INTRODUCTION

India covers an area of 3.29 million km^2. Of this total, 51% is characterised as arable land, 16% as forest, 4% as permanent pasture and other grazing land, and 29% as degraded land unsuitable for cultivation. The eco-climate of the country varies from extreme arid to super humid. The arid and semi-arid regions together constitute over 40% of the country's total land surface and are spread over ten States (Table 1). The climatic conditions in these areas do not support much growth and regeneration of plant species. Consequently, the vegetation is quite sparse. The forest cover in arid and semi-arid tracts of India varies from 1 to 10%. Furthermore, the forests in these regions are not species rich.

Table 1. Extent of arid and semi-arid regions in India.

State	Percentage of total land area	
	Arid	Semi-arid
Andhra Pradesh	7	14
Gujarat	20	9
Haryana	4	3
Karnataka	3	15
Madhya Pradesh	0	6
Maharashtra	<1	20
Punjab	5	3
Rajasthan	61	13
Tamil Nadu	0	10
Uttar Pradesh	0	7

From time immemorial, human populations in arid and semi-arid regions have used the forest/woody resources freely for subsistence agriculture and for other small-scale economic activities like iron working and carpentry. Trees in the farming systems of arid and semi-arid tracts supply considerable amounts of timber, fuel and fodder. However, with ever increasing human and livestock population pressure during the last half century, deforestation has reached an alarming stage. This state of affairs has created a wide gap between the demand and supply of forest products. For example, the availability

of fuelwood from legitimate resources in India during 1980 was 17 million m^3 against the actual demand of 184 million m^3. The demand is expected to increase to 225 million m^3 by the year 2001. Since wood remains the main source of cooking fuel for about 70% of the population, it is obvious that much of the wood comes from illegitimate felling and cutting of trees. Though this trend is similar for the entire country, it is particularly so in arid and semi-arid regions.

Since colonial times, planners, policy makers and forestry experts have given much emphasis to introducing fast growing and well adapted exotic woody species from iso-climatic regions of the world into arid and semi-arid India. Some of these exhibited remarkable adaptability and growth in their new habitats. *Prosopis juliflora* (Swartz) DC is one of these species that has performed much better than many native woody species. At the moment, *P. juliflora* provides approximately 75% of the fuelwood needs of rural people in arid and semi-arid regions of India. The species has become naturalised and has spread over the greater part of north-west, central, west and south India.

With its tremendous ability to adapt to arid and semi-arid environments, and its fast growth and multiple utility, it has long been recognised by foresters as a versatile species for afforestation. However, rural people in arid and semi-arid regions of India are a little apprehensive of this species as (i) they consider that the species adversely affects crop growth and production; (ii) there is a fear that it may become a weed; and (iii) the thorny stems and branches of the species often cause injury to humans and animals, and hinder agricultural operations.

Whatever advantages and disadvantages may be associated with the species, *P. juliflora* has become a prominent woody species in agro-ecosystems of arid and semi-arid regions of India. The species is used widely in plantation forestry activities in wastelands, village common lands, grazing lands, along railway lines and roads, canal and village pond banks, and degraded forested lands. Moreover, natural regeneration is profuse throughout the entire arid and semi-arid regions of the country.

Although *P. juliflora* is of great importance to most rural communities in arid and semi-arid tracts of India, its full potential in the rural forestry sector has not been realised to the extent that it deserves. In particular there is a need to increase the level of information related to plantation,

management and utility of this multipurpose species among rural communities and developmental agencies such as state forest departments, agriculture departments, district rural developmental agencies and non-governmental organisations.

This technical manual on *Prosopis juliflora* provides basic information and guidance to rural people and to those who instruct farmers and land managers on the use of this species in various environments and agricultural settings. The manual aims to (i) provide techniques for nursery production, out-planting, plantation care and management of the species, and (ii) guide the users regarding utilisation of the species. The techniques described may also be suitable for management and processing of other tree species with similar characteristics.

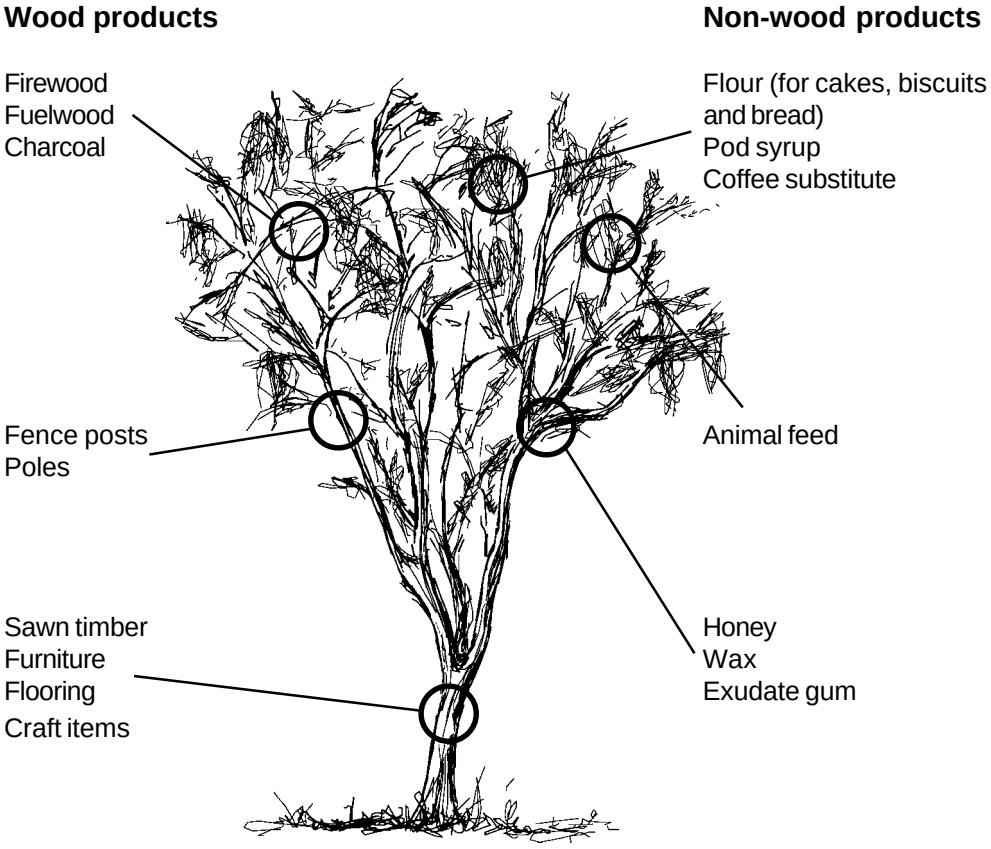

Figure 1. Successfully marketed *P. juliflora* and *P. pallida* tree products.

I. DISTRIBUTION OF *PROSOPIS*

The history of the first introduction of *Prosopis juliflora* into India is about 130 years old. Introduction of the species was first seriously attempted in 1870. Owing to its fast growth and drought hardiness, the species has since been introduced in many other parts of India from the north-west to extreme southern parts. The species proved its potential as a versatile plantation forestry species from the very first introduction and has been grown in highly saline areas, alkaline soils, coastal areas, sand dunes of the Thar desert, in ravines of many north, central and south Indian rivers, and in dry and degraded grasslands.

P. juliflora has become an acclimatised exotic in large parts of arid and semi-arid tropical India (Figure 2). It is found especially in areas with 150-750 mm mean annual rainfall and maximum shade temperatures of 40-45^{o}C. From north-west to south, the species is distributed from the States of Punjab to Tamil Nadu, and in an east-west direction, it is found from Kutchh region of Gujarat State to drier parts of Orissa. The States where it mainly occurs are: Andhra Pradesh, Delhi, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh. The domain of the species in arid and semi-arid tropical regions is mostly in plains and valleys but in many places it grows at altitudes of up to 1200 m above mean sea level.

Box 1. The potential for *Prosopis.*

Salt affected lands in India account for ten million hectares (ha). Thirteen million ha of wastelands in arid and semi-arid tracts can support plantations of drought hardy woody species. Thus, 23 million ha are readily available for plantations of *P. juliflora*. Considering an average production (a conservative estimate) of about 3 m^3 per ha, the annual production could be approximately 70 million m^3, which represents about 250% of the current annual production of fuelwood from forest resources in the country.

P. juliflora is capable of growing in a wide variety of soils and situations. It is, however, generally not found in frost prone areas, the Himalayan region or in warm humid tracts such as the north eastern region, West Bengal and Kerala. However, in Kerala, and

also in Bihar and Orissa, farmers use the species as a live fence around fields and farms.

The most abundant distribution of this species is found in the Kutchh region of Gujarat, the arid western part of Rajasthan, western and south-central parts of UP, the western part of Haryana, and in a few pockets of extreme north Andhra Pradesh. In its entire range of distribution, thickets of the species are found here and there in a variety of habitats and settings. Block plantations of the species are very few but the species is planted systematically along road sides, railway lines, canal banks, village pond sides, village common lands and farm boundaries.

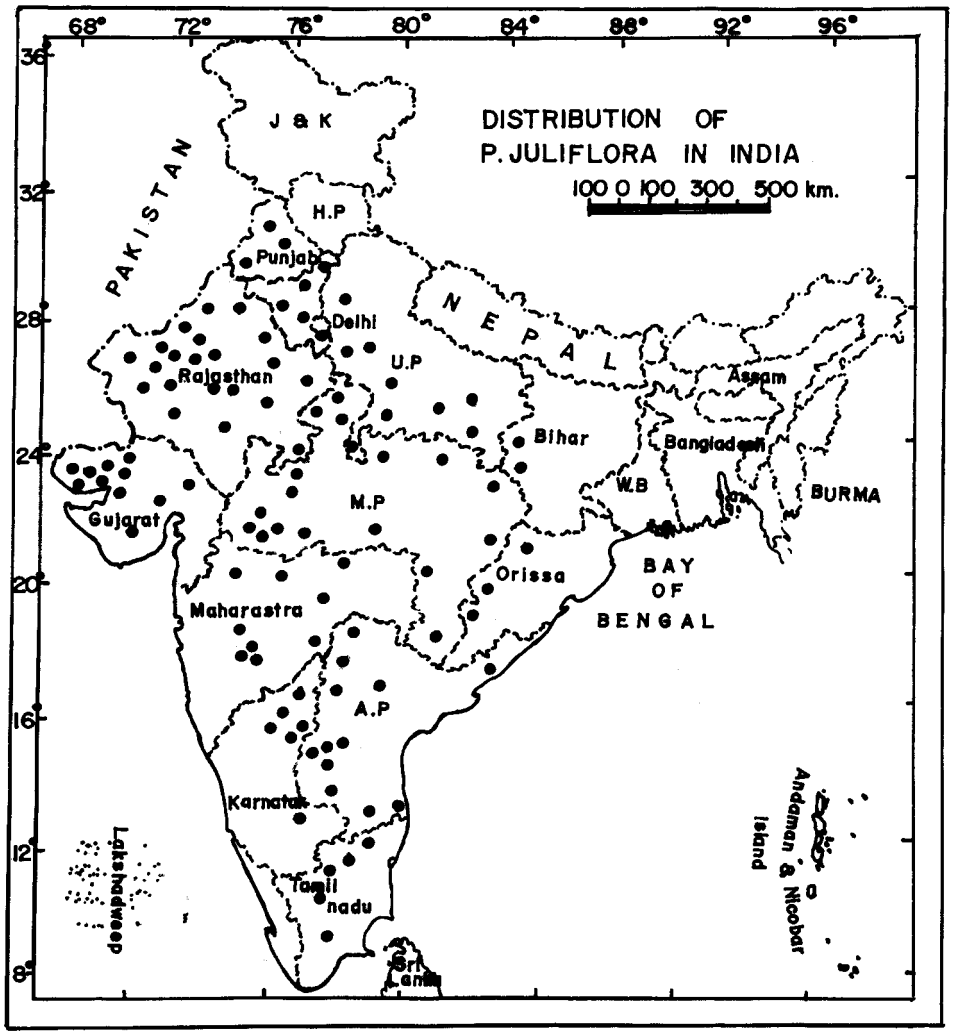

Figure 2. Distribution of *P. juliflora* in India.

Box 2. *Prosopis* advancement in Kutchh.

The State Forest Department of Gujarat initially planted exclusively *P. juliflora* on about 31,550 ha of Banni grasslands of Kutchh to check the advancement of Rann. The prevailing conditions in Banni, including successive droughts, increasing salinity and excessive grazing pressure, provided a highly suitable environment for the growth and spread of the hardy *P. juliflora*, which is today a dominant species of the vegetation complex. In fact, it ranks first in terms of distribution, abundance and aggressive encroachment of rangelands. It has been reported that the area under *P. juliflora* has increased from 378 to 684 km^2 (an 81% increase) in 12 years (i.e. 1980-1992). Analysis of remote sensing data clearly stated that the species is expanding in the Banni area at a rate of about 25 km^2 per year.

P. juliflora occurs most frequently as bushy thickets, and dominates wastelands and degraded grazing lands, around river beds, roads, railway lines, canals and other fallow lands. Farmers do not allow the species to grow on cultivable land because of its strong and sharply pointed thorns and also because of their apprehension that the species adversely affects crop growth and production.

In addition to *P. juliflora*, a few other exotic *Prosopis* species, mainly of Latin American origin, *P. alba, P. chilensis, P. glandulosa, P. flexuosa, P. nigra,* and *P. pallida* have also been introduced into India. However, the history of introduction of these species is only a few decades old. To date, most planting of these species is still at an experimental stage in the premises of research and development institutions. This manual deals mainly with *P. juliflora* but, when this species was introduced, many seeds of other exotic *Prosopis* species like *P. chilensis*, *P. alba* and *P. pallida* were mixed in the seed lots. On close examination of *P. juliflora* stands, from north-west to extreme southern parts of India, one can find the individuals of other exotic *Prosopis* species scattered here and there along with *P. juliflora*. As the taxonomy of the genus *Prosopis* is very complex and confusing, an understanding of at least basic structural features of the various species to differentiate them is required. However, it is beyond doubt that, today, *P. juliflora* is amongst the most widely distributed woody species in India.

II. THE INTRODUCED *PROSOPIS* SPECIES

This section aims to provide users with a brief guide to the genus *Prosopis* and especially *Prosopis juliflora* for correct identification. The distinctive features of some important introduced *Prosopis* species in India are described.

The genus *Prosopis* is widespread and consists of 44 species, mostly thorny trees and shrubs. The area covered by the genus spreads over dry tropical and sub-tropical regions of America, Africa and Asia. In India, besides the introduced *P. juliflora*, the most commonly occurring *Prosopis* species is *P. cineraria*, which is indigenous to Indian sub-continent.

To recognise the different introduced exotic *Prosopis* species in India, features have been identified by studying samples from several plants for each species. However, these features are intended only as a guide, as variations are encountered among individuals. Therefore, to identify a species, samples from several individual plants should be studied and compared with identification features of each species.

Figure 3. *P. juliflora* near a household in a village.

A. *Prosopis juliflora* (Swartz) DC

Common names: Mesquite and honey mesquite (English-USA), algarrobo (Spanish-Latin America), vilayati babool (Hindi), vilayati khejra (Hindi, especially Haryana), vilayati kikar (Marathi), angrezi bavaliya (Marwari), gando baval (Gujarati), belari jari (Tamil).

Features

In areas where it is widespread, *P. juliflora* commonly takes the form of a spreading shrub. This is due to the fact that people cut the plant for fuelwood as soon as it reaches 1-1.5 m high and new coppice shoots emerge in the subsequent growing season. However, the tree form is also common (Figure 3).

The species seeds prolifically and has tremendous regeneration capacity, and can withstand droughts even at seedling stage. Where most other species fail to withstand drought and environmental harshness, *P. juliflora* can successfully establish and colonise wastelands and other similar habitats.

Stems and leaves

In India, the shrubby thicket form with spreading branches is common. The stem height of these shrubs varies but generally ranges between 1 and 3 m. The tree form varies from 4-12 m or sometimes even more (especially in valleys, areas with more moisture and also in well protected areas). The clear bole length of tree forms range from 1-3.5 m. The tree bark is 2-3 cm thick, grey or dark purple with a blackish tinge, splitting off in long strips. Branches have thorns which are usually paired, straight and up to 5 cm long. The branchlets are zig-zag, cylindrical, green and spiny with persistent, green foliage. These are typical features of shrubby thicket forms. The dark purple wood is very hard.

Leaves cluster on short shoots along the branches. They are bipinnate, with 13-25 pairs of obliquely oblong, dark green leaflets per pinna (Figure 5). The leaflets are generally 5-24 mm long, 1.5-5.2 mm wide and spaced along the rachis usually at a greater distance apart than their width.

Flowers

Inflorescence is an axillary spike, 8-10 cm long and bearing greenish-white flowers that turn light yellow when mature. Plants start flowering at three or four years of age. The calyx is five-toothed, campamelate, one mm long. The corolla is pentamerous free, tomentose, on the inner surface towards apex. There are five stamens which are 3-6 mm long. The plant flowers three times a year, in August-September, November-December and February-March. Trees usually start flowering earlier in the south than in the north. The fruits or pods from August-September flowering mature by early November and those from November-December flowering ripen by late February to early March. The pods from February-March flowering mature by early May. Thus the plant appears to be flowering almost any time of the year except from hot summer (May) to mid rainy season (August).

Pods and seeds

The pods are usually flattened and straight, but incurved at the apex. Some pods may be sickle shaped. In general, pods are 6-30 cm long, 5-16 mm wide and 4-9 mm thick. With age, the pods swell and become pulpy and yellowish brown in colour. The prominent outline of seeds in immature green pods is no longer discernible in mature pods. The endocarp may have up to 29 rounded, rectangular segments, each carrying a seed. The seeds are hard, flattened, 7 x 4 mm in size and ovoid, and have shiny yellowish brown colour.

B. *Prosopis pallida* (Humboldt & Bonpland ex Willdenow) HBK

P. pallida is native to Peru, Colombia and Ecuador and was introduced systematically in India only two decades ago. However, a few plants are found in old and dense *P. juliflora* thickets in arid regions of India. Seeds of this species may also have been mixed in with *P. juliflora* seed lots during introduction. At Jodhpur (Rajasthan), it was first systematically introduced in 1985 in an experimental plantation and a second experimental plantation was established in 1991. Other experimental plantations of the species are located at Karnal (Haryana), Lucknow (UP) and Phaltan (Maharashtra). The species is a valuable shade tree in dry areas and its pods are used for forage.

Common names: Algarroba, algaroba, huarango (Spanish-Latin America), Peruvian *Prosopis* (English). In India those who can differentiate introduced *Prosopis* species call it thornless vilayati babool.

Features

It appears that *P. pallida* has the best tree form among the introduced *Prosopis* species in India. In a decade-old plantation at Jodhpur, some individuals have attained a height of 10 m. The collar diameter is on average 20 cm. The species is a prolific pod/seed bearer.

Stems and leaves

The plant is reported to assume a height of 8-20 m with a trunk of 60 cm in diameter in favourable and protected sites. The majority of accessions introduced in India are not armed with spines and, therefore, are often referred to as thornless exotic vilayati babool. In other types, branches have paired and axillary spines which are less than 4 cm long. In India, they are less than 1 cm long, but thorns are not common in any plantations of the species raised so far.

Leaves and leaflets of *P. pallida* are much smaller than those of *P. juliflora.* There are up to 4 pairs of pinnae per leaf (Figure 6), but in the majority of cases only one pinnae is observed. The pinnae are 1.5-6.2 cm long with a cup shaped gland at the junction with the petiole. There are 6-15 pairs leaflets per pinna. The leaflets are arranged very close on the rachis but they do not touch at any point. Leaflets are oblong to ovate and 2.4-8 mm in length and 1.2-4 mm in width.

Pods are straw-yellowish in colour. They are straight or curved and resemble *P. juliflora* pods but they are relatively thicker. They are 9-24 cm long, 1-1.4 cm broad and 5-9 mm thick. The segments of the pods are broader than they are long. There are up to 28 oblong seeds in each pod. Seeds are brown in colour and their length is about 6 mm (Figure 4).

Figure 4. *Prosopis pallida* showing position of seed.

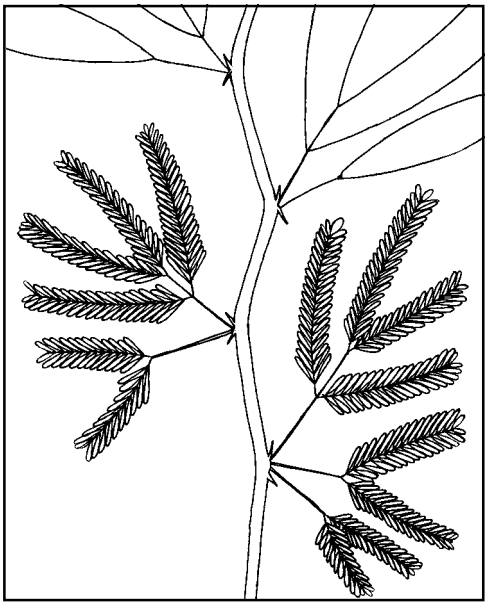

Figure 5. *Prosopis juliflora* (x 0.3).

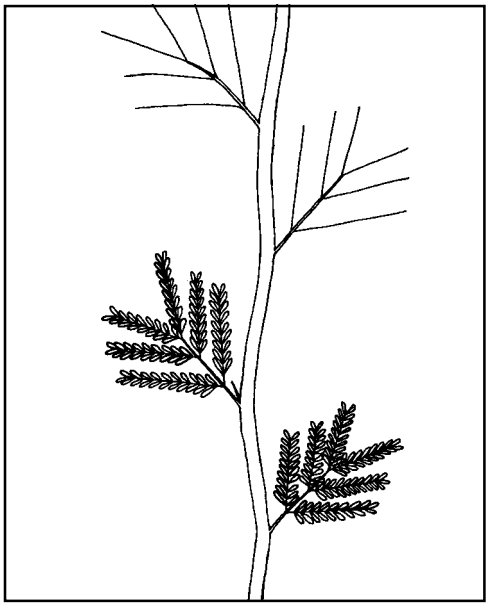

Figure 6. *Prosopis pallida* (x 0.3).

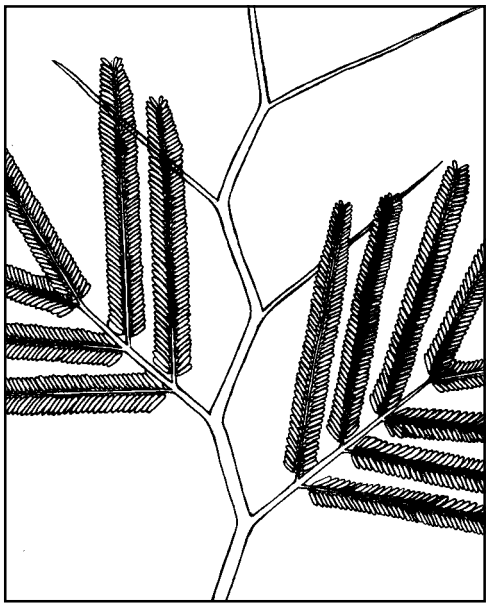

Figure 7. *Prosopis alba* (x 0.3).

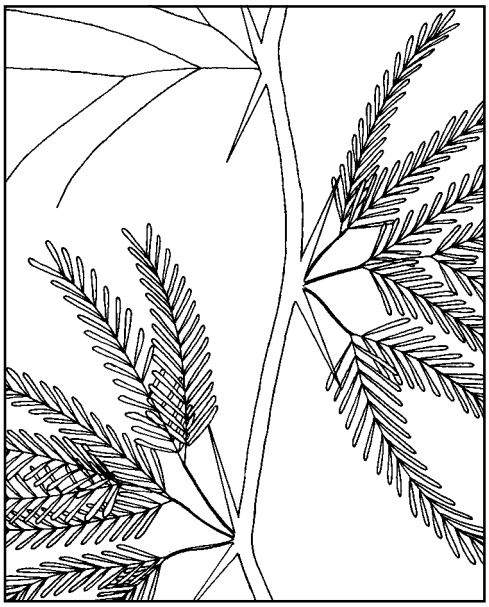

Figure 8. *Prosopis chilensis* (x 0.3).

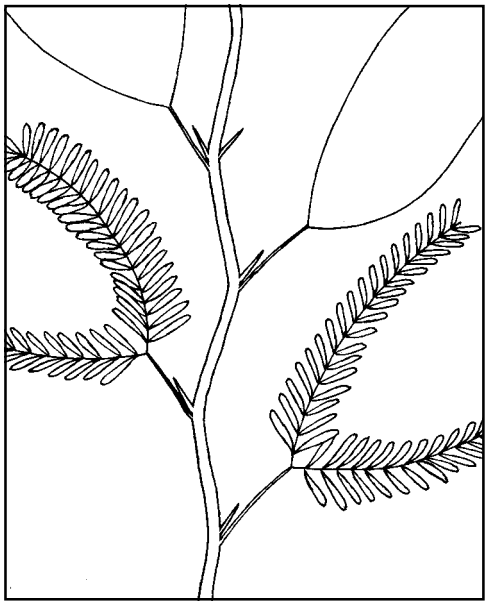

Figure 9. *Prosopis glandulosa* (x 0.3).

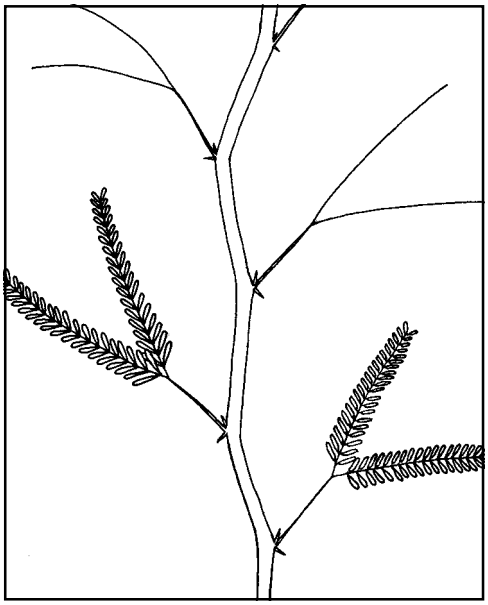

Figure 10. *Prosopis flexuosa* (x 0.3).

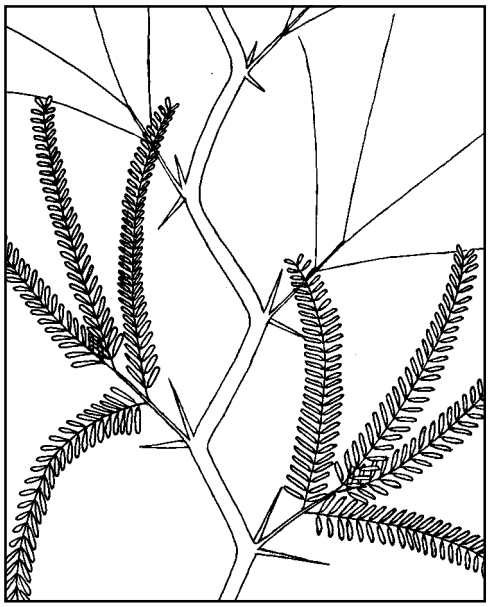

Figure 11. *Prosopis nigra* (x 0.3).

C. *Prosopis alba* (Grisebach)

Common names	Algarrobo blanco (Spanish Latin America), alba (India).
Form and size	Tree form, 7-15 m high and 45-48 cm diameter.
Leaves	Leaflets are much smaller than that of *P. juliflora*, with many more pinnae. 3-4 pairs pinnae per leaf.
Spines	Hardened stipules, paired, small and scarce and found only in strong shoots. Spineless trees have been found.
Pods	Sickle or ring shaped, straw-yellow in colour, linear and compressed with parallel margins. 10-23 cm long, 8-20 mm wide and 4-5 mm thick, with 12-30 endocarp segments that are more broad than long.
Comments	Pods are sweet and make excellent livestock food.

P. alba was introduced to India in Jodhpur (Rajasthan) in the early 1980s. It has also been introduced to other areas such as Karnal (Haryana), Lucknow (UP) and Phaltan (Maharashtra). The species is not widespread, however it is gradually occupying space in arid and semi-arid tracts of Rajasthan, Gujarat, Maharashtra and UP through systematic plantations by the forest departments of respective states (Figure 7).

D. *Prosopis chilensis* (Molina) Stuntz emend. Burkart

Common names	Algarrobo blanco (Spanish Latin America), vilayati babool (Hindi). Vilayati babool is used to describe both *P. juliflora* and *P. chilensis* in India.
Form and size	Tree form in protected sites. Bushy unless managed. 5-11 m high
Leaves	Leaflets are much larger, more widely spaced and on a longer rachis than *P. juliflora*. Normally only 1 pair pinnae per leaf.
Branches	Flexuous, knotty and partly spinous
Spines	Spines Paired and axillary, and some reach 6-7 cm in length, but not all nodes.
Pods	Straight or sickle shaped, flattened and linear. 10-16 cm long, 1-0.5 cm broad and 0.4-0.5 cm thick with parallel margins.
Comments	Trees are sometimes deciduous. Pods are excellent fodder and timber is excellent as construction material.

P. chilensis is often found in association with *P. juliflora*. This may be because some seeds of *P. chilensis* were mixed with the seeds of *P. juliflora* during its introduction. In the last two decades, a few plantations of *P. chilensis* have been raised at Jodhpur (Rajasthan), Lucknow (UP), Karnal (Haryana) and Phaltan (Maharashtra) (Figure 8). The name *P. chilensis* has often been misused to describe *P. juliflora* (Swartz) DC.

E. *Prosopis glandulosa* (Torrey)

Common names	Honey mesquite (English-USA), bilayati kikar (Punjabi).
Form and size	Shrubby, but good management can produce a tree form. 3-9 m high.
Leaves	Leaflets are large and widely spaced, similar to *P. chilensis*.
Spines	Axillary and 1-4.5 cm long. Usually the spines are solitary but in some individuals are paired.
Pods	Curved or straight. Linear, flat. Yellow. 8-20 cm long, 0.9-1.4 cm broad and 0.4-0.7 cm thick. Similar to *P. juliflora*.
Comments	Good fodder and fuelwood. Excellent source of nectar for honey bees. Trees are deciduous.

P. glandulosa was introduced to India in the early 1890s. Experimental plantations of the species exist at Jodhpur (Rajasthan), Phaltan (Maharashtra) and Lucknow (UP) (Figure 9). Natural stands are found in Punjab and Haryana, particularly in association with *P. juliflora.*

F. *Prosopis flexuosa* (DC)

Common names	Algarroba (Spanish-Chile), lamaro (Spanish-Argentina).
Form and size	Erect shrub form, but in protected sites, with proper management it can also take a tree form. Shrub 3-5m high. Tree 10 m high.
Leaves	Leaflets are smaller than those of *P. juliflora*. There is one pair of pinna per leaf.
Branches	Zig-zag appearance. Drooping ultimate branchlets.
Spines	Spines are small or absent. White with yellowish tinge or yellow. Axillary and paired. 3-5 cm long.
Pods	Often nearly straight but sometimes arched. Yellow with black-violet tinge. Pod pulp is very sweet. 5-28 cm long and 0.7-1.2 cm broad with undulating margin.
Comments	Trees are deciduous. Good fodder (pods), fuel and flooring in houses.

P. flexuosa is commonly found in northern Chile. Its introduction to India is very recent. It was introduced to Jodhpur and Karnal in the early 1990s (Figure 10).

G. *Prosopis nigra* (Grisebach) Hieronymus

Common names	Algarrabo negro (Spanish-Argentina), kala vilayati kikar (Hindi).
Form and size	Tree form. 4-10 m. Stem has persistent fissured dark bark.
Leaves	Leaflets are small and similar to *P. flexuosa*. There are normally 2 pairs of pinnae per leaf which are much longer than other species.
Branches	Flexuous and erect long shoots are quite spiny. Ultimate branchlets are downward arching and almost spineless.
Spines	0.4-3.4 cm.
Pods	Mature pods are yellow with slightly violet tinge. Thick and fleshy. 10-15 cm long and 0.5-0.9 cm broad.
Comments	Valuable timber tree. Pods are very sweet.

P. nigra is native to Bolivia, Argentina and Paraguay. It was introduced to India only fifteen years ago (Figure 11).

III. POD COLLECTION, STORAGE AND SEED EXTRACTION

The methodologies described in this section from pod collection to clean seed extraction are simple and practical. A nursery grower, whether he/she is a farmer, a nursery manager of an established nursery belonging to a Government Department, NGO or private company, or even a novice in the field, can easily obtain good quality seeds if the procedures are followed step by step. Knowledge and experience of these methodologies form the sound foundation of raising quality stock of the species in the nurseries.

This section deals with *P. juliflora,* but the same methods can also be used with seed of other introduced *Prosopis* species.

A. Collection of pods for seeds

Although pods appear continuously from November to May, the plant canopy is fully laden with ripe pods from November to December and from March to May (Figure 12 and Figure 13).

Collection of pods from trees

If pods are to be used for planting, they should be collected from trees that have been identified for desirable traits such as erect form, high pod production, spinelessness or very few spines. November to December and March to May are the best times for pod collection.

P. juliflora pods can be collected from trees by;

- manual shaking (pole and rope method)
- manual shaking and cutting-sawing method

Manual shaking is a useful method as the mature pods are easy to detach. In shrubby forms of the species this method is quite workable. However, branches cannot be shaken directly by hands as they contain numerous spines. Therefore, branches are shaken using a pole or a rope thrown over the branches.

In India, the most common method of collecting *P. juliflora* seed is a combination of manual shaking and cutting-sawing methods. A bamboo pole (6-8 m long) which is permanently fixed to a serrated

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Figure 12. Canopy of a *P. juliflora* tree laden with pods in December.

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Figure 13. A bunch of *P. juliflora* pods.

steel sickle is used in this method. The pod collector brings the sickle close to the bunch of pods by raising the bamboo pole and then pulls it down in one stroke. In the process, mature pods fall to the ground. This simple tool is very good for collecting seeds from the middle portion of the crown of erect trees. By using the reverse (blunt) side of the sickle, the collector can harvest pods from branches higher in the crown by beating them a few times.

A canvas should be spread on the ground to collect pods that fall. Pods are then transferred into sacks, usually in 5-10 kg or 15-30 kg lots depending on the amount harvested. While filling the sacks, pods that appear immature or diseased should be discarded.

Naturally fallen pods

Pods that have fallen naturally on the ground can be collected, but their viability may be low due to the following:

- cattle, sheep, goats and other animals may eat and damage many of the pods.
- the seeds are more likely to have been destroyed by seed-eating insects.
- fungi that adversely affect seed health may infest pods that lie on damp ground.

If pods are collected from the ground for seed, the following points should be carefully considered:

Pod size: Only healthy pods with an average length of more than 10 cm and width over 0.5 cm, and with a sufficiently thick mesocarp, should be collected.

Collecting time: The first pods to fall naturally are often of poor quality. In the November to December fruiting season, collection should begin only at the end of November as half of the pods ripening earlier than this are not fully mature.

Damage: Insect, bird, livestock or fungi damaged pods should not be collected even if the damage is very slight. Small round holes with the pulp coming out in a powdery form or a scratched seed surface, are symptoms of bruchid (commonly known as seed weevils) damage. These pods should not be collected for seed but can be fed to livestock.

B. Pod drying and storage

After collection, the pods should be brought to a storage place or nursery. Debris mixed with the pods at the time of collection should be removed by hand. Individual pods should be separated if they remain in bunches. Now the pods are ready for drying.

Drying

The most common method used for drying pods in India is sun drying. Pods are spread on the ground after sunrise and returned to sacks at sunset. From March to May, pods should be dried in the shade as temperatures are very high. This process is repeated for two or three days or up to five days if necessary to reduce the moisture content to 6-10%.

***Precaution*: Drying should always be carried out on clear and sunny days. If the process is carried out on a cloudy day, when the winds are moisture laden, it is likely that pods will re-absorb moisture.**

Storage

Once the pods are dried, they are ready to be stored. Before treating and storing check the pods one more time for signs of insect damage or fungal attack which may have occurred during the drying process. Discard any damaged seed.

***Precaution:* Stored damaged pods are a risk as they are likely to infect and destroy the other clean pods.**

To minimise insect attack, it is recommended that pods are first treated. Using neem is a traditional and effective way of treating seeds and pods. If the problem persists seek the advice of an expert.

Box 3. Using neem to prevent storage damage.

Neem can be used in many ways to protect stored pods or seeds. For example, if pods are stored in a container, a 1.5 cm layer of fresh neem leaves, is placed in the bottom of a storage container. Then a layer of sun dried pods/grain (up to 30 cm) is placed on top of this followed by another layer of neem leaves. These layers can be repeated until the container is full, finishing with a thicker layer of leaves.

If grain is being stored in sacks, neem leaf powder can be mixed directly with the grain. Mix 1 or 2 kilograms (kg) of powder to 100 kg of grain. Alternatively, neem oil can be used. Mix 2 to 3 ml of neem oil for every 1 kg of seeds before storing. The oil may have a bitter taste but it is not reported to change the taste of stored beans for humans to eat.

Dry pods can be stored for two to three years. Store the pods using either of the following methods. The choice of method depends on convenience and available resources.

- air-tight tin or aluminium containers with 20-25 kg storage capacity
- jute sacs (70 x 110 cm) with 40-45 kg capacity
- storage structures made from mud with a thatched roof with 1-1.5 t capacity

Box 4. Pods for fodder.

In India, *P. juliflora* pods generally are not stored for a long duration, as is practised for other types of fodder. The pods are generally only collected during the peak fruiting season as a livestock ration for 4-5 days. Once it is exhausted, then fresh collections are made for the next 4-5 days. As fruiting occurs continuously from November to May, at most times, grazing goats, sheep and cattle eat the pods as soon as they fall from trees naturally or after manual shaking.

In South America, *Prosopis* pods are also gathered and stored in sacks, baskets, brick rooms or wooden barns. They are then either sold or used in times of forage scarcity.

C. Seed extraction

Within the pod, the seeds are embedded in a pulpy matrix. The seeds are separated from each other by compartments. An impermeable protective covering surrounds each seed. Pods broken into segments can be used to propagate the species but the resulting seed germination is very poor.

For better germination and growth, it is essential to have pure and clean seeds. The following methods are commonly used to achieve this and the choice of method depends on convenience and available resources:

- feeding pods to livestock
- mechanical methods
- mechano-chemical method

Feeding pods to livestock

The collected pods are stall fed to ruminants, for example cattle, buffalo, sheep and goat. (Figure 14 and Figure 15). Seeds recovered from the faeces are washed thoroughly. While the seeds pass through the animal they are subjected to the mild acidic action of digestive juices which helps germination, however:

- such seeds often have less than 40% germination when sown in the nursery
- this method is not feasible when large quantities of seed are required

Figure 14. An ass feeding on *P. juliflora* pods.

Figure 15. *P. juliflora* seeds spread on the ground in animal dung.

Mechanical methods

A few mechanical methods are available to extract clean seeds from the pods. However, they are not widely used in the country. Their use is limited to some research and development organisations and a few tree nurseries of State Forest Departments.

Box 5. Adapting equipment for *Prosopis* seed extraction.

A **meat grinder** with some modifications has successfully been used to clean seeds. Dried pods are placed in a meat grinder with an end plate having 9.5 mm diameter holes. Operating the grinder liberates 20% of seeds from the pods. The rest of the seeds remain within the endocarp. The 9.5 mm end plate in the grinder is then replaced with one having 6.35 mm holes and the encapsulated seeds obtained in the previous grinding operation are further ground. By this operation the endocarp is removed from the remaining 80% of the seeds and clean seeds are obtained. This method is suitable for medium size nurseries as 7000 clean seeds per hour can be processed. It is quite easy to purchase a meat grinder from the market and obtain the correct size end plates from a small iron works enterprise.

Mechano-chemical method

This is the most widely used method to obtain clean seeds from pods and large quantities of seeds can be extracted. This method is practised in almost all parts of the country where *P. juliflora* grows. It is a suitable method for nursery growers and can be adopted by farmers. It involves both mechanical and chemical treatments. Follow these steps:

1. Break the pods into segments by repeated hammering with a wooden hammer.
2. Separate the encapsulated seeds from the sugary mesocarp by soaking in either 2-3% solution of hydrochloric acid (HCl),or 1% solution of sodium hydroxide (NaOH) for a period of 24hrs.
3. Wash the seeds thoroughly with water and dry in the sun for one whole day.
4. The following day thresh the dried encapsulated seeds by driving a tractor over them.

IV. RAISING *P. JULIFLORA* IN THE NURSERY

In nurseries, *P. juliflora* is propagated mostly from seed. Although it can also be propagated through cuttings, seed propagation is easier and more cost effective. The procedure to obtain clean seeds has been discussed in Chapter 3. This chapter deals with essential elements of raising nursery plants. Instructions are given step by step for better management.

A. Seed pre-treatment

Seeds of *P. juliflora* which have been stored have hard, impermeable coats which stops them from germinating because no water can reach the seed. Water is the trigger for germination, so it is essential to break the hard coat of *P. juliflora* seeds in order to raise seedling stock.

Several pre-treatments have been recommended and their suitability and efficacy differ from situation to situation. In general, according to the nature and size of the nursery, three scarification pre-treatments are recommended:

- mechanical
- chemical (acid)
- hot/boiling water

Mechanical scarification

For small-scale nurseries where relatively few (5-10,000) seedlings are raised, mechanical scarification is the best proposition as germination is always over 95%. All methods of mechanical scarification aim to weaken or puncture the hard seed coat of the species to facilitate better and quicker water absorption, and gaseous exchange, which allow germination.

The seeds of *P. juliflora* can be scarified by making small scratches on the seed coat of each seed with sand paper, by cutting the seed coat with a knife, or with a hot needle.

Sand paper: Place a seed on a sheet of sand paper and then rub it across with a finger.

Knife: Take a sharp knife or blade and hold the seed in fingers and cut a small portion of the seed coat. Take care to avoid the embryo at the pointed end of the seed.

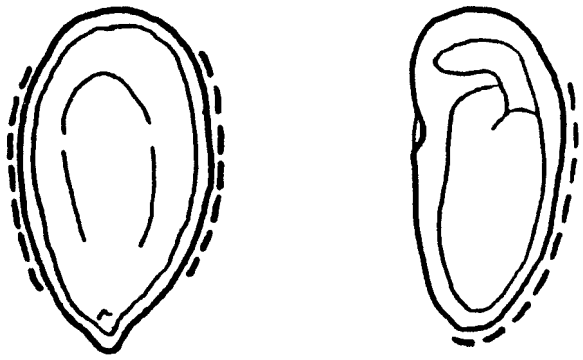

Figure 16. *Prosopis juliflora* seed showing where the seed coat may be correctly scarified (Source: NFTA).

Hot needle: Place the clean seeds on a table and take a long iron needle with a plastic or wooden handle. Heat the needle tip in the flame of a spirit lamp or candle and put the red hot tip of the needle in the centre of the flat surface of the seed for a few seconds. This method can scarify 2000-2500 seeds in an hour.

Chemical (acid) scarification

Mechanical treatments are too costly and time consuming for large-scale commercial or State nurseries, which produce many thousands of seedlings. In these nurseries, chemical treatment of seeds is the only viable proposition. Sulphuric acid (H_2SO_4) treatment is the best option when large quantities of seeds are to be treated and can lead to 80-90% germination.

Precaution

- **Treating seeds with sulphuric acid requires a certain degree of skill and great care because concentrated sulphuric acid can burn the skin.**
- **Acid should only be used by workers who have been thoroughly trained.**
- **Workers must wear protective clothing.**
- **If acid is splashed on clothes or the skin, remove clothing and wash thoroughly immediately with large quantities of water.**

The method for scarifying using sulphuric acid is outlined below:

1. Put the quantity of seeds to be treated in a flat 'Tagari' (a circular broad based iron pan, 60-70 cm in diameter, 10 cm in depth).
2. Add the sulphuric acid drop by drop, gently stirring the seed continuously with a wooden stick as the acid is poured. You will need approximately 0.5 litres of acid for 1 kg of seed.
3. Observe the seeds thoroughly. Once all the seeds have been soaked in the acid, stop pouring the acid and continue stirring.
4. After some time the seeds will start sticking to one another and cracks will develop in the seed coats. During summer months, when the air temperature is very high this takes 5-8 minutes but during winter it takes 10-15 minutes.
5. Soon after the appearance of cracks on the coat of seeds, stop the stirring process and transfer the seeds to a bucket full of water for washing.
6. Wash the treated seeds two or three times in clean water. If running water is available, wash the seeds in it thoroughly.
7. After that, spread the seeds on a cloth or on a pucca floor for air-drying for few hours.

Boiling water scarification

For Kisan nurseries, when farmers themselves raise seedlings in the vicinity of their farms, boiling water is the most suitable pre-treatment for breaking hard coat dormancy and can give 60% germination.

1. Boil the water in a large pan. Boil enough water to cover the seeds.
2. Pour the boiling water onto seeds kept in another pan and leave it to cool down.
3. Leave the seeds in the water for 24 hours.

With practice, farmers can also scarify small numbers of seed mechanically as described above.

B. Nursery techniques

Propagation by seeds

Raising *P. juliflora* seedlings under nursery conditions is not difficult if a systematic approach is followed to establish a containerised nursery.

Site selection

The following points must be taken into consideration when starting a nursery.

Road access: The nursery should be near to planting sites and, in the case of a large nursery, should be accessible by road for easy transportation.

Size: The area of land should be not less than 0.4 ha for every 50,000 seedlings. However, small nurseries run by farmers can be established in 300 m^2 to raise 4000-5000 seedlings.

Water availability: Water rights must be obtained from any water source and it must be available year round. Water drawn from wells is probably one of the best irrigation source for most locations. The water should have a pH 5.5-7.5 and less than 400 ppm dissolved salts.

Soil: Sandy loam to loamy sand with good drainage is excellent for nurseries in arid and semi-arid regions. The selected site should have no salinity.

Location: High wind velocity, particularly where humidity is low (as in the case of arid and semi-arid regions) are quite harmful for growing seedlings and, therefore, in these places the nursery site should have some sort of protection, preferably with hedges or tree rows as shelterbelts all around.

Nursery layout

The nursery should be arranged in a series of beds with pathways in between them. Excavate a 1 x 10 m area to a depth of 18-19 cm, that is slightly less than the height of the polybags (20 cm). These beds are known as housing beds (Figure 17). Prepare the second bed in a similar fashion but leave 1-1.5 m between two beds as a pathway.

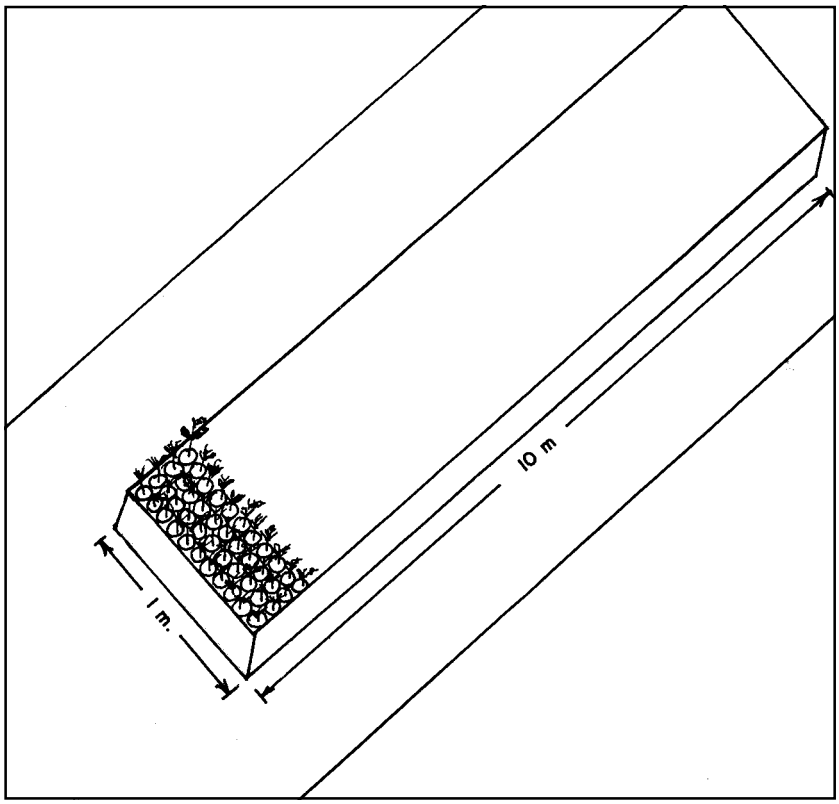

Figure 17. A simple nursery bed (housing bed) for placing polybags.

Housing beds of 1 x 10 m can accommodate 2000-2200 polybags filled with growing medium. Thus the number of housing beds in a nursery depends on the number of seedlings to be raised.

Containers for nursery

In India, the most easily available and widely used containers are polybags. They are closed at the base and have drainage holes punched in the sides around the base. If drainage holes are not punched in the polybags, use a thick nail to make 5-8 holes around the base. Polybags of various sizes are available in the market, but

12.5 x 20 cm when laid flat (275 gauge) is the most suitable size for raising seedlings of *P. juliflora*. The present market rate of these polybags is Rs 80-100 per kg and the number of polybags in 1 kg ranges range between 225 and 250.

Growing medium or nursery mix

Growing medium or nursery mix provides anchorage, nutrients and moisture for the growing seedlings. Characteristics of a good nursery mix are:

- slightly acidic pH
- high cation exchange capacity
- adequate porosity
- free from pests
- free from sticks, stones and other large debris

Preparation of the nursery mix

The following nursery mix is prepared throughout the arid and semi-arid regions of India. To prepare nursery mix, follow these steps:

1. Take two parts of fine sand, one part of pond silt and one part of farmyard manure.
2. Sieve each component to 2-3 mm separately and mix them thoroughly.
3. To protect seeds and seedlings from termite attack, mix 5% neem cake or shredded neem leaves in the prepared nursery mix. Chemical-based products are also available for this.

The quantity of nursery mix depends on the number of polybags to be filled for raising seedlings. A polybag of 12.5 x 20 cm (lay flat) size requires approximately one kg dry nursery mix.

Filling polybags

Before filling the polybags, be sure that there are drainage holes in the side of the lower portion of the tubes (polybags). Now take an open polybag, and pour in the nursery mix. Fill the polybag properly by pressing the soil mix two or three times by hand. However, leave the uppermost 2 cm of polybags free of nursery mix. Before sowing the seed, be sure that the polybags are well filled and pressed down, so that there are no air gaps in the column of nursery mix.

Seed sowing

Variability in seeds: *P. juliflora* seeds vary greatly in size and weight. Seed length, width and thickness varies from 4.7 to 6.8 mm, 3.24 to 5 mm and 1.4 to 2.2 mm respectively. The weight of 100 seed varies from 1.2 to 4 g.

Note: *Always select good quality, heavy seeds for sowing, as these give better germination and better quality seedlings.*

Sowing time: Throughout the arid and semi-arid tracts of India, the species is sown in nurseries in the second fortnight of February at the beginning of the spring season. The seed sowing operations should be completed by the end of February, although this period can be extended up to first week of March.

Box 6. Viability of stored *Prosopis juliflora* seed.

Viability of *P. juliflora* seeds is usually above 85-90% for 2 to 3 years at room temperature in arid and semi-arid regions of India. Therefore, two-year-old, properly stored seeds can safely be used.

Sowing method:

1. Arrange the polybags filled with nursery mix in lines in the prepared housing beds. Arrange the polybags in the beds in such a way that they remain vertically upright and are neither too compact nor too distant.
2. Water the polybags with 20-22 litres of water per 100 polybags. Wait until the soil mix columns in the polybags are saturated with water.
3. Now place two pre-treated *P. juliflora* seeds on the top layer of nursery mix in each polybag. The purpose of sowing two seeds per polybag is to ensure sufficient germination to give the required number of seedlings.
4. Press the seeds gently into the soil mix and then spread a thin layer of well-sieved dry sand over the seeds. This layer of sand should not be more than 5 mm. Then lightly water all the polybags again.
5. Watering in nurseries is often done with a watering can (capacity = 16-17 litres) fitted with a rose (shower). In large commercial nurseries, watering can be done by permanently fitted sprinklers.

C. Germination, seedling growth and care

Germination

Pre-treated seeds generally begin to germinate four days after sowing. By the fifth and sixth day about 50% seeds should have germinated and the process should be complete within 10-12 days. During this period, polybags should be watered on alternate days. It is highly desirable to water the seedlings either in early morning or at sunset to avoid evaporation of the water.

Thinning: After 10-12 days remove the weaker seedlings to leave one seedling in each polybag. If there is no germination in some polybags, transplant spare seedling into these polybags taking care not to damage or bend the roots. Discard left over seedlings.

Watering: By the end of March, the temperature in the arid and semi-arid tropics of India starts rising and may reach 40°C. Therefore, watering should be done regularly until the onset of the monsoon season. During the month of May and first fortnight of June, the temperature is always very high, often 45-48°C. During such hot periods, seedlings should be watered twice a day, in the morning and evening.

Note: *Never water excessively as this will encourage root and stem diseases. It will also leach soluble nutrients from the root zone, reducing the amount available to the growing seedlings.*

Seedling growth

After germination, the seedlings start growing and the majority of seedlings attain the two-leaf stage four or five days after emergence. Four-week old seedlings, on average, attain a height of 9 cm, and by this time, the number of leaves per seedling ranges between 7 and 11.

The stem of seedlings grows slowly for six weeks after emergence, referred to as the initial growth phase. During this period the root system is developed. After this period, the stems of seedlings grow very rapidly and by the end of the 12th or 13th week, the seedlings attain a height of 27-30 cm.

The seedlings stem continues to grow, reaching 40-50 cm height after 18 weeks. The collar diameter measurements of healthy seedling by this period should reach between 4 and 6 mm. The length of the longest roots by this period should be 40-45 cm. By the end of the 19th or 20th week, the seedlings are ready for outplanting. In arid and semi-arid regions of India, this period coincides with onset of the monsoon season (when the seeds are sown in the second fortnight of February or first week of March).

Moving bags: As the seedlings grow, roots will tend to penetrate into soil in housing beds through the drainage holes in the polybags. This must be checked by regularly shifting the bags from one bed to another (at least once in 4-6 weeks) and pruning off any protruding roots with a sharp knife.

Watering: When watering, particular care must be given to seedlings on the sides and corners of nursery beds, because they tend to receive less than adequate water. Closely examine polybags to be sure that water has penetrated to the bottom of the bags.

Fertilising: *P. juliflora* and other species of *Prosopis* are nitrogen fixing plants. Therefore, the common practice in many parts of India of occasionally fertilising growing seedlings of the species with urea is not useful. There is no need for any chemical fertiliser in raising seedlings of *P. juliflora* in the nursery.

Shading: There is no need to shade the housing beds, as *P. juliflora* can withstand very high temperatures provided watering is timely and appropriate.

Weeding: Any weeds or grasses that appear in polybags during the course of seedling growth should be removed.

Crusting: If a soil surface crust appears in polybags, break it with the help of a khurpi (an iron tool used commonly for clearing weeds). This allows better soil aeration and facilitates quicker movement of water in the nursery mix.

Box 7. Delayed planting.

If the plants have to be held over for a longer period than planned, for example by the long delay or failure of rains, then certain precautionary measures are needed. In such situations, remove the polybags (containing seedlings) from the housing bed in which they are placed and shift them to another housing bed, but this time keep the space between two polybags double that of the original beds. Strip 75% off the leaves of the seedlings. This will help retard the growth in the off season. However, a more suitable method to hold the stock for longer durations than planned is to transplant the seedlings to larger size polybags, about double the size of the original ones.

Seedling protection

Fortunately, in arid and semi-arid regions, fungal and insect pest damage to the seedlings of *P. juliflora* is negligible. Root rot and wilt of seedlings are occasionally reported. Sometimes, aphids cause harm to growing seedlings. However, squirrels in many cases cut the collar of 20-25 day old seedlings and cause much loss. As different fungal pathogens and insect/animal pests require different control measures, if such situation arises, immediately contact a pest management specialist for proper advice and guidance.

Box 8. Soil solarisation.

Soil solarisation of the nursery mix before filling the polybags is very effective in controlling soil borne diseases in growing seedlings. The method is very simple and cheap. On a warm sunny day, spread the nursery mix out on the ground and cover it with a polyethylene sheet. Keep covered for four to five days. Soil borne fungal pathogens, if present in the nursery mix, will be killed by the high temperature. Use this technique only if days during the polybag filling period are clear and sunny.

Note: *Timely advice and guidance from a specialist can save the seedlings from mortality.*

Seedling quality

Many factors influence the quality of seedlings. If care has been taken in raising and managing plants in the nursery, the seedlings should be of good quality. There are many indices used to determine seedling quality but a single factor which is useful for quick and easy testing is ‘collar diameter’. The collar is the point where root and stems join, and where the stem emerges from the soil. The collar diameter can be checked with a simple gauge (Figure 18). *P. juliflora* seedlings 18-20 weeks old, with a collar diameter of over 5 mm are considered ideal for outplanting.

Vegetative propagation

P. juliflora can be vegetatively propagated through:

- rooted cuttings
- grafting
- stump cutting

These techniques are not widely used in India because of the high cost and the requirement for skilled workers. However, in research and development organisations like CAZRI, Jodhpur; Central Soil Salinity Research Institute, Karnal; and National Botanical Research Institute, Lucknow, these techniques have been perfected and are being used successfully.

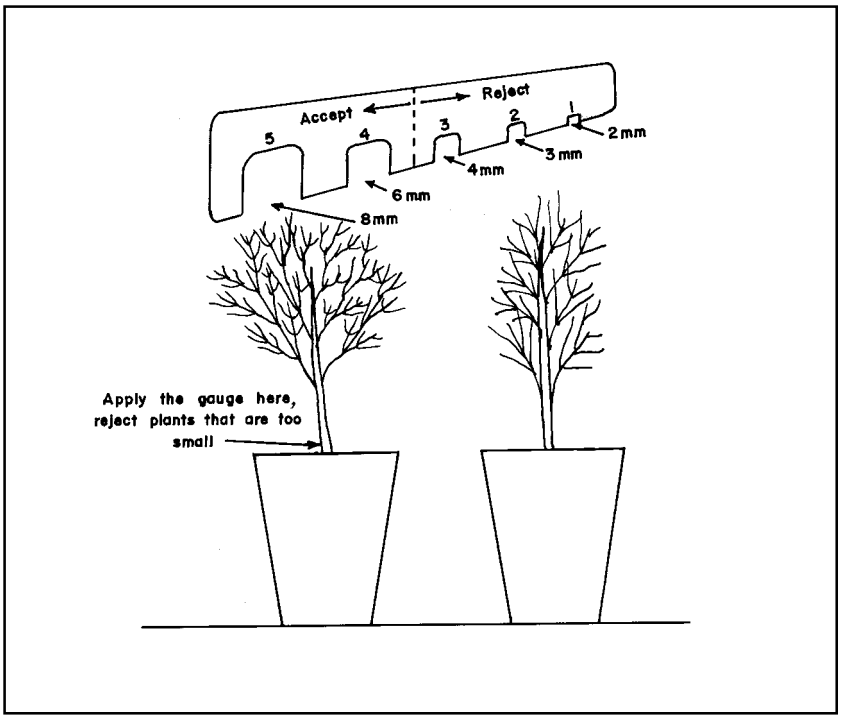

Figure 18. Simple gauge to assess seedling quality

Rooted cuttings

To propagate *P. juliflora* from stem cuttings in open nurseries, follow these steps:

1. Take polybags of the same size filled with the same nursery mix as used for raising seedlings from seed.
2. Take stem cuttings from juvenile plants with 4-5 mm diameter and 15-25 cm long.
3. Cuttings can be propagated without the use of rooting hormones, although the success rate may be lower. If hormones are available place the lower cut end of stem cutting in a solution of IBA (indole butyric acid), concentration 2000-4000 ppm for 2 minutes. Insert the IBA-treated end of the cutting in the nursery mix in the polybag, keeping one-third of the stem cutting in the nursery mix and two-thirds in the air. Cuttings should be slightly slanted in the polybags.
4. Cover the upper cut surface of the cutting with a cap of clay soil to prevent moisture loss.
5. Water the cuttings regularly. If frequent misting is possible in the nursery, water for 10-15 seconds, at intervals of 45 minutes to 1 hour throughout the day.

The cuttings will start sprouting after 8-10 days. Watch them closely. If rooting starts, the number of new sprouts will increase rapidly and small branch initiation can be observed within 30-35 days (Figure 19). If they fail to root, the new sprouts will not increase in number and size, and after some time they will die back. Pull out one cutting from the polybag and observe it for root formation. If roots are there, observe the structural features of above ground part of the cuttings. In this way one can differentiate between rooted cuttings and those that have failed to root.

Though rooting the stem cuttings in open nurseries is possible, success rate is usually only 20-25%. However, the technique is useful for propagating small numbers of plants from superior material.

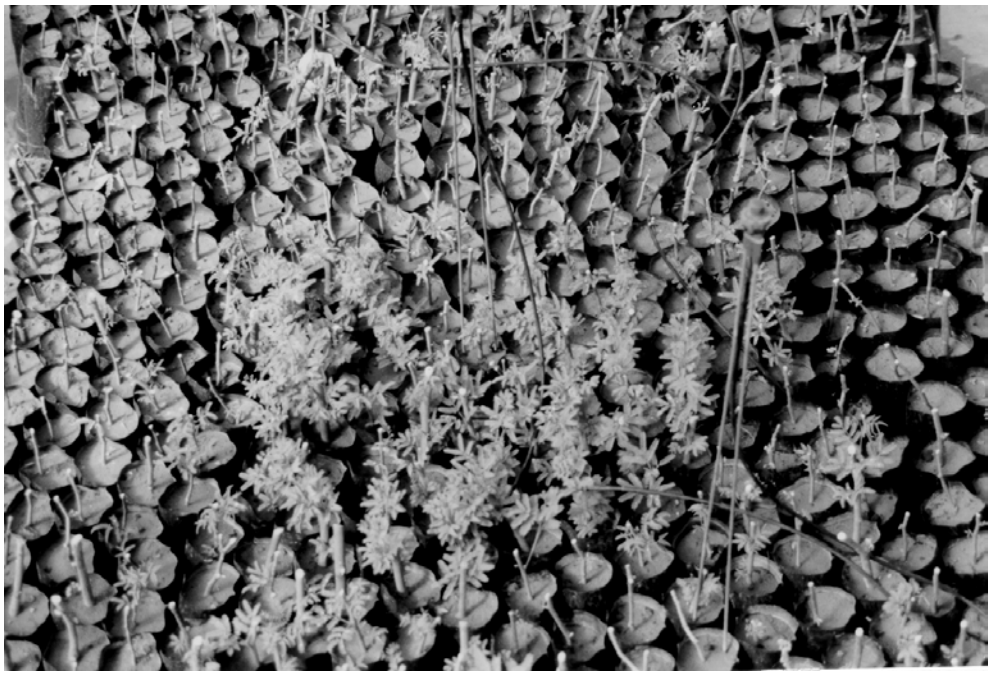

Figure 19. Rooted cuttings in a nursery benefiting from frequent mist irrigation.

Box 9. Mist propagators.

Stem cuttings can be raised without much difficulty in automatic mist control chambers providing frequent misting. In a mist house 50-60% success can be achieved in raising the stem cuttings of *P. juliflora* compared with 20-25% in the open. The most suitable growing medium for stem cuttings in mist chambers is mixture of sand, pebbles, and peat moss in a ratio of 2:1:1.

Grafting

P. juliflora can be raised successfully in the nursery by cleft grafting. The technique is ideal for propagation of superior material for plantations. The procedure of cleft grafting is very simple.

1. Raise *P. juliflora* seedlings in the nursery through seeds.
2. When the seedling is 4-5 months old, cut it at a height of 4-5cm and remove the side branches and leaves with secateurs. This will serve as the rootstock.
3. Cut the rootstock vertically into two equal halves between 2-2.5 cm downward with a sharp knife to form a cleft (Figure 20).
4. Take a 6-8 cm juvenile twig (bud wood) from the plant that is to be propagated. The diameter of bud wood should be 3-5 mm.
5. Remove all the leaves from this twig. This is called the scion (Figure 21).
6. Hold the scion in one hand and cut the end where it was severed from the parent tree into a wedge shape using a sharp knife.
7. Insert the wedged end of the scion into the cleft of the rootstock (Figure 22).
8. Tie this joint firmly with a ribbon such as strip of polyethylene and wrap this polyethylene strip spirally upward on the scion leaving open the part that contains vegetative buds. The upper open end of scion should be covered firmly all around.
9. Water the polybag regularly. Figure 23 shows successfully sprouted grafts.

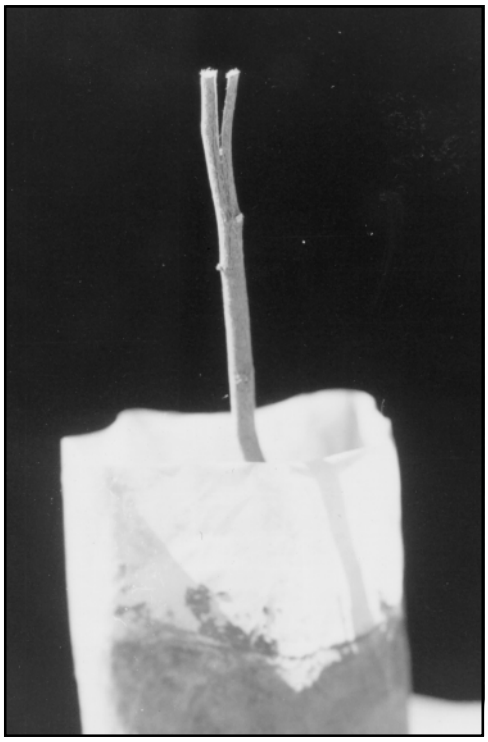

Figure 20 .
Root stock cut into two.

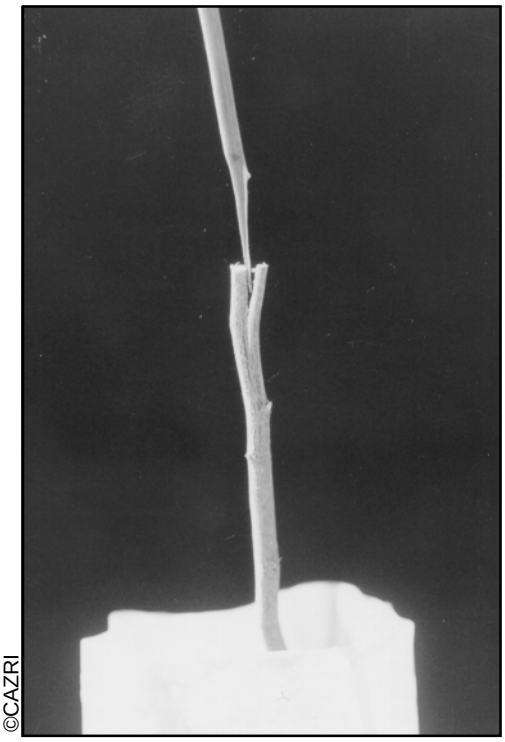

Figure 21.
Wedged scion inserted in root stock.

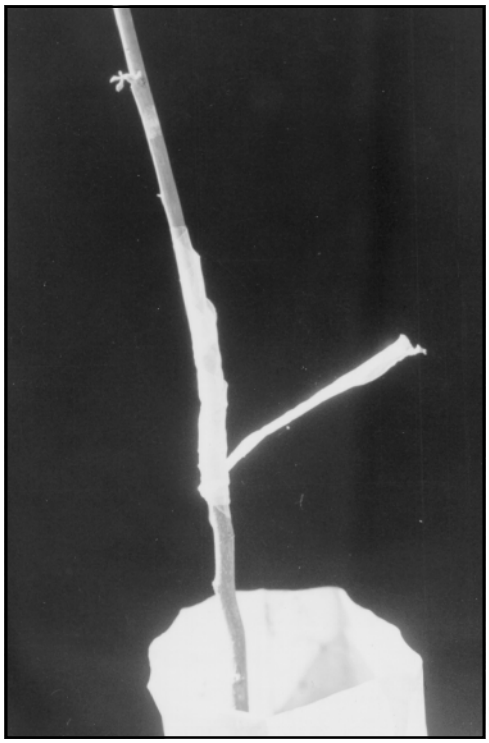

Figure 22.
Wedged scion tied with a strip of polythene.

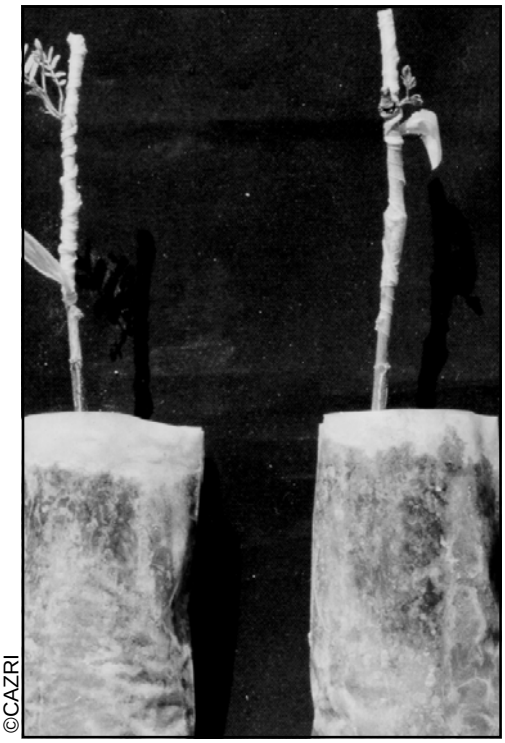

Figure 23.
Successfully sprouted grafts.

After two weeks buds will begin to sprout. The sprout will elongate slowly. After 30 days, the sprouted shoots attain a length of 5-8 cm or more. Remove the polyethylene strip after 35-40 days. By that time, root stock and scion have firmly attached to each other. Allow all the sprouted shoots to grow for 45-50 days after emergence. Then examine the sprouted shoots closely and select the best one. Remove all the sprouted shoots except the selected one and allow it to grow further. By the end of 100 days, the propagated material is ready for out-planting. The success rate in this sort of vegetative propagation is often more than 65%.

Box 10. Grafting.

P. juliflora is graft compatible with other *Prosopis* species of section Algarobia. At CAZRI, Jodhpur, the cleft grafting technique has been used to graft non-spiny and high pod producing accessions of *P. alba, P. glandulosa* and *P. pallida* onto *P. juliflora* rootstock in the nursery and field.

Stump cuttings

P. juliflora can also be propagated through pre-sprouted stumps. For raising stump cuttings, two-year old out-planted individuals have been found best for collecting stumps.

1. Collect stumps of approximately 1.5 cm collar diameter, 2.5 cm shoot length and 15-17 cm of root length. Use a spade and secateurs to collect the stumps.
2. Transplant these stumps into large polybags (18 x 28 cm flat) containing the same nursery mix as used for raising seedlings from seed. These operations should be done during the second fortnight of February.
3. The rest of the requirements and operations are the same as for raising plants from seed.

By the end of June, these stump cuttings are ready for out-planting. The success rate in such stump cuttings is always more than 70% and, moreover, they exhibit rapid growth compared with seedlings raised from seed.

V. PLANTATION ESTABLISHMENT ON BARE SITES

Arid and semi-arid regions of India account for 40% of the total land area. Millions of hectares of land in these areas are affected by soil erosion and land degradation. The domain of *Prosopis juliflora* extends throughout these regions and the species is capable of thriving in degraded sites. In the arid and semi-arid regions eight major land formations can be recognised:

- sandy plains
- sand dunes
- shallow sandy soils
- rocky and semi-rocky terrains
- heavy clayey soils
- alkaline soils
- saline soils and brackish water areas
- ravines

A. Common planting methods

The methods for planting out seedlings raised from seeds require different skills and practices for the above land formations and are listed below. However, some techniques are common to all land types:

- Planting-out of seedlings throughout the country is carried out after the first effective rains, from the last week of June to the third week of July.
- Four month old seedlings from seeds sown in the second fortnight of February or first week of March are suitable for transplanting in any land formation.
- The tree is removed by cutting the polybag with a sharp knife. Remove the bag from the soil mass that covers the roots (Figure 24).

B. Sandy plains

The range of rainfall in arid and semi-arid sandy plains is 200-350 mm and 400-800 mm respectively. However, rainfall in some pockets of semi-arid sandy plains of UP State exceeds more than 800 mm. In all the cases more than 90% of total annual rainfall is received from mid June to mid September. Not much land preparation is required for out-planting of *Prosopis* in these areas.

1. Remove shrubs, climbers and large creepers like *Citrullus colocythis* (Tumba) from the planting site.
2. Excavate a pit of 50 x 50 x 50 cm.

Note: *These operations should be executed in the first week of June, prior to first effective rain.*

3. In arid areas, where the rainfall is under 350 mm, construct a saucer basin of one metre diameter around the pit to make more rain water available to the growing seedling.
4. Out-planting should be started after the first effective monsoon rain (over 20 mm in one incident).
5. Before backfilling, the soil collected outside each pit during the excavation process is mixed with 4-5 kg of farmyard manure and 50 g of neem cake (if available).
6. Gently hold the seedling by the root-ball and place it in the half-filled pit.
7. Fill the pit completely with the treated soil and press the soil to pack it firmly all around the tree.

Note: *If planting-out is carried out when it is raining or soon after, there is no need for any supplemental irrigation. If it is done the day after rain, as in most cases, water the out-planted seedling with two litres per pit. If adequate rainfall occurs at 10-15 day intervals regularly during the rainy season, no irrigation is required at all. However, if the interval between two incidences of effective rainfall exceeds 20 days, provide life saving irrigation at 2-3 litres per seedling.*

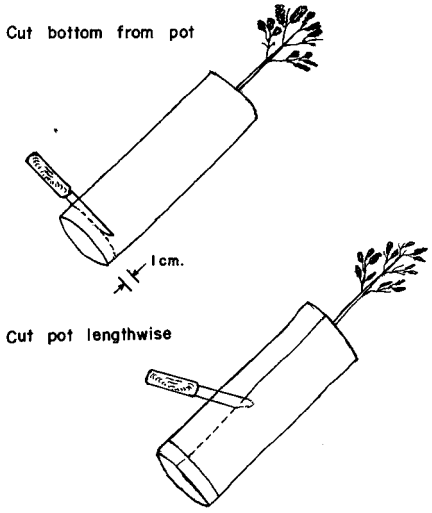

Figure 24. Preparing the seedling for planting out (adapted from Weber and Stoney 1986)

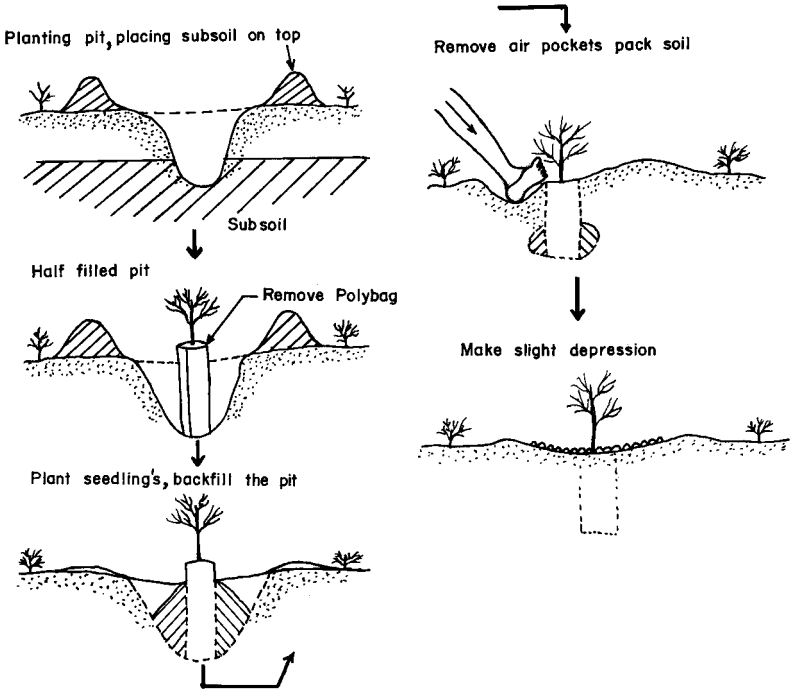

Figure 25. Steps to planting out seedlings (adapted from Weber and Stoney 1986).

C. Sand dunes

About 113 thousand km^2 of west Rajasthan, better known as Thar desert, is covered with different types and intensities of sand dunes. Dune formations are also found in coastal areas, especially on western coasts. The moving sand dunes are a serious menace to communication networks, village settlements and agricultural land.

P. juliflora is a versatile species for sand dune afforestation. The technique employed is somewhat specialised and involves three steps.

1. Protect the dune from biotic interference: Fence the dune boundaries with barbed wire fixed to iron posts. Posts should be 1.5 m high and no more than 10 m apart. Fencing should have three rows of barbed wires and should be 1.4 m high. The first row of barbed wire should be 35 cm above the ground, the second row should be 45 cm above first one and last row should be 60 cm above the second one. The operation is expensive; the cost of barbed wire fencing is Rs 120 per metre (approximately US $ 2.8).

Box 11. Alternatives to barbed wire.

The alternative to barbed wire fencing is to keep strict watch and prevent any human or livestock activity in the dunes that are to be stabilised. The protection of dunes from biotic interference should begin at least 4-6 months before out-planting the seedlings.

2. Fix the micro-windbreaks: Build micro-windbreaks against the dominant wind direction in a checker board design at a spacing of 2 m apart at the top of dune and 5 m apart on the slope and heel of the dune. This will protect the seedlings from deposition of moving sand or from the exposure of seedling roots. The whole operation is manual and must be accomplished before the onset of the monsoon in June.

Box 12. Alternative windbreaks.

For micro windbreaks, cut and collect locally available shrubs like *Zizyphus* spp., *Crotolaria bhuria*, *Leptadenia pyrotechnica* (kheep), *Calotropis procera* (akra or aak); and also collect any unused material like crop residues, twigs and leaves of trees, iron poles or containers.

3. Planting: After the first effective rain, transport the seedlings of *P. juliflora* from the nursery to the planting site. Start excavation of pits one day prior to planting. In sand dunes, 40 x 40 x 40 cm pits are satisfactory and can be excavated with ease.

If available, mix 2-3 kg of farmyard manure with the soil to backfill the pits.

D. Shallow sandy soils

Many arid and semi-arid regions of India, for example Pali District, adjoining areas of western Rajasthan, many parts of Gujarat State and drylands of Maharashtra and Andhra Pradesh have gravely and shallow sandy soils. In such areas, where soil depth is 20-40 cm, excavate a pit of 60 x 60 x 60 cm for out-planting nursery-raised seedlings.

Points to note:

- If a calcareous layer is present below the planting hole, break it up with a crowbar. This is essential to facilitate root development. If the calcareous layer is too thick to be broken with a simple crowbar, use a tractor-mounted auger for digging pits. This auger can easily dig pits of 20-25 cm in diameter and break the underneath calcareous layer in one attempt.
- If the site is in an arid area (under 350 mm rainfall), construct a saucer shape basin around the pit as described above for sandy plains.
- If the land is sloping, construct water harvesting structures to prevent run-off and soil erosion. However, the first consideration in such a situation is to select microsites for digging planting pits. Select microsites where soil depth is not limiting. Moving a planting pit a metre or so from the

originally planned design can sometimes make a big difference in the soil available to out-planted seedling. So inspect the ground situation closely when preparing a planting-out plan. If the slope is gentle, construct a half moon or crescent shaped basin around the pit.

- If the planting site has steep slopes, then adopt staggered ridge and furrow system of planting. In this system planting is always done in the furrows, so that the growing seedlings can make maximum use of the available rainfall.

E. Rocky and semi-rocky terrain

Rocky and semi-rocky terrains are found scattered in many arid and semi-arid areas. Many landforms throughout Aravali ranges (extending from the southern part of Haryana, through the whole of Rajasthan, and touching the northern part of Gujarat), Vindhyan ranges (Madhya Pradesh) and Satpura ranges (Maharashtra) are rocky and semi-rocky. Such terrains are also found scattered around in many parts of Andhra Pradesh, Karnataka and Maharashtra. In arid western Rajasthan, rocky and semi-rocky terrains are the dominant land formation.

Planting-out nursery raised seedlings of *P. juliflora* requires skill in these areas. The first consideration is to select microsite pockets with accumulation of some soil, and then to design the plantation programme.

Dig pits of 60 x 60 x 60 cm in the microsite. The planting-out technique for transplanting nursery raised seedlings in the pits is the same as for the sandy plains. Construct a crescent shaped ridge of 15 cm height across the local slope from remaining soil and pebbles to harvest the rain water for the planted-out seedlings.

To backfill the pits, good soil is required. Therefore, import good soil (preferably 2 parts sand and 1 part pond silt) before digging out the pit. The pit should be backfilled with a mixture of half weathered soil and half imported good soil. Add 4-5 kg of farmyard manure to the soil mixture. Watering and other operations are the same as those described for sandy plains.

F. Heavy clayey soils

In many parts of the semi-arid tropics, especially in Andhra Pradesh, Madhya Pradesh, UP and Maharashtra, there are pockets of heavy clay soils with poor drainage. These soils generally have a very thick calcareous layer, commonly referred to as the kankar pan, which is 1.5 to over 2 m beneath the soil surface.

To plant-out *Prosopis* seedlings in these soils, first dig a test pit at least 3 m deep at many locations within the planting site to see the depth of the kankar pan. If the kankar pan is less than 1.5 m deep, then consider using a tractor mounted mechanical auger to break through the kankar pan at each planting site. If the kankar pan is more than 1.5 m deep, the movement of the auger can further compact the soil on the sides, which restricts the formation of surface roots. This is disadvantageous. Under these conditions manual digging of pits is most desirable and the kankar pan can be broken with a crowbar.

The pits should be 60 x 60 cm and 90 cm deep. Imported sand is required to backfill the pit after out-planting the seedlings. The planting out technique is the same as discussed in the case of sandy plains, however at the time of backfilling the pits, mix the sand in the soil as well as 2-3 kg of farmyard manure.

Box 13. Augers.

A special type of tractor mounted auger has been designed to make planting holes for *Prosopis* seedlings in shallow sandy soils, heavy clay soils, alkaline soils or any other soils where there is a hard Kankar pan below the planting hole (Figure 26). This auger has a diameter of 15 cm and can dig pits as deep as 130 cm without any difficulty. Such pits generally have a diameter around 20 cm.

Figure 26. A tractor mounted auger for planting *P. juliflora* and other tree species in alkaline and other soils with a kankar pan.

G. Alkaline soils

Many pockets of alkaline soils are found in semi-arid tracts, especially in the north-western part of the country and in many areas along the Ganga and Yamuna rivers in western and central UP. *P. juliflora* grows naturally as a weedy thicket in these tracts. However, there are only a few systematic plantations of the species. There is great scope for raising *P. juliflora* commercially in such lands.

In these soils, dense clay or calcareous layers (kankar pan) are often present beneath the soil in various depths. However, alkaline areas along the river Ganga are free from this calcareous layer. Use a tractor-mounted auger to dig the pits for planting out seedlings in alkaline soils with a kankar pan.

Mix 3 kg gypsum and 8 kg of farmyard manure with the soil obtained from digging each pit and use this for backfilling. The seedlings are planted and watered as described for sandy plains.

Box 14. Survival and growth of *Prosopis* seedlings planted in a auger-dug hole.

In an intensive study by researchers of CSSRI, Karnal, it was found that *P. juliflora* seedlings planted in saline-alkaline areas using a tractor-mounted auger and gypsum and farmyard manure soil amendments exhibited far superior survival, growth and biomass production than seedlings planted in manually-dug pits without soil amendments.

H. Saline soils and brackish water areas

There are large areas of salt affected land in the arid and semi-arid regions of India. For example, the entire Kutchh region, covering an area of 45652 km^2, is affected by salt. Similarly in Rajasthan, especially in arid western Rajasthan, there are many thousands of hectares of saline patches. Many areas in semi-arid regions of Gujarat, Maharashtra and Andhra Pradesh also have soils affected by salinity. In such situations, one often encounters bushy thickets of *P. juliflora* and nothing else.

The method of out-planting nursery raised *P. juliflora* seedlings in such lands is quite different from those described above. Here the planting is done on the raised bunds (Figure 27). The width of the bunds should be 1 m at the base and 75 cm at the top. If the terrain is flat at the planting site, disc the site one to three times using a tractor, then construct the bunds manually. The whole operation is labour intensive.

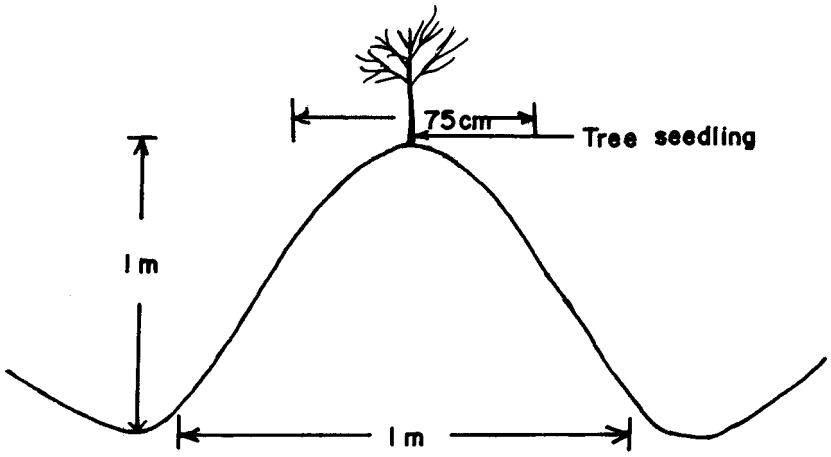

Figure 27. Raised bunds for planting-out *P. juliflora* in saline or brackish water.

Once the bunds are constructed, dig pits 45 x 45 x 45 cm at the top of bunds, approximately in the centre. Mix 4 kg of farmyard manure and 2 kg gypsum in the excavated soil for each pit. Use this for backfilling the pits. Planting and watering is similar to that discussed for sandy soil.

Note: *The quantity of farmyard manure and gypsum to be applied depends on the level of salinity. If the salinity level is quite high, the quantities of farmyard manure and gypsum can be doubled. In sites with very high salinity-alkalinity, import good soil for backfilling the pits.*

Precautions:

- **Never use brackish water for irrigation. If life-saving irrigation is needed, always irrigate the seedlings with fresh water.**
- **Never use very highly saline-alkaline soil collected during digging the pits. Backfill the pit after transplanting the seedling with imported good soil where possible.**

I. Ravines

The term 'ravine' means a deep gorge. It is usually associated with land containing a system of gullies running more or less parallel to each other in a deep alluvium before entering a nearby river flowing much lower than the surrounding land. In UP, 1.2 million ha land around major river systems is affected by such erosion. Of this, the ravines of the Yamuna river accounts for 32% and that of Betwa river around 19%. The ravines of the Yamuna and Chambal rivers form continuous belts of more than 10 km at many places in UP. The environmental features of the areas where these ravines exist are typically semi-arid and the only species showing success in plantations is *P. juliflora*. The depth of the river largely governs the maximum depth of ravines and, therefore, the ravine system along the tributaries is shallower than along the main river. The depth classification of ravines is generally:

- shallow - less than 2 m
- medium - between 2-6 m
- deep - above 6 m

Soils are generally deep in these areas and are loam to clay loam in texture. For *P. juliflora* plantations in ravines, the emphasis should be on:

- preventing movement of soil
- checking further extension of ravines
- reclaiming the eroded land

All gully heads should be filled up with brushwood from bottom to top well before the south-west monsoon sets in (last week of June or first week of July). At planting-out time, first plant some branch cuttings of species like Karonda (*Adhatoda vasica*), Jhar ber (*Zizyphus* spp.) and other locally-available sprouting shrubs on the sloping sides and tops of the ridges of the plugged gully after the first rains. These plants will help in arresting soil erosion during the active monsoon.

Box 15. Brushwood gully plugs.

Brushwood gully plugs will break the speed of flowing water and will filter silt from the water. The gully plugs should be made from top to bottom of the gully in such a manner that the base of the upper bund is level with the top of the lower bund. The bunds should be 25 cm high, 50 cm wide at the top and 200 cm at the base. This will give a slope angle of 18^{o} on either side. As far as possible, the bunds should be at right angles to the stream flow. The objective of these bunds is not to store water but to slow it down. After the first rains some bunds may get breached while others get filled up. Soil so collected between two bunds is rich and fertile.

As soon as the monsoon becomes weak, during August-September, the nursery raised seedlings of *P. juliflora* are brought near to the planting site. Dig pits of 30 x 30 x 30 cm in the rich and fertile soil collected between two bunds and plant the seedlings as described for sandy plains. There is no need to add farmyard manure and pits are backfilled with soil excavated from the pits. If required, provide supplemental irrigation as for sandy plains.

Box 16. Planting out vegetatively propagated material.

As discussed above, *P. juliflora* can also be raised from stem and stump cuttings or through cleft grafting. The time of planting and method of transplanting vegetatively propagated material in pits in the field is exactly similar the same as described for planting-out nursery raised seedlings in the field in various land forms. However, the vegetatively propagated material should be not less than 6 months old and 8-9 month old material is most suitable. After planting out, vegetatively propagated material requires a good soil moisture regime as it is not so hardy as material raised from seeds. Therefore, irrigate with 5-8 litres of water per pit after 10 days without significant rainfall and continue this until the onset of the autumn season, i.e. October.

VI. MANAGING PLANTATIONS

The management of *P. juliflora* depends on the purpose of the plantation. For a better understanding, we can divide plantation management into three broad aspects:

- stocking for production or protection
- maintenance and aftercare
- growth and yields

A. Stocking for production or protection

There is no unanimity among researchers, development workers, forest managers, and end users like farmers and livestock owners about the planting density of *P. juliflora*. The information in Table 2 is based on long experience of the authors in research and development activities with *Prosopis* species. No report is available in India on the optimum spacing for pod production, a most useful output of the species.

Note: *Though spacing is an important consideration in planting for different purposes, the site conditions are equally important for working out the optimum density. For example, in degraded land it is common to deviate a little from the originally planned planting-out programme to take available microsites into consideration. This may result in a slight increase or decrease in stocking rate on, for example lower density on poorer and drier sites or higher densities on richer, irrigated areas.*

Table 2. Spacing requirement for various types of *P. juliflora* plantations.

Plantation type	Purpose		Spacing		Density (individuals/ha)
	Main	Secondary	Row to Row (m)	Plant to Plant (m)	
Afforestation of degraded land (government wastelands, village common lands, etc.)	Land/soil conservation	Fuel wood production	3	3	1111
Sand dune stabilisation	Land/soil conservation	Fuel wood production	5	5	400
Energy plantation	Fuel wood production	(a) Charcoal making (b) Pod/seed production	(a) 3 (b) 2	(a) 1 (b) 2	(a) 3333 (b) 2500
Fodder production	Pod production	(a) Fuel wood production (b) Seed collection	(a) 6 (b) 5	(a) 4 (b) 5	(a) 416 (b) 400
Timber production	Timber	Pods for fodder / seeds	10	5	200
Seed orchard	Improved seed	Pods for fodder	6	6	278
Hedgerow	Live fences	-	0.3 or 0.5	0.5	-(1)
Agri-silviculture	Fuel; fodder (pod)	Production of associated arable crop	10	10	100
Silvo-pastoral	Fuel; fodder (pod)	Production of grasses/animals; Shade for animals	10	5	200
Avenue, canal bank & railway line side plantations, Agricultural field boundary	Aesthetic value, soil conservation, windbreak	Pods for fodder	Single row (2)	3-5	-(1)
Shelterbelts (3)	Soil/moisture conservation, reducing wind speed	Pods for fodder, shade for livestock	3	3	-(1)

(1) Density per hectare will depend on the number of rows of the species incorporated in the shelterbelt and total running meter length.
(2) If the plantation plan is for two or more rows, then keep row to row distance 3 m. However, planting should be done in staggered manner.
(3) For three-row shelterbelts plant *P. juliflora* in the inner and outer rows. For five-row shelterbelts plant *P. juliflora* in the second inner and second outer rows.

(Adapted from Harsh 1993, Dagar 1998, Singh 1998, ICFRE 1993)

B. Maintenance and aftercare

In arid and semi-arid landscapes, on any land formation in any type of plantation, young out-planted tree seedlings have four critical needs:

- watering
- protection
- casualty replacement
- tending

Watering

If there is sufficient well-distributed rain, there may be no need to irrigate the out-planted seedlings until the end of the rainy season. In semi-arid regions, watering is not required in the autumn season, but in arid regions irrigate once with 5-7 litres of water per seedling when temperatures are high. If the watering regime as discussed is followed, there will be no need for any irrigation until the first fortnight of March.

After the second week of March, temperatures start rising, sometimes very abruptly, especially in arid regions. Therefore, during the second fortnight of March and onwards, it becomes essential to irrigate the out-planted seedlings.

Note: *The second fortnight of March until the onset of south-west monsoon, in June, is the most crucial period for growing seedlings in the field. It may be difficult to provide irrigation for the out-planted seedlings, but survival and growth of the seedling may depend on it receiving some water, even if only a little, during this dry period.*

Give 10-12 litres of water per seedling of *P. juliflora* during the second week of April, the middle of May and during the second week of June.

Note: *This watering regime is only required for the first year. There is no need to irrigation the plants once they survive the first summer season of their life in the field.*

Box 17. Preparing for irrigation.

It is advisable to make prior arrangements for artificial irrigation from a nearby source of water for first dry season. Often water is not available near the plantation site and must be transported to the site in 30000-40000 litre capacity water tankers. On average, the transportation cost of a tanker of water is Rs 100-150 (US $ 2.5-3.7) and 5000-6500 seedlings can be irrigated with each tanker of this capacity.

Protection of seedlings

P. juliflora leaves are non-palatable, and animals do not normally eat the seedlings. However, when they are the only green material in bare sites, they are likely to get slightly browsed at the top. Once browsed at the growing tip, plants exhibit bushy, branched growth. Such plants are very difficult to manage.

Nothing is more harmful to a tree seedling than being damaged, even if damage is very slight.

Thus protection from grazing animals is essential. There are two approaches to protect the plantation:

- physical barriers
- social fencing

Physical barriers

If resources permit, establish barbed wire fencing having three rows of wires as discussed in the case of planting methods on sandy plains. This can be used in any land formation or soil type.

If soil is **clay or silty-clay, gravel or otherwise relatively stable**, a trench-cum-mound fence can be made. Dig a one metre deep trench (0.5 m wide at the bottom and about 1.4 m wide at the top) all around the plantation. Pile excavated material on the inside of the trench and sow seeds of any thorny shrub or even treated seeds of *P. juliflora* by broadcasting.

On **rocky and semi-rocky sites**, where digging is difficult, there is usually enough stone nearby to build a dry stone wall to exclude livestock. Make sure that the height of the dry stone wall is about 1.5 m.

On the exclusively **sandy sites**, either barbed wire fencing or live fencing are the only means of protection because neither trench-cum-mound fencing nor dry stone wall fencing are feasible.

Box 18. Live fencing.

If the plantation programme is well planned, then live fencing alone can be effective. Sow seeds of the plants to be used as live fencing at least a year before out-planting the *P. juliflora* seedlings. Any thorny shrub or even *P. juliflora* itself can be used. Sowing should be done all around the site for plantation after the first effective rain during the monsoon season. By the next year, when planting out of *P. juliflora* is done, the live fence will already be established. During establishment of the live fencing, monitor its progress regularly. If any gaps appear, sow seed again or plant seedlings to fill in the gaps.

Social fencing

This type of fencing works very well in village common lands or other types of community land. Villagers should be sensitised to the protection of plantations during early years of establishment. Livestock owners must agree to send their animals in a different direction, making the tree plantation 'out of bounds' for several years until the trees attain a reasonable height. If possible, with agreement of entire village communities near the planting site, make a provision of appointing a herder, who always remains present at the planting site to keep animals away from the young seedlings.

Casualty replacement

In all types of plantation on any land formation 10-15% of seedlings die soon after planting. There may be many reasons for such casualties including the following:

- transportation shock
- failure to follow correct procedure for out-planting
- presence of some barriers like pebbles in the vicinity of the seedling root zone
- damage due to termite infestation
- damage by rodents

Therefore, it is advisable to keep a sufficient number of seedlings in reserve at the nursery or planting site. Make temporary housing beds near the planting site wherever some shade is available, generally at a place where two or more mature trees with good canopies are growing together.

Plant seedlings from this reserve in the pits in which planted seedlings have died. Replace casualties as soon as possible. If seedlings are not available in the same season, replace the casualties early in the next season. Follow the same procedure as for planting-out nursery raised seedlings.

Note: *If problems exist in and the around planting pit, make the necessary correction. For example if there are pebbles, dig the pit deeper and remove the pebbles.*

Tending

Tending is defined as operations carried out for the benefit of the forest crop at any stage of its life from seedling to maturity. Tending operations are performed on the tree crop and also on the competing vegetation. This includes, weeding, cleaning, pruning and thinning.

Weeding

Removal of weeds reduces the competition for moisture, nutrient and light and provides sufficient space for growing seedling. As *P. juliflora* is a fast growing species, spot ring weeding is the best method. Hoe in a circular ring of one metre diameter around the plant.

During the first year, remove the weeds around the plants at least three times:

- soon after the rainy season, in mid October
- in early spring, in late February or early March
- during late summer, just prior to onset of south-west monsoon

From the second year onwards remove weeds at least twice a year:

- at the beginning of spring season
- at the end of rainy season.

Note: *There is no single operation (other than watering) that has a bigger effect on survival and growth of seedlings than keeping them clean-weeded.*

In sandy plains and other sites with flat topography, if spacings between rows and plants within rows are both more than 3 m, disc the field twice using a tractor. The second discing should be perpendicular to the first. This type of complete weeding should be done at least once a year, preferably just before the onset of monsoon. Complete weeding also helps moisture conservation in arid and semi-arid regions.

Cleaning

When the plantation attains an age of two years, cleaning is carried out. Use a small garden axe to cut and remove undesirable local woody species and climbers. If possible, excavate some soil beneath these undesirable plants and uproot them.

P. juliflora seedlings often have two or more branches from ground level and this habit indicates that the plant will become bushy. Singling is essential to make the plants grow straight and has to be done in more than 90% of cases.

Cut all the side branches up to 1 m above ground level and leave one or two straight growing stems. If many branches originate from the base, cut them all except the healthiest one. Remove the bark from all the stumps.

After the plantation has attained the age of three years, cut out the second stem, if one was kept, leaving the healthier one. If second stem branch originates from the base of the main stem, do not cut it exactly at the point where it joins the main stem, which is to be left. Leave 5-8 cm of the second stem on the main stem. Remove the bark from this portion.

If new branches emerge, either from the basal part of the stem or from the ground, remove or cut them in the same fashion. If undesirable perennial plants or climbers again appear, remove them once again. Repeat these operations once a year until the trees are approximately five years old.

Pruning

If the objective is to have a straight tree form, artificial pruning is essential to remove green side branches from the main stem.

Cut the side branches with a sharp axe or hand saw as near to the trunk as possible. Leave upper branches covering the growing tip of the stem. Repeat periodically until the clear bole of the tree reaches a desirable height.

In the juvenile stage, branches regenerate quickly on the main stem, but after the plant reaches 8-9 years old there is little or no side branch formation from the main stem.

Removal of dead branches is also necessary. Cut the dead branches periodically from the growing plant. However, when plants attain a good height and have well extended crowns, in high density plantations, these lower branches gradually dry up and drop naturally.

Thinning

Thinning is practised to improve the growth and form of the plant. It increases the spacing and decreases the trees per unit area. As *P. juliflora* is not raised for timber in any part of India, thinning is very uncommon in plantations of the species. However, when the standing

crop is to be used for silvo-pastoral or agri-silvicultural purposes, then plantations are sometimes thinned to 10 x 5 m or 10 x 10 m.

To achieve the desired spacing, first make a plan of the plantation site and mark the trees that are to be removed to achieve the target spacing. Cut the tree at the base using a broad axe, a hand saw or a power saw. Remove the bark of the stump. Thinning must be carried out as early as possible as removing the stump of this species is very difficult.

The same process of thinning can be used for managing the plantation for any specific purpose.

C. Growth and yields

The available growth and yield information for *P. juliflora* is generally estimated from research plots. Only one or two studies are available from India on the yields of trees from large-scale plantations.

In a well managed plantation of *P. juliflora* at CAZRI, Jodhpur, the average height growth and collar diameter followed the trend as given in Table 3. In this plantation, row to row spacing was 4 m and plant to plant spacing was 3 m, giving 833 plants per hectare.

Table 3. Average growth of *P. juliflora* over five years (stocking density = 833 trees/ha).

Year	Plant height (m)	Collar diameter (cm)
1	0.4	1.5
2	0.7	2.5
3	1.9	6.0
4	3.0	8.5
5	4.6	11.5

(Source: CAZRI 1995)

P. juliflora plantations raised for fuelwood on degraded land at a spacing of 1.5 x 1.5 m attained an average height of 2.7 m and basal diameter of 3 cm in three years.

In UP, under optimum conditions, the tree grows at an average rate of 2.5-4 cm per year in girth and 30-60 cm in height. At the age of 20-25 years trees reaches an average height of 12 m and an average girth of 1.5 m.

In sandy loam soil of the arid tract, 4.3 t/ha fuelwood production from a three year old well managed *P. juliflora* plantation with spacing 4 x 3 m has been estimated. There are also reports of two year old, high density plantations of the species in saline-alkaline usar soils producing 6.7 t/ha dry wood and 0.6 t/ha dry wood in ravines.

An extensive study on systematic plantations of *P. juliflora* on different land forms and soil types, reveals the following volume table for the species (Table 4).

Table 4. Volume table for *P. juliflora* (with bark).

dbh* class (cm)	Height of tree (m)			
	6	9	12	15
5-10	0.034	0.040	0.045	0.051
10-15	0.054	0.069	0.084	0.099
15-20	0.083	0.113	0.143	0.172
20-25	0.122	0.117	0.220	0.270
25-30	0.171	0.244	0.318	0.392
30-35	0.229	0.332	0.435	0.538
35-40	0.297	0.434	0.571	0.708

* dbh: diameter at breast height. (Source: Chaturvedi 1985)

Wide differences are observed in fuelwood yields from different agro-climatic zones and even in the same land formation. Slight differences in soil and climate can result in much variability in biomass production. However, one common factor is that the species has enormous potential to adapt to any habitat in arid and semi-arid tropics.

Fuelwood yields from plantations established on bare sites in different localities of Thar desert are shown in Table 5.

Table 5. Average fuelwood yield of *P. juliflora* at four locations in the Thar desert, Rajastan.

Tree age (yrs)	Fuelwood yield (kg/tree)			
	Jhunjunu (RF* = 395mm)	Sardarshahar (RF* = 268 mm)	Bikaner (RF* = 285 mm)	Gadra Road (RF* = 285 mm)
4	-	42	15	16
5	-	37	24	42
6	-	36	-	44
7	79	38	-	-
8	139	50	-	-
9	52	42	-	-
10	137	54	-	-

RF = Average total annual rainfall. (Source: Muthana and Arora 1983)

VII. MANAGEMENT OF EXISTING NATURALLY REGENERATED STANDS

More than 70% of the *P. juliflora* stands in the arid and semi-arid tropics of India are naturally regenerated in the form of a weedy invasion. Natural regeneration occurs freely from seed, which is dispersed by livestock or wildlife that eat the pods of the species, and from root suckers.

The massive extension of naturally regenerated weedy stands of *P. juliflora* is satisfying the fuelwood and fodder demand of an increasing human and livestock population, but is posing a threat of invasion to fertile agricultural lands. It is very difficult to eradicate *P. juliflora* once it is established so the 'million dollar' question is how to manage naturally regenerated stands of *P. juliflora.* Unfortunately, with the exception of a few singling studies on small experimental plots, no records are available from India, regarding how to manage large weedy coppice stands of the species.

A. Types of naturally regenerated stands

The naturally regenerated stands of *P. juliflora* can be classified into bushy thickets and woodlands (Figure 28 and Figure 29). According to a conservative estimate, approximately 70-75% of naturally regenerated stands are immature bushy thickets.

These bushy thickets are often considered as a weedy invasion when they occur in the vicinity of agricultural fields. The bushy thickets can be further grouped into three categories:

- dense infestation with around 9000 stems/ha
- closed thickets with 1000-1100 trees/ha (5200-6700 stems/ha)
- open thickets with plant density 500-600 trees/ha (2600 to 3100 stems/ha)

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Figure 28. A bushy thicket of *P. juliflora*.

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Figure 29. A woodland of *P. juliflora* in village common land.

The primary reason for the predominance of bushy thickets is that the individuals are repeatedly coppiced for fuel from less than 2 years old. Bushy thickets are the most problematic to manage. They occur commonly in revenue lands (government lands that are permanently fallow) and other types of wasteland.

P. juliflora constitutes approximately 30% of all naturally regenerated woodlands. These are commonly found in Common Property Resources (CPRs) which are overused or abused throughout the country. Some of the CPRs are paithan (catchment areas of village water reservoir), orans or dev vans (woodlands designated to honour village deity or saint and preserved meticulously on socio-religious grounds) and gochar (village grazing lands). Besides CPRs, *P. juliflora* woodlands are also found in protected and/or reserved forest areas. They are generally 'closed stands' or 'extensive grazing areas' having 200-250 trees/ha (1000-1300 stems/ha) and open silvo-pastoral areas consisting of 100-125 trees/ha (500-650 stems/ha). Such naturally regenerated woodlands are relatively easy to manage.

B. Management options

Management of bushy thickets

The bushy thickets of *P. juliflora* range from patches of 80-100 ha to widespread distribution in thousands of hectares. Because of lack of resources, it is impossible to kill the entire stand of the species with aerial application of herbicides or by severing the roots of trees using heavy equipment like bulldozers.

Root ploughing provides virtually 100% kill of *Prosopis* in the stand, but 10-15 years after root ploughing, a similar high density stand of *Prosopis* often occurs from the seed bank in the soil.

In India, bushy thickets of *P. juliflora* are harvested for fuelwood or for making charcoal. The harvesting for fuel or charcoal is very painstaking manual work. Silvicultural systems for *P. juliflora* have not been developed in India but reports from elsewhere suggest that such thickets can be managed for better production and efficient utilisation.

Once *P. juliflora* has occupied an area, the only permanent and sustainable solution is to thin the dense impenetrable stands to isolated trees that can be encouraged to grow into large trees. These will help prevent the dense encroachment of young weedy forms of the species.

To manage a stand, first map the area. An approximate map will work. If the stand is too large (say more than 100 ha), divide it into sections of 50-60 ha. Record the number of trees, number of stems per tree and their diameters, preferably collar diameter, by laying 10 m x 10 m quadrate at a number of places. By doing so one can calculate the density of trees/stems per hectare, average diameter/ tree or stem and total basal area or diameter per ha. These values will give the exact picture of stocking rate on the stand compartment to be managed.

If the stand compartment has plain topography, first do strip thinning of 6-8 m width in two perpendicular directions. Thinning should be done more or less centrally in the stand/compartment. A bulldozer is required to perform such strip thinning, otherwise it is a very time consuming and labour intensive operation. These strips are essential for the movement of labourers and equipment. Now each stand/ compartment will have four sections.

On close examination of each stand/compartment, a few well developed trees can be found within the bushy growth. The next operation is initial thinning. This thinning is required to bring down the density of stems to 3000 stems/ha in 'dense infestation' and 'closed thickets'. Try to cut down the stems having a collar diameter of less than 10 cm using a sharp axe or power saw. If a power saw is available, the operation can be executed quickly.

The cut stems can be used for fuel and for making charcoal. On average a stem of 10 cm collar diameter has 5 kg fresh weight of fuelwood.

Cut the stems at ground level, as these stems will exhibit very low re-sprouting, whereas stems that are cut above ground level show very high degree of re-sprouting.

In open thickets, there are often many individuals that already have a good tree form. These can be left alone as part of the final stand. Thin such thickets to bring down the number of stems from 2600-3000 stems/ha to approximately 1000 stems/ha.

For undulating and hilly terrain, the strip and initial thinning operations are the same as for flat terrain but the strip widths can be reduced to 4-5 m as all the operations will have to be executed manually. To perform these operations, 150 man days per ha are required.

After strip thinning and initial thinning, remove all underlying seedlings or small saplings of the species with their roots. After the growing season is over, employ second thinning. Cut all stems less than 12 cm diameter. This will bring down the density in 'dense infestation', 'closed thickets' and 'open thickets' to approximately 500-600 stems/ha.

After the second thinning sufficient space will be available to plough the area. Disc the area, wherever a tractor can be operated and in those areas where the tractor operation is not possible, plough the area using conventional means, i.e. bullocks.

Allow the remaining stems to grow next season. Select about 150 of the most sturdy and straight stems per hectare. Prune the side branches of the selected trees. Disc or plough the field if possible. If there is new coppice growth cut and remove it. Monitor the growth rate of the stem.

During the fourth year maintain a density of 100-150 stems/ha. During the fourth year and subsequent years, disc or plough the field twice per year. Prune the side branches regularly after the termination of growth each year, after the first fortnight of November but before the onset of spring, the second fortnight of February.

Coppice shoots often emerge in managed weedy thickets. Cut them, each year if possible, otherwise in alternate years.

After approximately seven years or so, pruning is not required because by this time trees will take the desired tree shape. However cleaning and ploughing of *P. juliflora* plantations should be done regularly to check any new emergence of seedlings of the species or encroachment by undesirable plants.

Box 19. Silvo-pastoral plantations.

If possible, convert managed weedy thickets into silvo-pastoral plantations. After the target of 100-150 trees/ha is achieved, sow perennial local palatable grass species. For example, *Cenchrus ciliaris*, *C. setigerus* or *Lasiurus sindicus* in arid lands of western Rajasthan; *Leptochloa fusca* in saline-alkaline soils of Haryana. Intercropping reduces seedling encroachment and increases tree growth. The rotation age for such *P. juliflora* based silvo-pastoral stands is generally 25 years and by that time a tree with a 35-40 cm diameter can be achieved.

Even if the purpose is to keep weedy thickets for fuelwood and/or charcoal, 'dense infestation' and 'close thicket' still require management for optimum production. Bushy thicket growth is often poor, whereas in managed close density plantations with 4444 stems/ha (spacing 1.5 x 1.5 m), 6.25 t/ha fuel wood (green weight) can be harvested. Therefore, it is advisable to bring down the stocking rate in such weedy thickets to around 3500 stems/ha.

Employ strip and initial thinning in the stand/compartment to be managed, as described above. Cut all the stems less than 5 cm in diameter at ground level. Leave others, especially those with a collar diameter of more than 8-9 cm.

Educate the villagers through extension agencies not to harvest stems from the same trees every time. In this way with care and management, dense infestation and close weedy thickets can be transformed into productive fuelwood plantation. Moreover, charcoal making units only buy stems which have more than 8-9 cm in diameter.

C. Management of woodlands

P. juliflora woodlands, i.e. closed stands (extensive grazing lands) and open silvo-pastoral areas, are managed using traditional guidelines. The reasonable goal of management of closed stands is to achieve 100-125 trees/ha with 35 cm basal diameter. This is comparable to the timber production objective.

Pragmatically, the first step in achieving this goal is conversion of trees with multiple stems arising from the base to single stems. To

convert individuals with multiple stems to single stems, cut or prune the stems, leaving only the sturdiest one with the largest basal diameter.

After this, select the 100-125 best individuals in a hectare and fell the rest at ground level. Remove the bark from the stump of the felled individuals. Selection of individual should be done in such a manner that the trees are spaced approximately 9-10 m apart.

Perennial grasses come up naturally on the ground and animals graze freely on such ground. Monitor the growth of managed individuals regularly. If some coppice growth emerges cut it immediately. After 6-7 years of continuous management, emergence of re-sprouts almost disappears.

D. Upgrading natural *P. juliflora* stands

There are also techniques for improving existing naturally regenerated stands of *P. juliflora*. Spineless or less spiny, straight boled and high pod yielding individuals/accessions of *P. alba* and *P. pallida* are graft compatible with *P. juliflora*.

Individual stems of *P. juliflora* are taken as stocks onto which is grafted budwood (scion) using the cleft grafting technique (Chapter 4). The grafted scion of the improved plant type grows rapidly. August and September are the best months in India for such grafting.

Box 20. Grafting different *Prosopis* species.

At CAZRI, Jodhpur, the use of *P. juliflora* as the woody component in arid zone agroforestry systems has been studied. The most encouraging results are obtained in upgraded/improved *P. juliflora* stands. In a natural weedy thicket of *P. juliflora*, plant density was brought down to 100 stems/ha (approximately 10 x 10 m) by repeated thinning and singling. Onto those single stems, scions of *Prosopis* sp.- Peruvian (most probably *P. pallida*), which have straight bole and spineless features were cleft grafted. The cluster bean (*Cymopsis tetragonoloba*) was sown in association with these trees. These upgraded trees exhibited rapid increment in height and in a span of four years, on average, they have attained a height of 2.5 m. Average cluster bean yield recorded was around 0.4 t/ha.

Regularly cut new sprouting shoots from the stock and allow the grafted material to grow. Employ light pruning, if branching takes place rapidly in the grafted scion after successful union. Use secateurs for such light pruning. This graft will develop into a tree form having the features of the scion.

Box 21. Community participation.

It is not so easy to manage existing naturally regenerated stands of *P. juliflora*. The management of such stands requires effort and dedication on the part of those associated with such programmes. Moreover, management operations are highly labour intensive. However, in the long term, management of *P. juliflora* stands can be beneficial from both wood productivity and commercial points of view. Joint Forest Management (JFM) has proved very successful in protecting and regenerating degraded and deforested areas in many states. Community participation is very important for the long term success of managing existing naturally regenerated *P. juliflora* stands. The more farmers and communities invest their ideas, labour and resources, the more likely the management system will be sustainable. Specific areas requiring attention are:

- policies that allow forest agencies (State Forest Departments, Wastelands Development Departments, Desert Development Agencies, District Rural Development Agencies, etc.) to formally empower community management groups.
- programmes that support community-oriented production from existing naturally regenerated *P. juliflora* stands.
- extension education programmes for villagers and communities so they can understand the benefits of management of such tree stands of *P. juliflora.*
- procedures for joint planning by the forest agencies and communities.

VIII. UTILISATION OF *PROSOPIS JULIFLORA*

In India, *P. juliflora* is mainly known for its firewood value and as a weedy infestation. Although the pods are used extensively as a livestock feed and, in tropical arid and semi-arid regions, provide a substantial amount of the livestock ration, the species is not given the credit it deserves. In South America, *P. juliflora* is considered a valuable multipurpose tree equivalent to that of *P. cineraria* (Khejri) in India and Pakistan. This chapter summarises the potential utilisation of *P. juliflora*, although some of the uses are not yet adopted in India.

A. Wood utilisation

Wood as direct fuel

P. juliflora wood is an important source of domestic fuel for the majority of rural households in tropical arid and semi-arid India. It is the most easily available wood resource in these regions. The wood burns evenly and does not spark or smoke excessively. The calorific value of wood is quite high (4200 kcal/kg).

The positive qualities of firewood are present even at the juvenile stage and this allows green branches to be burned for cooking food after sun drying for only a day or so. Because long periods of storage and drying are not required, rural folk often cut it on a day to day basis for use directly in their traditional mud stoves (chullah).

P. juliflora wood is also used as an industrial fuel, especially in small scale industries. It is used for oven and kilns for treating and purifying minerals; firing pottery, especially traditional earthenware for kullarh (cup), handi (vessel for cooking food), ghara (pitcher for water storage), and gamla (pot for growing plants); and baking bread and biscuits. These industrial processes require a large quantity of wood and therefore, stems of over 10 cm in diameter are often used.

For firewood, all branches with 1-10 cm diameter are cut to length, often approximately 1 m long and 10-15. Such branches are tied into headloads which are carried from source to village/towns, either for personal use or for sale. In India, short wood (length of 0.5 m or less) and long wood (length over 1 m) are sold separately. A headload of

short wood costs Rs 10-15 and that of long wood around Rs 15-25. For domestic firewood purposes mostly branches of less than 10 cm diameter are preferred because they can be cut with ease by a hand axe.

A common practice in Thar desert region of Rajasthan is to cut juvenile branches of *P. juliflora* after the monsoon season is over (late September to mid October). These are then left for 15-20 days to dry before they are collected and stored near the dwellings. A common practice is observed in local communities that the same person or his/her representative who cuts it also collects the dried branches. There is no such rule in village institutions like panchayats but the practice is followed as a social agreement.

Box 22. Electricity from *P. juliflora.*

P. juliflora wood has been considered as a fuel for generation of electricity, either by direct burning or via gasification. The woody biomass is low in sulphur and, therefore, not as polluting as other sources such as coal. Some preliminary studies in this regard are available from USA and India. However, much research and development efforts are still required in this direction. If a foolproof procedure is developed to convert *P. juliflora* biomass into electricity, the vast available resource of the species in India can be utilised profitably.

Wood as charcoal

Firewood is bulky and expensive to transport as it is a low value product. Conversion to charcoal reduces the weight and increases the energy and economic value of the product. Charcoal is consumed mostly in urban areas in restaurants, bakeries, small-scale iron works, and for parching and popping food grains like corn and rice for snacks. The price of charcoal varies from location to location and also depends on transportation cost. In general, a 20 kg bag of *P. juliflora* charcoal is sold for Rs 50 (approximately US $1.2).

Charcoal is often produced at a considerable distance from the point of consumption. In Kutchh area of Gujarat and Pali, Jalore, Sirohi and Rajsamand districts of Rajasthan in India, charcoal manufacturing from *P. juliflora* forms an integral part of daily activity of a large part of the rural population. Revenue earned from charcoal manufacture plays a vital role in rural livelihoods of these areas.

Larger diameter trunks (over 10 cm) are used to make charcoal, by burning stems, branches and the upper root stock of trees under anaerobic condition. Traditionally, charcoal is prepared in an earth covered mound.

Before processing, wood is first sorted into more or less similar diameter trunks/branches. These pieces of wood are stacked and after that moistened slightly. Then the stack is covered with soil. Once the process is completed this earthen kiln is fired. The stack burns very slowly for several days. The burning depends on the size and condition of stack and site. Consequently 3-8 days are required to complete the process. The stack is then opened, and the charcoal is removed and allowed to cool. Finally, it is graded and bagged up for sale.

Discarded oil drums and tar barrels fitted with air ducts are also used in some places to manufacture charcoal. As drums and barrels are portable, they can easily be taken to the source of fuel.

To produce 1 kg charcoal, approximately 6-9 kg *P. juliflora* wood are required, depending on the method used.

Box 23. Retort kilns for charcoal making.

Though not yet available in India, in many other countries where *P. juliflora* grows, 'retort kilns' are becoming popular. Wood is stacked into one or two large metal cylinders (approximately 2 m long and 1 m diameter) and heat from a small wood-fired oven is circulated through the metal cylinder. Charcoal can be prepared within 8-48 hours in such kilns. The advantage of retort kilns over earth kilns is that they have a higher conversion efficiency (approximately 32%) and that they produce charcoal in a shorter length of time (two days).

Wood as timber

The wood of *P. juliflora* can be used as roundwood or processed into chips or sawnwood. Long and relatively less straight pieces can be used for posts and poles. These can be simply fashioned into fence posts or poles for light construction, for incorporation into house structures or for supporting shuttering while concrete is being cast. Chipping of *Prosopis* wood is done to manufacture plywood, particle

board, paper and cardboard. However, before chipping, wood is treated chemically or by direct heating.

The maximum value that can be obtained for *P. juliflora* wood is when converted into boards and cants. Sawing can be carried out by hand, but timber is more often processed by chainsaw, circular saw or band saw.

Note: *Trees with a clean bole of around 2 m length (lumber) are best for making furniture. Unfortunately at the moment, most* P. juliflora *lumber is only 1-1.5 m length and 20-30 cm wide and often with cracks and knotholes. This calls for immediate attention to better manage commercial* P. juliflora *plantations.*

Box 24. Marketable timber from small *P. juliflora* logs.

For all sawing processing, maximising timber recovery is an important aspect. The sawing of short and crooked logs into marketable timber is becoming an increasingly important aspect in timber processing. A survey of kitchen cabinet manufactures in the USA found that 90% of the pieces of wood used are less than 10 cm wide and less than 1.6 m long. Thus, even the smallest *Prosopis* logs (1 m long by 20 cm diameter) can yield marketable timber in the form of hardwood blanks.

These should be squared on all sides and could be planed as required. *P. juliflora* logs are often slightly crooked. When sawing with a single blade, the log should be positioned so that the first cut approaches the concave face. One or two cuts will produce the first straight edge. The log is then turned so the straight side faces down. The log can be cut into boards with one straight edge, or squared into a cant by successive turnings, once another straight face is cut. Some sawing processes, for squaring up on conventional table saws can also produce boards and cants with no straight edges.

In India, use of *Prosopis* wood in furniture industries is very limited, because of non-availability of straight bole trees and also to some extent because of a lack of knowledge. In other countries, *Prosopis* species are widely used for making furniture because of their high quality wood. The wood quality is comparable to shisham or Indian rose wood (*Dalbergia latifolia*) and Indian teak (*Tectona grandis*) (Table 6).

Table 6. Some physical and mechanical properties of *P. juliflora*, shisham or Indian rose wood (*Dalbergia latifolia*) and teak (*Tectona grandis*).

Property	*P. juliflora*	*D. latifolia*	*T. grandis*
Density (kg/m^3)	721	850	641
Bending strength (MOE* X 10^3)	97	125	102
Shrinkage (%):			
Volumetric	4.7	8.5	7.0
Tengential	2.2	5.8	5.8
Radial	2.6	2.7	2.5
Side hardiness (kg)	1059	1437	453

***MOE: Modulus of elasticity

In fact, *Prosopis* wood equals or surpasses the physical and mechanical properties of other commonly recognised fine hardwoods in India. The surface hardness of the wood makes it ideal for furniture and flooring applications and makes it possible for *P. juliflora* wood to take a good finish and natural high polish.

Prosopis wood displays a distinctive straight or swirling grain that ranges from golden brown to dark reddish orange in colour. The wood colour compares favourably to the purple grain of Indian rose wood (shisham). Therefore, *P. juliflora* wood displays the beauty of grain sought after by consumers and wood workers, who produce distinctive cabinetry, furniture, craft and flooring. Considering all these properties *Prosopis* wood ranks as one of the fine tropical hardwoods of the world.

Box 25. *Prosopis* sawmills.

The simplest mechanical processing of logs is with a chainsaw, either hand held or increasingly with some form of chainsaw jig or specially designed chainsaw table or 'micro sawmill'. A skilled chainsaw operator can cut a *Prosopis* log by hand on the ground into boards or cants that are relatively straight and suitable for further processing. The thinnest boards that can practically be cut by hand are approximately 5 cm thick with a length of 1-2 m.

Specially designed sawmills, of both the circular saw and band saw types, are used successfully for large quantities of Prosopis logs, especially in USA and Latin America. Sawmills with large, single circular saw blades are the traditional mills used for processing timber, where logs are fixed onto an adjustable platform, which is then rolled past the blade, affecting the cut. Such traditional saw mills using a single circular blade with an adjustable platform are most commonly used in India and neighbouring countries. However, band-saws of different designs, which can be used for processing small and crooked logs of *P. juliflora* are now on the market.

In India, at the moment, large stands of well managed *P. juliflora* trees are not available (with very few exception). However, some good trees are always available in bushy thickets, village common lands, farm boundaries and near dwellings in villages. In such situations, portable saw mills may be more economically viable than a central saw mill as the transportation of logs will be too costly. In places where timber of the species is plentiful like canal side areas of IGNP (Indira Gandhi Nahar Pariyojana), a central sawmill will be more economically viable.

Before timber can be processed it must first be seasoned. Drying must reduce the moisture content of the wood from approximately 50% to below 10% without causing unacceptable levels of deformation. Boards and cants can be stacked and air dried in 3-12 months depending on board thickness and spacing, stack covering and location, and climatic conditions of the locality. Alternatively, kiln drying is possible.

Kiln drying schedules have been developed for *P. juliflora* in India, which reduce moisture content from 45 to 11% in 15 days with minimal deformation. Although kiln drying requires capital investment and labour, it greatly increases turnover, while also eliminating losses from wood boring beetles that might otherwise require chemical treatment.

Portable kilns are commercially available in southern USA, Mexico andSouth America, where *Prosopis* grows abundantly.

Prosopis wood has been assessed for use in making many products including gunstocks, drink barrels, musical instruments and pencils, and is commonly used for making small craft items. In India, there is increasing use of *P. juliflora* wood of the species as timber for manufacture of furniture (Figure 30), small craft items and agricultural implements.

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Figure 30. Dining table and chairs made from *Prosopis* wood.

B. Pod utilisation

Pods as animal feed

P. juliflora pods have long been fed to cattle, sheep, goats, camels and horses in India. Livestock consume ripe or unripe pods directly in the majority of cases. In arid and semi-arid landscapes, it is common to find a herder with his/her animals around the trees during the fruiting season. Animals consume naturally fallen pods or pods made to fall by the herder, as soon as they touch the ground. More than 60% of pods are consumed raw by livestock.

Box 26. *Prosopis* pod yields.

No systematic information regarding pod production in India is available. An extensive survey was carried out by the scientists of CAZRI, Jodhpur, India during 1991-92, in parts of Gujarat, Rajasthan and Uttar Pradesh. Pod production from more than 50 trees was assessed. Average pod production was approximately 20 kg/tree with a range of 5-50 kg/tree. A report from Brazil indicated that in a well managed plantation (spacing 10 x 10 m) of *P. juliflora*, an average 6 t pods/ha/year are produced with some trees producing as much as 170 kg of pods annually.

Some efforts have been made in the country to use the pods as a processed livestock ration. The pods are broken into 4-5 cm long pieces and dried at 60^{o}C for 8 hours to reduce the moisture content below 7%. These pods are then ground in a disc-mill setting the gap between two discs at 3-4 mm to allow endocarp and seeds to pass without breaking. Then they are sieved through a 1.2 mm sieve. In this way, *P. juliflora* pod flour can be prepared for cattle feed. The pod flour is then mixed with wheat straw, groundnut husk, cotton seed, rice husk, etc.

Box 27. Pods increase milk yields from cattle.

It has been reported by the Vivekanand Research and Training Institute (VRTI), Mandvi, Bhuj, that cattle owners have come to the Institute with very high demand for *Prosopis* cattle feed. The farmers consider that cattle feed prepared by the VRTI has increased milk yield by more than 20%. At VRTI, a mechanical unit has been fabricated to process the pods of *P. juliflora* (Figure 31 and Figure 32). In this unit, the pod flour and seeds are efficiently separated.

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Figure 31. Threshing machine for processing *P. juliflora* pods.

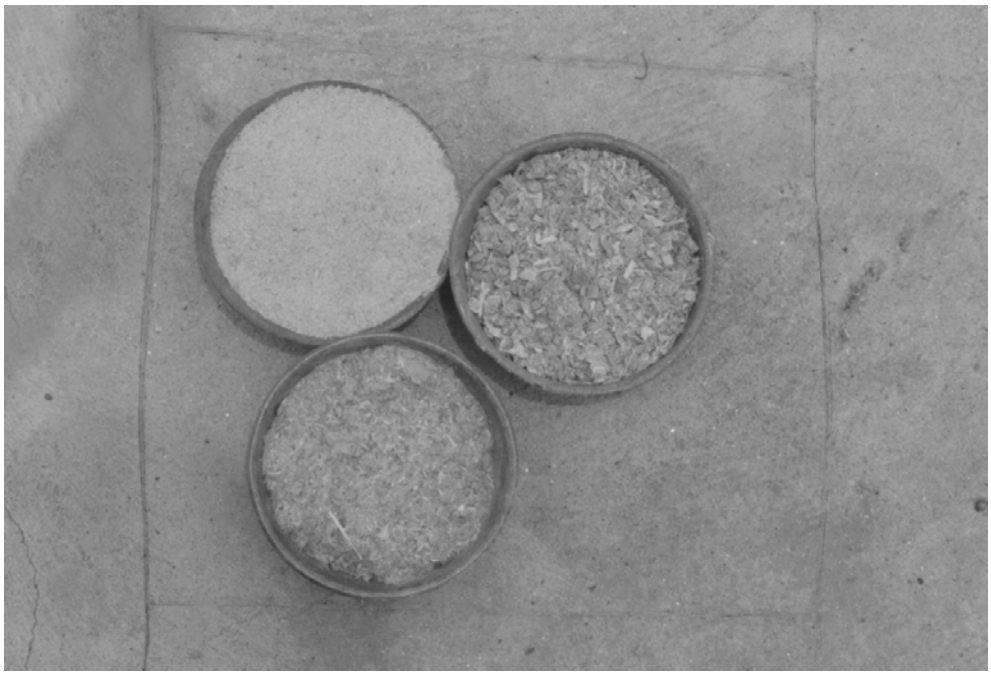

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Figure 32. *P. juliflora* flour for cattle feed.

The great value of *P. juliflora* as fodder lies in its pods. *P. juliflora* pods are very palatable and provide good nutritive value to cattle, sheep, goats, camels and horses. The ripened pods, on average contain the following:

moisture	12%
protein	10%
digestible protein	8%
fat (ether extract)	2%
fibre	14%
total soluble carbohydrates	55%
calcium	0.20%
phosphorus	0.15%

Pods as human food

The pods of the native Indian *Prosopis* species, *P. cineraria*, are widely used as human food in the Thar desert region. The green and dried pods of *P. cineraria*, commonly known as sangri are cooked as a vegetable. Dried sangri costs around Rs 85 (approximately US $ 2) per kg in the market. However, *P. juliflora* pods do not seem to be used in any form for human food in the entire Indian sub-continent. In Latin American countries, especially Peru, *Prosopis* pods are used as human food. To give a brief idea to users of this manual, the following description summarises how the pods of the species are used as human food in countries stated above.

Pod flour in confectionery

Pod flour can be obtained through the process as described for animal feed, but when used in confectionery items like bread and biscuits for human consumption, the final sieving should be done by 250 µm sieve. In this way fine flour is obtained. For making biscuits, up to 24% fine *P. juliflora* flour is mixed with wheat flour. For the preparation of biscuits mix, wheat flour, *P. juliflora* pod flour, sugar, sugar syrup, milk powder and other ingredients and knead until homogenous dough is formed. This is baked at 205^{o}C for 15 minutes. Table 7 shows the ingredients of conventional biscuits and biscuits prepared with *P. juliflora* pod flour.

Table 7. Ingredients for biscuits prepared using conventional methods and using *P. juliflora* pod flour (for 6 kg biscuits).

Ingredients	Conventional biscuits (g)	*P. juliflora* biscuits (g)
Wheat flour	4000	3200
P. juliflora pod flour	-	1000
Sugar	1200	1000
Sugar syrup	320	320
Shortening	1200	1200
Powder milk	160	160

Approximately 6 kg of biscuits can be prepared from the quantity of ingredients in Table 7. These biscuits taste like normal ones. In fact, it is impossible to differentiate between the taste of the two types of biscuits.

©G Cruz

Figure 33. Human food products derived from *P. pallida* pods.

Pods as coffee substitute

In Brazil and Peru, *Prosopis* pods are used to prepare coffee. Pods are well dried and manually crushed. After crushing they are toasted in a clay pot. Four teaspoons of sugar are added to 1 kg pods at the end of toasting process, a few minutes before removing the pot from the fire. This toasting requires 30 minutes. After cooling, the product is ground in a coffee mill or pestle and mortar. The powder is known as *Prosopis* coffee. For one litre of water one heaped table spoon of *Prosopis* coffee is required. Some people in the region use this coffee directly while some mix 50:50 *Prosopis* coffee and normal coffee powder to create real coffee flavour.

Pods for preparation of Prosopis *syrup*

The inhabitants of northern Peru prepare and consume 'algarrobina' - a concentrated sugary extract from the pods. To prepare algarrobina, 350 g of pods are boiled with one litre of water and then boiled for two hours. Then the pods are pressed and the extract is filtered. Finally, the extract is concentrated by evaporation to a texture thicker than honey. The algarrobina syrup can be consumed in different ways.

The rural people add it to juice and milk as both sweetener and flavouring agent. In the towns and cities, the syrup is used as an ingredient in home confectionery and to prepare a very typical alcoholic cocktail.

C. Other direct uses

Exuded gum

P. juliflora exudes gum from the sapwood during winter and summer months. On average, 30-40 g gum is produced from one tree. The quality of the gum is not very good because of presence of alkaloids, which gives it a bitter taste. Therefore, *Prosopis* gum is mainly used for sizing in textile mills, in confectioneries and in processing betel for use in '*pan*' (betel leaves), which are chewed by people throughout the Indian sub-continent. *P. juliflora* gum is also used for making adhesives. If systematic collections of gum could be undertaken from existing plantations of the species, revenue of millions of rupees can be earned every year.

Seed gum

P. juliflora seeds contain galactomannan polysaccharide. This seed gum is used as a thickener, stabiliser and gelifier in products like ice cream, sauces, cheese, yoghurt and sausages. The value is similar to that of guar gum. Because of the interest in new sources for food gums, seed galactomannan of *P. juliflora* is being studied currently by several researchers.

Box 28. *Prosopis* gum research trials.

The viscosity of *P. juliflora* gum solutions is, in general, comparable to that of guar gum. With regard to the separation procedures of endosperm from the whole seeds, either an aqueous extraction, a mechanical splitting or an acid destroying of the coat has been tested. So far, the mechanical separation of splits (endosperm and seed coat) from the cotyledon is feasible, although with low yields. However, the isolation of the endosperm from the splits is possible only by aqueous extraction.

Medicinal uses

P. juliflora has been shown to have several medicinal uses including the following:

- *P. juliflora* syrup is given to children showing weight deficiencies or retardation in motor development.
- *P. juliflora* syrup is considered to increase lactation in breast-feeding mothers.
- *P. juliflora* syrup is used in preparation of expectoration purpose.
- Coffee prepared from *P. juliflora* pods is considered good for digestive disturbances and skin lesions.

D. Indirect uses

Honey and bees wax

P. juliflora is a major source of honey, especially in Kutchh region of Gujarat. The honey bees (*Apis florea*) prepare the comb. These combs are semi-circular and become more semi-eliptical with age. The comb size varies from 10 x 12 cm to 45 x 60 cm at varying height on the trees. The large stores of honey leading to major flow are observed from March to April. November and December has been observed to be a period of minor flow of honey. Hence March to May is the best time to harvest honey.

While harvesting, the honey hunter puffs smoke into the nest. The bees instantly leave the honey portion and the adjacent brood area and cluster on the twigs of other trees in the vicinity. The collector cuts away the upper and side portions of the stores, leaving the rest of the comb untouched. The honey is later strained through a cloth and collected. The quantity of honey ranges between 175-800 g per comb depending on the size of the comb.

After collecting the honey, the honey combs are crushed and bees wax is obtained. The bees wax has great economic potential as it is used in a number of industrial processes.

Box 29. *Prosopis* management in Kutchh.

The arid zone of Gujarat, covers an area of 62,180 km^2, of which Kutchh district accounts for 73%. The entire area in this district is full of *P. juliflora*. Gujarat State Forest Development Corporation (GSFDC) has been using this species for 15 years for the benefit of rural communities. During the last five years GSFDC collected 400 t honey, 15 t bee wax, 57 t grade-I gum and 716 t grade-II gum from *P. juliflora* thickets and woodlands. These activities of GSFDC generated employment for local people, especially rural folk to the tune of 0.72 million man-days. Thus *P. juliflora* in Kutchh area is the major source of livelihood to villagers.

Honey from *P. juliflora* plantations can be collected in other areas where it grows. If bees are not available, these can be introduced. If planned systematically, this can be one of the best sources of income for the rural population in arid and semi-arid tropical regions of India.

Agroforestry applications

Except the extreme western margins, the Thar Desert region is characterised by sparsely distributed *P. cineraria* trees with arable crops or grass growing beneath them (especially during monsoon season, as agriculture is pre-dominantly rainfed), with distantly spaced settlements. *P. juliflora* also grows abundantly throughout the region but is never found in cultivable land. Farmers prefer *P. juliflora* only on farm boundaries as wind break and/or living fence.

Intercropping with *Prosopis juliflora*

In north-eastern Brazil, the prickly pear cactus *Opuntia ficus* var. *indica* (fodder or edible varieties) is commonly grown in association with *P. juliflora*. Edible crops also can be grown in association with *P. juliflora* during plantation establishment stage. The spacings of 10 x 10 m and 2 x 1 m were recommended for corn (*Zea mays*) and macaausar bean (*Vigna unguiculata*) in alternate rows. With buffel grass (*Cenchrus ciliaris*), leaving 2 m diameter around the *P. juliflora* trees free of grass is recommended.

Silvo-pastoral system for India

In India, a silvo-pastoral model, consisting of *P. juliflora* trees as the woody component and *Leptachloa fusca* grass as the herbaceous component has been found to be highly productive in alkaline soils. *Leptachloa* in association with *P. juliflora* planted at 5 x 3 m spacing produced 46 t of green fodder in 15 cuttings over a 4 year period without any fertiliser or soil amendments. *P. juliflora* produced about 80 t/ha of air dried wood in 6 years. This silvo-pastoral system improved the soil to such an extent that it was possible to plough under the *Leptachloa* after four and a half years. After this, less alkaline tolerant, but more palatable fodder species like *Trifolium resupinatum* and *T. alexandrium* can be grown.

Box 30. Productivity of *P. juliflora* in a silvo-pastoral system.

A report from the Indian Grassland and Fodder Research Institute (IGFRI), Jhansi, on long term silvo-pastoral trials on two sites indicated that *P. juliflora* is compatible with many grass species in semi-arid lands. At one site, a typical degraded plain land with shallow, sandy loam, pH 6.9, *P. juliflora* seedlings were out-planted at a spacing of 5 x 5 m with pasture grasses *Cenchrus ciliaris* and *Chrysopogan fulvus* in the interspaces. At a second site, a typical ravine situation, pH 9.8, *C. ciliaris*, *C. fulvus* and *Borthrochloa intermeida* were planted in the interspaces between *P. juliflora* at the same spacing. Productivity was assessed after 9 years and after 18 years at Site 1.

	Productivity (t/ha/year)		
	Site I		Site II
	9 years	18 years	9 years
Forage (pasture grasses)	3.70	2.41	2.97
Top feed (pod)	0.25	0.47	0.21
Manure (tree leaf)	0.10	0.24	0.08
Firewood (branches)	1.64	3.79	1.68
Minor timber (bole)	1.25	2.90	1.13
Total	6.94	9.81	6.07

(Source: Tomer *et al.* 1999)

Soil conservation

More than 58% of western Rajasthan is covered by either moving sand dunes or semi-established dunes which are a menace to the inhabitants of the region. The dunes block roads, railway lines, irrigation channels, and often engulf settlements. It is reported that more that 2 t per ha of soil erodes from dune areas during the summer period. Vegetation cover is one of the best methods to conserve the soil and reduce or stop sand movement. Trees, grasses and creepers have been used, and among tree species, *P. juliflora* and *Acacia tortilis* have been found to be the best. With these species more than 60% of soil erosion can be checked. In western Rajasthan alone, more

than 1,00,000 ha have been stabilised by raising *P. juliflora* and *A. tortilis* plantations.

There are various ways of planting *P. juliflora* for soil conservation including the following:

- block planting on sand dunes
- strip planting on river banks (stream bank protection)
- single row planting on both the sides of road
- shelterbelt planting (single or two rows) around farm boundaries

Soil amelioration

P. juliflora plays an important role in soil improvement both in sandy and saline/alkaline soils through nutrient recycling by litter fall and also by rootlet decomposition. The long term effect of *P. juliflora* on highly alkaline soils results in a reduction in the pH of the soil from pH 10.9 to 9.2 in 20 years. The organic carbon increases from 0.12% to 0.33%, which is much higher than even under plantations of some broad leaf tree species. Likewise, with *P. juliflora* on afforested sand dunes, it has been noticed that the organic carbon, nitrogen and phosphorus increased with time.

Craft uses of Prosopis juliflora

P. juliflora can be utilised in many other ways than described above depending on the socio-economic, cultural and agro-environmental situation in different parts of the country where it grows. For example, with the use of indigenous technical knowledge of rural folk, bushy growth of the species can be utilised in basket making, which is fairly remunerative. Slightly larger stems, having diameter of 10-12 cm, can be used in making small kitchen implements, commonly used in Indian households, and craft items.

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