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MANAGING *PROSOPIS* FOR LIVELIHOOD SECURITY IN SALT AFFECTED AND DRY AREAS

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A view of *Prosopis* species planted at the CSSRI experimental farm, Karnal

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MANAGING *PROSOPIS* FOR LIVELIHOOD SECURITY IN SALT AFFECTED AND DRY AREAS

Introduction

Trees of the genus *Prosopis* are found growing in all kinds of lands in arid and semi arid areas of the world. In India, the trees are also found in almost all the states and agro-climatic regions except the areas which are prone to the incidence of periodic frost during winter months. The *Prosopis* trees are considered native to North America, South America, Africa and South Asia and genus *Prosopis* has about 45 species differing in morphological, physiological and genetic characteristics. The range of variation includes from small bushy shrubs to large trees with a trunk of more than 60 cm diameter; strong thorny canopy to thornless species and great variation in pod and foliage production. These trees are playing a vital role in sustaining the livelihoods of the rural poor, including the landless labourers, small farmers and artisans in dry regions. The people who depend upon these trees are the least vocal groups of society with disadvantaged resources. In the rural areas, *Prosopis juliflora* is the only source of fuel, small timber wood and in some cases used as dry season fodder. The trees provide alternative livelihood security during the severe drought period when no other vegetation remains green and productive. It is estimated that more than 50 per cent of the total fuel wood requirement in arid and semi arid areas is met by *Prosopis juliflora* trees. However, a *Prosopis* debate is going on in several countries of the world including India due to the reason that the trees are becoming an aggressive weed in several situations. Ecologists and environmentalists are strongly advocating invasion of grass lands, protected forests, nature reserves and even the crop lands by *Prosopis juliflora* trees because of its luxurious growth without inputs and care and large scale invasion of irrigated agricultural lands. Progressive and commercial farmers are afraid that their income may be at stake if the trees continue to invade the agricultural fields. Such groups of people have been putting pressure on Central and State governments for large scale removal/eradication of *Prosopis juliflora* from the landscapes and to ban *Prosopis* plantations. Such campaigns are getting momentum in several states including Gujarat, Rajasthan, Haryana, Delhi and Tamil Nadu. Similarly, *Prosopis* has also become a hot topic of discussion and policy in many parts of the world including Africa, South Asia, Australia and America. However, large number of farmers, artisans as well as researchers feel that *Prosopis* would be a valuable resource and eradication of this tree will be extremely difficult or impossible. They strongly believe that there is a need to manage this tree through its exploitation as a resource by better management techniques to reduce its invasiveness and adding value to products which are available from this tree almost free of cost. Many scientists believe genus *Prosopis* a nature's gift to reclaim wastelands and a source of livehilood to the poorest in the poor category. Several countries including USA, Argentina, India, Pakistan and Sudan have tried to eradicate *Prosopis* with herbicides and through mechanical methods. Though

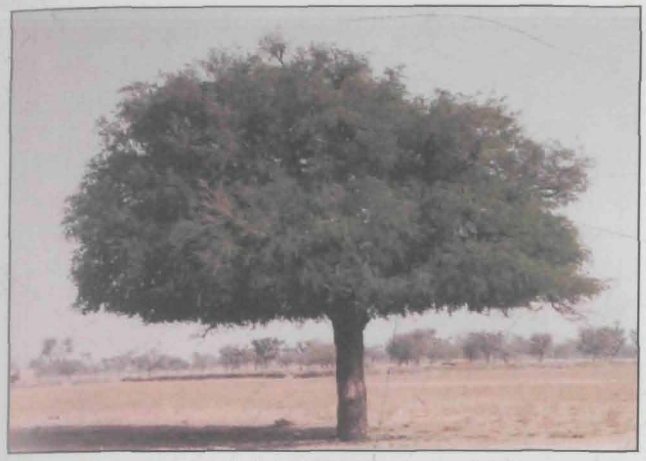
Unmanaged Prosopis juliflora growing naturally in a salt-affected wasteland

Proper stand management allows the trees to grow single stem for timber production

millions of dollars have been spent by these countries but still no cost effective solution has been found because this tree returns more vigorously after eradication and removal programmes. Biological control has also been tried in some countries. For example in South Africa, bruchid beetles have been tried to control *Prosopis* invasion, probably without much success. It clearly indicates that eradication may not be a viable solution and there are several management and control techniques, if applied properly can convert weedy stands into productive, profitable and sustainable employment, livelihood and poverty reduction source in salt affected and dry areas. The present bulletin reports upon the several ways and options through which *Prosopis juliflora* trees (considered waste and dangerous species) can be converted into national wealth and virtues for the welfare of millions of resource poor farmers settled in rainfed ecologies.

Introduction of *Prosopis juliflora* in India

There are several diverse opinions about the introduction of *Prosopis juliflora* in India. *Prosopis cineraria* locally known as Khejri is considered native to India and is serving as livelihood source in the Thar desert. The trees are a part of agricultural systems and provide fodder, fuel wood and vegetable to the poor people of Rajasthan. The land having more number of Khejri trees fetches premium price in Rajasthan. However, the number of Khejri trees in the Thar desert is showing a declining trend probably due to large scale mechanization, introduction of irrigation and climatic changes. Because of non competitive nature of *Prosopis cineraria* with associated crops, several arid land crops can be cultivated in the interspaces between tree rows in a unified agroforestry system. However, *Prosopis juliflora* is an introduced species and different people have different views about its introduction in India. Gupta and Blara (1972) reported that *Prosopis* was introduced to India in 1857 from Mexico. Similarly, Konda Reddy (1978) reported that the tree was introduced during 1876 at Camdapur of Cuddaph district in the old Madras Presidency by Lt. Col. R.H. Beddome, who was conservator of forest at that time and from there it had spread to other parts of India. On the other hand, Kaul (1956) reported that the tree was first introduced in Sind during 1877. Similarly, Rawat *et al.* (1992) believe that *Prosopis* was first introduced in Punjab during 1875 and from there, it has spread to other parts of India. These reports indicate that the



A compact canopy Khejri (Prosopis cineraria) Tree : source of energy, food, shelter and livelihood in the Thar desert

Several dry land crops can be cultivated in association with Khejri trees

tree was introduced somewhere during 1870s. Though, it was an introduced species but it was declared "Royal Plant" in 1940 by the Former King of Jodhpur state and it was placed under government protection. Large scale aerial seeding of this tree was undertaken to establish sand dunes and sand storms in Rajasthan. Over the years different morphological variations were reported in India among the natural stand of *Prosopis juliflora* in different parts of the country and attributed reason was the existence of different forms as existed in different countries. Because of natural inter species hybridization in genus *Prosopis* several variant trees differing in morphological and physiological characters are also found in India. Within *juliflora* there is a great variation in terms of number of stems, straightness, pod production, size and shape of thorns, thornlessness and size and shape of canopies.

Global Distribution of Genus *Prosopis*

Mesquite is the English name for trees of the genus *Prosopis*. The trees may exist either in the form of 2-3 m tall shrub or as a 15 to 20m tall tree with a stem girth of 100-150cm. About 45 species of genus *Prosopis* are found in North and South America, Africa and Asia. *Prosopis* trees are met in the sub tropical deserts of Colombia, Venezuela, Ecuador and Peru and in the Chilean desert. The largest subtropical *Prosopis (Prosopis alba, Prosopis chilensis, Prosopis hassleri* and *Prosopia nigra*) are found in Argentina. Taxonomists believe that understanding systematics of *Prosopis* are most confusing due to naturally occurring interspecific hybridization that results in hybrid swarms with intermediate morphological characters. This taxonomic confusion has been further complicated by the introduction of additional *Prosopis* species to arid environments of Africa, Asia and Latin America where new hybrids have appeared. Many of such tropical *Prosopis* species have become naturalized in arid and semi arid regions such as India, Pakistan, Brazil, Senegal and Sudan where they have been widely used by poor people for fuel. Most common cultivated species found in India are *Prosopis juliflora* and *Prosopis cineraria*. A brief account of important *Prosopis* species found around the globe is given in Table 1.

Table 1 : Comparison of the most widely cultivated *Prosopis* species in the world

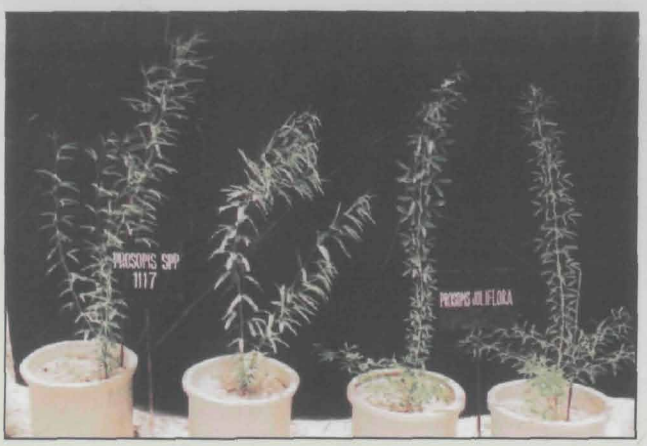
Species name	Common / English Name	Synonym	Distribution	Main attributes/ description	Environment requirements	Main uses	Limitations
Prosopis juliflora (Swartz) DC	Mesquite/ Algarroba, Pahari Kikar, Balayati Babul	*Mimosa juliflora* (Swartz)	Central America, South America, Africa, Asia	Thorny, deciduous, large crowned, may grow upto 10m or more, wood specific gravity 0.76 or more	Grows in very warm, dry climates, upto 1500 m altitude. Found in all agro-climatic zones except those prone to frost in winter	Excellent timber and fuelwood, food, fodder, honey. Owing to high heat value, forms excellent fuel wood, charcoal	Aggressive invader, the wood is called 'Wooden Anthracite' sensitive to frost
Prosopis alba (Griseb)	Algarrobo Blanco	--	Argentina, Paraguay, Bolivia	Round crowned tree, 5-15 m tall. The sapwood yellowish and heart wood dark brown. Both thorny and thorn less varieties	Sensitive to frost, grows in areas with an average winter temperature of 15°C, grows upto 1000 m altitude	Timber, fodder, food and roadside planting	Research on clonal propagation required
Prosopis chilensis (Mol.) Stuntz	Algarroba, Kiawe, Mesquite	--	Pacific coast of Peru, Central Chile, Argentina and Hawaii	Most drought resistant and highest biomass producer. Grows 8 to 15 m high, hard, heavy and strong wood (specific gravity 0.8-0.9), ornamental thornless verities are becoming popular	Withstands extremely high desert temperatures, grows upto elevation of 2,900 m. Poorly adopted to cold and requires temperatures of about 27°C for good growth	Excellent firewood, pods good source of feed, foliage as fodder	Aggressive invader

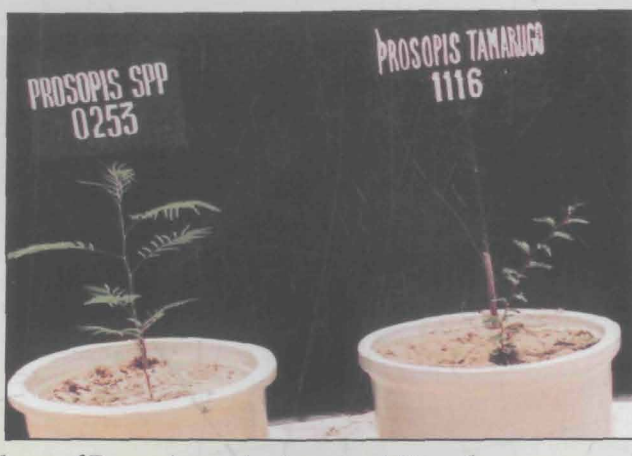
Contd...

Species name	Common / English Name	Synonym	Distribution	Main attributes/ description	Environment requirements	Main uses	Limitations
Prosopis cineraria (L.) Druce	Jand, Khejri, *ghaf* (Arabia)	*Prosopis spicigera* L.	North west India, Central and southern India, Pakistan, Afghanistan, Iran and Arabia	A thorny tree, grows 5-9 m tall and has open crown. Becomes leafless before flowering. Does not compete for moisture with crops	Low altitude tree, withstands both slight frost and high temperatures	Best browse plant for animals in deserts, human food, firewood and timber	Planted in sub-humid areas, they may become weeds
Prosopis pallida (Hum boldt and Bonpiand ex Willdenow). H.B.K.	Algarrobo, Kiawe	*Prosopis chilensis* (Bentham)	Peru, Colombia, Eucador, Puerto Rico, Hawaii, India, Australia	A tree 18-20 m high, with a girth of 60 cm. Usually thorny but thonless trees are available	More frost sensitive than other *Prosopis* species. Used for charcoal and requires more water for growth	Both leaves and pods are fed to cattle. Pods used to make sweet syrup	May become invader and form thickets
Prosopis tamarugo F. Phil	Tamarugo	--	Atacama Desert northern Chile known as *Pampa del tamarugal*	Only tree able to survive on the arid salt flats of Chile. It is deciduous, open crowned tree, reaching 8 - 15 m in height	It tolerates wide temperature range from -12° to 36°C, best growth between 1000-1500 m altitude	Only forage, fuel and timber tree in Chile salt desert	May become serious weed if planted in more equable climates than those of the harsh *Tamarugal* area

Prosopis Germplasm Collection and Introduction at Karnal

Large number of *Prosopis* species were introduced by the author from Texas A and M University Kingsville, Texas, USA and Hennry Double Day Research Association (HDRA) U.K between 1991 and 1995. The species introduced are listed in Table 2. The basic purpose of introducing several species of the genus *Prosopis* available around the world at Karnal was (i) to improve thorny and bushy *Prosopis juliflora* for better bole and thornless characters, (ii) to study the salt tolerance limits of different *Prosopis* species and their biomass production potential in salt affected soils and (iii) to establish permanent source of seed/planting material of promising species.





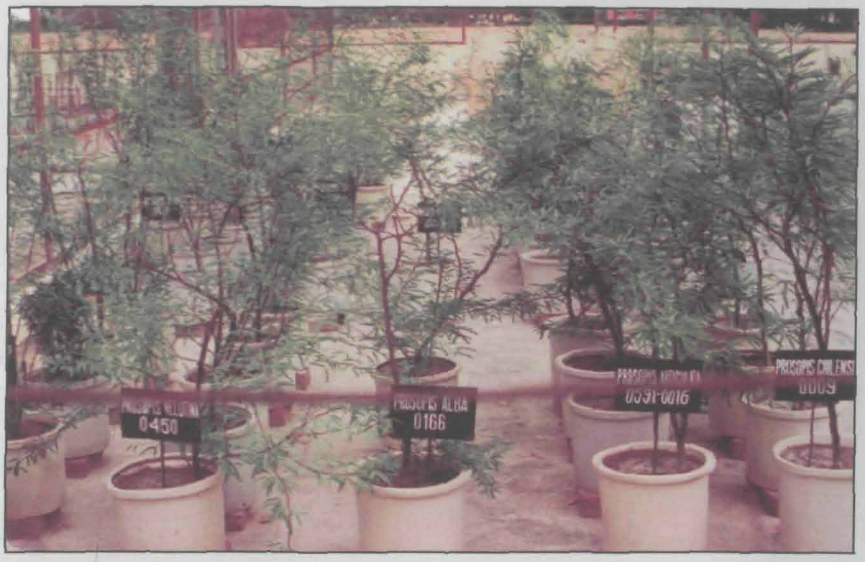
Raising of mother plants of introduced germplasm of Prosopis species in pots at Karnal

Table 2 : List of genus *Prosopis* species introduced from Dr. Peter Felker's collections in USA and Dr. Phil Harris germplasm bank in UK

Texas A and M, USA	HDRA, UK
Prosopis alba (Thornless)	*P. alba* (0465)
P. glandulosa	*P. alba* (0759)
P. articulata	*P. caldenia* AH 30, 86
P. pallida	*P. chilensis*
P. tamarugo	*P. glandulosa* (0475)
P. chilensis	*P. juliflora* cv 197
P. velutina	*P. levigata* OF 178/93/2
P. spp.(0457)	*P. nigra* (0744)
P. spp.(1117)	*P. velutina* 0454
P. spp.(0253)	*P. velutina* 0943
	P. velutina 0644
	P. velutina 0933
	P. alba (0751)

Germplasm Multiplication

The seeds of introduced germplasm were first grown in poly bags filled with normal soil, sand and farm yard manure to raise saplings for further investigations. Saplings of selected species were grown in 30 kg capacity ceramic pots filled with good soil to serve as mother plants for further multiplication of germplasm. Using saplings raised in poly bags; several pot, microplot and field level investigations were undertaken. Permanent seed orchards of the introduced species were also established as germplasm source. The mother plants were maintained in the mist chamber and methods for asexual propagation of *Prosopis* species were standardized. The studies indicated that *Prosopis* can be raised through stem cuttings using growth harmones like Indole acetic acid (IAA), indole butyric acid (IBA) and NAA. Interspecies grafting is also possible in genus *Prosopis*. Thornless *Prosopis alba* can be successfully grafted on highly salt tolerant and thorny *Prosopis juliflora*. This approach can be adopted to convert weedy and bushy *Prosopis juliflora* plantations into thornless shade and fodder value thornless *Prosopis alba* trees.



Mother plants of Prosopis species raised in ceramic pots for germplasm multiplication

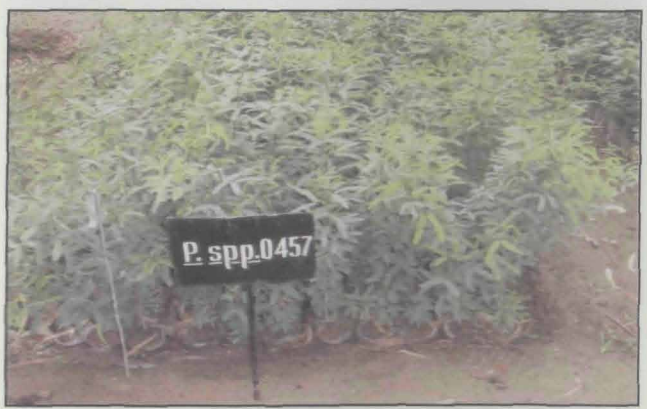
Dr. Peter Felker from Texas, USA and Dr. Nick from HDDRA, UK are examining their germplasm planted at CSSRI, Karnal

Planting Material

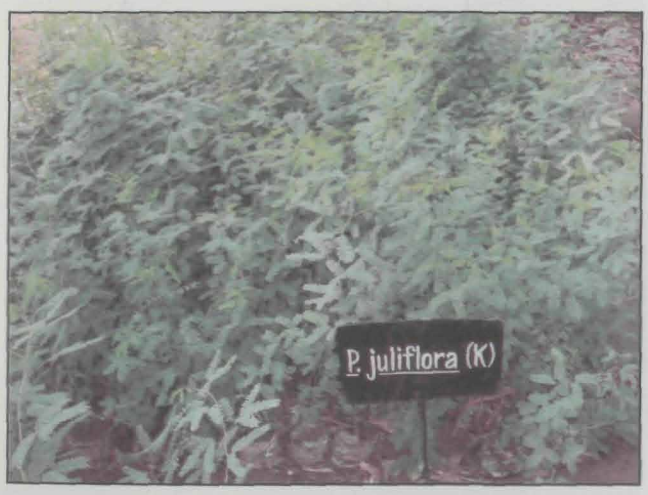
Prosopis seeds have impermeable seed coat and require treatment before planting. The seeds are reported to remain viable in the soil for 10 or more years. Some studies also indicated viability even upto 50 years when put under dry storage condition. Seeds of *Prosopis juliflora* taken from the middle position of the pod generally give more vigorous seedlings compared to those seeds collected from proximal and distal position. Immersion of seeds in cold water for 24 hours improves the germination. However, soaking for longer period (72 to 96 hours) results in more than 70 per cent germination. The germination further improves if the seeds are soaked in hot water or boiling water for 24 hours. Several workers reported that acid scarification gives better germination of seeds than mechanical scarification and hot water treatment. Treating with 0.1 normal hydrochloric acid for 24 hours has also been recommended. Treating the seeds with concentrated sulphuric acid for 10 minutes also improves seed germination significantly. The direct sowing of seeds gives only about 50 per cent germination and survival. The germination is reported better in light loam soils than medium and heavy loam soils. Studies in Iraq using sand, clay and loamy soils have indicated that sandy soil was the best for germination. Emergence of *Prosopis* seeds is greatly influenced by the temperature. The optimum temperature for germination is between 25 to 30°C. Seed and saplings are most commonly used for raising *Prosopis* plantations. *Prosopis* seeds are formed surrounded by leathery capsule in pods. Pods when ripen fall on the ground. In general, seeds are about 10 per cent by weight of the pods. Storage of pods after collection in a freezer kills the bruchids without effecting seed viability. Due to high sugar content of pods and presence of leathery capsule around the seed, separation of seed from the pod is difficult. Now power operated machines are available for seed separation from *Prosopis* pods. Scarification of *Prosopis* seed is necessary to break hard seed coat for early germination. The most common and easiest method is to hand scarify the seed by nicking the blunt end of the seed with a knife. In this case, about 95 per cent emergence will occur in four days from a depth of 1.5 cm when the temperature is between 30 to 35°C. Raising nursery in 22.5 cm x 10 cm poly bags filled with normal good soil plus farm yard manure and river sand is important to raise successful plantation. The *Prosopis* saplings in poly bags become ready for planting in 3-6 months. To ensure purity and uniform stand, the rooted cuttings may be preferred as planting material over seedlings. It is difficult to raise *Prosopis* from cuttings as compared to other trees. However, under mist chamber, where temperature and humidity are controlled, the *Prosopis* can be raised successfully from stem cuttings also. Studies conducted at CSSRI, Karnal indicated that 10 to 20 per cent of the cuttings of *Prosopis alba* planted in the open, sprouted and formed roots in the monsoon season (July to September). Similarly, good success was also achieved through air layering/*gutti* method of asexual propagation. Propagation of *Prosopis* through tissue culture is not successful so far. Efforts are required to standardize asexual propagation methods for multiplication of *Prosopis juliflora* to ensure uniform quality plantations under field conditions.

Asexual methods of propagation of different *Prosopis* species have been studied at CSSRI, Karnal. It has been proved that several *Prosopis* species can be multiplied through cuttings, air layering and grafting techniques.

Prosopis species raised through different asexual methods of propagation at CSSRI, Karnal



Saplings of almost all species are available for sale at CSSRI, Karnal



Saplings of Prosopis ready for sale at CSSRI, Karnal

Tolerance to Salinity

Trees of the genus *Prosopis* are reported highly resistant to salts in soil and water. Most of the introduced species were evaluated for their tolerance to salt stress. It is reported that *Prosopis juliflora* can grow in a soil salinity regime almost equivalent to sea water salinity. Scientists in Texas A & I University, USA have found that all species of *Prosopis* can tolerate 6000 mg/l salinity with little reduction in growth. Species like *Prosopis velutina* can tolerate about 12000 mg/l salinity level. Similarly, *Prosopis articulata, Prosopis pallida* and *Prosopis tamarugo* can be grown successfully in salinity levels between 18,000 to 36,000 mg/l NaCl. Even Indian studies indicate that satisfactory growth of *Prosopis juliflora* can be expected in soils having electrical conductivity of 27 dS/m or even more. Large area in the west coast of India (Kutch region) is invaded by *Prosopis juliflora*. The area is subjected to periodic sea water intrusion and salinity in Kutch soils is quite high. In India, *Prosopis juliflora* is found growing in almost all kinds of salt affected areas including coastal areas of Andhra Pradesh, Tamil Nadu, Orissa and Gujarat.

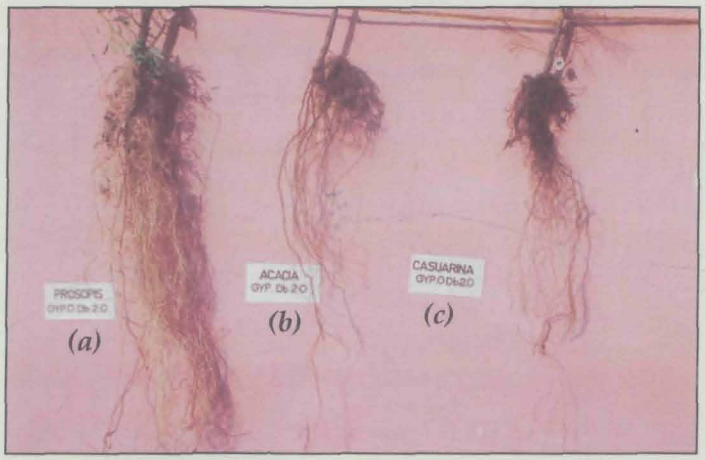
Tolerance to Sodicity/Alkalinity

Several field studies indicate that *Prosopis* grows naturally in the soils having pH_2 upto 10.0. However, survival and growth is limited if the profile pH_2 is more than 10.0. The CSSRI scientists have developed a site preparation technique called "augerhole technique" for growing *Prosopis* in high pH soils. This technique ensures more than 80% survival of *Prosopis* trees even after 8-10 years of plantation. In this method, auger bores of 20-25 cm diameter and about 120 cm deep are made by tractor driven augers to pierce through the hard calcium carbonate layer which is present at about one m depth in highly sodic soils. These auger bores are filled back with a mixture of original alkali soil plus 3-4 kg gypsum ($CaSO_4.2H_2O$) and 7-8 kg farm yard manure before planting *Prosopis* saplings..

Tractor driven auger developed for planting trees in highly sodic soils

The State Forest Departments and others engaged in tree plantations in waste lands are adopting this technique to raise *Prosopis* plantations in highly sodic soils. This species has a capacity to extend its roots beyond the hard sub-surface soil layers and can tap moisture available through capillary fringe from the ground water in the soil profile. A photograph below shows the spread of root systems of *Prosopis juliflora* and other species when grown in sodic soils packed to a bulk density 2.0 in collapsible iron columns. Even in non-amended highly sodic soil this species was able to extend its roots quite deeper and outside the iron column sides.

A view of collapsible iron columns for root studies



Root spread of Prosopis juliflora (a), Acacia nilotica (b) and Casuarina equisetifolia (c) trees in alkali soil packed to bulk density 2.0 g/cm^3 grown in iron columns

Biomass Production

Prosopis juliflora is one of the highest biomass producing tree species in arid and semi-arid regions/salt affected soils. However, the biomass production potential is governed by the factors like average rainfall of the area, quality of planting material, planting geometry and cultural

Table 3 : Growth performance and biomass production by *Prosopis juliflora* and other salt tolerant trees in a soil of 10.4 pH_s, 10 years after planting

Growth Parameters	Tree Plantations			
	Prosopis juliflora	*Acacia nilotica*	*Casuarina equisetifolia*	*Eucalyptus tereticornis*
Height (m)	12.9	11.6	14.5	14.9
DSH (cm)	15.9	15.4	15.6	13.6
DBH (cm)	12.5	13.6	12.0	11.0
Bole weight (kg/tree)	112.6	85.4	84.2	65.6
Branches + Leaves weight (kg/tree)	43.2	43.8	28.4	23.5

DSH : Diameter at stump height (5cm above the ground level)
DBH : Diameter at breast height (137 cm above the ground level)

practices used for raising and maintaining the plantation. Growth performance and biomass production by 10 years old *Prosopis juliflora* in comparison with other tree species in a soil of 10.4 pH is reported in Table 3. These growth and biomass figures are from a sodic land (village community land) near Panipat, Haryana. These plantations received irrigation during first two years of establishment. Later on, the trees grew with the rainfall which was about 650 mm/year; 80% of which was received between July and September.

Well managed Prosopis juliflora stand in a sodic soil of pH_s 10.4

Similarly, a comparison of biomass production of *Prosopis juliflora* in relation to nine other commonly grown species at Shivri farm near Lucknow is given in Table 4. The yearly lopped biomass reported in Table 4 was maximum in *Prosopis juliflora* and *Prosopis alba*. The pruned/lopped biomass estimates indicate that the trees have enough potential to meet periodic fuelwood/energy needs. Periodic pruning/lopping of *Prosopis juliflora* also helps the tree to grow straight and ensures cultivation of inter crops between tree rows. The trees also yield high quality litter in terms of leaf and small twigs which fall on the ground and increases humus content in otherwise organic matter deficient soils. The ten years observations on litter fall showed maximum litter production (6.1 t/ha/year) under *Prosopis juliflora* canopies.

The biomass production potential of this versatile tree can be regulated by adjusting spacing and management techniques. In case, the trees are raised for energy/electricity generation, closer planting may be preferred in the initial years to generate periodic biomass for the gassifier. These closely raised plantations can be thinned through lopping after 3-4 years of planting to generate

Table 4 : Growth performance of *Prosopis juliflora* and other trees in a highly sodic soil (pH_2 10.2 to 10.6), near Lucknow10 years after planting

Tree species	Survival (%)	Diameter at breast height(cm)	Lopped biomass (kg/tree/year)	Litter fall (t/ha/year)
Terminalia arjuna	100	9.20	6.15	5.1
Azadirachta indica	93	8.46	2.40	2.8
Prosopis juliflora	100	12.32	11.30	6.1
Pongamia pinnata	100	9.27	6.10	5.0
Casuarina equisetifolia	97	12.14	6.34	5.7
Prosopis alba	50	8.46	9.25	2.0
Acacia nilotica	95	14.12	4.10	5.4
Eucalyptus tereticornis	99	13.10	3.50	1.3
Pithecellobium dulce	100	10.15	5.50	2.4
Cassia siamea	96	6.63	1.30	1.3
LSD(p=0.05)	-	0.65	1.12	-

sufficient biomass for energy and at the same time maintaining 50% of the trees for future harvest. This way, a cycle of biomass production can be achieved to meet biomass needs for energy generation. Several experiments were conducted at CSSRI experimental farms to study biomass production potential of *Prosopis juliflora* under different spacings and other cultural practices. For example, biomass accumulation in five years was 39 kg/tree when 5,000 plants were grown/ha as compared to 32.2 kg/tree when the planting density was 10,000 plants/ha. To meet fodder requirement, salt tolerant grasses like Kallar grass (*Leptochloa fusca)* can also be cultivated in the inter spaces between tree rows. Biomass production in 6 years by *Prosopis* and *Leptocloa* grass under different spacing is given in Table 5.

Information in Table 5 clearly indicates that grasses like *Leptocloa fusca* can be grown successfully as inter crop between *Prosopis* rows. The grasses should be introduced after one year when the trees are well established. *Leptochloa* is a halophytic forage grass which produces significant biomass even at the soil pH of 10.4. This grass has a mechanism to fix nitrogen in the soil through free living bacteria known as *Klebsilla phenomeneae*. Association of such grasses with *Prosopis* further hastens the reclamation process. The reclaiming effects of *Prosopis* and *Leptochloa* grass are illustrated in Figure 1.

A view of Prosopis juliflora plantation in an original soil pH_2>10.0 at Shivri Farm, Lucknow

Table 5 : Biomass production in 6 years by *Prosopis* and *Leptochloa* grass under different spacing in an alkali soil of original pH_2 10.0 to 10.2

Spacings	Biomass (t / ha)			
	Prosopis			*Leptochloa*
	Lopped	Harvested	Total	
2x2 m	49.1	112.2	161.3	55.6
3x3 m	31.6	55.2	86.8	68.7
4x4 m	25.0	36.1	61.1	80.9

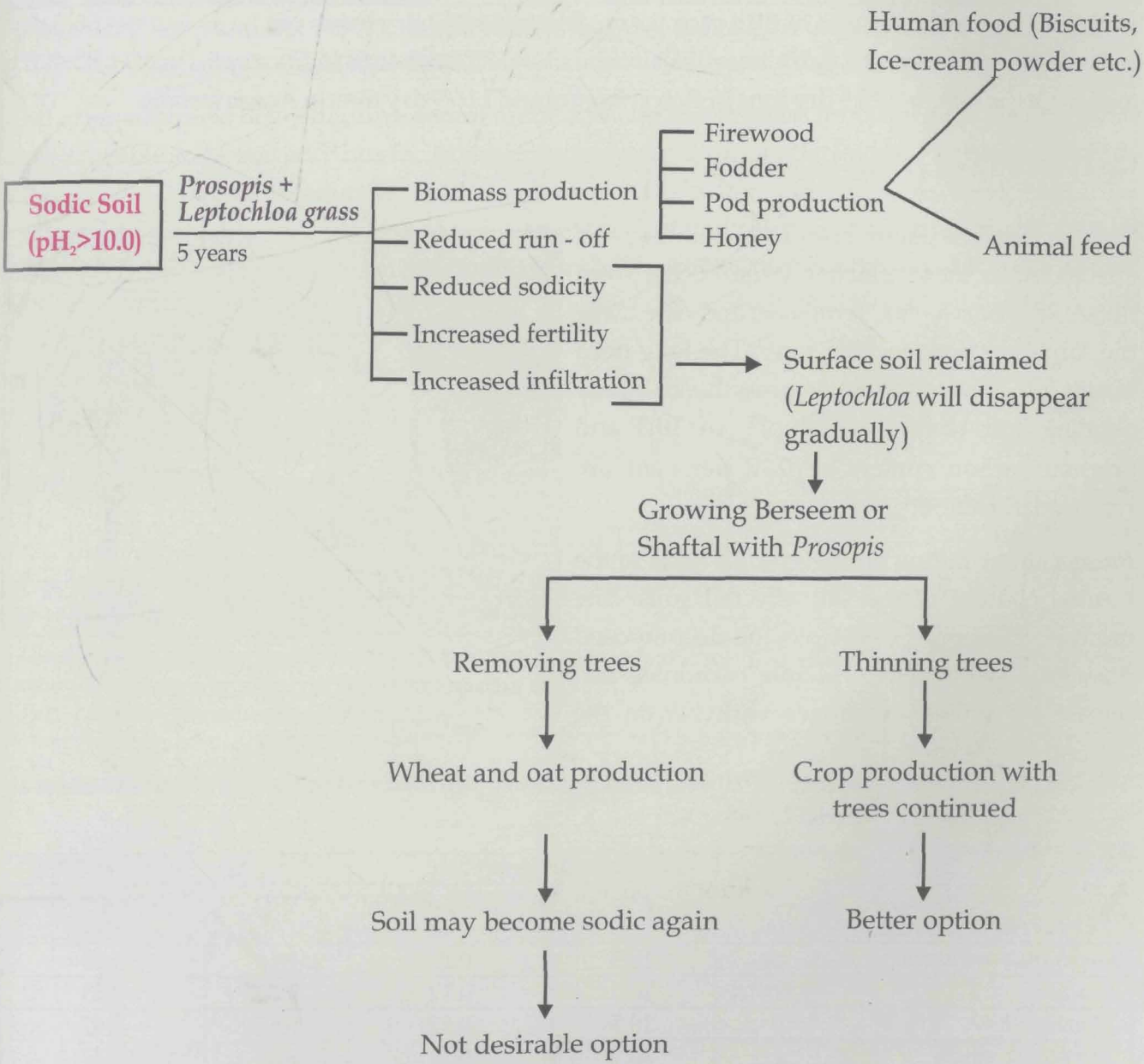


Fig. I : Silvi-Pasture Model for Biomass Production and Soil Reclamation

Biomass Production in Relation to other Trees in Arid Region

Prosopis juliflora is considered as an excellent candidate for short rotation energy plantations considering its fast growing nature, higher biomass production potential, drought and heat tolerance and excellent coppicing ability. In Gujarat, three years old plantations of *Prosopis juliflora* are reported to produce a total biomass of 114 dry tonnes per ha. Similarly, in other plantations at Gandhinagar, Gujarat, *Prosopis juliflora* ranked first amongst the high biomass producing native trees of arid and semi arid regions of India. At the age of 18 months, *Prosopis juliflora* is reported to produce the highest biomass of 19 dry tones per ha as against 13.6 dry tones per ha of eucalyptus under similar edaphic and climatic conditions. The biomass yields from the same plantations at the end of fifth year were : *Prosopis* 167.2 dry tones per ha as against 66.3 dry tons in *Albizzia lebbeck*, 82.0 dry tons in *Dalbergia sissoo*, 83.4 dry tons in *Eucalyptus hybrid*, 85.4 dry tons in *Cassia siamea*, 113.5 dry tons in *Acacia nilotica* and 116.9 dry tons in *Acacia tortilis*.

Soil Reclamation by *Prosopis juliflora*

Prosopis juliflora plants help in reclaiming salt affected soils more effectively than other trees like *Acacia, Eucalyptus, Terminalia* and *Albizzia* of the same age and stocking rate. The long term effects of 20 years *Prosopis* growth on highly alkaline soil having initial pH_2 of 10.3 and original carbon content of 0.12 per cent are reported in Table 6.

Growth of Prosopis on alkali soil reclaims such lands to such an extent that agricultural crops can be grown without amendments

Prosopis litter falling on the ground adds to the humus content of the salt affected soils. The organic acids produced from the decomposed litter react with native calcium carbonate and release Ca which exchanges with Na on the

Table 6 : Ameliorating effects of 20 years old *Prosopis juliflora* and other tree plantations on an alkali soil at Karnal

Species	Original		After 20 years	
	pH_2	Organic carbon (%)	pH_2	Organic carbon (%)
Eucalyptus tereticornis	10.3	0.12	9.18	0.33
Acacia nilotica	10.3	0.12	9.03	0.55
Albizzia lebbek	10.3	0.12	8.67	0.47
Terminalia arjuna	10.3	0.12	8.15	0.47
Prosopis juliflora	10.3	0.12	8.03	0.58

pH_2: Measured in 1:2, soil-water suspension

Mechanisim of reclamation: The CO_2 released by the roots during respiration reacts with water to produce acids. These organic acids facilitate dissolution of precipitated $CaCO_3$ available in plenty in sodic soils

exchange complex. Being highly tolerant to soil sodicity, the *Prosopis* roots open up the otherwise impermeable sodic soil and thus facilitates entry of water in the deeper layers. The carbon dioxide released by its roots during respiration interacts with water and produces weak acids like carbonic acid. Such acids facilitate dissolution of precipitated calcium carbonate already present in sodic soils. Thus help in reclamation of the soil. Several studies conducted at Karnal proved that sodic soils can be reclaimed by growing *Prosopis juliflora* plantation to raise all kinds of crops (Figure II).

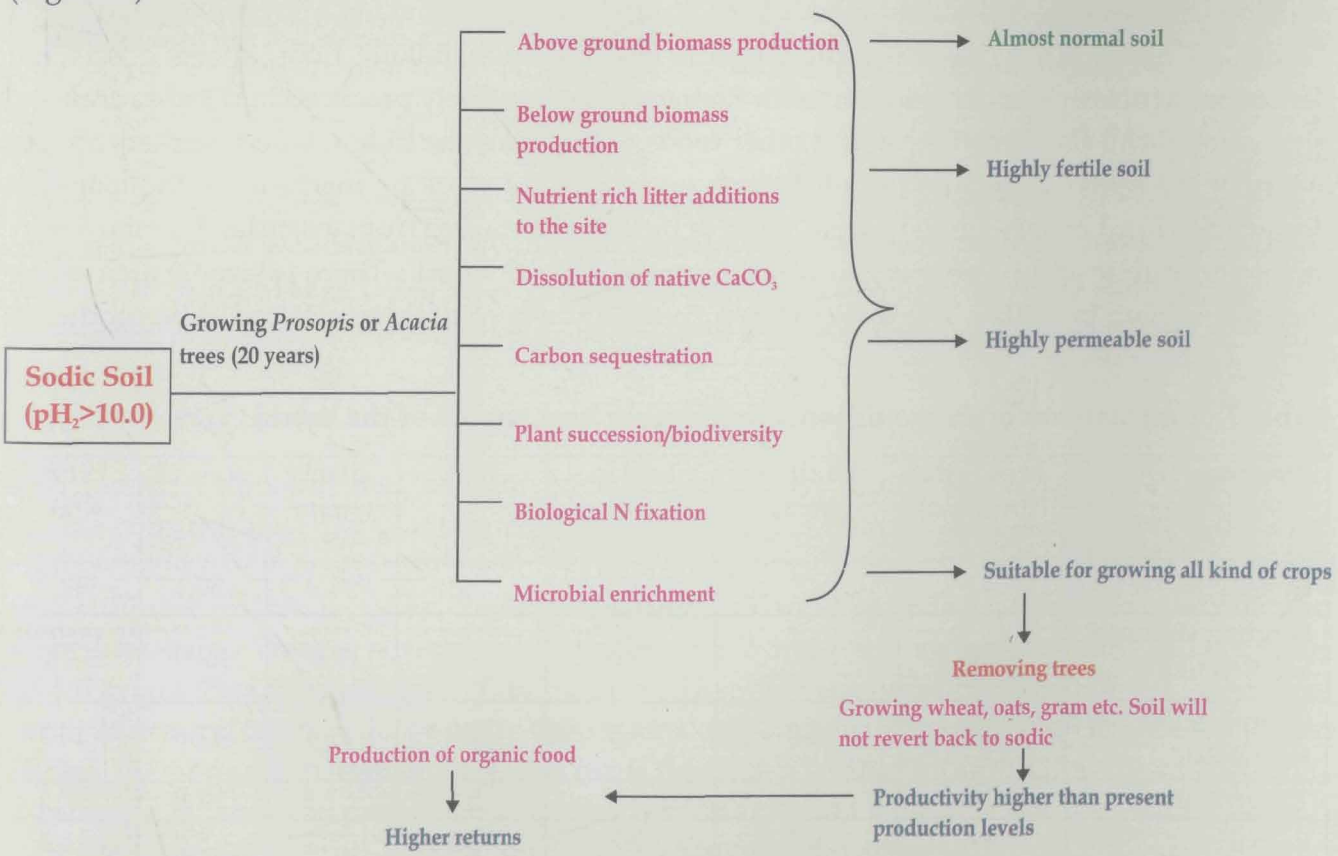


Fig. II : Silvi-Agricultural Model

Quality of *Prosopis* Wood

Prosopis juliflora trees are generally considered as a bush (not as timber tree) in India. Since this is the only versatile, freely available fuel wood species in dry regions, small, marginal and landless labourers frequently cut the apical portion of this plant to meet their daily fuel wood needs and do not allow it to grow as a timber tree. However, large branches and trunks of this tree, if managed properly, yield a high quality timber, comparable in colour and finish to most sought for hardwoods like Indian rosewood tree and other commercial hardwoods like teak, cherry, walnut and willow etc. The wood is reported to have excellent physical attributes. Because of its beauty and working properties, *Prosopis juliflora* wood is considered even better than other hard woods like oak, walnut and cherry. Its density and chlorific value is greater than many other fuelwood species native to salt affected soils. The large branches are also used as posts and poles. The comparative wood characters of *Prosopis juliflora* vis-à-vis other important timber yielding trees in the world are given in Table 7. Its exceptional property is its negligible shrinkage (4.17%) which is much less than for oak, maple or walnut trees (14-16%). Because of this quality furniture items made from *Prosopis* wood develop little or no cracking or warping later on. *Prosopis* wood also has good fuel value (8050 Btu/Pound), with a wood density between 0.7 to 0.9. The information given in the table clearly indicates that *Prosopis* wood can be rated as excellent for making furniture and other articles.

All kinds of furniture including tables, chairs, sofa-sets etc. can be made from *Prosopis* wood. In Texas and many other countries, the wood is also used for making floor, sports goods and decorative articles. Further, cooking with *Prosopis* wood is widely practiced in US restaurants to give a delightful flavour to meat and other foods. However, the Indian wood workers are not aware of the remarkable qualities of *Prosopis* wood. Wood working machines in India are not designed to lumber *Prosopis* hard logs. Most of the wood obtained from waste lands, community lands and public and private organizations is used as fuel wood. There is sizable area under *Prosopis juliflora* in India. The tree grows successfully where nothing else could be produced.

Table 7. Comparison of *Prosopis* wood with other best woods of the world

Property	Mesquite (*Prosopis*)	Brazilian cherry	Indian Rosewood (Shisham)	Teak	Black cherry	Walnut	White Oak
Density(lbs/ft^3)	45		53	40	34.9	39.1	47.5
Bending strength MOE (X10^3)	1380	2160	1780	1450	1490	1680	1780
Shrinkage(%) volumetric	4.7	12.7	8.5	7.0	11.5	12.8	16.3
Tangential	2.2	8.5	5.8	5.8	7.1	7.8	10.5
Radial	2.6	4.5	2.7	2.5	3.7	5.5	5.6
Slide hardness	2336	2350-3290	3170	1000	950	1010	1360

Prosopis wood obtained from Prosopis glandulosa (a common species found in US and Mexico)

Prosopis use as flooring wood

Prosopis use as furniture

Decorative craft articles made from Prosopis wood (The author took this picture in 1991 during a Prosopis workshop in Dallas, USA)

These trees if properly managed, lumbered and processed can contribute significantly in increasing timber wood availability in the country. There is a strong case to train Indian wood workers in countries like USA, Mexico, Argentina and Brazil to upgrade their skills for logging, lumbering, processing and making value added products from *Prosopis* wood.

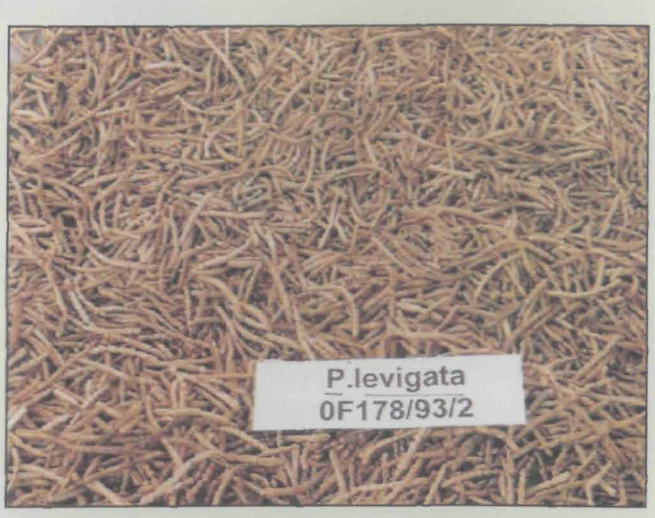
Pod Production

The trees produce sufficient quantity of high protein and sugar content pods for animal and human consumption. The plant breeders around the world have developed several varieties of *Prosopis* having high pod yielding ability. There is a great variation in pod yield within the species and within the trees in a species. Pod yields as high as 30 to 50 kg pods per tree have been reported in the literature. Trees of several species yield pods 2-3 times in a year. Several kinds of value added products can be made from *Prosopis* pods. In several countries like USA, Brazil, Argentina, South Africa and Mexico, the pods are used for making biscuits, ice-cream and candies. In Gujarat (India), the pods are extensively used as cattle feed. It is further reported that the cattle feed is substituted by about 30 per cent by *Prosopis juliflora* pods in Gujarat. It is reported that Gujarat State Forest Development Corporation (GSFDC) has collected about 2000 metric tons of pods and generated about 100000 mandays of employment during a span of 5 years. It is estimated that

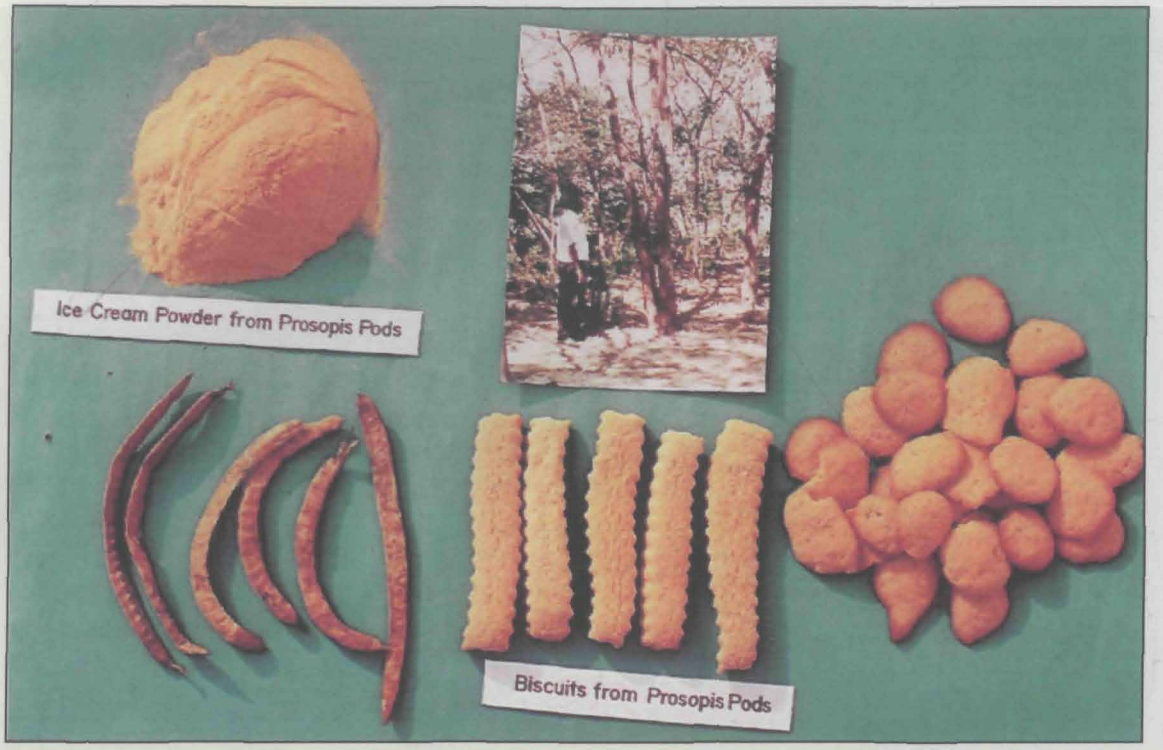
about 5 mt of pods could be collected from an estimated area of about 500000 ha north western zone of Gujarat. Vivekananda Research and Training Institute, Mandvi, Kutch has installed a livestock feed manufacturing plant. The institute has succeeded in preparing highly nutritive livestock feed from these pods after seed separation. Anand Agricultural University, Anand has made several studies on the nutritive value and palatability of pods and reported that the pods are eaten by livestock particularly goats, sheep and camels. In the recent past, it has also been reported that the pods of some Peruvian improved varieties are also used to make flour for human consumption. The flour is reported to be sold in food stores in some developed countries of the world. No major efforts, however, so far have been made in India to convert *Prosopis* pods, which are available free of cost in the country, as value added products. One can see large quantity of *Prosopis* pods scattered under the trees on road sides, railway tracks, waste lands and *panchayat* lands. Wherever trees are growing, they are producing pods once or twice a year. These pods are reported to contain 10-16% proteins, 20 to 30% sucrose, 4.2% fat, 10-15%moisture, digestible protein 8%, 16.8% fibre, 5.4% ash, 0.33% Ca, 0.44% P, 12-15 ppm Cu, 22ppm Mn, 18-28 ppm Zn and 203 to 639 ppm Fe. There is a need to develop a network programme with developed countries where *Prosopis* pods have been exploited as animal and human food to effectively utilize *Prosopis* pods as value added products for animals and human beings in India. It will be worthwhile to mention here that during 2002 drought in India, it were the *Prosopis* trees which provided livelihood security to the rural population settled in arid and semi arid drought prone regions of the country. *Prosopis juliflora* trees maintain their greenery and continue to grow even during severest of the severe droughts in desert states like Rajasthan. It has been reported by the Vivekananda Research and Training Institute(VRTI) Mandvi, Bhuj that cattle owners have approached the institute with very heavy demand for *Prosopis* cattle feed. The farmers reported that this kind of cattle feed has increased milk yield of their animals by 20%.

A view of Prosopis species orchard in Karnal

Variability in shape, size and colour of Prosopis pods



Pods obtained from a straight bole Prosopis juliflora and Prosopis levigata trees identified through selection



Value added products such as biscuits and ice-cream from Prosopis pods for human consumption. The author took these pictures during an International Workshop on Prosopis in Washington, DC, USA (1996)

Prosopis Biomass for Electricity Generation

There is an increased interest in raising *Prosopis* plantations for biomass production to generate electricity. Several private companies in India are purchasing and/or taking on rent/lease waste and abandoned lands for raising plantations of *Prosopis juliflora, Leucaena leucocephala* and *Eucalyptus tereticornis.* Even the agricultural wastes like cotton sticks, chillies sticks, paddy straw and rice husk etc. are also used to supplement biomass need for electricity generation. The Non-conventional Energy Development Corporation (NEDCAP) of Andhra Pradesh is encouraging woody biomass based power generation plants for the last about 10 years in Andhra Pradesh. The basic idea of advocating raising tree plantations on waste lands is to enable the farmers to get additional income from their wasted and abandoned lands. It is reported that there is a potential of 627 megawat (MW) biomass based power in Andhra Pradesh alone. It is further reported that NEDCAP has so far issued licenses to 50 power plants with a capacity of about 350 MW. It is mentioned that only 38 power plants have been commissioned with an installed capacity of 207.8 MW. These plants are producing annually 1456 million units of electricity. Mostly these plants are using *Prosopis juliflora, Leucaena* and *Eucalyptus* besides agricultural wastes and coal. Out of these 50 power plants, 8 power plants are depending totally on energy plantations. It is reported that one power plant named M/s. Jyothi Bio-energy Ltd., located at Gundlapalli village, Maddipadu Mandal, Prakasam district has already been commissioned and producing 6 MW power. It is estimated that about 130 ha of energy plantations are required to produce one MW of electricity. A company called Genco is purchasing the power generated from biomass @ Rs.3.18 per unit of electricity. It is further reported that all the 38 power plants are running in profits.

CSSRI in association with a Delhi based NGO, Development Alternatives and an International organization, Organization for Agriculture in Saline Environments (OASE, Netherlands) is planning to initiate a pilot project to generate electricity from *Prosopis juliflora* biomass. Under this proposal about 1000 ha of salt affected abandoned community land is proposed to be acquired in the districts of Faridabad, Mewat and Gurgaon (Haryana) to raise *Prosopis juliflora*, a highly salt tolerant species to generate electricity. Wherever thickets of *Prosopis juliflora* are existing in the country and there is danger of encroachments to agricultural fields, the trees can be harvested to generate electricity. Kutch region of Gujarat has ample scope for electricity production as *Prosopis* thickets are naturally growing in this tract.

Tentative calculations made about electricity generation from biomass based upon pure gas mode technology revealed that 1.4 kg biomass is required to generate one unit of electricity. It indicates that 110 KWe plant will need 545 tons biomass per year when it runs for 16 hours a day for 300 days in a year. Cost of biomass based electricity generation will be around Rs. 5.75/unit.

Prosopis juliflora biomass is reported to be better for electricity generation because of higher heating value of its biomass. Heating value or calorific value is the heat released by the fuel under ideal combustion conditions. The heating value is usually determined using Bomb calorimeter, where the combustion process takes place at constant volume in a bomb. In almost all the furnaces or other thermo chemical conversion processes such as gasification and pyrolysis, the process occurs at constant pressure and vapours leaving the process as such without getting condensed. The heating value at constant pressure and water vapours as such is called lower heating value (LHV). Lower heating value is more relevant when making material and energy balance calculation in a furnace or a gasifier. When latent heat of vaporization is also counted and added up in heating value it is called higher heating value(HHV). Fuel characteristics relevant to the design of biomass conversion include heating value, bulk density, moisture, chemicals, elemental and proximate analysis. The physical properties of the biomass include : density, equilibrium moisture content(EMC); chemical properties (alcohol, benzene extractives, cellulose, lignin and pentosan); elemental analysis (C, H, N, Na, P, Ca, Mg and Silica) and proximate analysis includes fixed carbon(FC), volatile matter(VM) and ash content. Physical and thermal characteristics and proximate and chemical analysis of biomass of different tree species as reported by workers at PAU, Ludhiana is given in Table 8.

The wood biomass is generally classified into three categories; hard woods, medium density biomass and low density biomass. Most of the hard woods including all fuel wood species and woody crop residues namely *Acacia auriculiformis, Acacia nilotica, Albizia lebbek, Albizia procera, Azadirachta indica, Dalbergia sissoo, Eucalyptus hybrid, Leucaena leucocephala, Pithecellobium dulce, Prosopis juliflora, Sesbania acculiata, Sesbania grandiflora, Terminalia arjuna,* etc. can be classified as hard woods due to their high density(more than 300 kgm^3). These materials in general have low ash content and high heating value and produce hard and stable charcoal on pyrolysis/combustion. Fixed carbon in most of the hard woods is above 15% and more suitable for gasification. Cellulose content of most of the hard woods are above 35% and are considered good feed stock for paper industries also. Stalks of many crops like pigeonpea, cotton, castor, sorghum, sunflower, *Casuarina equisettifolia* etc. are grouped as medium density biomass

Table 8 : Physical and thermal characteristics and proximate and chemical analysis of biomass (Based on moisture free basis) of different trees/plants

Biomass	Density (kgm^3)	EMC (%)	CV ($MJkg^{-1}$)		Proximate analysis (%)			Chemical analysis (%)			
			HHV	LHV	FC	VM	ASH	Cell	Pent.	Lignin	Extr.
Acacia auriculiformis	700	29.5	19.6	18.03	16.1	81.8	2.2	33.38	10.27	38.97	10.00
Acacia nilotica	820	24.8	19.2	17.83	16.8	80.8	2.3	30.99	13.91	37.03	7.97
Azadirachta indica	700	30.7	18.2	16.79	15.9	80.7	3.3	34.78	11.80	40.10	5.90
Castor stalks	-	-	16.5	-	18.4	77.9	3.8	-	-	-	-
Casuarina equisetifolia	-	-	18.5	-	19.2	77.2	3.6	-	-	-	-
Cotton sticks	160	27.1	17.4	16.29	15.3	81.4	3.3	41.90	19.00	27.20	9.30
Dalbergia sissoo	710	24.6	18.7	17.29	15.7	80.4	3.9	33.20	10.20	39.40	7.50
Eucalyptus hybrid	770	30.4	19.4	17.99	16.6	82.4	0.9	34.20	12.90	39.20	7.31
Leucaena leucocephala	730	30.4	19.4	18.24	16.6	84.4	1.0	44.87	17.74	22.36	9.73
Maize stalks	50	38.2	16.7	15.74	17.1	79.6	3.4	43.40	19.60	22.80	9.30
Pithecellobium dulce	670	28.1	19.4	17.78	16.4	81.5	2.0	30.34	13.50	39.10	11.40
Rice husk	105	29.4	15.5	14.36	12.5	71.0	16.5	44.10	17.80	17.20	3.40
Rice straw	30	36.7	15.0	13.83	11.1	69.7	19.2	41.40	20.40	12.10	5.60
Sesbania grandiflora	340	25.9	17.9	17.03	11.7	82.3	6.0	30.40	18.82	36.07	6.01
Sunflower stalks	-	-	15.5	-	8.8	75.4	8.9	-	-	-	-
Wheat straw	60	34.0	17.2	15.97	17.9	73.6	8.5	39.60	24.10	17.00	7.30

Note : True density ; CV calorific value; Cell- cellulose, Pent-Pentosan and Extra-benzene alcohol extractives (Modified from Jain, 1997)

(100-300 Kgm^3). Straws of crops like wheat and paddy, maize stalks etc. have very low bulk densities (below 100 kgm^3). Most of these materials have low lignin content and rated as poor density biomass. *Prospis juliflora* is hardest of the hard woods and most suitable for charcoal making and electricity generation.

Charcoal Production from *Prosopis juliflora*

One of the most common uses of *Prosopis juliflora* in south India is for charcoal making. It is reported that *Prosopis juliflora* was introduced in Tamil Nadu during 1960s in Ramanathapuram and Tiruchirapalli districts as live fence due to its thorniness and non-palatable nature of foliage. Presently, *Prosopis* is the native vegetation in all kinds of waste lands in southern India including salt affected southern districts of Tamil Nadu viz. Virudhunagar, Tirunelveli, Tuticorin, Sivaganga, Pudukottai, Ramanathapuram and Tiruchirappalli districts. The arid and semi-arid kind of climate with scanty unreliable rainfall, which is not sufficient to raise alternate trees coupled with ability of *Prosopis* to thrive well in extremes of weather and no management conditions have made the farmers to allow their lands infested with *Prosopis*. More than 80 per cent of *Prosopis* felled is used for charcoal production which is mainly sent to northern states like Rajasthan, Gujarat and Maharashtra. There are no authenticated figures for the area under *Prosopis juliflora* in Tamil Nadu. Even at the country level such information is missing.

In Tiruchirappalli, there are three big traders who procure charcoal from local farmers and market it through rail wagons to other states. The charcoal production is done throughout the year with peak period between June to September. The traders opined that charcoal from *Prosopis* is

preferred than other sources due to its high carbon content and calorific value. The traders make payment on the basis of moisture content which should in general be less than 10 per cent. Depending upon the end users, felling time varies in *Prosopis juliflora*. For charcoal making, it is usually felled at the age of 3-4 years (before heartwood formation) while 5-8 years for fuel wood. For timber use, the trees are cut at the age of 10-15 years. In south India, about 80 percent of the *Prosopis juliflora* plantations are felled for charcoal making and rest for fuel wood. The first felling is usually done at the end of 3rd and 4th year and thereafter coppice growth is felled at the interval of 3-4 years.

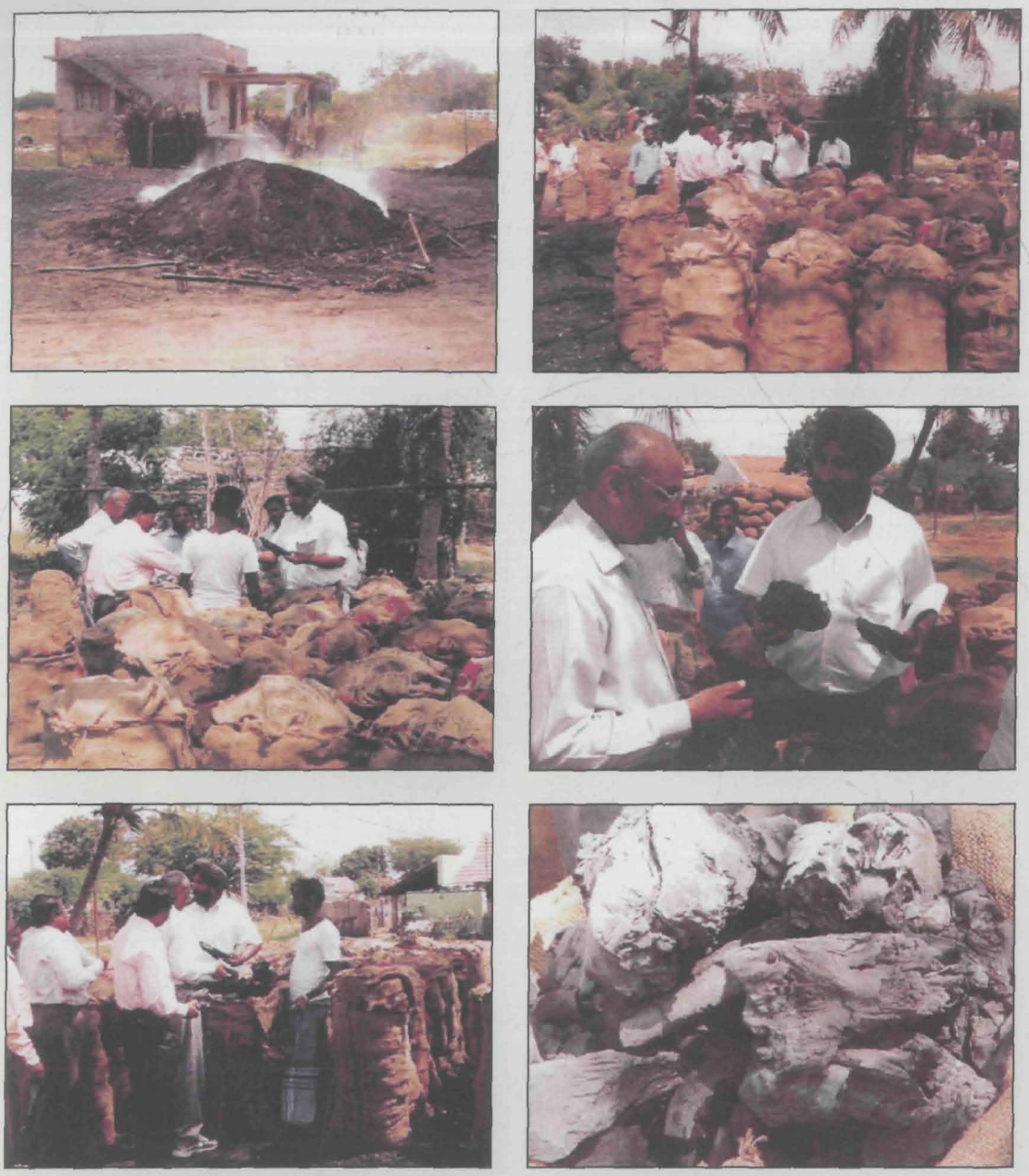
Various steps involved in charcoal production are listed below:

- *Prosopis* is felled after 3-4 years for charcoal production
- The cost of *Prosopis* wood is Rs. 700 per tonne (Rs. 500 for cutting or labour charges and Rs. 200 to farmer)
- Recovery of charcoal is about 25 per cent
- Price of charcoal is Rs. 4000 per tonne
- Economics of one tonne charcoal production
  - Cost of 4 tonnes of wood @ Rs. 700 per tonne - Rs. 2800
  - Stacking charges for 3 men and 3 women labourers - Rs. 360
  - Firing, dismantling and packing charges - Rs. 400

Total - Rs. 3560

Net profit - Rs. 440

Gujarat State Forest Development Corporation (GSFDC) has been entrusted with manufacturing charcoal from *Prosopis juliflora* by the government of Gujarat. This activity has given significant employment opportunities to the local people. It is reported that in the last five years, the corporation has manufactured about 300,000 bags of charcoal (1 bag = 30 kg) and generated about 300,000 mandays of labour. The corporation has also delivered charcoal to the Forest Department for meeting the bonafide needs of the local population of the district. As a result, with its one million population, Kutch is the only district in India that is self-sufficient in its fuel wood requirements. *Prosopis* charcoal from Kutch is also sent to other districts of Gujarat state to meet their fuel wood requirements. Assuming that 500 trees/ha produce 24 kg dry biomass per tree at the end of five years (12 dry metric tons/5 years = 2.4 t yr^{-1}). The approximately 5,00,000 ha of *Prosopis juliflora* would yield about 200,000 metric tons of charcoal per year in perpetuity on a five-year cycle. Thus, annually 6.66 million bags of charcoal worth Rs. 500 million could be available (one 30 kg bag of charcoal costs Rs. 75/-). In this way, millions of mandays of labour could be generated for employment. Only one third or one fourth of the total quantity of fuel wood processed becomes charcoal. Dry wood, on destructive distillation gives 33.9% charcoal and 1.24% methanol. *Prosopis* wood, together with rice husk and other agro-wastes, can be briquetted to form a good quality white coal. Charcoal-manufacturing activities have been carried out in remote and backward areas of the districts like Kutch, Banaskantha and Surendranagar by forming co-operatives and societies. The District Rural Development Agency, Banaskantha, has sponsored the scheme of Development of Women and Children in Rural Areas (DWACRA) to



A view of charcoal making from Prosopis juliflora near Trichi, Tamil Nadu

generate employment and income for poor people. Under this scheme, thousands of families have been benefited by preparing charcoal in *Prosopis juliflora* dominated areas. 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. In Kutch, Bhal and Bara tract regions of Gujarat charcoal manufacturing from *Prosopis juliflora* forms an integral part of daily activity of a large chunk of the rural population.

Honey Production

The honey extracted from *Prosopis* species was reported to be of superior quality with attractive flavour. It is reported that in India, about 100 tonnes of honey is produced annually from the

Prosopis infested Kutch district of Gujarat by the Gujarat State Forest Department. Kutch district is predominantly inhabited by the *Prosopis juliflora* trees. Many types of biochemicals such as tannin, ellagic acid, glycosides, amino acids, steroids, alkaloids, phenols, growth regulators like triacontanol are reported to be present in different *Prosopis* species. The potential of obtaining several industrial products such as alcohol, gums, cocoa powder substitute and sweetening agents from pods of *Prosopis* species are also reported. Some species of genus *Prosopis* are also reported to have medicinal value for treatment of rheumatism and also against miscarriage. Some of the alkaloids of *Prosopis* species are reported to be antifungal and antibacterial. Tests have indicated that writing and printing papers could be produced from *Prosopis juliflora* logs having 30 to 50 cm in girth with 50 per cent cellulose and 30 per cent lignin. Several of such value added products from *Prosopis* can be linked to livelihood generation in dry salt affected areas.

Prosopis juliflora's Role in Livelihood Security in Gujarat

Prosopis juliflora grows well on highly saline soils of Gujarat. It also flourishes well in waterlogged conditions. This species has been selected by the Forest Department of Gujarat state under the intensive afforestation programme to check desertificiation in arid areas. The arid zone in Gujarat occupies geographical area of 3.5 m ha, of which a large portion is covered by saline desert called the Rann of Kutch. It is reported that *Prosopis juliflora* covers about 5 lac ha. *Prosopis* species, in this desert ecosystem constitute one of the efficient primary producers converting sum energy into biomass, producing about 15-30 tonne per ha per year of biomass. The state Forest Department of Gujarat planted exclusively *Prosopis juliflora* on about 31,550 ha of Banni grasslands of Kutch to check the advancement of Rann. The prevailing conditions in Banni including successive droughts, increasing salinity and excessive grazing pressure provided a highly congenial environment for the growth and spread of the hardy *Prosopis juliflora,* which is today a dominant species of the vegetation complex. In fact, it ranks first in term of distribution, abundance and aggressive encroachment of rangelands. It has been reported that the area under *Prosopis juliflora* has increased from 378 km^2 to 684 km^2, an increase of 81% between 1980 to 1992. Analysis of remote sensing data clearly stated that the species is expanding in the Banni area at the rate of about 25 km^2 per year.

It has been further estimated that by 2020 about 56% of Banni grasslands in Kutch will be under *Prosopis juliflora.* The sheep and goat munch and crunch happily on the proteinaceous pods of *Prosopis juliflora.* The rural folk whose lands were getting buried under the drifting sands are grateful to the forester and *Prosopis,* and the poor folk who had no fuel to cook now have *Prosopis.* They collect the fuel in leisure and sell in the towns for a decent price. Gujarat State Forest Development Corporation Ltd., (GSFDC); Gujarat Agricultural University, Anand; Vivekanand Research and Training Institute, Mandvi-Kutch have been active in developing management techniques for this species. For example, GSFDC has undertaken a programme of collection, processing and marketing of various minor forest products from different parts of *Prosopis juliflora.*

The *Prosopis* wood burns evenly and does not spark or smoke excessively. The calorific value of wood is quite high (approximately 4200-4800 kcal/kg). The positive qualities of firewood are

present even at the juvenile stage and this allows green branches to be burnt 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). A common practice in this region 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 (village judicial bodies) but this practice is followed as a social agreement.

In a recent communication Dr. Peter Felker informed that a California State Agency has been charged with reclamation of 1,00,000 ha of salinity affected area in California using *Prosopis alba* as a reforestation species. It is reported that this agency has established several test plots in collaboration with farmers. Further, Dr. Felker's group in California is importing mesocarp flour from Peru and Argentina and are moving strongly ahead with a national marketing plan of organically certified flour of mesquite.

Research on molecular characterization of genes in *Prosopis* has gained momentum in the recent past. The scientists are looking for genes for salinity tolerance, insect resistance and pod sugar in *Prosopis*. For example, Dr. Hans Bohnert, University of Illinois and Drs. Beatriz Saidman and Juan Vilardi at the University of Buenos Aires who are considered world leaders in molecular taxonomy and DNA characterization of *Prosopis* are engaged in developing global collaborations in genetic engineering and biotechnological aspects of genus *Prosopis*. In India, M.S. Swaminathan Foundation, Chennai has developed Expressed Sequence Tag (EST) library for *Prosopis*. Workers at the Jai Narayan Vyas University, Jodhpur are also undertaking molecular characterization work on *Prosopis*. This suggests that there is a need to initiate attempts for bilateral scientific cooperation on the genetic improvement and molecular characterization for *Prosopis* in Argentina and India for tolerance to high pH, salinity, pests, pod characters and silvicultural traits.

Research, Development and Policy Needs

- There is a need to establish a network programme involving all the dry land centres in the country on genus *Prosopis* to exploit remarkable qualities of *Prosopis juliflora* to generate livelihoods in dry areas.
- National workshop on *Prosopis* should be organized to share current status of knowledge on genus *Prosopis* and to plan agenda for the future. All stakeholders, farmers and farmers organizations, scientists, development managers, NGO's, environmentalists and policy managers should be involved in this workshop. Some international experts on *Prosopis* should also be invited to participate from Mexico, Brazil, USA, Argentina and Peru where the genus *Prosopis* is commercially exploited as human and animal feed and for its value added products.
- There is a need to document the area under *Prosopis* in India and indigenous technical knowledge how the trees are used in rural livelihood support. The areas and regions where

the trees are encroaching the agricultural lands, bird sanctuaries and national parks etc. needs proper documentation to initiate timely preventive measures.

- One of the most important value added products being obtained from *Prosopis* is charcoal. The indigenous methods and techniques used in making charcoal in rural India are laborious, time consuming, less effective and less profitable. These methods and techniques need to be upgraded to make them more commercial, efficient and credit worthy.
- *Prosopis* pods are a good source of livestock fodder feed in drought prone areas. This is cheaper, more nutritious and locally available fodder resource. The state governments need to develop a mechanism for linking *Prosopis* pod flour with the livelihood of rural people in rainfed regions through incentives, value addition and marketing.
- Creation of awareness among the rural masses about the remarkable value added products of *Prosopis* especially of women and uneducated unemployed youth should receive high priority.
- There seems a strong case to establish *Prosopis* demonstrations in drought prone areas of the country including training on all kinds of value added products such as furniture from wood, animal fodder and human food from pods, biomass to generate energy/electricity and honey production etc.
- Publication of pamphlets/leaflets in local languages and their free distribution in rural areas. Establishment of self help groups involving landless poor people in areas where these trees are naturaly growing and linking their livelihood and employment generation with *Prosopis* based activities.
- Establishment of quality seed and planting material sources of promising species like thornless *Prosopis alba*. As far as possible these modern nurseries should be established at representative sites in drought prone areas.
- There is a need to develop cultural/ management practices to obtain optimum rotation period for energy, pod and furniture production. The inter-crops particularly grasses which can be cultivated in association with *Prosopis* trees in a unified agroforestry system needs to be identified to get maximum biomass per unit land and time.

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