or dense soils and appropriately treated with fertilisers and gypsum. The seedlings should be planted according to a predetermined plan with mounds, irrigation trenches, etc. appropriate for the soil type. Finally, grazing must be controlled.

Salt-tolerant trees for fuel and forage production

Plant characteristics, salt and waterlogging tolerance, adaptation, uses, propagation and management, and productivity are important factors for saline agriculture. Profiles of these features are presented for the following salt-tolerant species: salt wattle (*Acacia ampliceps*), kikar (*Acacia nilotica*), siris (*Albizzia lebbek*), jangli saru (*Casuarina equisetifolia*), suphaida (*Eucalyptus camaldulensis*), iple iple (*Leucaena leucocephala*), vilaiti kikar (*Parkinsonia aculeata*), jand (*Prosopis cineraria*), jangli kikar (*Prosopis juliflora*), dhancha (*Sesbania bispinosa*), jantar (*Sesbania sesban*) and frash (*Tamarix aphylla*).

Salt-tolerant fruit trees

Profiles are also presented for the following salt-tolerant fruit tree species: phalsa (*Grewia asiatica*), chiku (*Manilkara zapota*), khajoor (*Phoenix dactylifera*), amrood (*Psidium guajava*), jamon (*Syzygium cuminii*) and ber (*Ziziphus mauritiana*).

6.1 Raising and Planting Trees

6.1.1 Sources of seed

Farmers wishing to obtain seed of salt-tolerant plants must be careful to specify the exact species they need. They may identify the required plant by a local name, but end up receiving a plant of unexpected form or performance. The reason for this is that different tree species can have the same name in the local language. This is illustrated in Table 6.1

Table 6.1. Examples of local names and the species they apply to.[a]

Local name	Species to which local name applied
Saphaida	*Eucalyptus camaldulensis*
	E. rudis
	E. microtheca
	E. tereticornis
Kikar	*Acacia nilotica*
	A. tortilis
Jangli kikar	*Prosopis juliflora*
	P. chilensis
	P. alba

a These examples have been selected from Ahmad (1996)—there must be many others

Even within a single species like *Eucalyptus camaldulensis*, there can be great variation depending on the provenance of the seed. For example, the provenance Lake Albacutya produces tall relatively unbranched trees of high value. On the other hand, the provenance Wiluna produces short highly branched trees of little commercial value (Photo 6.1).

There can also be profound differences in salt tolerance between provenances of the same species. For example, with *Acacia ampliceps*, the salinity (EC_w) at which plants stop growing varies from 65 decisiemens per metre (Lake Dora and Wave Hill provenances) to 128 decisiemens per metre (Halls Creek provenance) (Aswathappa et al. 1987).

Photo 6.1. *The importance of seed provenance in trees. Both photographs show* Eucalyptus camaldulensis *at the same age. (A) Provenance Lake Agnes. (B) Provenance Wiluna. [PHOTOGRAPHS: R. MAZANEC]*

6.1.2 Nursery techniques

Trees and shrubs can be established in the field by planting seed, planting cuttings,[1] transplanting nursery-raised seedlings in polythene bags, and transplanting nursery-raised bare-rooted seedlings. The optimal method of propagation depends on the soil salinity of the field and the species to be planted.

For salt-affected soils, the chances of establishment are best using nursery-raised seedlings in polythene bags. Polythene bags are also required for the establishment of small seeded trees and shrubs like *Eucalyptus camaldulensis*.

Alternatively, the trees are established in the nursery in raised beds, removed from these, and transplanted into the field as bare-rooted seedlings. Species for which this is possible include: kikar (*Acacia nilotica*), jand (*Prosopis cineraria*), jamon (*Syzygium cuminii*), ber (*Zizyphus mauritiana*), amrood (*Psidium guajava*) and phalsa (*Grewia asiatica*).

1 Species for which this is possible include: sheesham (*Dalbergia sissoo*) and poplar (*Populus deltoides*).

Photo 6.2. *Polythene bag nursery being irrigated. [PHOTOGRAPH: E. BARRETT-LENNARD]*

The polythene bag nursery

- *Location* — nurseries should be easily accessible, free of frost and sheltered from wind. They should have a good supply of irrigation water (Photo 6.2). The soil in the area should be level, non-saline, well drained, and loamy in texture.
- *Layout* — the typical layout of a polythene bag nursery is shown in Figure 6.1. The nursery is bounded by an inspection path (1.5 metres wide) on one side and an irrigation channel (0.75–1 metre wide) on the other. The 4 to 5-metre wide area between these is subdivided into shallow excavated beds about 1–1.5 metres wide and 20 centimetres deep, each bounded by small paths (45 centimetres wide). The filled polythene bags are stood upright in the beds. Each bed can be separately irrigated from the nearby irrigation channel.
- *Preparation of soil mixture* — silt from canals or watercourses is completely mixed in equal amounts with good-quality loamy soil. Well-rotted organic matter (one-third by volume) is added to this mixture to improve soil moisture retention.
- *Preparation of polythene bags* — the bags generally used are 10 centimetres wide and 22 centimetres high. These are sold on a weight basis (about 400 plastic bags per kilogram if they are made of 0.002-millimetre thick polythene). Excess water is drained from the bags through 3-millimetre diameter holes made with a cork borer or a hollow punch. Each bag should have 12–16 holes. After filling with soil mixture, the bags are placed upright in the nursery beds.

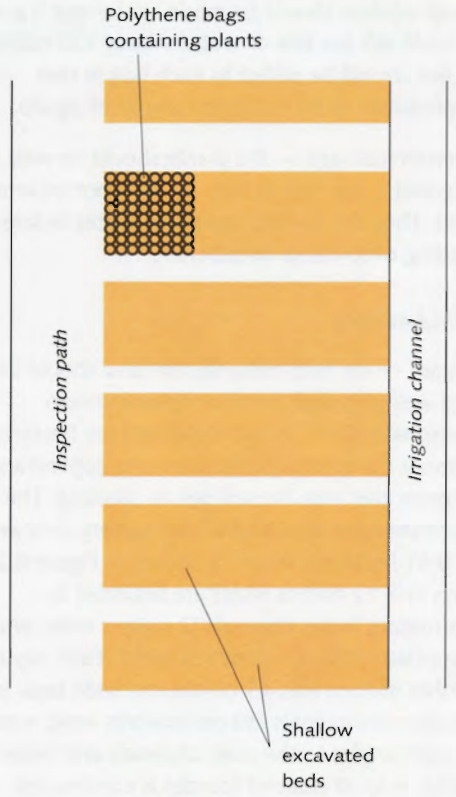

Figure 6.1. *Typical layout of a polythene bag nursery.*

- *Seed sowing and thinning* — seeds are sown onto the surface of the soil in the bags in September to October, or February to March, when temperatures are 20–30°C. Fine seeds are covered with a thin layer of dust. The bags are irrigated by seepage through the nursery beds or by light sprinkling. The bags can be covered with rice straw mulch to decrease evaporation. Once germination has occurred, seedlings are thinned so that there is no more than one seedling per bag.
- *Weeding, moving and culling* — bags should be kept free of weeds and moved regularly (at least once per week when the seedlings are growing quickly) to prevent the seedlings rooting into the nursery beds. The establishing plants are sorted into different beds according to size; weak plants should be culled.
- *Hardening* — if seedlings are to be transplanted into salt-affected soils, it is advisable to harden the plants by applying some salt to each bag. We suggest that

a salt solution should be made containing 5 grams of table salt per litre of water. About 100 millilitres of this should be added to each bag in two applications of 50 millilitres (one week apart).

- *Transfer/carriage* — the plants should be well irrigated 1 day before they are transported into the field. They are stacked upright in crates before loading onto trucks or trailers.

The field nursery

- *Layout* — for field nurseries the land should be level and well prepared. Fertiliser (diammonium phosphate [DAP] at 125 kilograms per hectare) and manure (50 tonnes per hectare) are applied and incorporated into the soil before planting. The recommended layout of a field nursery over an area of 0.41 hectares (1 acre) is shown in Figure 6.2. Bays (10–12 metres wide) are bounded by alternating water channels (2 metres wide) and inspection paths (1–2 metres wide). Each bay is further divided into 45-centimetre wide beds by smaller subchannels (30 centimetres wide) running at right angles to the main channels and inspection paths. A small channel (pustle) is constructed alongside and parallel to the bigger channel to irrigate the subchannels.
- *Planting* — seeds or cuttings are planted in two to three rows per bed. Irrigation is applied as and when required through the subchannels. This provides seepage to the seeds or cuttings planted on the beds. Over-irrigation and under-irrigation should be avoided.
- *Weeding/culling* — the nursery should be kept free of weeds and weak plants should be culled out regularly.
- *Removal of plants from the beds* — the soil is watered so that it is soft and one edge of the bed is cut open with the blade of a spade. The spade is then used to loosen the soil around the cut face so that the plants can be withdrawn without breaking any of their major roots.
- *Production* — field nurseries are able to produce large numbers of seedlings. For example, we estimate that a nursery planted on 0.41 hectares (one acre) of land would have more than 10 kilometres of row length, and could produce more than 200 000 seedlings per year.

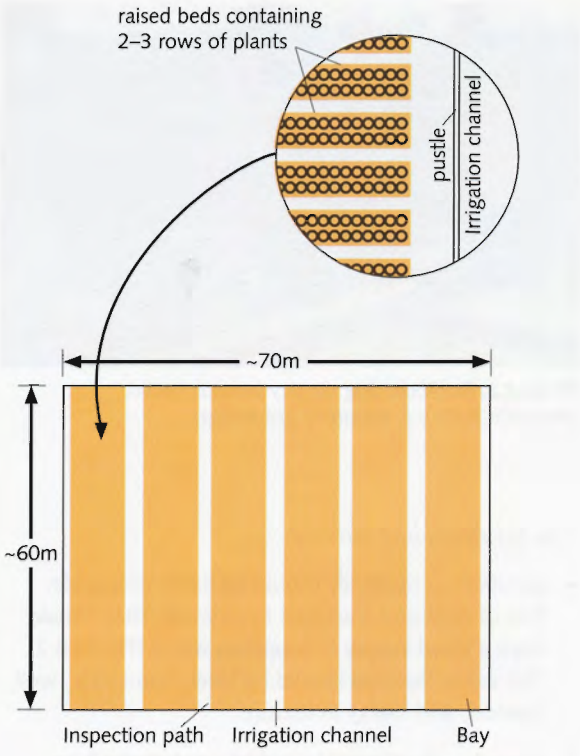

Figure 6.2. *Typical layout of a field nursery.*

6.1.3 Land preparation and planting

The steps involved in preparing land for the planting of trees and shrubs are summarised below.

- *Level the land* — poor land levelling is one of the major obstacles to the effective management and irrigation of salt-affected soils. Efforts should be made to precisely level the land by cultivating and planking or, if possible, by laser levelling.
- *Plan the furrow lines and the location of each tree.*
- *Plan the fertiliser strategy.*
- *Overcome problems of dense soils/hardpans* — salt-affected soils frequently have profiles with a zone of high density or a hardpan. This can be a major hindrance to the downward leaching of salts, the development of roots and the growth of plants (Photo 6.3). Such problems can be overcome by deep ploughing, ripping or chiselling, or using a

Photo 6.3. *Effects of tillage in overcoming dense soils. The larger trees on the left were planted into rotavated soil; those on the right had only conventional cultivation. [PHOTOGRAPH: E. BARRETT-LENNARD]*

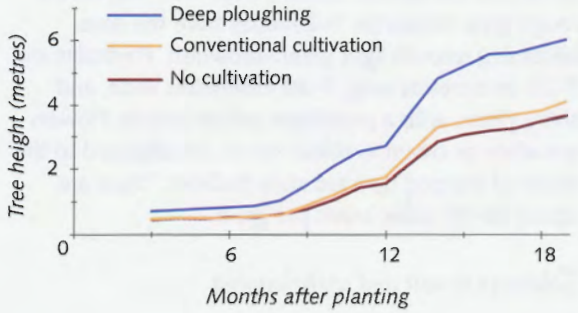

Figure 6.3. *Advantages of deep ploughing. The advantages of deep ploughing were particularly apparent on the growth of trees at a site near Aman Kot in the Peshawar Valley (unpublished data Prof. Abdur Rashid and Mr Pervez Khan). After 19 months growth, trees established with deep ploughing were nearly 2 metres higher than trees established with conventional cultivation or no cultivation.*

posthole digger to dig a hole about 15 centimetres in diameter and 1.5 metres deep for each tree. Figure 6.3 shows the advantage of deep ploughing over conventional or no cultivation.

- *Apply gypsum and farmyard manure* — one of two methods can be used to apply soil amendments.

  (i) Incorporate gypsum and well-rotted farmyard manure into the soil beneath the irrigation furrows. This can be done by laying down gypsum (0.75 kilograms per metre) and farmyard manure (2–3 kilograms per metre) in rows at 3-metre intervals across the field. The irrigation furrows (30 centimetres wide) are then ripped along these lines with a chisel plough. The ripping excavates the furrow to a depth of about 30 centimetres and incorporates the amendments into the soil on the bottom and sides of the furrow.

  (ii) Mix gypsum (0.75–1 kilogram per hole) and well-rotted farmyard manure (2–3 kilograms per hole) into the soil from each post hole[2]. The pits (holes) may be subsequently connected by 30-centimetre-deep channels for irrigation.

- *Plant the trees or shrubs* — the location of the planted seedling with respect to the irrigation trench depends on the degree of internal drainage in the soil (Photo 6.4):

  – soils with good drainage (high water intake rates) — the seedling should be planted in the bottom of 30-centimetre-deep irrigation trenches;

  – soils with poor drainage — the seedlings should be planted on the shoulder of the trench so they are not affected by waterlogging after irrigation; and

  – waterlogged soils — the trees should be planted on bunds or mounds to avoid waterlogging.

- *Control the grazing* — controlling grazing is essential if planted tree seedlings are to survive and grow. It is often forgotten that quite successful revegetation is possible simply by controlling grazing (Photo 6.5).

The density of tree planting depends not only on the tree species but also on whether the trees are to be planted in blocks, mixed with shrub species, or used in alley farming. In the Satiana area, we recommended that *Eucalyptus camaldulensis* should be planted in rows 3 metres apart, with the trees within rows at 2 metres apart (a planting density of about 1700 trees per hectare). After 1–2 years, saltbushes (*Atriplex lentiformis* or *A. amnicola*) can be planted between the trees.

In alley farming, belts of trees are planted across the landscape, leaving bays of unplanted land for the growth of crops. For example, Mr Adbul Rauf, a farmer from Jaranwala (near Faisalabad), is planting belts of

2 Note that if the roots of a transplanted seedling come into direct contact with gypsum or fertilisers, the plants may be severely burnt. Therefore, the gypsum and farmyard manure must be well mixed into the subsoil in the hole.

Photo 6.4. *The location of the planted seedling depends on the degree of internal drainage in the soil. (A) In soils with good drainage, plant the trees in the irrigation trench. (B) In soils with poor drainage, plant the trees on the shoulder of the irrigation trench. [PHOTOGRAPHS: E. BARRETT-LENNARD]*

Photo 6.5. *Tree seedlings volunteering following the control of grazing on a saline site near Faisalabad. [PHOTOGRAPH: E. BARRETT-LENNARD]*

E. camaldulensis 12 metres apart in a well-drained salt-affected soil. In the bays between the tree belts, he is planting wheat and other crops. The integration of trees and agriculture is discussed more fully in Chapter 8.

6.2 Salt-Tolerant Trees for Fuel and Forage Production[3]

6.2.1 *Acacia ampliceps* Maslin[4]

Description

Acacia ampliceps Maslin is from the Fabaceae family, and is known as salt wattle, jila jila bush and nyalka.

This plant is a fast-growing dense shrub or a small tree (2–8 metres tall) with a spreading crown (6–12 metres wide) and one to four stems (Photo 6.6). The bark is rough grey–brown for 1–2 metres from the base, becoming smooth light green–brownish. Phyllodes are 7–25 centimetres long, 7–30 millimetres wide, and shiny green, with a prominent yellow midrib. Flowers are white or cream in colour. Seeds are attached to the inside of the pod by a red stalk (funicle). There are about 30–40 viable seeds per gram.

Tolerance to salt and waterlogging

A. ampliceps is tolerant of highly saline, sodic and alkaline soils, but intolerant of acid soils and waterlogging. Researchers from Australia have noted reduced growth at EC_e values of 10–15 decisiemens per metre and reduced survival above 20 decisiemens per metre (Marcar et al. 1995, p. 29). Some provenances have been reported to survive in nutrient solutions at concentrations in excess of 65 decisiemens per metre (Aswathappa et al. 1987). In Pakistan, 2-year-old plants had 25 and 50% reductions in dry weight at 17 and 20 decisiemens per metre (calculated from the data of Ansari et al. 1994, Table 4). In an adaptation trial on a saline site in Sind (EC_e values of 5–40 decisiemens per metre), there was 77–98% survival after 2 years, but 3 months of flooding eliminated survivors in three provenances and caused substantial mortality in a fourth (Ansari et al. 1994, Tables 2 and 3).

3 Unless otherwise indicated, the species names, synonyms and authorities used in this chapter are as indicated in Terrell et al. (1986) and National Academy of Sciences (1986).

4 This species profile has been adapted from Marcar et al. (1995) p. 29 and the REX'96 database.

Other comments on adaptation

- *Pakistan* — there is little familiarity with this species in Pakistan. It has been recently introduced into the country as part of the activities of ACIAR Project 8633. Promising results have been obtained under saline conditions in Sind.
- *Australia* — in Australia it occurs in sandy plains and floodplains, and along drainage lines or low-lying plains among rough hill country or low hilly tracts. It grows best in alkaline soils that are freely drained with access to good water. It cannot tolerate acid soils or frost. It can tolerate long periods of drought.

Uses

- *General* — this plant is excellent for windbreaks and soil conservation and can be used for reclamation of salt-affected land and dune stabilisation. It also has value as an ornamental plant.
- *Fodder* — it has potential as fodder for goats, sheep and cattle. Goats prefer it after the leaves have wilted for some time after cutting.
- *Wood* — the wood is a good fuel and burns well. It is hard and tough, and can be used as posts and small poles.

Propagation and management

Propagation is similar to *A. nilotica*. Rows should be 2–3 metres apart, with plants 2–3 metres apart within rows. In Pakistan, it can establish by direct seeding on saline soils. Once established it can spread by root suckering; stands can therefore become quite dense.

Productivity and economic value

No information is available on the long-term economic value of *A. ampliceps*. However, we can make some assessments based on production data after 2 years in Sind. In a highly saline field (average EC_e 15 decisiemens per metre), 2-year-old plants at a density of 2500 plants per hectare had an average weight of about 23 kilograms per tree (calculated from the data of Ansari et al. 1994, Table 4). If this wood had a value of 0.5 Pakistan rupees (PKR) per kilogram, then a stand of this density would be worth about 28 000 PKR per hectare.[5]

5 For currency exchange rates see page 4.

Photo 6.6. Acacia ampliceps. *(A) Young tree. (B) Mature tree. (C) Detail of leaves. [PHOTOGRAPHS: E. BARRETT-LENNARD AND S. NAWAZ]*

6.2.2 *Acacia nilotica* (L.) Willd. ex Del.[6]

Description

Acacia nilotica (L.) Willd. ex Del., also known as *A. arabica* and *Mimosa arabica*, is from the Fabaceae family. Its English name is gum arabica, and it is known locally as *kikar* or *babul*.

This is a moderately tall tree, reaching a height of 10–20 metres with a trunk diameter of up to 1 metre (Photo 6.7). It is evergreen and has thorns, especially when young. Its pods are 7–15 centimetres long. The leaves are compound and 2.5–7.5 centimetres long. Flowers are yellow to bright yellow, growing in

6 These notes were adapted from Quraishi et al. (1993) pp. 95–96; Sheikh (1993) p. 21; Baquar (1995) pp. 205–206; National Academy of Sciences (1986) p. 72.

Photo 6.7. Acacia nilotica.
[PHOTOGRAPH: S. NAWAZ]

bunches, and they mature year round depending upon subspecies and geographic location. In Pakistan, flowering is generally from June to September or October. Pods ripen from April to June. The young pods contain 15–20% protein and are relished by goats and other animals. The bark is dark brown with regular deep longitudinal fissures. The crown form varies from conical to spreading.

Tolerance to salt and waterlogging

A. nilotica can tolerate moderately saline and sodic conditions as well as soils with a cemented pan. It has a 40% reduction in growth (dry weight) at an EC_e of about 8 decisiemens per metre (Singh et al. 1991). It is relatively tolerant to waterlogging. In a trial in Sind, 80% of 2-year-old established plants survived a 3-month period of flooding (Ansari et al. 1994, Tables 2 and 3). In longer-term field experiments near Faisalabad it produced more wood per plant than *Prosopis cineraria* on a saline soil, and on a dense saline soil its production was more highly ranked than *Leucaena leucocephala, Terminalia arjuna* or *Dalbergia sisoo* (Qureshi et al. 1993).[7]

7 For the saline soil, the average EC_e in the upper 90 centimetres of the profile was 14–15 decisiemens per metre. For the dense saline soil, the average EC_e in the upper 90 centimetres of the profile was 11–21 decisiemens per metre.

Other comments on adaptation

A. nilotica is tolerant to drought and prefers semiarid subtropical and tropical climates. It is native to Pakistan and occurs in wild and cultivated stands in all four provinces at altitudes of up to 600 metres. It is well adapted to a variety of soil conditions but prefers well-drained soils. Rainfall between 125 and 1300 millimetres per year is helpful. It tolerates light frost.

Uses

- *A. nilotica* is highly valued for its fuel, timber, and as a source of bark, gum and fodder. The tree also fixes nitrogen in the soil.
- *Fuel* — the calorific value of sapwood ranges from 20 112 to 20 740 kilojoules per kilogram; it is the most preferred firewood in Pakistan. The wood can also be converted into charcoal.
- *Timber* — the wood is hard, durable and resistant to termites. It is used in making cheap furniture, implements, carts and railway sleepers, and in boat building (as it is impervious to water).
- *Bark* — the bark contains approximately 27% tannin, which is highly valued by tanners. In Sind the tree is also used to produce lac. Bark is also used for medicinal purposes such as control of diarrhea.
- *Fodder* — branches can be lopped occasionally for feeding to goats, sheep and buffalos.
- *Gum* — gum produced by *A. nilotica* is put to many uses such as in the manufacture of matches, inks, paints and confectionery.

Propagation and management

A. nilotica is aggressive and is easily established. It can be easily reproduced from seed. Indeed, the use of seed is cheaper and generally as successful as the use of nursery-raised seedlings. However, obtaining good germination may require the seed to be soaked in boiling water to break the 'hard-seededness' (see Box 6.1).

The land should be prepared according to the general methods described in Section 6.1.3. Rows of seedlings are planted in furrows 30 centimetres deep and 10 metres apart. The plant-to-plant distance within rows is 8–10 metres for a 20-year rotation, or 3–5 metres for a 7–10-year rotation. About three to

five seeds are planted at each point. The best seeding season is August to September but transplanting seedlings can be delayed up to October or November. In soils with good drainage, the plants should be located at the bottom of the furrow, whereas for soils with restricted drainage, the plants should be located along the ridges on the side of the furrow. Irrigation should be applied immediately after planting. Later irrigation during the hot summer will help in achieving faster growth. The side branches of the trees should be pruned to encourage upward growth. Young plants must be protected from grazing animals.

Productivity and economic value

In general, wood production varies between 4 and 15 cubic metres per hectare per year in a 20-year rotation (not including biomass removed due to lopping).[8] There is a report of a fuelwood yield of 13 tonnes per hectare from cuttings of side branches during a 40-month growth period (Singh et al. 1993).

Forage (leaves) yields of 5.3 tonnes of dry matter per hectare per year have been obtained. Annual forage yields of more than 4 tonnes per hectare have been reported from riverine forests in Sind (Sheikh 1993; Baquar 1995; National Academy of Sciences 1986).

Dry pods contain 11.5–15.7% crude protein and 8.4–21.4% crude fibre. A single tree yields about 18 kilograms of pods per year (Quraishi et al. 1993, p. 96). Well-stocked plantations therefore yield about 8–10 tonnes of pods per hectare per year.

There are no comprehensive figures available on the economic value of kikar. One study on a saline–sodic soil near Faisalabad reported wood yields of 150 kilograms per tree after seven and a half years of growth. The gross value of this production was estimated to be about 24 710 PKR per hectare per year (Qureshi et al. 1993, Tables 3, 4 and 7).[9]

Box 6.1 Scarification of seeds with hard seedcoats[a]

Some trees (like *Acacia* and *Leucaena* species) have seeds with very hard seedcoats. These need to be softened or broken before the seed will germinate. Treatment varies with the species; here are five options. Once the seeds have been treated they may be used immediately or dried for storage.

Cool water scarification

Put the seed into a muslin bag and soak in water for specified time.

Hot water scarification

Put the seed into a muslin bag and soak in water at 80°C for specified time.

Boiling water scarification

Pour boiling water over the seed in a pot. Stir for 1 minute, allow to cool and pour off the water.

Chemical scarification[b]

Concentrated sulfuric acid weakens seedcoats to permit the entry of water. It must be used with great care to avoid burns to the skin, and violent reactions when it is added to water. Soak the seed in concentrated sulfuric acid for the specified time. Carefully pour off the acid. Wash the seeds thoroughly in running water.

Mechanical scarification

Rub the seed with sandpaper until the seedcoat is punctured. Alternatively the seed coat can be 'nicked' with a razor, knife or scissors. Care should be taken to remove only enough of the seedcoat to allow the seed to absorb water.

a Adapted from Beldt and Brewbaker (1985)
b When diluting sulfuric acid with water, *always* carefully add the acid to the water, *not* vice versa.

6.2.3 *Albizzia lebbek* (L.) Benth.[10]

Description

Albizzia lebbek (L.) Benth., also known as *Mimosa lebbek* and *M. sirissa*, is from the Fabaceae family. Its English name is lebbek, and it is known locally as *shirin* (Punjabi) or *siris* (Urdu).

A. lebbek is a fast-growing, large (12–30 metres tall), deciduous, ornamental tree (Photo 6.8). The crown is open, flat and umbrella-like. The foliage is feathery

8 Although higher yields of 20–30 cubic metres per hectare per year have been reported in National Academy of Sciences (1986).

9 Specific details of this investigation were as follows:

Soil conditions. The soil was a sandy clay loam, with EC_e and sodium adsorption ratio (SAR) values (averaged over the upper 90 cm of the profile) of 14 decisiemens per metre and 32 respectively.

Planting density. The trees were planted at 2500 stems per hectare. There was 64% survival after 1 month.

Financial calculation. The calculation assumed the wood to have a value of 0.50 PKR per kilogram. A stocking rate of 1000 trees per acre (2470 plants per hectare) was assumed.

10 These notes were adapted from Quraishi et al. (1993) p.96; Sheikh (1993) p. 32; Baquar (1995) p. 218; National Academy of Sciences (1986) p.72; Qureshi et al. (1993) p.268.

Photo 6.8. Albizzia lebbek. *(A) Whole tree. (B) Detail of leaves and fruits. [PHOTOGRAPHS: S. NAWAZ]*

with compound leaves. The bark is dark grey, rough and cracked. Flowers appear in April to May, and pods mature in June to September. The timber is dark brown with lighter or darker streaks.

Tolerance to salt and waterlogging

A. lebbek tolerates moderate salinity, sodicity and high pH (8.7–9.4).

Other comments on adaptation

Native to the sub-Himalayan area, *A. lebbek* is planted throughout the plains of Sind and Punjab. It tolerates light frost and will grow at altitudes up to 1200 metres. It prefers subtropical to tropical climates, with a temperature range of 4–40°C, and rainfall of 500–2000 millimetres per year. Seedlings are susceptible to frost damage. The species is tolerant to drought but prefers moist conditions. *A. lebbek* grows in a variety of soils, but prefers well-drained loamy soils. Growth is restricted in stiff clays and dry gravelly sites.

Uses

- *Wood* — the wood is dense and useful as a timber and fuel. As fuel, the wood has high calorific value (21 788 kilojoules per kilogram). As timber, it is used as poles and for making agricultural implements.
- *Forage* — it can be lopped for fodder. Tender leaves contain 20% protein; pods formed in August are also fed to livestock.
- *Honey* — this tree is popular with beekeepers for honey production.
- *Erosion control* — the tree is best for water-eroded areas and roadside plantations. It is a good soil binder and can be used for land stabilisation. It fixes nitrogen in the soil.
- *Amenity value* — it is a good shade tree and is used as an ornamental in avenues.

Propagation and management

This species can be easily propagated through direct seeding. Pretreating the seed by soaking it overnight in water increases germination (see Box 6.1). It can also be propagated by stem cuttings. Seedlings are planted at distances of 2–3 metres × 3 metres. Seedlings need protection against frost and grazing by animals.

A. lebbek coppices well. However, the trees are attacked by fungi and bark beetles.

Productivity and economic value

Yields of *A. lebbek* have been estimated at about 5 cubic metres per hectare per year in India.[11] In one study on a saline–sodic soil near Faisalabad, wood yields of 99 kilograms per tree were reported after

11 Although higher yields of 10–15 cubic metres per hectare per year have been reported in National Academy of Sciences (1986).

Photo 6.9 Casuarina equisetifolia. *(A) Whole trees (dioecious: male and female). (B) Details of leaves, flowers and fruit (monoecious). [PHOTOGRAPHS: KHONZAK PINYOPUSARERCK]*

seven and a half years of growth. The gross value of this production was estimated to be about 16 309 PKR per hectare per year (Qureshi et al. 1993, Tables 3, 4 and 7).[12]

12 Specific details of this investigation were as follows:

Soil conditions. EC_e and SAR values averaged over the upper 90 cm of the soil were 14 decisiemens per metre and 38 respectively.

Planting density. The trees were planted at 2500 stems per hectare. There was 98% survival after 1 month.

Financial calculation. The calculation assumed the wood to have a value of 0.50 PKR per kilogram. A stocking rate of 1000 trees per acre (2470 plants per hectare) was assumed.

6.2.4 *Casuarina equisetifolia* Forst.[13]

Description

Casuarina equisetifolia Forst., also known as *Casuarina litorea* L., is from the Casuarinaceae family. Its English names are casuarina, coastal sheoak, horsetail sheoak, Australian pine, whistling pine and beef wood. Locally, it is known as *jangli saru* (Urdu).

C. equisetifolia is a large erect evergreen tree with a 'conifer-like' appearance. Two varieties are recognised: *equisetifolia* grows to 10–40 metres, whereas variety *incana* grows only to 6–10 metres. Average trunk diameter is 1 metre. Flowers open in March and cones mature in June to July. It is monoecious or dioecious. It usually grows on sea coasts. Individual plants have strong phenotypic variation in the crown shape, branch angle, length of branchlets and size and shape of cones. It hybridises easily with other casuarinas like *C. glauca*. The leaves are reduced to white or brown scales fused laterally at the base in whorls that define nodes on the branchlets. It fixes nitrogen through symbiosis with the filamentous bacterium *Frankia*. It is not prone to any serious pest or disease.

Tolerance to salt and waterlogging

C. equisetifolia grows in calcareous and slightly alkaline soils, where it withstands salinity but not waterlogging. In nutrient solution culture, *C. equisetifolia* is reported to have a 25% reduction in growth with an electrical conductivity of 12 decisiemens per metre (Miyamoto 1996, Table 3), and survive salinities of 56 decisiemens per metre under drained but not waterlogged conditions (Moezel et al. 1989).[14] In Pakistan, irrigation with water of electrical conductivity of 9–10 decisiemens per metre caused 16–18% decreases in height and stem diameter. In an adaptation trial on a saline site in Sind (EC_e values of 5–40 decisiemens per metre), there was 60% survival after 2 years, but 3 months of flooding eliminated all survivors (Ansari et al. 1994, Tables 2 and 3).

Other comments on adaptation

C. equisetifolia is adapted to the warm subhumid zone with a precipitation of 700–2000 millimetres per year. Variety *equisetifolia* is a heat-loving lowland tree which grows at altitudes up to 600 metres. It can tolerate drought for 6–8 months. It grows in a variety of soils,

13 Species authority as noted by Doran and Hall (1983). These notes were adapted from Sheikh (1993) p. 48; Dommergues (1990); Baquar (1995) p. 253; Singh et al. (1993) p.555; Doran and Hall (1983); Kondas (1983).

14 Other species which are more tolerant to salt–waterlogging interaction include *C. glauca* and *C. obesa* (see Table 4.5).

Photo 6.10. Eucalyptus camaldulensis. *(A) Whole tree. (B) Detail of leaves. (C) Bark and trunk. [PHOTOGRAPHS: S. NAWAZ]*

but does best on sandy soils along the coast where moisture is supplemented by sea sprays. It is resistant to salt-laden wind. The nitrogen-fixing capacity of the species depends on the availability of adequate moisture. It grows poorly on clay soils.

Uses

- *Wood* — *C. equisetifolia* produces good fuelwood; it burns vigorously (calorific value of 20 950 kilojoules per kilogram) and makes good charcoal. The wood is very hard (1000 kilograms per cubic metre) and is resistant to decomposition in soil and salt water. However, it is liable to split and warp. It is used for making piles, poles and fences. It also makes good pulp.
- *Erosion control* — *C. equisetifolia* has a remarkable ability to colonise and stabilise sand dunes. In India it is used extensively as a windbreak in locations where control of drifting sand is required (e.g. near railway lines, adjacent to farmland). It is also used for lowland agroforestry, and as an ornamental plant for urban beautification, parks and seaside resorts.
- *Nitrogen fixation* — in India *C. equisetifolia* has been reported to increase soil fertility through nitrogen fixation. Rates of fixation of 90 kilograms of nitrogen per hectare per year have been calculated at a planting density of 2000 trees per hectare.

Propagation and management

C. equisetifolia can be reproduced from seed. Ripe green cones are collected from mature trees and dried in the sun. One kilogram of green cones yields 20–60 grams of seed, and there are 300 000 to 700 000 seeds per kilogram. Seed viability is reduced to 30–40% within 3 years, so seed should not be stored for more than 1 or 2 years. Seeds are sown in the nursery to obtain 10–15-centimetre-tall seedlings. These are transplanted into containers and allowed to grow to 50–70 centimetres before transplanting into the field.

Plantation densities of 2000 trees per hectare are commonly used. Sometimes farmers plant at densities of up to 8000 to 10 000 trees per hectare. Young plants can be attacked by white ants, grasshoppers, etc. and browsed by animals.

Productivity and economic value

Volume yield is maximum with a 15 to 20-year rotation (7–10 cubic metres per hectare per year) or 30-year rotation (6–18 cubic metres per hectare per year). Plantations are usually managed on a rotation of 7–15 years.

In India, a 6–8-year-old plantation of *C. equisetifolia* on a saline soil produced about 15 tonnes of fuelwood and small timber per hectare. On this same soil, *Acacia nilotica* produced about 20 tonnes of wood and *Prosopis juliflora* produced 25–30 tonnes of wood. Under these conditions, *C. equisetifolia* would have had a value of about 1070 PKR per hectare per year.[15]

6.2.5 *Eucalyptus camaldulensis* Dehnh.[16]

Description

Eucalyptus camaldulensis Dehnh., also known as *E. rostrata* Schldl., is a member of the Myrtaceae family. Its English names are river red gum, red gum, river gum, Murray red gum, and it is known locally as *suphaida* or *ratta suphaida* (Urdu, Punjabi).

E. camaldulensis is a medium to tall (20–45 metres) tree, with a thick trunk (diameter of 1–2 metres) (Photo 6.10). Dense stands have trunk diameters of about 0.5 metres when mature. It coppices well (Photo 6.11). The crown is thin and large, although in dense stands it is dense and small. The species has very large variation between provenances (see Photo 6.1). The Pakistan type has a single main trunk with fewer branches, especially towards the base. The leaves are lance shaped, 6–30 centimetres long and 0.8–2 centimetres wide, and they have a special fragrance when crushed. The bark sheds in long strips or irregular flakes. Flowers bloom in May and June, and the fruits mature in September and October. The fruits consist of a capsule containing many seeds.

Tolerance to salt and waterlogging

E. camaldulensis grows in slightly alkaline soils, where it can withstand some salinity and waterlogging. The situation regarding the salt and waterlogging tolerance of the species is confused. This may be because of the enormous variation between provenances. In irrigated sand culture, plant height and stem diameter decreased by 36 and 55% respectively, when water with an

Photo 6.11. *Recovery after coppicing in* E. camaldulensis. *[PHOTOGRAPH: E. BARRETT-LENNARD]*

electrical conductivity (EC_w) of 9–10 decisiemens per metre was used (compared to control plants irrigated with water of EC_w 1.6 decisiemens per metre; Ahmad 1987, p. 147). However, the species has survived in nutrient solutions with electrical conductivities up to 50 decisiemens per metre (drained conditions; Marcar 1989) and 42 decisiemens per metre (both drained and waterlogged conditions; Moezel et al. 1988). A confused picture also emerges from experiments in the field. On a saline/waterlogged site in Australia there was a 50% decrease in canopy volume with an increase in EC_e in the upper 60 centimetres of the soil profile to 5 decisiemens per metre (Marcar et al. 1994). In one adaptation trial near Tando Jam, only 13% of the plants survived for 24 months; this performance was eclipsed by every other genotype in the trial (Ansari et al. 1994, Table 2). However, in an adaptation trial near Faisalabad, the species performed better than 11 other species over seven and a half years (Qureshi et al. 1993, Tables 3 and 4).[17] Fast growth of *E. camaldulensis* has been observed on saline land near Satiana (Photo 6.12).

15 Calculated assuming that fuelwood has a market value of 0.50 PKR per kilogram (c.f. Qureshi et al. 1993).

16 These notes were adapted from Sheikh (1993) p.65; Marcar et al. (1995) p.42; Baqaur (1995) p.296; National Academy of Sciences (1986) p.73; Qureshi et al. (1993) pp. 259–269.

17 In this trial, the *E. camaldulensis* had EC_e and SAR values averaged over the upper 90 centimetres of the soil of 10 decisiemens per metre and 29 respectively. The *E. camaldulensis* grew better than *Acacia nilotica*, *Albizzia lebbek* and *Leucaena leucocephala*, although the latter species were grown in soil of higher average EC_e and SAR (14 dS/m and 30–38 respectively).

Photo 6.12. *Growth of a mixed stand of* E. camaldulensis *and saltbush on saline land near Satiana. (A) Shortly after planting. (B) After one and a half years. (C) After three and a half years. [PHOTOGRAPHS: E. BARRETT-LENNARD]*

Other comments on adaptation

E. camaldulensis is native to Australia, but is now grown extensively in Pakistan in the plains and the hills. The species prefers a semiarid subtropical climate (temperatures of –5 to 40°C) with high winter or monsoon rainfall. Various provenances grow in rainfall regimes varying from 250 to 2500 millimetres per year. It is frost and drought-tolerant and can stand a dry season of up to 7 months. It is not well adapted to calcareous soils. The following have been named as the best-performing provenances under conditions of salinity and waterlogging: De Grey River, Wiluna, Katherine, Mt Benstead, Lake Albacutya, Douglas River and Silverton (Marcar et al. 1995). It grows well on soils with shallow watertables, which it can lower because of its high rates of transpiration (see Chapter 8).

Uses

- *Fuelwood* — *E. camaldulensis* produces excellent firewood with a calorific value of 20 531 kilojoules per kilogram. It also makes good charcoal.
- *Timber* — the wood is hard and durable. Old wood has a density of 900 kilograms per cubic metre; the wood of young plants has a density of about 650 kilograms per cubic metre. It can be used for heavy construction, railway sleepers, flooring, plywood, chipboard and fencing. It is also used for the construction of modest furniture.
- *Other uses* — it produces good-quality pulp for paper manufacturing. Leaves are used for oil extraction. It is a very good source of nectar and pollen.
- *Saltland revegetation* — the species is extensively used in Pakistan and India for the revegetation of salt-affected wasteland.

Propagation and management

E. camaldulensis reproduces from seed. There are about 600 000 seeds per kilogram. The tree nursery is raised as described in Section 6.1.2. Seedlings should be 30–45 centimetres tall at planting. Although planting can be successful at all times except for the severely arid hot season, best results in salt-affected soils occur when seedlings are transplanted in October–November, or in February–March.

The stage at which trees are harvested varies with the requirements of the market. Younger plants (stem diameter of 15–20 centimetres) are harvested for pulp, chipboard and poles; older plants are preferred for use as fuelwood and timber. The plants can be cut above ground and allowed to resprout, saving the cost of replanting. *E. camaldulensis* can be harvested up to six times on a 7–10-year coppice rotation. For poles and timber, trees should be harvested during the winter season to allow slow drying of the timber.

In Pakistan, there are no serious pests of *E. camaldulensis* except for termites, which can be controlled using the insecticide heptachlor followed by irrigation.[18]

E. camaldulensis is a good farm–forestry tree but can compete strongly with crops for moisture and nutrients (see Section 8.2). The trees are usually planted on a 3 × 2-metre configuration. On sites subject to severe waterlogging, they should be planted on raised bunds or mounds in May when the watertable is at its deepest.

Productivity and economic value

E. camaldulensis grows quickly; average yields vary from 10 to 25 cubic metres per hectare per year. There are reports of yields of 20–25 cubic metres per hectare per year from Argentina, and 30 cubic metres per hectare per year from Israel (National Academy of Sciences 1986, p. 73). Under saline well-drained conditions (average EC_e [at 0–90 centimetres] of 10 decisiemens per metre) fresh timber yields of about 200 kilograms per plant were obtained from a seven-and-a-half-year-old plantation (Qureshi et al. 1993, Tables 3 and 4). It has been calculated that this productivity would have yielded a gross return of about 40 000 PKR per hectare per year (Qureshi et al. 1993, Table 7).

6.2.6 *Leucaena leucocephala* (Lam.) de Wit[19]

Description

Leucaena leucocephala (Lam.) de Wit, also known as *L. glauca*, is from the Fabaceae family. Its English name is leucaena, and it is known locally as *iple iple, subabul* and *American shirin*.

L. leucocephala is a multipurpose, nitrogen-fixing evergreen shrub or tree that is fast growing (Photo 6.13). It has more than 100 varieties. Some varieties grow to 20 metres high. Leucaena varies widely in leaf and tree shape. The foliage is bipinnate and feathery; leaves are 7–15 centimetres long; the leaflets are about 3 centimetres long. Flowers range from bright yellow and pink to white. It is a self-pollinated species. Clustered vertical brown pods, 8–25 centimetres in length, are a distinguishing mark.

Tolerance to salt and waterlogging

L. leucocephala grows well on light-textured saline soils that are well drained. However, it is sensitive to waterlogging. In irrigated sand and gravel cultures, water with electrical conductivities of 9–10 decisiemens per metre did not adversely affect growth (Ahmad 1987, p. 147). Two field experiments examined the adaptation of the species to saline soils at Faisalabad. The first of these examined the effects on survival of 3 months flooding of the soil surface. Under drained conditions there was 80–100% survival, but under flooded conditions there was no survival (Qureshi et al. 1993, Figure 1). In a longer-term adaptation experiment on a saline–sodic soil, leucaena produced 90 kilograms of timber per plant over a seven-and-a-half -year period (Qureshi et al. 1993, Tables 3 and 4).[20]

Other comments on adaptation

L. leucocephala is an aggressive species that grows on a variety of soils. It can establish in sandy, gravelly, shallow and steep soils, but it grows best on deep fertile soils. It grows well with a summer precipitation of 500–2000 millimetres per year and prefers a moist tropical climate. However, it can survive severe drought. Leucaenas grow on soils of pH 5.5–8; they do not grow on highly acid soils. The species is attacked by the psyllid *Heteropsylla cubana*, but tolerant varieties are available. It grows at elevations from sea-level to 2000 metres. Its seedlings are sensitive to frost. It volunteers (self-sows) and coppices readily.

18 Application rate: 50 millilitres of heptachlor is added to 1 litre of water and applied to each tree.

19 These notes were adapted from Quraishi et al. (1993) p. 99; Sheikh (1993) p. 80; Nitrogen Fixing Tree Association Staff (1990); Baquar (1995) p. 344; National Academy of Sciences (1986) p. 71.

20 The soil had an EC_e and SAR (averaged over the upper 90 centimetres) of 14 decisiemens per metre and 30 respectively.

Photo 6.13. Leucaena leucocephala. *(A) Whole tree. (B) Detail of leaves and fruits. [PHOTOGRAPHS: S. NAWAZ]*

Uses

- *L. leucocephala* is used to produce wood and forage. It is also an excellent tree for alley farming.
- *Wood* — the wood can be used as a timber (for posts, house building), as a pulpwood, and for fuel. As a fuel, the wood has a calorific value of 18 855 to 19 903 kilojoules per kilogram. It burns with little smoke or ash. The wood can also be used to produce high yields of good-quality charcoal.
- *Fodder* — the leaves of the tree are a good fodder (digestibility 55–70%) for ruminants. They are a rich source of carotene and vitamins, especially vitamin A. High mimosine contents can be toxic to non-ruminants, but varieties low in mimosine are available. Mimosine breakdown in ruminants produces a toxic byproduct called 3,4-dihydroxy pyridine (DHP). However, some ruminants contain bacteria in their guts that can break down DHP and detoxify it. These bacteria can be obtained for rumen inoculation. Leucaena is growing well in the Pabbi Hills near Kharian in Punjab Province where it has been planted to supplement grass fodder.
- *Alley farming* — leucaena is a model tree for alley farming, as the crops grown between the rows of trees benefit from the decay of the nitrogen-rich leaves that fall on the ground. Planting trees on a 3 metre × 3 metre grid is estimated to add 100 kilograms of nitrogen per hectare per year to the soil.

Propagation and management

Leucaena can be propagated through direct seeding, or the planting of container seedlings, bare-rooted seedlings, or stump cuttings.[21] There are 10 000 to 80 000 seeds per kilogram. The seeds have hard coats which should be scarified using the 'boiling water' or 'mechanical' methods (see Box 6.1).

Nitrogen fixation occurs in the roots in small nodules that are infected with bacteria from the genus *Rhizobium*. New areas for planting may require inoculation with *Rhizobium* as well as the planting of seed.

Seedlings and young plants must be protected from grazing animals. Plantation densities vary between 2500 and 5000 plants per hectare.

21 Stump cuttings are seedlings that have been severely pruned, leaving only a short stump and a short piece of the main root.

Productivity

Under favourable conditions, wood yields are similar to those from the most productive tropical trees. In general, yields below 15 cubic metres per hectare per year are considered poor, indicating poor adaptation, low soil fertility or poor management. Yields above 30 cubic metres per hectare per year are good, indicating good sites and management (Beldt and Brewbaker 1985).

For fuelwood plantations, a short rotation of 2–3 years is practiced. In many cases, yields will be greater for coppice regrowth, where weed competition no longer exists, and existing root systems are well established.

In one study on a saline–sodic soil near Faisalabad, wood yields of 90 kilograms per tree were reported after seven and half years of growth. The gross value of this production was estimated to be about 14 830 PKR per hectare per year (Qureshi et al. 1993, Tables 3, 4 and 7).[22]

For fodder production, the plants are cut more frequently to a height of 1 metre. The Hawaiian giant K-8 planted at a density of 5000 plants per hectare has yielded 7.5 tonnes of forage per hectare at an age of one and a half years (Nitrogen Fixing Tree Association Staff 1990).

6.2.7 *Parkinsonia aculeata* L.[23]

Description

Parkinsonia aculeata L. is a member of the family Fabaceae. Its English names are Parkinsonia, Jerusalem thorn, prickly broom, and it is known locally as *vilaiti kikar* (Urdu, Punjabi).

P. aculeata is native to America and was introduced into Pakistan mainly as an ornamental and avenue plant (Photo 6.14). It is a small evergreen tree or shrub with a broad crown, an average height of 5–9 metres, and an average trunk diameter of 0.3 metres. It has sharp woody spines. It produces yellow flowers in May. The pods mature in June and July. The leaves are compound bipinnate with tiny leaflets borne on long flat leaves. The bark is smooth and has a greenish colour.

Photo 6.14. Parkinsonia aculeata. *(A) Whole tree. (B) Detail of leaves. [PHOTOGRAPHS: S. NAWAZ]*

22 Specific details of this investigation were as follows:

Soil conditions. EC_e and SAR values averaged over the upper 90 centimetres of the soil were 14 decisiemens per metre and 30 respectively.

Planting density. The trees were planted at 2500 stems per hectare. There was 90% survival after 1 month.

Financial calculation. The calculation assumed the wood to have a value of 0.50 PKR per kilogram. A stocking rate of 1000 trees per acre (2470 plants per hectare) was assumed.

23 These notes were adapted from Baquar (1995) p. 375 and Sheikh (1993) p. 87.

Tolerance to salt and waterlogging

P. aculeata grows well under conditions of high salinity, but is sensitive to waterlogged conditions.

Other comments on adaptation

P. aculeata is planted in Pakistan on the plains at elevations of up to 1300 metres and in areas with rainfall in the range 200–1000 millimetres per year. It is adapted to a variety of soil conditions and survives at temperatures between –3 and 38°C. It can tolerate drought.

Uses

P. aculeata is an excellent avenue and ornamental shrub/tree in salt-affected areas. It is used extensively as a shelter, hedge, or windbreak plant. In Mexico and Puerto Rico it is also used as a fuelwood and for charcoal production. The seeds, pods and young branches are used to feed sheep and goats.

Propagation and management

P. aculeata is easily established by direct seeding or through vegetative measures. Soaking the seed in water for 3–4 days helps to break seedcoat dormancy (see Box 6.1). It has to be protected against termites and grazing animals.

Productivity

P. aculeata is a relatively fast-growing tree. In one study on a saline–sodic soil near Faisalabad, wood yields of 38 kilograms per tree were reported after seven and a half years of growth (Qureshi et al. 1993, Tables 3 and 4).[24]

6.2.8 *Prosopis cineraria* (L.) Druce[25]

Description

Prosopis cineraria (L.) Druce, also known as *P. spicigera*, is a member of the Fabaceae family. Locally it is known as *jhau, jand* (Urdu and Punjabi) and *kandi* (Sindhi).

P. cineraria is a large shrub or a small tree about 10–12 metres tall. It is thorny and evergreen with an open and spreading crown. It flowers from December to May. It is leafless for a short time before flowering. The leaves are arranged in bunches 1–2.5 centimetres long. The pods mature between April and August. The bark is rough, grey and exfoliating.

Tolerance to salt and waterlogging

P. cineraria grows successfully in highly saline and alkaline soils (pH values up to 9.8).

Other comments on adaptation

P. cineraria is grown in all four provinces of Pakistan. It is an important feature of desert landscapes in Southern and South Eastern Pakistan and the Potwar Plateau. It volunteers in the harsh climate of the Cholistan Desert and in the deserts of Oman and other Middle East countries. It is widely adapted to a variety of soil and climatic conditions. It grows well in sandy and clayey soils over a temperature range of –6 to 50°C and an annual rainfall range of 75–850 millimetres. It is highly drought tolerant; its taproot can reach groundwater at 20 metres depth. Seedlings can be damaged by frost and by grazing animals.

Uses

P. cineraria is an agroforestry species with value as a timber and for the production of fuel and fodder.

- *Agroforestry role* — the tree is favoured for agroforestry as it fixes large amounts of nitrogen and does not affect growth of plants under the canopy. Good honey is produced on large plantations.
- *Timber* — the timber is used for building houses, posts and tool handles.
- *Fuel* — the wood has a calorific value of 20 950 kilojoules per kilogram.
- *Fodder* — the tree produces good-value fodder in the form of lopped foliage and pods.

Propagation and management

P. cineraria is reproduced easily from seeds or by shoot cuttings. Germination is assisted by scarifying the seeds by soaking them in water or sulfuric acid (see Box 6.1). Seed can be stored for a long time. Plantation techniques are similar to those used for *A. nilotica*. The tree coppices readily.

24 EC_e and SAR values averaged over the upper 90 centimetres of the soil were 14 decisiemens per metre and 29 respectively. The trees were planted at 2500 stems per hectare. There was 100% survival after 1 month.

25 These notes were adapted from Quraishi et al. (1993) p. 103; Qureshi et al. (1993) p. 264; Sheikh (1993) p. 107; Baqar (1995) p. 391; National Academy of Sciences (1986) p. 74.

Productivity

Under favourable conditions, the tree can attain a height of 7 metres in 11 years. Yields of wood of 3–5 cubic metres per hectare per year are common. However, there is a report of a yield of 21 cubic metres per hectare per year (National Academy of Sciences 1986).

In one study on a saline–sodic soil near Faisalabad, wood yields of 52 kilograms per tree were reported after seven and a half years of growth (Qureshi et al. 1993, Tables 3 and 4).[26]

In the desert, the leaves and branches are a favoured feed of livestock. It is heavily lopped during winter and yields 59 kilograms of fodder per tree (with complete lopping), 28 kilograms of fodder per tree (with partial lopping) or 20 kilograms of fodder per tree (when the lower third of the crown is lopped). The pods are also used as feed for animals; pod yields of 150 kilograms per hectare are typical. Pods contain 9–13% protein, 13–16% sucrose (sugar) and 45–55% carbohydrate.

6.2.9 *Prosopis juliflora* (Swartz) D.C.[27]

Description

Prosopis juliflora (Swartz) D.C., also known as *Mimosa juliflora*, is a member of the Fabaceae family. Its English name is mesquite, and it is known locally as *pahari kikar* or *jangli kikar*.

P. juliflora is a large shrub or small evergreen thorny tree that grows 12–15 metres high. The thorns are strong and straight, and can even puncture tractor tyres. Stems are up to 20 centimetres in diameter. Leaves are alternate and bipinnate. It produces small, densely crowded, fragrant flowers (greenish or golden yellow in colour) between March and June followed by profuse pods. The species fixes atmospheric nitrogen.

Tolerance to salt and waterlogging

P. juliflora is an aggressive species[28] that grows under conditions of moderate to high salinity and sodicity, high alkalinity (pH values up to 9.8) and intermittent flooding. It can be quite successful in lowering watertables on dense saline–sodic soils with shallow groundwater. Plantations can be established and/or grown using irrigation with saline groundwater[29] or sea water.[30] The influence of salinity on growth cannot be confirmed as experiments were affected by fungal disease; nevertheless 25% reductions in shoot extension with irrigation water of electrical conductivity 30 decisiemens per metre seem likely (Rhodes and Felker 1988; Miyamoto 1996). There are reports that production is decreased by about 25% as the soil pH increases from 8.0 to 10.5 (Fagg and Stewart 1994).

Other comments on adaptation

P. juliflora was introduced to Pakistan in the early 1950s to stabilise sand dunes and produce wood. It grows naturally on some of the most difficult sites in Pakistan. It is found on arid wastelands throughout the country. It is adapted to semiarid and subtropical climates, and soils varying from sands to clays. It requires a precipitation of 150–750 millimetres and tolerates temperatures between –12 and 50°C. It establishes well when rainfall is more than 300 millimetres, intermittent irrigation from drainage water is available, or watertables are within 10 metres depth. It is extremely drought tolerant. It has a great promise for sand dune stabilisation projects and fuelwood production using saline water sources, especially near the coast.

Uses

P. juliflora is a multipurpose tree for dry lands; it is an important source of fuelwood, timber and forage, and has a variety of other benefits.

- *Timber* — the wood is used for fence posts and light carpentry work. In India, it is used for the construction of good furniture.
- *Fuelwood* — this species is an important source of fuel for the rural and urban poor. By adopting proper management techniques of thinning and pruning, it can provide small diameter fuelwood and poles. Nomads use it to produce good charcoal that burns slowly and evenly.
- *Forage* — milled pods contain about 17% protein and are relished by sheep and cattle. Its beans can

26 EC_e and SAR values averaged over the upper 90 centimetres of the soil were 15 decisiemens per metre and 43 respectively. The trees were planted at 2500 stems per hectare. There was 93% survival after 1 month.

27 These notes were adapted from Quraishi et al. (1993) p. 104; Sheikh (1993) p. 108; Baquar (1995) p. 393; National Academy of Sciences (1986) p. 74; Singh and Singh (1993).

28 Note that care may need to be exercised when planting *P. juliflora* in moist areas. On such sites this species can behave like a noxious weed and its eradication can be a severe problem.

29 Ahmad (1987) reported on the growth of *Prosopis* on the Karachi coast using groundwater of salinity 7–21 decisiemens per metre (equivalent to about 10–40% of the salinity of sea water).

30 At Texas A & I University *P. juliflora* survived irrigation with salinities equivalent to 100% sea water (Rhodes and Felker 1988).

be toxic if used as a sole source of animal fodder. However, such problems do not occur if they are mixed with other rations to prepare a balanced diet.

- *Other benefits* — it is a good source of nectar for the production of honey. It has great potential for sand stabilisation programs. Alkali soils have been greatly improved (in terms of a decrease in pH). It is a good shade tree in many communities.

Propagation and management

P. juliflora can be propagated by direct seeding, or by the planting of stem cuttings or nursery-raised seedlings. Germination can be increased by scarification of the seed (soaking in water for 36–48 hours, soaking in boiling water for 5–7 minutes, or dipping into sulfuric acid for 5 minutes — see Box 6.1).

Nursery-raised seedlings can be established in the field using relatively saline irrigation water. For example, on the coastal sands of the Makran coast (Baluchistan Province), there was 70–80% establishment of nursery-raised seedlings irrigated with groundwater of electrical conductivity 7–21 decisiemens per metre (Ahmad 1987, p. 84).

P. juliflora has a good capacity to regrow after coppicing; it also spreads by making suckers. Thinning and pruning of the trees is extremely important for obtaining a thick straight trunk and for developing shade trees. The use of thornless clones can greatly assist in the handling of cut branches and wood.

Productivity

P. juliflora yields about 5 kilograms of wood per plant per year (calculated from the data in Figure 6.4). The density of this wood depends on plant age; it is initially relatively light (650 kilograms per cubic metre in year 1) but increases in density with time (950 kilograms per cubic metre in year 10).[31]

On 15-year rotation, the expected yield of fuelwood is 75–100 tonnes per hectare; on a 10-year rotation, it may be 50–60 tonnes per hectare (National Academy of Sciences 1986). In India, a planting on a 2 metre × 2 metre grid (2500 plants per hectare) gave about 13 tonnes per hectare from cut side-branches after 40 months of growth. Income from such plantations was estimated at 8175 PKR per hectare per year from alkaline soils, and 3587 PKR per hectare per year on saline soils (Singh and Singh 1993).

31 The density of wood (in grams per cubic centimetre) = $0.577 + 0.0823x - 0.0046x^2$, where x is the age in years. (Ahmad 1987, p. 96).

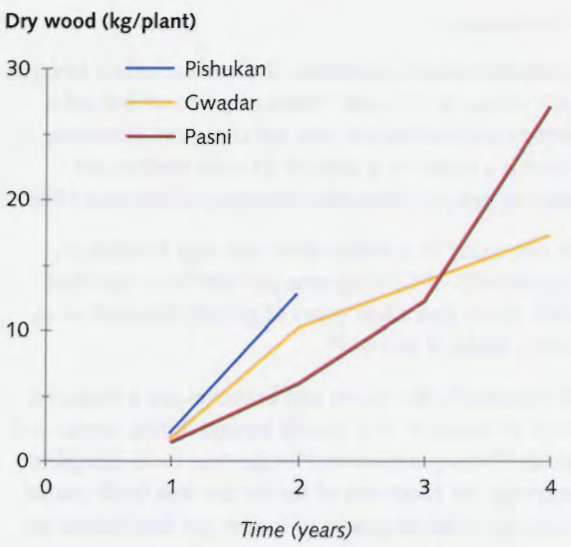

Figure 6.4. *Typical average growth of* Prosopis juliflora *at three localities on the Makran coast (*Baluchistan Province*) (Ahmad 1987, Table 21).*

On a shallow watertable site in Brazil, widely spaced 15-year-old mesquite trees produced between 5 and 115 kilograms of pods per tree per year (Lima 1986).

6.2.10 *Sesbania bispinosa* (Jacq.) W.F. Wight[32]

Description

Sesbania bispinosa (Jacq.) W.F. Wight, also known as *S. aculeata*, is a member of the Fabaceae family. Locally it is known as *dhancha*.

S. bispinosa is an erect annual or biennial legume, which reaches a height of about 3.5 metres (Photo 6.15). In crowded stands it grows tall and straight. Its leaves have 12–30 pairs of leaflets. Leaflets are narrow (3–4 millimetres wide) and oblong (10–20 millimetres long). The flowers consist of a raceme (stalk) bearing between 3 and 12 flowers on short pedicels (6–11 millimetres long). The pods are slender (15–25 centimetres long and 2–3 millimetres wide) and contain 35–40 seeds. The seeds are dark brown and are about 4 millimetres long.

Tolerance to salt and waterlogging

S. bispinosa is commonly grown for the reclamation of salt-affected soils (see Section 2.2). It is adapted to a variety of soil conditions, varying from waterlogged to

32 These notes were adapted from Evans and Rotar (1987) and National Academy of Sciences (1986) p. 71.

saline, and from sands to clays. It has a 50% decrease in growth in soils with an EC_e of 13 decisiemens per metre (Sandhu and Haq 1981).

Other comments on adaptation

S. bispinosa is native to Pakistan and India. It is commonly grown in Pakistan in the plains and foothills of all four provinces. It is drought resistant and grows from March to September/October. It grows up to an altitude of 1200 metres and within a rainfall range of 550 to 1100 millimetres. It grows vigorously after the plants are established and reaches a height of about 2 metres in 3 months.

Uses

S. bispinosa is used for green manuring and fodder production.

- *Green manure* — it is one of the best available green manuring crops and is widely used in the reclamation of salt-affected soils. It fixes large amounts of nitrogen; a good crop can add 5000–7000 kilograms of organic matter and 85–110 kilograms of nitrogen per hectare. The root system greatly helps in opening up the soil and acidifying the root environment through the production of carbon dioxide and acidic exudates.
- *Fodder* — it is a high-quality fodder rich in protein (18%) and minerals (9%). Animals relish it because of its succulence and large foliage. It sells at high prices during *Eid-ul-Azha* for the feeding of sacrificial animals.
- *Other uses* — the sticks of *dhancha* are extensively used for roofing mud houses and as a fuelwood.

Propagation and management

The seedbed is prepared by levelling and cultivating the land twice. The crop is sown at a rate of 50–60 kilograms of seed per hectare (by broadcasting or drilling). When broadcast, the seed should be mixed into the upper 5 centimetres of the soil with a light ploughing. In dense salt-affected soils, the seed may be broadcast into standing water after irrigating the prepared seedbed.

The crop can be sown from March to June. For green manuring before rice cultivation, the crop is sown at the end of February to early March and ploughed

Photo 6.15. Sesbania bispinosa. *(A) Whole shoots. (B) Detail of leaves. [PHOTOGRAPHS: S. NAWAZ]*

Photo 6.16. Sesbania sesban.
[PHOTOGRAPH: S. NAWAZ]

under at the flowering stage. For green manuring before planting wheat, *dhancha* is sown in June or July and ploughed under in August or September.

For better yields, urea (50 kilograms per hectare) and single superphosphate (250 kilograms per hectare) are recommended at sowing. The first irrigation is given 25–30 days after sowing, and the crop matures with two or three irrigations.

For forage production, the crop should be harvested after two and a half months. For green manuring, the crop is ploughed under at flowering. It is firstly knocked over using a heavy plank, and then incorporated using a disc harrow followed by a rotavator. These steps are followed by a heavy irrigation.

Productivity

From salt-affected soils about 2.5–4 tonnes per hectare of green manure can be obtained, while 1–1.5 tonnes per hectare of seed are obtained at maturity. In Italy, a yield of 15 tonnes per hectare per year has been reported (National Academy of Sciences 1980, p. 60).

6.2.11 *Sesbania sesban* (L.) Merr.[33]

Description

Sesbania sesban (L.) Merr., also known as *Sesbania aegyptica*, is a member of the Fabaceae family. It is know locally as *jantar*.

S. sesban is a small to medium-sized leguminous tree (height of 6–8 metres; see Photo 6.16). It is more or less evergreen and very fast growing (a stem growth of 5 metres height in 1 year has been reported). The raceme bears 4–20 flowers. The petals of the flowers are pale yellow, usually with purple streaks and spots. Flowering occurs in the spring and autumn. Pods are slightly twisted, up to 25 centimetres long, and each contains 20–30 seeds.

Tolerance to salt and waterlogging

S. sesban can tolerate waterlogging, salinity and alkalinity (pH values as high as 10). Experiments in which plants were grown in sand cultures irrigated with water of different salinities show that:

- 46% decreases in stem diameter can be expected at an electrical conductivity of 16 decisiemens per metre (calculated from Ahmad et al. 1985);
- 15–22% decreases in height and stem diameter can be expected at electrical conductivities of 9–10 decisiemens per metre (Ahmad 1987, p. 153).

Other comments on adaptation

S. sesban is adapted to a range of climatic conditions. It is widespread in the tropics of Asia and Africa and has been introduced into tropical America and elsewhere. In general, it grows at low elevations (300–500 metres), although some varieties have become naturalised to cooler high elevation regions (e.g. as high as 2000–2300 metres in East Africa). It grows in semiarid to subhumid climates with annual rainfall ranging from 500 to 2000 millimetres. It can tolerate drought. It is planted extensively in the Punjab and North West Frontier Province (NWFP) in Pakistan.

33 These notes were adapted from Quraishi et al. (1993) p. 106; Sheikh (1993) p. 125; Evans and Macklin (1990) pp. 1–41.

Uses

S. sesban is used as a fodder, source of wood and landcare species.

- *Fodder* — *Sesbania* has high protein concentrations (17–30% on a dry matter basis), and a dry matter digestibility exceeding 60%. It is a good fodder for cattle, sheep and goats. It is used as a supplement for feeding to ruminants. The diet may contain 15–30% *Sesbania* with the balance consisting of high-energy roughages such as rice straw and maize. The fodder can be fed fresh, wilted or dried. Saponins have been reported in leaves of some genotypes.
- *Wood* — the wood can be used for fuel; it is fast burning and can be handled easily. Stems (poles) can be used for the roofing of huts and animal sheds and may last up to 6 years. The wood can be used as support stakes for vegetables. The wood can also be used for pulp production for the manufacture of paper.
- *Landcare role* — it makes good windbreaks. In some cases, it is used in alley farming (Evans and Macklin 1990). It is also used to improve the soil because of its nitrogen-fixing properties. It can be grown as shade trees.

Propagation and management

S. sesban can be planted through direct seeding. Germination is increased by scarifying the seed by dipping it into hot water (just below boiling point) for 30 seconds, or into water at 80°C for 10 minutes (see Box 6.1). Seeds are planted at a depth of 1–2 centimetres in well-prepared soil. Seeds germinate rapidly; plants can be 10 centimetres high in 20 days, and up to 2 metres high in 12 weeks. Plants can also be established in the nursery by planting seeds in planter bags. Young plants must be protected against grazing.

Moderate doses of farmyard manure and phosphate help growth. Plants for fodder should be established in rows 1–2 metres apart, with 25–50 centimetres between plants. The species coppices well but can die if proper care is not exercised in cutting. It may be harvested up to five times per year if growth is good; fodder yields are maximised if cut at 75–100 centimetres above the ground; if the plants are cut below 50 centimetres or too frequently, there may be increased mortality. For wood production, the plants should be cut at least 50 centimetres above the ground. When pruning, 5–25% of the foliage should be left on the plant. A number of fungal diseases and insects can attack the species, but no serious pests have been reported in Pakistan.

Productivity

For wood, block plantings on fallow soil or sloping land can produce 15–20 tonnes dry weight per hectare per year. Even higher production is possible with reduced plant spacing (1 metre × 1 metre). For fodder, 20 tonnes dry weight per hectare per year can be harvested from plantings with rows 1–2 metres apart, and plants 25–50 centimetres apart within rows.

6.2.12 *Tamarix aphylla* (L.) Karsten[34]

Description

Tamarix aphylla (L.) Karsten, also known as *T. articulata* or *T. orientalis*, is a member of the Tamaricaceae family. Its common name is tamarix or salt cedar, and locally it is known as *frash, pharwan* (Punjabi), *laljhau, chotimain* (Urdu), and *shakarghaz, siaghazz* (Balochi).

T. aphylla is a heavily branched large shrub or a small 'coniferous-looking' tree, which grows to a height of 10–15 metres (Photo 6.17). It has an erect trunk with rough bark. The leaves are reduced to tiny 'scales' that ensheath the wiry twigs. It excretes salt; salty 'tears' drip from the leaf glands at night. The minute flowers are white or pink, bisexual or unisexual, and are borne on spikes. Flowering occurs between April and September. Seeds mature between December and January.

Tolerance to salt and waterlogging

T. aphylla can tolerate high levels of salinity and sodicity. It is a common tree of salt-affected wastelands. Studies at the University of Agriculture Faisalabad show it to be highly tolerant to salinity and waterlogging (Qureshi et al. 1993). There are reports of its survival when irrigated with water of electrical conductivity 56 decisiemens per metre (Aronson 1989).

34 These notes were adapted from National Academy of Sciences (1986) p. 74; Sheikh (1993) p.128; Quraishi et al. (1993) p.106; Baquar (1995) p. 444; Qureshi et al. (1993) p. 266.

Photo 6.17. Tamarix aphylla. *(A) Whole tree in flower. (B) Detail of leaves. [PHOTOGRAPHS: S. NAWAZ]*

Other comments on adaptation

T. aphylla is a versatile species which grows well on drained sandy soils. It is native to Pakistan and the Middle East. It can stand prolonged drought and temperatures up to 50°C. It grows well with an annual rainfall of 300–500 millimetres. It prefers arid to hot subtropical winter monsoon conditions. It is usually insect free. It is frost hardy and coppices well. The species is commonly grown on the plains of all four provinces. It has been planted extensively on the sand dunes of the Thal Desert.

Uses

- *T. aphylla* has value as a fuelwood, as a timber and as a shelter plant.
- *Fuelwood* — tamarix is slow to catch fire but has good burning quality. The wood can be used to prepare charcoal. Leaf litter and small branches will not burn because of their high salt content.
- *Timber* — the timber is good for making agricultural implements such as ploughs and Persian wheels, and is good for turning.
- *Shelter* — the trees have value as shelterbelts (windbreaks), for erosion control and sand dune stabilisation. Washing the salt off the surfaces of the leaves tends to kill vegetation beneath the trees; rows of tamarix can therefore be used as firebreaks.

Propagation and management

T. aphylla can be easily propagated through nursery-raised seedlings (raised from seed)[35], stem cuttings and root suckers. It reproduces well naturally in the field.

Seeds are small and are mixed with ash or sand for sowing in nursery beds. For plantations into saline–sodic soils, cuttings should be planted into and established in plastic bags (in a manner similar to seedlings), and then transplanted into the field once they have been hardened. Plants are established in rows 3 metres apart, with plants at 2 metres apart within the rows. Under natural conditions, the crop is harvested in a 20-year rotation. However, under irrigated conditions, this time can be reduced to 10–12 years.

35 There are reports that tamarix seeds rapidly lose viability (National Academy of Sciences 1980). Seed should therefore be used immediately after collection.

Productivity

Wood production of 5–10 cubic metres per hectare per year has been reported. In one study on a saline–sodic soil near Faisalabad, wood yields of 35 kilograms per tree were reported after five and a half years of growth. The gross value of this production was estimated at about 7860 PKR per hectare per year (Qureshi et al. 1993, Tables 5A, 5B and 7).[36]

6.3 Salt-Tolerant Fruit Trees

6.3.1 *Grewia asiatica* L.[37]

Description

Grewia asiatica L. is a member of the Tiliaceae family, and is known locally as *phalsa* (*falsa*).

There are more than 100 species in the genus *Grewia*. The cultivated form of phalsa is the species *G. asiatica* which is considered to be native to the Indo–Pakistan subcontinent.

G. asiatica is a deciduous bush which grows 3 or 4 metres high (Photo 6.18). It has greyish-white to grey–brown bark. The branchlets and underside of leaves vary from being hairless to densely covered in soft short hairs. The leaves are broad with five (sometimes four) basal nerves; they vary from being heart to egg shaped, with a more or less distinctly toothed leaf margin. The fruits are globular, with an outer fleshy layer overlying an inner hard seed. The fruits have a pleasantly acid pulp. Phalsa flowers in late March and April, varying with the time of pruning. The fruit ripens in May–June in Hyderabad Division and June–July in the submountain areas. If the plants are pruned in summer (July), a second crop occurs in November–December.

The fruit is borne in the axil of leaves in the later half of the current year's growth. It is borne in clusters of 18–24 fruits. Innumerable shoots (sometimes over 100) are borne on a plant, each bearing 9–15 clusters.

Photo 6.18. Grewia asiatica. *(A) Whole tree. (B) Detail of leaves. [PHOTOGRAPHS: S. NAWAZ]*

36 Specific details of this investigation were as follows:

Soil conditions. EC_e and SAR values averaged over the upper 90 cm of the soil were 15 decisiemens per metre and 34 respectively.

Planting density. The trees were planted at 2500 stems per hectare. There was 71% survival after five and a half years.

Financial calculation. The calculation assumed the wood to have a value of 0.50 PKR per kilogram. A stocking rate of 1000 trees per acre (2470 plants per hectare) was assumed.

37 These notes were adapted from Ginai (1968) pp. 233–236; Food and Agriculture Organization (1982) pp. 91–94.

Tolerance to salt and waterlogging

G. asiatica had excellent survival under saline–sodic conditions in a five-and-a-half-year field trial near Faisalabad (Qureshi et al. 1993, Table 5A).[38]

Other comments on adaptation

Phalsa thrives best in tropical climates, but it will tolerate other climates, except at high altitude. It can withstand light frost and tolerates drought. Hot dry summers are considered necessary for the ripening of fruit. Rich loam soils are considered best, although there can be satisfactory results on clays and sands; it can grow in alkaline soils. Clay soils produce heavy vegetative growth and the plants become tall and bushy.

Uses

Owing to the poor keeping quality of the fruit, phalsa is grown on a limited scale, mostly in the vicinity of towns where it can be quickly marketed. However, there are considerable prospects for making phalsa juice and syrup, which are highly esteemed as a refreshing and cooling drink. The long stems, which are removed as prunings, may be used for supporting garden crops such as peas or made into baskets.

Propagation and management

Phalsa is generally propagated by seed. Tree-ripened fruits are collected in earthen pots in June and allowed to rot. The rotted fruit is mixed with well-rotten farmyard manure and rubbed so that the seeds are separated with a coating of manure. These are broadcast into well-prepared beds and are irrigated. Alternatively fully ripe soft fruit may be sorted from the harvested crop and sown in slightly raised nursery beds without any other treatment. The nursery beds are sprinkled with water daily till the seedlings are established. Once established they can be irrigated at intervals of 5–7 days. The seeds take about 2–3 weeks to germinate, and the seedlings are ready for transplantation in February to March of the following year.

Seedlings are ordinarily planted on a 3-metre grid. On poorer soils, they can be planted closer together, on a 2.5 or 2-metre grid.

Farmyard manure at 8 kilograms per plant is applied in early February immediately after pruning. The manure is spread around the base of the plant, hoed in and followed by irrigation.

Phalsa is very drought resistant and can be grown entirely under rainfed conditions in areas like Rawalpindi, where annual rainfall is above 750 millimetres and is spread throughout the year. In lower rainfall areas, phalsa should be periodically irrigated especially during January–May when growth takes place and fruit is borne. Frequent irrigation on salt-affected soils improves yield.

Annual pruning is important as fruit is borne on new growth. Plants are pruned when they are about to lose their leaves in the middle of winter (about the second fortnight of January). Pruning at a height of about 1.2 metres is considered best as it results in a larger number of shoots and a much higher yield than lower pruning. If a second (winter) crop is required, the trees may be pruned in July.

The fruit-picking season lasts for about a month. Several pickings are necessary. The fruit is picked by country women on a contract basis.

Productivity

Average yields of fruit are about 8–12 kilograms per bush, or 750 kilograms per hectare. There are about 2200 fruits to the kilogram.

6.3.2 *Manilkara zapota* (L.) P. Royen[39]

Description

Manilkara zapota (L.) P. Royen, also known as *Achras sapota*, is a member of the Sapotaceae family. Its common names are sapodilla, sapota or zapota, and it is known locally as *chiku*.

M. zapota is an evergreen tree of medium height (5–20 metres) with dense dark green foliage. The fruits are brown round, oval or conical berries, with soft, sweet flesh containing black seeds. The tree blooms twice a year, in March–April and in August–September. The spring bloom and crop are longer than those of autumn.

38 Specific details of this investigation were as follows:

Soil conditions. EC_e and SAR values averaged over the upper 90 centimetres of the soil were 16 decisiemens per metre and 28 respectively.

Planting density. The trees were planted at 2500 stems per hectare. There was 100% survival after five and a half years.

Plant condition. The condition of the trees was poorer than that of *Tamarix aphylla* and neem (*Azadarachta indica*), probably because there was no irrigation or weed control after the first 6 months.

39 These notes were adapted from Chaudhry (1994) and Nicholson et al. (1969), p. 98.

Tolerance to salt and waterlogging

M. zapota can be grown in highly saline soils and with brackish waters on sandy soils. Successful growth of chiku with highly saline irrigation water has been seen near Muscat (Oman). In Pakistan, it is grown on a small scale in coastal districts of Sind. The species needs to be tried in salt-affected areas of Punjab.

Other comments on adaptation

M. zapota originates from the tropics of Central America, but temperatures greater than 44°C are injurious. Deep sandy loam soils are best for growth.

Uses

M. zapota produces a highly nutritious fruit.

Propagation and management

The tree can be planted from seed or propagated by grafting. In the latter case, seedlings or plants raised by the asexual method of *'gooti'* are grafted onto *'khirni' (Mimusops hexandra)* and planted on a 10-metre grid. Farmyard manure should be added at the time of land preparation before planting. Weekly irrigation during summer and the fruiting season is recommended. Fruit is picked when of full size and ripens later (in 4–6 days) during storage and transportation.

Productivity

Average fruit yields are about 150 kilograms per plant.

6.3.3 *Phoenix dactylifera* L.[40]

Description

Phoenix dactylifera L. is a member of the Arecaceae family. Its common name is the date palm, and it is known locally as *khajoor* or *khajji*.

P. dactylifera is a dioecious monocotyledonous tree with a vertical trunk of uniform girth (100–150 centimetres) covered with the persistent bases of long-dead fronds (Photo 6.19). The tree reaches a height of 30–35 metres. It has an adventitious root system.

The leaves are pinnate (compound with numerous leaflets occurring along a spine) and 3–4 metres long. Up to 30 leaves are produced annually, each lasting 3–7 years.

Photo 6.19. Phoenix dactylifera *growing on saline-waterlogged soil near Satiana.* *[PHOTOGRAPH: E. BARRETT-LENNARD]*

The young inflorescence is enclosed in a strong spathe that splits open in March–April. The male spathes are shorter and wider than the female. Each spathe encloses either 10 000–15 000 male flowers or 2000–3000 female flowers borne on a stout main axis. This axis elongates rapidly as the fruits enlarge so that the mature bunch hangs down well clear of the foliage. Seven to 12 inflorescences are produced each year. Fruits are variable in size, 1.5–5 centimetres long, and 1–2 centimetres broad. They are sweet, and reddish or yellowish-brown in colour.

Tolerance to salt and waterlogging

According to the criteria of Maas and Hoffman (see Table 4.1), dates are 'tolerant' to salinity. Their salinity (EC_e) threshold for reduction in yield is 4 decisiemens per metre, and they have a 50% reduction in yield at 17.9 decisiemens per metre (Maas 1986). We have personally observed good growth in date palms located within 100 metres or more from the sea in Muscat (Oman) where the electrical conductivity of the groundwater was around 10 decisiemens per metre.

40 These notes were adapted from Chaudhry (1994) pp. 458–461; Baqar (1995) p. 378; Nicholson et al. (1969) pp. 106–107; Maggs (1984).

Other comments on adaptation

Dates are the third most important fruit in Pakistan, covering an area of 41 800 hectares with a production of 284 000 tonnes per year (Chaudhry 1994). Sind has the highest area, followed by Punjab, Baluchistan and North West Frontier Province. The tree was probably introduced to the subcontinent by Muslims from the Middle East. For good crops, the soils should be deep, light textured and well drained. Rocky, calcareous and compact soils are not suitable. Dates grow successfully in arid hot climates and saline environments where enough water is available for irrigation. They require sunlight and are resistant to heat, withstanding temperatures up to 58°C for short periods. They can tolerate low temperatures, but do not grow below 10°C, and do not set and develop fruit until the temperatures are above 25°C. At the time of fruit ripening, temperatures should be high (45–50°C) and humidity should be low. Rains during pollination and ripening are hazardous.

Uses

Date palms are sources of fruit, sap and fibre.

- *Fruit* — dates are nourishing, sweet and tasty. They can be eaten fresh or dried.
- *Sap* — the crown of the date palm can be tapped to provide a sugary sap, which can be boiled down to provide sugar or fermented to make palm wine or 'toddy'.
- *Fibre* — date leaves can be used as a source of fibre and to make thatched roofs for huts.

Propagation and management

The plants are commonly propagated by transplanting suckers, which emerge from the ground at the base of the stem. Rooted suckers 3–5 years old are carefully removed from the parent tree and planted in February–March or August–September. The trees are planted on a grid 7 metres apart. Occasional male trees (3% of total number) are planted at suitable locations to enable pollination to occur. The important varieties of date palm are:

Sind:	Aseel
Punjab:	Hillawi, Khardrawi, Zaidi
Baluchistan:	Berni, Begum Jangi
NWFP:	Dhaki

Artificial pollination is essential for good yields. Mature male inflorescences are detached from the tree, warmed in sunlight and shaken over the opened female spathes. This has to be repeated four to five times because not all female spathes open at the same time.

Irrigation requirements vary with the stage of growth, watertable, soil type and climatic conditions. New plantations should be irrigated daily for 1 month. Mature plants require weekly irrigation during fruit development. Irrigation at other times will depend on the temperature. Use of farmyard manure equivalent to 1 kilogram of nitrogen per tree is recommended for good yields.

For proper ripening and quality, the interaction of temperature and humidity is important. Hot dry regions produce hard and dry rather than syrupy dates. High humidity may delay ripening and cause other problems like black nose. Rains during pollination and ripening seriously damage productivity.

Some pruning can be required for good yields. With the Deglet Noor variety, some green fronds are removed to reduce the humidity in the microenvironment around the fruiting bunches. In addition, the removal of spines from the base of fronds can facilitate pollination, and some fruiting strands are pruned to improve the size of the remaining fruit.

Productivity

Average yields of fruit are between 6 and 7 tonnes per hectare per year.

6.3.4 *Psidium guajava* L.[41]

Description

Psidium guajava L. is a member of the Myrtaceae family. Its English name is the common guava, and it is known locally as *amrood* (*amrud*).

The guava is a bushy tree with a spreading crown that reaches an average height of 4–5 metres. It can be readily recognised by the characteristic bark of the younger branches, which is smooth and reddish brown, and peels off in thin flakes. The fruits have a characteristic musky flavour with mild acidity. They are pendulous and highly variable in size, shape and flesh colour, and have a large seedy core. The colour of the flesh may be red, yellow or white.

41 These notes were adapted from Chaudhry (1994), Nicholson et al. (1969) pp. 98–99, Batten (1984).

Tolerance to salt and waterlogging

Guavas can be successfully grown in wet and moderately saline soils. Guava survived well but with reduced growth under saline–sodic conditions in a seven-and-a-half-year field trial near Faisalabad (Qureshi et al. 1993, Table 3).[42]

Other comments on adaptation

Guavas are frost sensitive, and tropical and subtropical climates with a distinct winter are preferred. The optimum summer temperature is 23–28°C. Rain and high humidity at ripening damage the skin of the fruit. They can be grown in a variety of soils ranging from heavy clays to sands with pH values varying from acidic to alkaline (4.5–8.5).

Guava is the fourth most important fruit in Pakistan; it is grown on 46 200 hectares with an annual production of 347 300 tonnes. It now fetches very attractive prices compared with those of a few years ago. In the Punjab, it is grown on a large scale in the districts of Sheikhupura, Gujranwala and Lahore. In Sind province, good-quality pear-shaped guavas with a small seed-core are grown in Larkana, Dadu, Shikarpur and Hyderabad districts. In North West Frontier Province, the districts of Mardan and Hazara are well known for excellent guavas.

Propagation and management

Guava is generally propagated from seed but the seedlings are not necessarily true to type. To obtain seeds, fruits are soaked in water for several days so that the seeds separate and settle at the bottom of the container. They are then planted in beds to raise seedlings. Guava can also be propagated vegetatively. Softwood stem cuttings can be side-grafted or budded onto rootstock during March–August. In the Hyderabad region of Sind, layering is also successful. In moderately saline–sodic soils, seedlings are planted on a grid 7–8 metres apart in a well-prepared soil, preferably treated with 2–3 tonnes of gypsum per hectare. Important commercial varieties of guava include Gola, Surkha, Allahabadi, Safeda, Kerala and Surahi.

Guava can bear fruit throughout the year but there are usually two distinct crops, one in summer and one in winter. In Pakistan the summer crop is often severely attacked by fruit fly; farmers have therefore started to consider winter as the cropping season. Summer fruiting is discouraged by withholding irrigation in spring and summer, and by removing any fruit that develops. Irrigation is then resumed during late summer to produce a heavy winter crop. Heavy irrigations are applied during fruiting.

Production of good winter crops requires application of nitrogen, phosphorus and potassium fertilisers. It is recommended that each tree receive applications of 500 grams of nitrogen (in two doses), 4 kilograms of single superphosphate (or about 1.25 kilograms of diammonium phosphate) and 1 kilogram of potassium sulfate, along with 40 kilograms of well-rotted farmyard manure in July–August.

Frequent pruning, weeding and insecticide spraying is necessary for a healthy crop. Fruit fly is a major problem for the summer crop. Some dieback can occur with weak and drought-stricken plants.

Productivity

Average yields are about 7.5 tonnes per hectare per year.

6.3.5 *Syzygium cuminii* (L.) Skeels[43]

Description

Syzygium cuminii (L.) Skeels, also known as *Eugenia jambolana*, is a member of the Myrtaceae family. Its common name is the rose apple or java plum, and it is known locally as *jamon* (*jaman*).

S. cuminii is an evergreen tree of the tropics and hottest parts of the subtropics. It grows to 10–20 metres in height. The leaves are coppery, oblong-lanceolate, 8–18 centimetres long and 5–9 centimetres wide. The flowers are greenish-white or pink and are borne on dense pyramidal panicles 5–12 centimetres long. The fruit is ovoid, 1–2 centimetres long and dark violet. Inside, the fruit has pale violet flesh and a central cavity containing a large seed. The flesh is tender and juicy with a special flavour suggestive of rose water and tannin. The fruit has poor keeping quality and is grown for local consumption as a dessert fruit.

42 Specific details of this investigation were as follows:

Soil conditions. EC_e and SAR values averaged over the upper 90 centimetres of the soil were 15 decisiemens per metre and 38 respectively.

Planting density. The trees were planted at 2500 stems per hectare. There was 100% establishment.

Plant condition. The condition of the trees after seven and a half years was poorer than that of *Eucalyptus camaldulensis*, *Leucaena leucocephala* and *Acacia nilotica*. This was attributed to the high sensitivity of guavas to frost on this site.

43 These notes were adapted from Ginai (1968) p. 227; Food and Agriculture Organization (1982) pp. 161–163.

Photo 6.20. Zizyphus mauritiana *on a saline soil near Satiana.* *[PHOTOGRAPH: E. BARRETT-LENNARD]*

Tolerance to salt and waterlogging

S. cuminii can tolerate salinity. In a seven-and-a-half-year adaptation trial on a saline–sodic soil at Faisalabad, it had 98% survival and similar vigour to *P. guajava* (guava) and *Zizyphus jujuba* (Qureshi et al. 1993).[44]

Other comments on adaptation

S. cuminii can be grown in all types of soils, although rich loams are preferable. The banks of rivers and canals are very suitable for commercial plantations. It requires high temperatures for the proper maturation of the fruit. Where the climate is humid, there is heavy vegetative growth but fruits do not develop well. It can withstand only light frosts.

Uses

The fruits of *S. cuminii* are highly relished when seasoned with salt, and are considered beneficial for people with enlarged spleens. It can also be used as a street tree, windbreak or ornamental. It produces large quantities of wood.

Propagation and management

S. cuminii is raised from seeds, which should be sown when fresh in the month of June or July in heavily manured nursery beds.[45] After 3–6 weeks, the seeds have germinated, and they are ready for transplanting into the field after 7–8 months. Alternatively, the seed may be sown in small beds at a depth of 2 centimetres and about 2 centimetres apart. When the seedlings are about 15 centimetres high they are transplanted into small pots; when they are 2 years old, they can be planted out into the field. The jamon seed is polyembryonic.

The seedlings should be transplanted in the rainy season into pits spaced at 10 metres × 10 metres. They do not require special training or pruning. The trees are frequently planted on the borders of fields.

Productivity

The trees begin to bear fruit after 7–8 years. The flowers appear in March and April, and the fruit are harvested in June and July. Rains during the harvesting period spoil the keeping quality of the fruit. A well-established tree will yield about 150–160 kilograms of fruit per year.

6.3.6 *Ziziphus mauritiana* Lam.[46]

Description

Ziziphus mauritiana Lam. is a member of the Rhamnaceae family. Its common name is Indian jujube, and it is know locally as *ber* (Urdu), *beri* or *mallah* (Punjabi). This species can be confused with *Z. jujuba* (Chinese jujube).

Z. mauritiana is a small to medium-sized thorny tree, rarely exceeding 12 metres tall (Photo 6.20). It has a widespread crown with drooping branches. The leaves are covered with velvety hairs on their lower surfaces, but are without hairs on their upper surfaces. Leaves are shed in March or April. Greenish yellow flowers appear from April–October and fruits ripen to a light reddish-brown colour in December–March. It is mostly grown as a windbreak or border tree. It used to be the most important tree in the rural landscape near villages but is now disappearing due to heavy lopping and browsing.

Tolerance to salt and waterlogging

Indian jujube can tolerate moderate to high salinity and sodicity.

44 For these three species, EC_e and SAR values averaged over the upper 90 centimetres of the soil were 15–19 decisiemens per metre and 38–70 respectively.

45 The seeds germinate well when fresh, but quickly lose their viability.

46 These notes were adapted from Chaudhry (1994) pp. 464–465; Baquar (1995) p. 463; Sheikh (1993) p. 133; Quraishi et al. (1993) p. 107; Food and Agriculture Organization (1982) pp. 174–177; National Academy of Sciences (1980) pp. 160–161.

Other comments on adaptation

Indian jujube is native to South Asia and grows all over Pakistan at elevations less than 600 metres. It is self-sown at elevations up to 200 metres. It prefers warm subtropical to tropical climates and an annual rainfall of 125–1000 millimetres per year. It can tolerate an extreme range of temperatures (–5 to 50°C). It is frost hardy and has a deep taproot system and is therefore extremely drought tolerant. It is commonly planted on sand dunes but grows best on deep, sandy loam soils.

Uses

Indian jujube is used to produce fruit, wood, forage and lac insects.

- *Fruit* — the fruit contains 25–30% starch, 2.5% protein, and is rich in vitamins A and C.
- *Wood* — the wood is hard and strong. It is used as fuelwood (with a calorific value of 24 721 kilojoules per kilogram), for making charcoal, for carpentry, and for the making of agricultural implements, sandals, tent pegs, golf clubs, and other products that need a durable, close-grained wood. The trees coppice well and grow vigorously from stumps and root-suckers.
- *Forage* — the young branches and leaves are browsed by livestock. Trees are therefore heavily lopped.
- *Lac insects* — this is one of the few trees that can be used to host lac insects. The resinous encrustation from these insects is used to produce shellac.

Propagation and management

Commercial varieties are budded or grafted. Seedlings are used as rootstock. Seeds need scarification to reduce germination time (see Box 6.1), and germinate *in situ* in 3–6 weeks. At the age of about 18 months, established seedlings are pruned to one shoot, and commercial material is shield budded to the seedlings. Budding is done in March–April or August–September. Varieties of grafted material include Umran No. 9, Umran No.13, Kernal, Local and Gohr. Trees are planted 12–13 metres apart in orchards, and 8–10 metres apart in windbreaks. Fruit is borne on the new growth, therefore pruning every 2–3 years is essential. Although the plant is highly drought tolerant, irrigation during fruit development and application of about 20 kilograms of farmyard manure during the rainy season will improve yields. Fruit fly is a serious pest and should be controlled by insecticide sprays.

Productivity

The average annual yield of fruit is about 100 kilograms per plant.