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ICAR

Prosopis juliflora
Past, Present and Future

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NAIP

Editors

J.C. Tewari, P. Ratha Krishnan, S.L. Harsha, H.C. Bohra

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PREFACE

Natural resources are the precise gift of God to meet the needs of the people not all the greed. But the population increase and civilization era compelled the human beings to exploit the natural resources to its extent potential. During that phase, some of the natural resources are facing threats and under pressure, one such resource is the vegetation/biomass/forest. The role of forests on environmental, biodiversity, production, aesthetic, health, etc is well understood and appreciated. The efforts made by the learned society to over come/fulfill the needs are cultivation and management of this renewable resource. In this context, production forestry fetches its significance over conservation forestry. Fast growths, adaptability to wide environment, biotic and abiotic resistance, economic and social values are the prime facts which decide the role of species to get chosen for the above purposes.

Eucalyptus, Prosopis and *Acacias* are the three worldwide distributed trees feeding the requirement of human beings and get introduced in to new areas than its nativity. It is also acceptable that, they also threat the ecosystem. Among them, *Prosopis juliflora* is one which proved its multidimensional role and potential. It is also a livelihood supporting species for the resource scare region like this arid part of India.

The overall objective of NAIP is to contribute to the sustainable transformation of Indian agricultural sector from an orientation of primarily food self sufficiency to one in which a market orientation is equally important for poverty alleviation and income generation. The project titled "Value chain on value added products derived from *Prosopis juliflora*" under the component–II, NAIP is a recent effort by CAZRI in which Researchers – Industry – NGO are working in consortium mode towards the development of *Prosopis* by the sustained stand management, value added products development and their scale up production towards maximizing the utilization and economic benefit of this species. A national workshop titled "*Prosopis Juliflora*: Past, Present and Future" as a part of this project is planned and this compendium is an effort made by the compilation of contributions made by the stakeholders of this species.

We are thankful to the National Director, NAIP, Director, CAZRI, HoDs, *Prosopis* stakeholders, Co-PIs of the project, Research Fellows and all the supporting hands for their timely contribution and help.

Editors

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FOREWORD

The Indian hot arid zone occupies an area of 0.32 M km^2 spread over western Rajasthan, north-eastern Gujarat, western parts of Punjab, Haryana and some sparse lands of peninsular India. This arid region contributes significantly to the economy of India in terms of mineral assets, crops, forage and livestock production, employment and industrial potentials. Innovative new means of technology with the due consideration of environmental, social and economic condition of the society, their involvement, usage of bottom-up approach, appreciation of indigenous technical knowledge will solve the complex problems of the resource scares regions like this arid zone.

Realizing the gravity of the problems, appraisal of natural resources and their judicious utilization are the top concerns of CAZRI, Jodhpur. Growing of arable crops in association with *Prosopis cineraria,* an indigenous MPT is an age-old tradition in arid India particularly in the Thar Desert. Realizing the slow growing nature of *P. cineraria,* another *Prosopis* species, *P. juliflora* was first introduced into India in 1857 from Latin America. This species reflected its potential in terms of adaptability and growth in these new environmental conditions immediately after introduction. The arid and semi-arid parts of the country were the most preferred habitats of *P. juliflora,* but over time this species has spread into other parts of the Indian sub-continent. *P. juliflora* is now well naturalized in the arid and semi-arid tracts of the region. Presently it is difficult to limit its spread/invading nature and management of natural regeneration. Depending on climatic and edaphic conditions, the density of species varies from 5 to 100 trees ha^{-1}.

It is fine to introduce the right adaptable species and utilize its all parts efficiently for the betterment of the society. In that way, CAZRI, Jodhpur is working for the ever sustained production techniques in arid parts of India by its contributions like sand dune stabilization techniques, shelter belt model to overcome the adverse effects to crops and other life forms, integrated land use management techniques, introduction of improved and suitable crops, trees, animal for this region and their value chain to secure environmental, economic and social enlistment. One among the successful interventions by us is the value added products/services tapped from *P. juliflora.* It is appropriate to host the national workshop on "*Prosopis Juliflora*: Past, Present and Future" at CAZRI towards appraisal the efforts of its stakeholders.

I wish every success for the positive outcome of the workshop.

(M. M. Roy)

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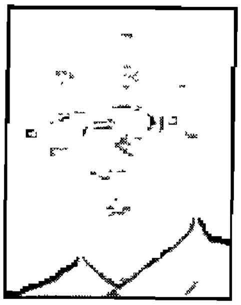

Message

I am delighted to note that Silva section under CAZRI, Jodhpur is organizing a national workshop on *"Prosopis juliflora:* Past, Present and Future" during 23rd & 24th March, 2011 under the component-II of NAIP. *Prosopis juliflora*, is one of the well acclimatized exotic in the driest zones of the world. Since it was introduced some 150 years back, it attains the status of "Royal plant" in erstwhile Marwar state while today, it is being considered as noxious weed. However, in entire arid western Rajasthan and Gujarat, it is an abundant woody resource supporting the rural livelihood.

The virtue of *P. juliflora* lies in its evergreen and fruit bearing nature even in the driest season of the year. Ecological, Social and economic impact of *P. juliflora* is a subject of debate towards its reorganization. CAZRI, Jodhpur is working for the sustainable productivity improvement of arid India through various innovative natural resource management technologies. For the two decades they also were working on improvement and utilization aspect of this species by active collaboration with leading regional, national and international *Prosopis* stakeholders. Value added services from the products viz., pod flour as mixture for bread & biscuit making, roasted & grinded pod as coffee powder, high sugary syrup of mesocarp as substitute of honey, high proteinous pod as non-conventional feed and high calorific fuel wood are the ways and attempts by them.

The contribution to the Component II of NAIP project "Value chain on value added products derived from *Prosopis juliflora*" is a valuable contribution by them towards show case the technology into adaptation to larger scale. As a leading partner in this aspect I strongly believed that present interactive national workshop is a good attempt to appraise and assemble the recent technologies in the value chain process of *P. juliflora.*

I am confident that the delegation of the workshop will be greatly beneficial to formulate the future planning towards better usage of this controversial species. This souvenir will be a composite document on up to date *P. juliflora* value addition.

I wish for the successful conduction of the workshop and their great endeavor.

Bangali baboo

(Bangali Baboo)

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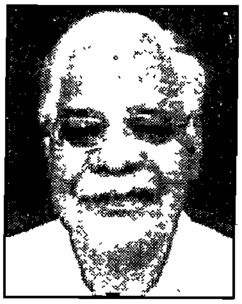

Message

I am glad to know that the Silva section of CAZRI, Jodhpur under the auspicious support of NAIP is organizing a National Workshop on "*Prosopis juliflora*: Past, Present and Future" on 23rd & 24th March, 2011 and also publishing a souvenir on this occasion.

The ruler of the princely state of Marwar introduced *P. juliflora* into Rajasthan in 1913. Fascinated by its excellent growth rates in the region, the then ruler of the state declared it a "Royal Plant" in 1940 and exhorted the public to protect it. Since then, the species was gradually introduced in many parts of the country including Haryana, Punjab, Uttar Pradesh, Madhya Pradesh, Maharastra and Tamil Nadu. At present, *P. juliflora* is thought to inhabit more than 500,000 ha, although plant densities vary with different areas and habitats. Due to its wide ecological amplitude and rapid colonizing ability, the species has spread rapidly over a large part of the arid and semi-arid tract, with the exception of frost prone areas. However in the recent past, this species is being considered as noxious weed.

It is needless to say that *Prosopis juliflora* is one of an exotics received attention of ecologists, economists and social workers due to the contributions towards ecological and economic succession. It has now become the main source of fuel wood in rural areas and various value added products are derived from its pod, seed and small wood. Other than the above facts, this species has the limitation of weedy invasiveness and allelopathic influence on under storey crops. CAZRI, Jodhpur is working for the sustainable agriculture in arid parts of India and significantly demonstrated the sand dune stabilization techniques, shelter belt model and efficient ways of using the natural resources available in that region in sustainable manner. One among the successful interventions by them is the value added products / services tapped from *P. juliflora.*

I feel that efforts put by this interactive national workshop of its stakeholders will result in optimized *P. juliflora* management technique towards yield improvement, ecosystem and economic sustainability and other value chain processes from this species. I am sure that this publication will be a consolidated document in all aspects of *P. juliflora* value chain.

It is worthwhile to appraise the efforts put by its stakeholders. I welcome the participants and wish the organizers the very best for the success of the workshop.

(J. C. Dagar)

CONTENTS

Prosopis juliflora: From Royal Tree to Disaster and Beyond

J.C. Tewari, Moola Ram, Manmohan Singh, Yogendra Singh and Anil Sharma
Central Arid Zone Research Institute, Jodhpur

The *Prosopis* Debate

P. juliflora- P. pallida complex often referred as *Prosopis,* is an important topic of discussion and policy in many parts of Africa, South Asia, Australia and America. Perhaps in South Asia, India and Pakistan are two countries, where farmers, ecologists, forest managers, NGOs and policy planners are alarmed by the invasion of *P. juliflora* in vast areas of land in last two decades. They have put pressure on governments, who in turn, have instructed related forest departments to stop planting of the species and even initiated eradication programmes (Tewari, 2009). In fact *P. juliflora* (Swartz) DC, a leguminous tree species, was first introduced in India approximately 135 years ago (Tewari *et al.,* 2006). Thus, history of the introduction of the species in the country is only 140 years old.

Owing to its fast growth and drought hardiness with extraordinary ecological amplitude, the species has been spread throughout the length and breadth of the country, from Haryana in north and down south upto Tamil Nadu, and from Kucch, Gujarat in west to drier parts of Orissa in east (Tewari *et al.,* 2000). The major concerns against the species are its thorny nature and its weedy spread. However, many researchers, farmers, artisans, and even thinking planners and politicians argue that the species is valuable resource. The debate is still continuing to see the species as a valuable resource or as a disaster. No one knows when this intensified debate will arrive to logical end.

The Royal Tree

P. juliflora, native to Central America and to the northern part of South America was introduced in Kucch area of Gujarat state during 1885-86 by then Maharao or ruler of the region. In arid western Rajasthan large scale aerial seeding of the species was done by then ruler of princely state of Jodhpur in early 1930s', and in 1940, the species was declared as "Royal tree" and officials were told to plant and protect it (Harsh *et al.,* 1996). Because of its exceptional drought tolerance ability and also tolerance of saline soil and water conditions, the species has been spread in larger parts of arid and semi-arid tropics of the country, which constitute 40% of the total geographical area of the country.

With its tremendous ability to adapt in tropical arid and semi-arid environments, and its fast growth and multiple utility, it has long been recognized by the foresters as a versatile species for the afforestation on various land forms of arid and semi-arid tropics like, sand dunes, inter-dunal plains, saline-sodic soils, rocky and semi rocky areas, around agricultural farm boundaries, etc. However, rural population in arid and semi-arid tropics are little apprehensive of the species as they consider that species adversely affects crop production and fear it may become a weed. In fact, thorny stems and branches of the species, which often causes injuries to humans and animals, and hinder agricultural operations are primary reasons related to disliking of the species by the villagers. But one thing is beyond doubt that *P. juliflora* has become a prominent woody species in agro-ecosystems of arid and semi-arid tropics of India despite the disadvantages associated with it.

The Weedy Invader with Exceptional Value

P. juliflora often colonizes disturbed, eroded, over-grazed or drought/salt affected lands, forming dense thickets. In addition to providing a hard and heavy wood (specific gravity = 0.70) that makes excellent fire wood and superior charcoal (NAS, 1980). *P. juliflora* and other similar species of section – Algarobia of Burkart's (1976) classification schemes of genus *Prosopis* also provide quality timber from managed stands (Table 1). The pods are used as a livestock ration and also as human food, and seeds are processed to extract endosperm gum similar in properties like guar gum (NAS, 1980; Tewari *et al.,* 2000).

Table-1. Some physical and mechanical attributes of *P. juliflora*, *Delbergia latifolia* (Shisham) and *Tectona grandis* (Teak) timber

Attribute		*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
	Tangential	2.2	5.8	5.8
	Radial	2.6	2.7	2.5

*MOE= Modules of elasticity

Great strides have been made in recent times in USA, Mexico, and Central and South American countries, where *P. juliflora* grows naturally to improve it using genetics and breeding to achieve gains in important traits, such as, rate of diameter and height growth, length of clear bole and pod production (Tewari and Harsh, 2009)

Certain scientists with vision predict that two plant genera will have major impact on man's survival: *Prosopis* and *Acacia* (Habit, 1985; Tewari *et al.,* 2001). In Indian context, *P. juliflora* is there in larger parts of arid and semi-arid tropics, providing sustainable fuel wood to the tune of 70% to rural population, which in turn saving superior biomass in one way or other but, environmentalists, researchers, foresters, planners and even thinking politicians voice their opinion regarding the species without any scientific basis, which often send confused message to end users-the rural folk. In fact, all the parts of plants are useful in one way or other, use of abundantly available pods as animal feed after processing suitably can be able to change the scenario of fodder deficit in many parts of rural landscape in arid and semi-arid tropics of India.

Central Arid Zone Research Institute (CAZRI), Jodhpur, India is involved in *P. juliflora* R&D programme in big way since last more than two decades. Impressed by the CAZRI's research findings related to *P. juliflora,* Texas A&M University, Texas, USA and Henry Doubleday Research Association (HDRA, UK) completed three major collaborative research programmes on *P. juliflora* so successfully that they opened the gate to address the issue of economic succession in context of very close binding of *P. juliflora* with rural communities, which was observed as *P. juliflora*-human-livestock continuum, wherever species exist. It was found that whatever positive and negative views are advocated regarding the species, but the species is playing important role in socio-economic-cultural fabrics of rural life in arid and semi-arid tropics of India.

The Reasons Seeing the Species as a Disaster

P. juliflora is most extensively distributed woody species in arid and semi-arid tropics in India, but its spread is being proclaimed as disaster in some quarters (Tewari *et el.,* 2001). It would be appropriate to cite the advancement of *P. juliflora* in Kucch region of Gujarat. The state forest department of Gujarat initially planted *P. juliflora* on about 31,550 ha of Banni grasslands of Kucch to check the advancement of Rann. The prevailing conditions in Banni, including successive droughts, increasing salinity and excessive grazing pressure, provided highly suitable environment for the growth and spread of the species. Once the species found optimum soil and climatic condition for the growth and development, it rapidly increased in other parts of grasslands in very little time (Tewari *et al.,* 2000). The ecological succession changed the structure of vegetation complex and entire area dominated by *P. juliflora* in terms of distribution, abundance, basal cover, canopy cover, etc. It has been reported that area under *P. juliflora* increased from 378 to 684 km^2 (81% increase) in 12 years (i.e., 1980-1992).

The encroachment of species in productive grassland was the result of failure of management system. Before planting the species, no body looked into aggressive colonizing ability of the species and after introduction, the forest department never made any working plan for silviculture and management of this species. The species was left as an orphan and this state of affair was most conducive for the species in successional gradient. The example of Banni indicates that before introducing the species on productive grassland, a precise working plan for management of the species must be there, which did not exist at all. Otherwise, the management of the species is very much possible, if proper care and set of management systems are employed from very beginning (HDRA, 2002).

In fact, the weedy growth of *P. juliflora* seen throughout the arid and semi-arid tropics of the country is resultant of two reasons, first absence of any sivlicultural and management system, and second, unfortunately the seedlots came to India time to time, majority of them were Mixican forms, which have primarily short statured, multi-stemmed architecture. The un-managed expansion of *P. juliflora* stands also resulted due to cutting of young growth for fire-wood from second year onwards. The cumulative effect of all these led to development of weedy thickets in larger parts of domain of the species in the country, for which now species is blamed as disaster (Tewari *et al.*, 2006). Without going into positive aspects related to species, proponents of this school of thought emphasize the weedy nature, aggressive colonizing ability, presence of thorns, unconfirmed belief that the species utilizes too much water and responsible for lowering of ground water table as their tools against the species. They voice opinion for eradication of the species and under their pressure state forest department of Rajasthan has initiated eradication programme of the species in some areas during last 7-8 years.

Is Eradication the Appropriate Solution?

In USA and Mexico for over 50 years ago efforts have been made to eradicate the species with range of herbicides and mechanical measures, but not much success is achieved. Smaller programmes of eradication in Argentina, Sudan, Australia and Pakistan met with same fate; because during initial years they were little bit effective for short time but *Prosopis* generally returns. During the course of such eradication programmes, millions of dollars have been spent but still no cost effective solution has been found.

In fact, once established *P. juliflora* becomes difficult to remove completely. Even in a seemingly *P. juliflora* eradicated area, their scattered seeds in soil germinate and tree spreads much faster than their original growth. Only recently authors encountered a small patch in Sanchore area of Rajasthan, where *Acacia* sp. was planted after removal of *P. juliflora*. However, new growth of *P. juliflora* has again started colonizing the area (Fig. 1). Thus, eradication does not provide optimum solution.

Fig. 1. New growth of *P. juliflora* in an area from which the species was removed and *Acacia* sp. was planted few years ago.

New Knowledge Applied

An international team led by HDRA, U.K. and CAZRI, Jodhpur, and funded by DFID, began a project in 1998 to gather the global knowledge on *P. juliflora –P. pallida* complex. An important conclusion of the project was that eradication is not a solution and there are many management and control technologies that can convert weedy stand into productive, profitable and sustainable agroforestry model (Pasiecznik *et al.*, 2001).

Management by Exploitation in Appropriate Strategy

With the production of fuel wood, pods and straight boles for timber, exploitation of *P. juliflora* can be profitable use of otherwise un-productive lands. Markets are developing around the world but work is still required to promote the species as a valuable tree of the desert. Integrated development is needed from basic stand management to product processing and marketing. Beside the cost benefit analysis, state and national governments should strike a balance between containment of *P. juliflora* through current eradication programme and development of profitable agroforestry landuse system through improved management.

Value Chain for Value Added Products Derived from *Prosopis juliflora*-Production to Consumption System: A New Initiative

Under National Agricultural Innovation Project (NAIP), CAZRI has successfully developed a value chain for value added products involving farmers, NGO and Industry. Technologies for processing concentrate ration, multinutrient feed blocks and supplemental feed blocks using *P. juliflora* pods have been perfected and transferred to Industry. Industry is producing and marketing these commodities. *P. juliflora* coffee preparation technology has also been standardized and passed to partner industry. However, toxicity analysis for human consumption of *P. juliflora* pod flour is in progress at NIN, Hyderabad. Once a clean chit is obtained in this context, *P. juliflora* coffee will also be launched in the market. This value chain is providing win-win situation to all the stakeholders. Sustainability of this value chain will definitely change the prevailing perception of *P. juliflora* as a noxious weed of no use to multipurpose woody species of economic value for rural population of arid and semi-arid tropics of India.

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Invasive *Prosopis juliflora* to Improve the Livelihood: A global Perspective

L.N. Harsh
Ex Principal Scientist, Central Arid Zone Research Institute, Jodhpur

The *Prosopis* (Greek Word: *Pros*- Towards and *opis*- Wife of Saturn, i.e. Greek godess of Saturn of abundance and agriculture) is native to central and south America spreading from southern Mexico to Panama from the Caribbean island to northern South America (Venezuela and Northern Peru). It was introduced Globally from last 30-150 years. Today it can found in various arid and semi-arid region like South America, Australia, India, Pakistan, Sri Lanka, Senegal, Arabic Peninsula, Iran, Iraq, Egypt and middle east Sahel region, Sudan, Ethiopia, Kenya, Namibia, South Africa, Eritiria, etc. (Fig.1)

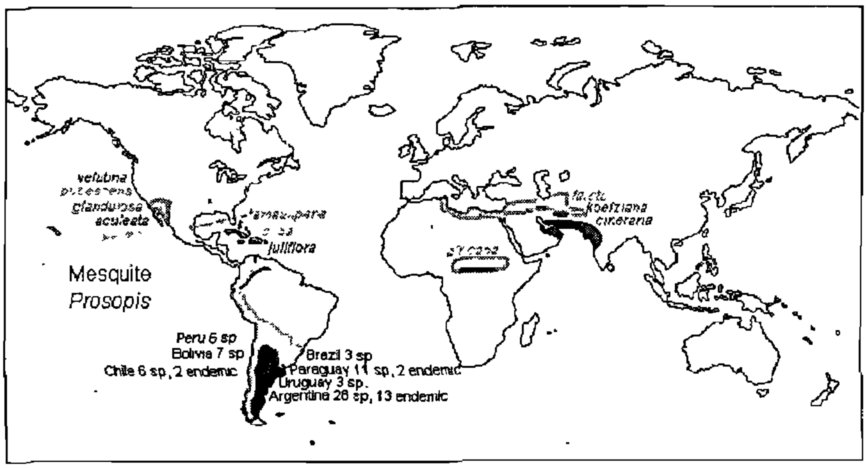


Fig. 1. Global distribution of *P. Juliflora - P. pallida* complex

The species were introduced in different regions during different periods. In India it was in 1877, in Sri Lanka 1880, in Queensland between 1920-1930, in Senegal 1822, South Africa in 1880, Egypt in 1900. It was introduced to different arid and semi arid regions with objective to stabilize the sand dunes to check the soil erosion, by erecting shelterbelt as ornamental trees on the roadside, to ameliorate the degraded soil, to reclaim saline sodic soils. The species have performed excellently and met the objectives with which it was introduced. But in a span of 30-130 years it has become invasive weed because of its wide ecological amplitude, it has colonized coastal marshes, desert areas, sand dunes, flat plains, hilly areas, dry stream beds, saline flats, waterlogged areas. Presently it is estimated that world wide it has covered 45 million ha of grazingland from sea level up to 1500 m.

In a short span of its introduction it has spread in larger areas because of its high production of small hard seeds which form soil seed bank. It has been estimated that mature tree produces 630000-980000 seeds/year or 60 million seeds/ha/year. Its seeds can remain viable for more than 20 years and more than 60% germination recorded even after 20 years of storage. Its pods are highly palatable to all types of livestock and wild animals. The undigested seed encapsulated in hard endocarp excreted out along with their feaces or droplets. Researchers have reported 1 kg droppings of each animal contained between 760 (Goat) and 2833 (Cattle) seeds, suggesting that cattle are more dispensers of seeds. It was also reported that animals are accelerating the increase of mesquite. Through camel dropping alone it has spread 1000 km^2 area begin from Egypt border to Sudan. Besides livestock, the seeds also disperse by water during heavy rains. Besides it is a good coppicier and can tolerate 8-10 harvesting. Its roots are very deep and can tolerate successive droughts.

Because of its adaptive characters, in the past few years it has been spreading @4000-5000 ha/year wherever it has been introduced in the past 20-30 years. In Ajmer district of Rajasthan state (India), from 1990 to 2006 it has spread at the rate of 26% or 2900 ha $year^{-1}$ (Table 1)

Table 1. *Prosopis juliflora* coverage in Ajmer District based on satellite imagery

Total geographical area	816937.0 ha
Area (ha) under *Prosopis juliflora* (1990)	37108.3 ha
Area (ha) under *Prosopis juliflora* (2006)	46949.6 ha
Growth rate of *P. juliflora* coverage	26.5%
Spread	2900 ha/yr

Similarly in Saurastra and Kutch region of Gujarat state (India), it spread @ 4350 ha $year^{-1}$. Ecoclimate modelling using 'CLIMEX' used for predicting potential distribution of two species (*P. juliflora* and *P. pallida)* in Saurastra and Kutch region (Table 2).

Table 2. *Prosopis* invasion & predicted values in Saurastra and Kutch

Years	Area (ha)	% Area
1980	118799.40	31.6
2005	149275.78	39.8
2010	171017.48	45.0
2015	192736.38	50.7
2025	214432.71	56.4

In Banni area of Kutch region it has been reported that from 1980 to 1988, it invaded @ 4188 ha yr^{-1}. In south Africa particularly in north-western Cape province it has spread in 180,400 ha and area considered to be at risk is 935,000 ha. It covers 30% area of Mahabubnagar district (AP), Ramanathpurum and Shivganga district of Tamil Nadu (India). It has been reported that in Pakistan *P. juliflora* during last 45 years has invaded all kinds of communities in the flat plains of Karachi and has now become dominant by completely eliminating the natural vegetation.

The Loss Due to *P. juliflora*

In New Mexico due to *P. juliflora* 75% of carrying capacity of arable lands have been reduced. The grazing land of Afar region of Ethiopia completely turned into inaccessible hostile *Prosopis* thickets. Similarly, Banni area once known for best grassland of Asia, now vanished due to invasion of *P. juliflora*. In general, it is estimated that 60% of pasture land degraded due to invasion of *P. juliflora*, where it has been introduced. In Ajmer district not only there is loss of Rs. 602 per household due to biodiversity loss but also livestock production reduced either due to mortality or injury. The intensive survey of Ajmer district revealed that due to death of animals average loss reported to be Rs. 32975 and due to injury it is estimated to be Rs. 2688 per household.

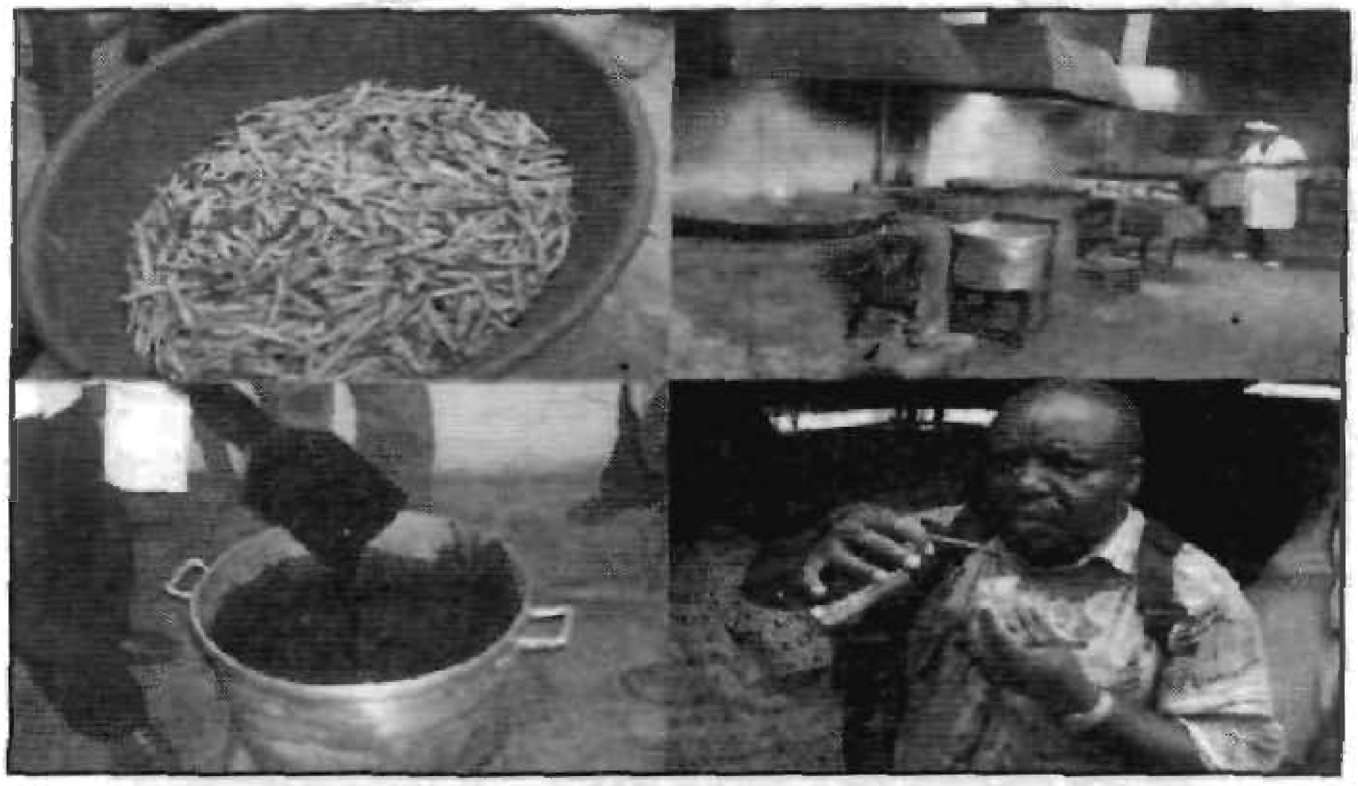
Keeping in view of its negative effect in the past, an effort were made to eradicate it completely but gone in vain. Because eradication by JCB becomes very costly it comes around Rs. 25000/- per ha, but after some time it again regenerates because of its seed bank in the soil or by stray animal faeces or droplets which contains treated seeds of *P. juliflora*. Therefore, due to failure in eradication, the scientists all over the world started to explore its optimum utilization. In the present context *P. juliflora* satisfy agenda 21of Reo Conference for combating desertification and ecological stabilization of desert areas, micro and macro climate change mitigation, the food security problem alleviation and alternate energy sources. Now in the recent past this plant has been explored and found that it has many uses. Indigenous population in America has long used the seeds pods of *Prosopis* as dietary products. The pods traditionally being dried and grounded into flours and processed into sweetener, sweet beverages or fermented into alcoholic beverage. In Peru alone 180,000 tons of Prosopis pods are collected and used for livestock feed.

Uses

As food: The use of *P. juliflora* for human consumption dates from far back when the Spaniards arrived in South America, especially in Peru, Chile and Argentina, they found that the Indians included *P. juliflora* pods in their diet. Many times Spaniards themselves ate *P. juliflora* pods and feeding also to their horses. Both honey like syrup and breads were made from the pods.

Pods are an important human food item in Peru, Chile and Argentina. It is also reported that pods utilized to make bread, syrup, coffee, cocktails, brandy and flour. "Algarobina cocktails" is very famous, and is good for stomach, with vitalizing and athrodisiac effect. It is also reported that rich and delicious flour could be made from purified pods from which seeds have been removed. This flour is used in preparation of sweets. The *P. juliflora* syrup – thick, dark and with consistency similar to Honey is widely used in the north of Peru to nourish, children, elderly and sick people. It is commonly mixed with milk (one to two spoons for a cup to milk), fruit, corn flour, etc. Rich delicious flour can be made from pulverized pods from which seeds has been removed. The cotyledons are pulverized which yields a flour rich in protein and sugar, appropriate for diabetic people. The pulverized mesocarp used in preparing breads, sweets, syrup, sweeteners, flavors in ice-cream, cookies, honey and coffee. Recently mesquite flour is most popular "Functional foods" in the health food industry due to its great taste and robust nutritional profile. The one pound of flour sold @ 14 dollar in the market.

As a fodder: Its pods have long been used as feed for bovines, equines and ovines in Peru, Argentina, Colombia, Venezuela, and Sudan. The greater value of *P. juliflora* as fodder is in its pods as they are very rich in sugar and protein. The pods are used commonly in livestock feed in India also. They provide 55% digestive carbohydrates (DC) and 6% digestible crude protein (DCP). Seed alone contains 41% DC and 25% DCP. It has been reported that live weight gain and body balances of nitrogen, calcium



and phosphorous were in positive order in the ration containing 30% of pods when fed to the bullocks.

The pods are used in concentrate ration for dairy cows at a ratio of approximately 40-60%. It was reported that pods have high digestibility. It revealed from many studies that digestibility of dry matter protein; either extract, raw fiber and non-nitrogen extract are 82.56, 80.13, 90.98, 70.89 and 83.19%, respectively. The replacement of wheat flour by *P. juliflora* pod flour from 0 to 20, 40, and 80% in the cattle feed increased the milk yield as well as body weight. In the recent past, in Banni area of Gujarat the people area using *P. juliflora* pod flour in the feed concentrate of cattle feed.

In arid and semi-arid zones of Mexico *Prosopis* is one of the most conspicuous genera in the plant cover. *P. juliflora* is the most ubiquitous, considering its traditional potential and actual uses. The puvarized whole pods flour may make upto 30% in concentrate ration for dairy cows. The short-fiber parts are also suitable for pigs and poultry (Table 3). By using the pod flour the milk of lactating animals increased by 20-25%. The weight of eggs of hen increased even using the 66% of pod flour and 34% of wheat bran.

Table 3 Utilization of *Prosopis* pod flour as substitute for wheat flour for egg laying hens.

Treatment		Egg mean weight (g)
Wheat bran 100%	*P.juliflora* flour 0%	58.76
Wheat bran 67%	*P.juliflora* flour 33%	59.48
Wheat bran 33%	*P.juliflora* flour 67%	59.0
Wheat bran 0%	*P.juliflora* flour 100%	59.34

Similarly the body weight gain in goat during dry season increased by 38% when 38% of grounded *P. juliflora* pods aremixed with sorghum + 5% cotton bran and 8% ground corn. The molasses can also be replaced by *P. juliflora* pod flour and reported that nitrogen balance can be improved as the proportion of *P. juliflora* pod flour was increased in the ration. By adding 25-33%of *P. juliflora* flour in concentrate of milching Tharparkar cow, the milk yield increased by 25%.

As source of honey and wax: The species is a major source of honey as it flowers round the year and provide nector to bees. It is a major honey source in Bolivia, Jamaica, India, Pakistan, Sri Lanks, Peru and Argentina. The quantity of honey ranges between 175-800g per comb depending on the size of the comb. After collecting the honey, the honey combs are crushed and wax is obtained. The bee wax has a great economical potential as it is used in a number of industrial processes.

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^{-1}).

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 period 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 kilns for treating and purifying minerals; firing pottery, especially traditional earthenware, for kullarh (cup), handi (vessel for growing plants, etc.) and baking bread and biscuits. These industrial processes require a large quantity of wood and therefore, stem 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 cm long and 10-15. Such branches are tied into head loads which are carried from source to village / towns, either for personal use or for sale.

Wood as charcoal: Firewood is bulky and expensive to transport, as it is 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 scales 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. 200-250.

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

Larger diameter trunks (over 10 cm) are used to make charcoal by burning stems, branches and the upper rootstock 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.

Recently, CAZRI, Jodhpur have used discarded oil drums fitted with air ducts for processing of charcoal. As drums are portable, they can easily be taken to the source of fuel. To produce 1 kg charcoal, approximately 6-9 kg *P. juliflora* wood is required, depending on the method used.

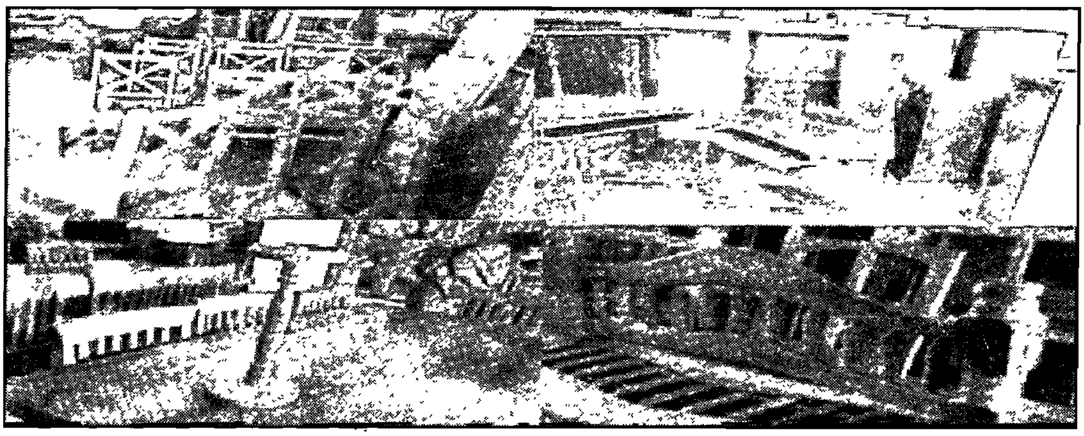
Role of *P. juliflora* in electricity generation: During the recent past, keeping in view of large amount of biomass produced by *P. juliflora*, it is used in electricity generation. The Department of Non-conventional Energy Resources has sanctioned more than 30-40 project on *P. juliflora* for generating electricity in Andra Pradesh, Tamil Nadu and Gujarat. It has been reported that for generating 1 MW of electricity, 6169 tones of fuel wood is required.

Table 4 - Biomass yield of *Prosopis juliflora* plantation from different rotation

Biomass type	First cut 3 years after planting t / ha	Coppice cut t /ha				t /ha
		First 7th year	Second 10th year	Third 13th year	Forth 17th year	
Utilizable biomass	20.49	24.06	26.68	23.26	19.8	114.83
Non-utilizable	9.60	11.90	12.90	10.90	8.90	54.20
Total biomass	30.09	36.50	39.58	34.16	28.70	169.20

The biomass of the species after different rotation was recorded. The biomass after 17th year was 169.2 t ha^{-1} of which 114.8 t was utilizable and 54.2 was non utilizable (Table 4).

Wood as timber: The wood of *P. juliflora* can be uses as round wood or processed into chips or sawnwood. Long and relativily less straight pieces can be used for posts and poles. . Chipping of *Prosopis* wood is done to manufacture plywood, practical 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 when it is converted into boards and cants. Sawing can be carried out by hand, or by chainsaws, circular saw or band saw.



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 *(Delbergia latifolia)* and Indian teak *(Tectona grandis)*.

Pod for biofuel: Recently *Prosopis* pods could be known as alternative substitute for ethanol production. The ethanol yield was found to be higher 141 g per liter when Zymononas mobilis was cultivated in mesquite hyderated mash under static condition. *P. juliflora* flour for preparing bio-ethanol has also been studied. The initial sugar concentration 13% was reduced to 0.15%, resulting into 6.14% alcohol by fermentation.

As gum, resin and protein: Reddish amber, similar in properties to gum Arabic produced by *A. senegal* often exuded from the stem and older branches of *P. juliflora*. On an average 30-40 g per tree gum is produced. The gum is mainly used for sizing in textile mills, in confectionaries and processing of beetle leaves, which are chewed by the people throughout the Indian sub-continent. It is also used for preparation of adhesive. The gum can also be extracted from seed of *P. juliflora* pods. The seed endocarp contains glactomannan, which is almost similar to guar gum (cluster bean and carob seed gum). The seed contains 32% gum. The seed gum is used as a thickener and galifier in products like ice-cream sauces, cheese, yogurt, etc.

The seed cotolyden are good source of protein (64%) whose quality is similar to other legume seed protein. *P.juliflora* heart wood contains significant amount of extractable polyphenolic compounds from which can be isolated unique flavinol compound used in fermentation of new phenol formaldehyde. The tenning from the wood can also be extracted but the yield is not exceeds by10%.

***Prosopis* in services**

Erosion control: *P. juliflora* has been used to arrest wind erosion and sand dune stabilization in many of the countries where it primarily introduced for the purpose.

Reclamation of lands: It is wildly planted for land reclamation because it is aggressive colonizer, tolerant to very poor degraded, saline alkaline soils. In USA, aerial seeding of mixture of *P. julifloira* and several *eucalyptus* sp. used to reclaim abundund copper mines. Similarly, in then Marwar state of Rajasthan it was aerial seeded in desert areas.

Nitrogen fixing: *P. juliflora* moderately enriches soil with atmospheric nitrogen obtained through symbiosis with cowpea type rizobium. The roots also form mycorrhizal association with *Glomus* fungi. Plants with both rhizobium and mycorrhizal association showed significant nitrogen fixation rates than those lacking mycorrhizia. The total nitrogen, sulpher and soluble salts as well as organic matter have been shown to increase by manyfolds in the upper 4-5 m of soils under its canopy.

Intercropping: It is a best species to be grown in association with *C. ciliaris*, *Opuntia* spp. and *Pennicum* maximum under silvi-pastoral system.

Ornamental: It is used to line motor ways. However, its thorns pos problem in pruning and maintenance. Therefore, recently cultivars of thornless *P. juliflora* are planted.

It can be concluded after reviewing the global research findings, that this invasive weed has multipurpose uses and if explored properly it can improve the livelihood of local people wherever it has been invaded.

Studies on Nutrient content of *Prosopis juliflora* Pods and its Milled Products

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Introduction

The genus *Prosopis* contain 44 species, is spread over throughout Africa, South America and South and South-east Asia. In the Indian sub continent *P. cineraria* is an endemic and *P. juliflora* an exotic, native to Central and South America, is now spread throughout the arid and semi-arid tropics. *P. juliflora* was first introduced into India in 1857 from Latin America. Although the earliest introduction of *P. juliflora* was in 1857 but first systematic plantations were carried out in 1876 in Kaddapa area of Andhra Pradesh. It was introduced in parts of Gujarat in 1882 and in Sindh (Pakistan) in 1877. The ruler of the princely state of Marwar introduced this plant into Rajasthan in 1913. Fascinated by its excellent growth rates in the region, the then ruler of the state declared it a royal plant in 1940 and exhorted the public to protect it. At present, this plant inhabits more than 500,000 ha of our country, on all the types of soils from sandy to saline alkaline soils, although its densities and productivity vary with different areas and habitats. The species of *Prosopis* are outstanding in their adaptation to the dry areas and human inhabiting these areas used the plant products since prehistoric times to meet his own needs as well as those of his livestock. *Prosopis juliflora* provides highly palatable and nutritious pods in large quantities and the flowers produce good quality nectar for honey and which is also consumed by birds. The pods are rich in protein and free sugars which gives them a sweet taste (Muthana and Arora, 1983). The sweet, mature pods are consumed by human beings and ripened pods which falls on the ground are avidly consumed by domestic as well as wild (Goyal *et al.,* 1988) herbivores. The small scale commercial processing of animal feed from *P. juliflora* pods had been initiated in Brazil. In Mexico ripened pods of some *Prosopis* species are ground into coarse flour (pinote) for human consumption and baked after removing the seeds; pods are also fermented and brewed into a weak beer, possible because of the high carbohydrate and protein content.

Back Ground Information

Pod Characteristics

Fresh, ripened *P. juliflora* pods are from light yellow (winter), straw (summer) to light brown coloured. There is a high variability in pod size and shape, varying from 8 to 29 cm but mainly from 12 to 25 cm in length, curved, 9-17 mm wide, 4-8 mm thick, and strip to 2 cm long. Some are straight with incurved apex, sometimes falcate, compressed, linear with parallel margins, stipitate, acuminate, and rectangular to sub-quadrate. Seeds are enclosed in a protective square shaped septum, which is enclosed in a sweet, thin, dry yellow pulp containing 20-30% sucrose. This makes the pod palatable to livestock, also being low (0.74-1.5%) in tannin content (Felker, 1982).

Alves *et al.*, (1988) have described anatomy of *P. juliflora* pods. They mentioned that, "Fruit in cross section shows epicarp epidermis cells with thick cellulosic walls. Functional guard cells of stomata contain little and numerous starch grains. Under the epidermis, 3-4 layers of iso-diametric thick-walled cells occur with reserve substances. The meso-carp is large and begins with parenchymatic cells of relatively thick cellulosic walls changing from iso-diametric to elongate in outline. In the parenchyma, different sclerenchyma areas containing gelatinous fibres were noticed partly encircling little vascular bundles in which xylem bulk is less than phloem bulk. On the dorsal and ventral suture region, the sclerenchyma forms a continuous semi-sheath that hinders the natural opening of the fruit for seed liberation. Next are several layers of palisade cells with thin cellulosic walls, apparently devoid of reserve substances but probably having some water content, ending in thick-walled cells with irregular outline. Endocarp comprises 3-4 layers of simple fibres and some sclereids and stone cells can also be noticed".

Each pod possesses up to 25 brown seeds, which are in oval shape and transverse. There are 25,000-36,000 seeds/kg. The structure of *P. juliflora* seed as described by Alves *et al.*, (1988), "The seed is ellipsoid in contour and smooth-textured. Its extraction from fruit is hard because it is surrounded by rigid endocarp tissues. Micropyle and hilum are located close to each other and at the slender end of the seed. Embryo axis is straight and about 3 mm long; coltyledons are 5 mm long, filling most of the tegumentary space. In cross section, the external tegument can be observed, with its high, cellulosic-walled, thick-cuticled epidermal cells. The internal tegument has up to 8 layers of cells with thick cellulosic walls and round in outline. Short, straight embryo axis and large cotyledonar blades enclosing many reserve substances and abundant endosperm are present. A lengthwise section at cotyledonar node level showed hypocotyls axis and cotyledonar blade with an indication of procambium".

Pod Production

The *P. juliflora* trees normally start bearing pods, 3 years after plantation. Pod production in the early years is very poor, increasing with age. The *P. juliflora* pods provide permanent and inexhaustible source of livestock feed. The average yield of pods has been found to be 18.95 kg/tree/year, with the main fruiting seasons being winter and summer but maximum were obtained during later season. There are great variability in pod production (5 to 40kg/tree), which depend upon rainfall and the habitat of the area.

Felker (1998) opined that there is an immense possibility for genetic improvement in pod quality and pod production due to enormous variation in these factors. Felker *et al.*, (1984) found that mean pod production per accession ranged from 7.1 kg to 10.0 kg/tree for 25 accessions. He further recorded that the accession with the greatest mean pod production had a range of 3.2 to 12.2 kg/tree. Felker and Waines (1977) harvested as high as 73 kg of pods from a single 8.5 m tall tree. Felker *et al.*, (1984) reported the yield of pods to range from 7.2 to 90 kg/tree/year. In new Maxico USA , Garcia (1916) reported 17 kg pods/tree while Jurriaanse (1973) reported 90-150 kg from 10 year old trees in Central Africa. Smith (1953) reported pod yield of 4-20 t/ha from mature *P. juliflora* stands, but some plant can annually yield from a few kg to 50-70 kg.

Studies conducted at Anand revealed production of about 19 kg pods/tree/year (Anon., 1981). According to Shukla et al (1986) 1-ha *Prosopis* plantation could yield about 12 t pods/ha/year (19 kg pods/tree and 625 trees/ha) and thus from 44.83 ha of *P. juliflora* plantations in Gujarat state alone can produce over 0.5 million tones of pods annually. Assuming that pods could be harvested from only 40% of all plantations of *P. juliflora*, the pod production from the whole country is estimated to be 1 million t/year. Saxena and Venkateshwarlu (1991) reported pod production of 2,300 kg/ha from a plantation with a density of 118 trees/ha. The pod production from saline areas of the Banni region of Gujarat varied from 15-20 kg/tree.

Pod storage: Vir and Jindal (1998) have studied the pests and recorded that the Caryedon serratus Olivier causes severe damage to pods as well as seeds of *P. juliflora* plant. The average length of healthy pods was 13.86 cm and seeds per 10 pods were 248.85 gm. 34.35% pods and 3.91% of seeds were found infested with the insect. 100 healthy seeds weighed 3.30 gm, whereas, 100 infested weighed 2.19 gm, thus insect infestation caused 35.06% loss in seed-weight and 3.04% in seed-biomass. They opined that pod and seed infestation of *P. juliflora* with *C. serratus* is alarming as the insect infest and multiply even during peak of summer when ambient temperature reach to 49°C, however, damaged caused by the insect-infestation can be minimized when the raw pods collected from the field are immediately dried (either under the sun or in the forced air draft oven), then milled to produce appropriate product, which can be then stored safely at dry place.

III. Pod Processing

The small scale commercial processing of animal feed from *P. juliflora* pods had been initiated in Brazil. Saunders *et al.*, (1986) described a 1000 kg/hr dry milling facility suitable for processing *Prosopis* pods into a high fibre fraction, a high protein, a high sugar fraction and a galacto-mannan gum fraction. They also described the suitability of the use of the pod flour into chapattis, crackers, flakes, leavened breads and tortilla chips.

Processing of *P. juliflora* was initiated in India at VRTI (Vivekanand Research and Training Institute, Mandhi, in Kutchch district, Gujarat), where a special pod-thresher and cleaner have been developed for seed extraction (Kanzaria and Varshney, 1998). Kanzaria and Varshney (1998) suggested that *P. juliflora* pods are ideal for the production of animal feed on a large scale and recommended that the pods can be used to supplement concentrate rations by as much as 30% of the total feed.

P. juliflora seed is enclosed in a gummy septum and encapsulated in the hard fibrous endocarp shell, having hard seed coat and even for germination it requires pretreatment. A few methods have been developed for the removal of seeds from the septum (Saxena and Khan, 1975). Pods are collected and spread in the sun until they became dry and brittle. These pods are threshed mechanically into small segments, each generally comprising of one seed encased in its gummy septum. The removal of seeds from the endocarp can then be undertaken by soaking the broken segments in 0.1 M ammonium chloride solution for 24 hrs, 95% sulphuric acid for 30 min, 1% sodium hydroxide for 30 min or in 70-80°C water for 10-15 min and then at room temperature for 24 hrs. The segments should be well rinsed with water and rubbing with a coarse cloth ensures 100% seed removal. Kanzaria and Varshney (1998) mentioned that although *P. juliflora* pods with seeds are good source of cattle feed, but the seeds could not be easily removed from the gummy pulp.

IV. Pod Composition

P. juliflora pods contain 13% crude protein, 60% nitrogen free extract, 0.15-0.44% phosphorus and 0.30-0.50% calcium on a dry matter basis (Shukla *et al.,* 1984). Ground pod fed to cattle did not show any adverse effects but under uncontrolled conditions feeding the pods gave deleterious effects resulting in the formation of compact ball of indigestible pods in the rumen which caused sickness and even death of cattle. Fresh ripen pods contained 7-10% preformed water and on dry matter basis, contain 9-17% crude protein, 1.2-4.3% ether extractives, 16-34% crude fibre, 47-61% nitrogen free extractives, 28% acid detergent fibre, 8% acid detergent lignin, 4-5% ash, 0.14-0.29% silica, 0.3-0.5% calcium and 0.40-0.44% phosphorus (Shukla *et al.,* 1984). According to Vimal and Tyagi (1986) the pods composed of 16.5% protein, 4.2% fat, 16.8% crude fibre, 57% carbohydrates, 5.4% ash, 0.33% calcium and 0.44% phosphorus. Shukla *et al.,* (1986) reported amino acid composition of *P. juliflora* pod-protein. According to them, it contained 0.99% aspartic acid, 0.28% threonine, 0.14% cystine, 0.43% valine, 0.10% methionine, 0.27% isoleucine, 0.52% leucine, 0.29% tyrosine, 0.33% phenylalanine, 0.37% alanine, 0.19% histidine, 0.32% lysine, 0.56% arginine, 0.41% serine, 1.4% gutamic acid and 0.51% glycine (Table 12). The dry pods contained reasonable amount of iron (208-639 ppm), copper (13-16 ppm) and manganese (22 ppm) but the zinc (13-16 ppm) content was below the critical level (40 ppm) suggested for the livestock feed.

The seed alone contained 31-37% crude protein and 3.4-8.5% crude fibre; excluding the seed coat, the true seed on a dry matter basis contained 60-69% crude protein (Felker and Bandurski, 1979). The seed yielded 17.3% fatty oils of 8.55 acid value, 69.75 iodine value and 179.1 saponification value. On dry matter basis, the raw seeds had 10.9% moisture and on dry matter basis contained 39.3% protein, 4.5% fat, 18.6% carbohydrates and 3.8% ash (Vimal and Tyagi, 1986). Seed protein constituted of 3.19% alanine, 3.80% arginine, 11.23% aspartic acid, 9.44% gutamic acid, 7.31% glycine-serine, 2.13% isoleucine-leucine, 1.77% histidine, 2.01% lysine, 0.53% methionine, 0.90% phenylalanine, 3.87 proline, 0.41% threonine, 0.43% tyrosine, 0.84% valine and traces of tryptophan (Table 12). Cyanogenic glycosides, as reported in other conventional feeds, did not reported in *P. juliflora* pods (Mahadevan, 1954). It is very low in tannins (1.5%) and oxalates (1.1%) (Talpada, 1985) and devoid of alkaloids (Gujarathi, 1979). Kanzaria and Varshney (1998) have given seasonal variation in the nutrient contents of *P. juliflora* pods (Table 11). Oden *et al.,* (1986) studied the chemical composition of 30 *Prosopis* accessions grown in 3 environments and found that the pod sugar composition and pod protein content varied from 11% to 18%, respectively.

V. Pod Utilization: Livestock Feeding

Felker (1984) has described several studies conducted on use of *P. juliflora* pods in animal ration. *P. juliflora* pods became a major source of nutrients especially for range foraging domestic- and free ranging wild ungulates during drought and scarcity conditions in arid- and semi-arid areas of Rajasthan and Kuchh district of Gujarat. Mathur and Bohra (1998) have reviewed the information available on productivity, composition, nutritive value, growth and productive performance of livestock offered *P. juliflora* pods. Although substantial information in literature is available on chemical composition of *P. juliflora* pods, but information on approximate components of various fractions of the pods, obtained by its milling is lacking. Therefore, proposed study has been undertaken to assess nutrient contents of various milling products of *P. juliflora* pods subjected to milling using modified multi-purpose thresher and feed-grain hammer mill.

Material and Methods

The mature *Prosopis Juliflora* and *P. Pallida* pods, fallen on the ground were collected from the field, from Jodhpur and Sanchor (Rajasthan), and Kutch (Gujarat), both during summer and winter seasons (February and April 2009, April 2010 and January, 2011), dried in the sun and then milled either using modified multi-purpose plot thresher or with the hammer mill. The sun dried whole pods as well as its milling products were analyzed for approximate principals, viz., total minerals, ether extractives, crude protein, total carbohydrates and gross energy values were determined, following A.O.A.C. (1965).

I. Milling (A)

In the present study, a multi-purpose plot thresher originally developed by CIAE, Bhopal was modified (Kushwaha *et al.,* 2009; Photo. 1) at CAZRI, Jodhpur, which was used for processing of *P. juliflora* pods for separation of various fractions viz., epi-carp, meso-carp, endo-carp and it seeds. Its powdered meso-carp (good source of sugar), *epicarp (fiber) and endocarp-with-seed, obtained were further processed to get various* fractions (Fig 1) of these milling products. The modified machine had a capacity to process 60-70 kg pods /hr. Output of the machine in terms of different component of pods were 37-54% endo-carp with seed, 19-31% meso-carp powder, 14-36% epi-carp (fiber), about 1-5% loss in the form of dust including weight loss due to moisture, etc. The original low capacity machine was poor in output and most of valuable meso-carp powder was blown out by aspirator/blower system. In the improved version, the blower was kept idle/without power and so meso-carp powder can be collected through fine sieves. The rotation and speed of the drum was changed so that most pods get threshed between concave and pegs/beaters. The other components of machine were modified likes; a new threshing drum was fabricated with high carbon steel pegs, which was provided with a lateral steel rod at the tip for better scrubbing, concave clearance was adjusted and fixed at 25 mm at feeding, which decreased up to 10 mm at the other end.

II. Milling (B)

Full circle Hammer mill (Photo 2), manufactured by M/S B.K. Allied, Khanna, Punjab, driven by 7.5 H.P. electric motor, which was basically used for milling concentrate feeds like, cereal and leguminous seeds, and oil seed cakes were used for coarse- and fine-milling of the sun dried *P. juliflora* pods.

III. Chemical Analysis

P. juliflora pods collected from the field, dried in the open sun, and then subjected to milling either by modified multi-purpose thresher or hammer mill. Duplicate samples of whole *P. juliflora* pods (for the comparison, *P. pallida* pods were also sampled) and its milling products were analyzed for the proximate principals following AOAC (1965). Moisture content was determined by drying the samples in forced air, draft type oven at 68-70 for 12 hrs; ash by firing it in the muffle furnace at 550°C for 4 hrs, allow to cool down up to 100°C in the furnace, and further cooled to room in the desiccators; crude protein content was estimated by multiplying the values of nitrogen content of the sample with 6.25, obtained by following Kjeldahl method using Palican's nitrogen analyser,; ether extractives were determine by extracting the fat soluble compounds by washing the samples with refluxing petroleum ether (60-80°C) for 12 hrs using Soxhlet extraction apparatus; values of total carbohydrates was estimated by deducting values of crude protein, ether extractives and ash from 100, and gross energy, expressed as kcal/100 gm, was calculated by adding the multiplication of the values of total carbohydrates, crude protein and ether extractives with 4.15, 5.65 and 9.4, respectively.

Results and Discussion

I. Chemical Composition of whole *P. juliflora* and *P. pallida* pods and its milling products

Chemical analysis of *P. juliflora* pods and its milling products have been presented in Table 1. The data revealed that the whole *P. juliflora* pods contained 4.15% minerals and 12.79% crude protein, whereas, its epicarp portion contained 3.75% total minerals, 9.75% ether extractives, 9.20% crude protein, 77.30 total carbohydrates and 464 kcal%, gross energy. Meso-carp portion of *P. juliflora* pods contained 3.75% minerals and 9.20% crude protein. The smallest particles (<72 mash) of meso-carp fraction contained highest level of total minerals (8.1%), ether extractives (6.65%), crude protein (10.37%) and gross energy (432 kcal%). These values showed decreasing trend as the particles size increases from <72 to >8 mesh. The whole seeds contained 13.20% minerals and 32.0% crude protein. The seed meal (de-gummed seeds) recorded highest level of crude protein (43.97%) but its mineral content was merely 2.77% (Aza *et al.*, 2009). Total minerals and crude protein content of un-ripened *P. pallida* pods were higher than its ripened pods (Table 2). Minerals as well as crude protein levels showed decreasing trend as meso-carp particle size increases from <72 to> 8 mesh. The data further indicated that minerals and crude protein content of *P. juliflora* and its milling products were higher than that of the whole pods and respective fractions of P. pallida pods (Harsh et al, 2009), however, a reverse trend has been recorded with the meso-carp fraction (<72 mash particles size) of these pods (Table 3).

II. Chemical analysis of multi-nutrient-feed block (MNB) produced from *P. juliflora* pod milling products (PJ-MP)

The schematic diagram of all the milling fractions of *P. juliflora* studied has been represented in Fig 1. The data on chemical analysis of these milling products (Table 1) revealed that out of all these fractions, 3 products viz., fibrous epicarp (A), fibrous endocarp (B) and amorphous meso-carp (C) can be used for production of multi-nutrient blocks (MNB-A, MNB-B and MNB-C). On an average A, B and C milling products, on fresh weigh basis, contained 6.9, 7.1 and 8.1% preformed water, and on dry matter basis contained 95.3, 95.8 and 94.0% organic matter, 4.7, 4.2, 6.0% minerals, 7.37, 10.70 and 12.76 crude protein, 3.92, 4.24 and 9.16% ether extractives, 84.41, 80.86 and 72.05% total carbohydrates, and 425 kcal, 436 kcal and 467 kcal gross energy, respectively (Table 4). The ingredient-composition, chemical constitution and physical characteristics of multi-nutrient-feed block prepared from A, B and C PJ-MP milling products, and for comparison, of standard formulation block have been presented in Table 5.

The standard formulation block, which comprised of 44.5% molasses, 4.31% urea dissolved in 4.0% water, 4.3% each common salt, vitamin-mineral mixture and dolomite, 32.10% wheat bran, 5.10% guar meal and 1.0% guar meal dust, which was used as a binder. All these ingredients were thoroughly mixed, pressed in screw type block making machine and dried in the solar dryer. Attempts were made to explore possibility to replace wheat bran (Table 7), which is used as fibrous fraction in standard feed block formulations, with 3 types of PJ-M Ps. Chemical composition of standard formulation block (StB) and the blocks (MNB-A, MNB-B, and MNB-C) in which the wheat bran has been replaced by A, B and C, PJ-MP is as follow: on an average the standard feed block and MNB-A, MNB-B, and MNB-C blocks on fresh weight basis contained 2.7, 3.0, 2.7 and 4% preformed water, and on dry matter basis, contained 78.3. 82.6, 82.8 and 84.1% organic matter, 21.7, 17.4, 17.2 and 15.9% minerals, 22.9, 20.7, 22.2 and 20.9% crude protein, 4.1, 7.0, 6.04 and 6.0 ether extractives, 51.3, 54.8, 54.6 and 57.2% total carbohydrates and 381, 411, 409 and 412 kcal gross energy, respectively. The initial weight, of all mixed ingredients for production of AB, BB and BC blocks was 2.4 kg and of dried blocks was 2.2, 2.4 and 2.2 kg, respectively. Thus the weight reduction in these blocks during drying was 12.7, 12.4 and 8.83%, respectively. The physical characteristics of the blocks prepared from PJMPs were also evaluated. The volume of AB, BB, and CB blocks was 2300, 2500 and 1857 cu cm, and bulk density was 0.97, 1.02 and 1.16 gm/cu cm. These values are comparable with the standard formulation feed blocks. The chemical analysis of the StB and AB, BB, and CB blocks indicated that the moisture content in both the types of blocks was comparable, ash contain was high in StB than PJMP blocks, organic matter in PJMP but protein values were comparable in both the types of blocks. The ether extractives as well as total carbohydrates content was appreciably high in PJMP blocks, which was reflected in higher gross energy content in PJMP than the StB (Table 5) The data indicated that the PJMP can be used for production of multi-nutrient feed-blocks for supplementation of essential nutrients to desert livestock.

Chemical analysis of multi-nutrient-feed mixtures (MNM) produced from *P. juliflora* pod milling products (PJ-MP)

Similarly 3 formulations of multi-nutrient mixture (MNM) using 3-different types of *P. juliflora* pod milling products (PJ-MP) viz., A, B and C have been tried. The composition of standard nutrient mixture (St-MNM) and those prepared from A, B and C (MNM-A, MNM-B and MNM-C) milling products are as follow. The St-MNM was prepared by mixing molasses, aqueous urea solution, common salt, dolomite, vitamin mineral mixture, wheat bran and guar meal. It contained 33.3% wheat bran (WB), whereas, in the MNM-A, MNM-B and MNM-C mixtures, wheat bran was replace by a mixture of wheat bran and one of the PJ-MPs. The MNM-A, mixture contained 21.7% WB and 25.10% A, MNM-B had 20.4% WB 25.5% B and MNM-C contained, 24.3% each WB and C. The chemical analysis of the final products (MNM-A, MNM-B and MNM-C) revealed that the moisture contain in all the samples were comparable, but ash content in St-MNM was appreciable higher than that of PJ-MP mixtures. The ether extractives content of and PJ-MP mixtures were comparable but total carbohydrate and gross energy content of PJMP mixtures were high, the protein content of MNM-B and MNM-C was also appreciably higher than that of MNM-A and St-MNM mixtures (Table 6). The data indicated that PJMPs can be used for production of multi-nutrient feed mixture. The mixtures produced from PJMPs are not only nutritionally superior, but cheaper over the standard formulation MNM.

Chemical composition of supplemental- (SFB) and complete-fodder (CFB) block produced from *P. juliflora* pod milling products (PJ-MP)

Attempts have also be made to develop aformulations and technology for production of supplement-feed and complete-fodder blocks using hydraulic fodder block making machine have been standardized. The chemical composition of wheat bran (WB), which is used a major feed-ingredient for production of standard formulation feed-block, and 2-types of *Prosopis juliflora* pods (A) milling products obtained by hammer milling of sun-dried whole pods and then passing through coarse (AC) and fine sieves (AF) were analyzed for proximate components with the objective to explore possibility of using these products for production of supplement- and complete-blocks. The data revealed that the wheat bran, whole pods and its AC and AF milling products, on fresh weight basis contained 7.5, 4.2, 5.4 and 6.3% preformed water, and on dry weight basis, contained 11.3, 6.7, 6.8 and 7.6% ash; 89.6, 93.3, 93.2 and 92.4% organic matter, 14.3, 14.0, 13.5 and 13.9% crude protein; 4.2, 4.9, 2.1 and 2.4% ether extractives, 70.3, 74.5, 77.7 and 76.1% total carbohydrates, and 411, 434, 418 and 417 kcal% gross energy, respectively. The data indicated that with respect to nutrient contents, AC and AF milling products are comparable with the wheat bran and thus these products can be used for production of supplement- and complete-blocks.

Attempts have been made to develop appropriate formulations of supplement- and complete feed blocks using *P. juliflora* milling products. The supplement-block comprised of 4.9% molasses, 2.0% urea, 1.5% each of vitamin-mineral mixture, common salt and dolomite, 8.2% guar meal, 73.5% AF milling product and 4.9% tumba seed cake, which on fresh weight basis contained, 8.0% preformed water, and on dry matter basis contained, 92.3% organic matter, 9.9% ash, 2.0% ether extractives, 20.3% crude protein, 67.9% total carbohydrates and 415 kcal% gross energy, was found to be superior over other formulation supplement blocks. Similarly, the complete fodder block comprised of 90% *P. juliflora* pods milling product (AF) and 10% molasses, which on fresh weight basis contained 7.5% preformed water and on dry matter basis contained 91.7% organic matter, 8.5% ash, 1.6% ether extractives, 11.7% crude protein, 78.6% total carbohydrates and 406 kcal% gross energy, was found to be better than other formulation fodder blocks.

Data pertains to chemical analysis of guar seed meal (which is used as a protein source in the MNB, MNM and fodder block) and *P. juliflora* seed meal has been presented in Table 7. It revealed that the former and later on dry matter basis contained 4.95 and 2.77% minerals, 12.1 and 8.35% ether extractives, 52.6% and 44.0% crude protein, 30.4 and 44.9% total carbohydrates, and 537 and 513 kcal%, gross energy, respectively (Table 7). Most of the nutrient content of wheat bran, *P. juliflora* epicarp and its fibrous miso-carp fraction (>8 mash) were also comparable, expect the crude protein content of the wheat bran, and carbohydrate content of the *P. juliflora* miso-carp fraction were appreciably high. Therefore, in feed block, nutrient-mixture and fodder block formulations, the guar meal can be replaced by the *P. juliflora* seed meal, and the wheat bran can be replaced by epi-carp or high fibrous meso-carp fraction of *P.juliflora* pods.

V. Composition of coffee beans, branded coffee and coffee-powder prepared from meso-carp fraction of *P. juliflora* pods

Samples of roasted coffee beans (CB), branded coffee (BC) and the processed *P. juliflora* meso-carp (PC), used for production of coffee-like drink were also analyzed (Table 10). The total mineral content of various samples did not varied but crude protein content was appreciably high in CB and BC samples, than the PC samples, however, carbohydrate content in PC samples was appreciably higher than that of CB or BC samples.

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Table 1. Chemical Composition (% on dry matter basis) of *Prosopis juliflora* pods and its milling products

Code No.	Fraction	Moisture*	Dry matter	Organic matter	Minerals	Ether extrac-tives	Crude protein	Total CHO	Gross energy, kcal
PJ-69	Ripened pods	6.39	93.61	95.85	4.15	12.10	12.79	70.96	480
PJ-72	Epi-carp	2.39	97.61	95.60	4.40	9.05	14.22	72.33	466
PJ-03	Meso-carp	5.37	94.63	96.25	3.75	9.75	9.20	77.30	464
PJ-16	MC >8 mesh	18.55	81.45	96.05	3.95	3.95	7.15	84.95	430
PJ-17	MC 8-10 mesh	12.69	87.31	96.15	3.85	3.55	7.29	85.31	429
PJ-18	MC 10 -16 mesh	9.18	90.82	95.75	4.25	4.05	8.04	83.66	431
PJ-19	MC 16 -30 mesh	8.52	91.48	94.90	5.10	5.35	8.79	80.76	435
PJ-20	MC 30 -72 mesh	8.32	91.68	92.35	7.65	6.60	9.84	75.91	433
PJ-21	MC <72	7.86	92.14	91.90	8.10	6.65	10.37	74.88	432
PJ-25	Endo-carp with seeds	3.90	96.10	96.45	3.55	6.64	25.33	64.48	473
PJ-26	Endo-carp sugary part	3.37	96.63	91.75	8.25	7.72	11.90	72.13	439
PJ-37	Husk/hull, acid treated	3.20	96.80	96.75	3.25	5.1	9.27	82.38	442
PJ-24	Seeds	3.29	96.71	86.80	13.20	6.84	32.0	47.96	444
PJ-58	Seed meal	6.46	93.54	97.22	2.77	8.35	43.97	44.91	513

*on as such basis.

Table 2. Chemical Composition (% on dry matter basis) of *Prosopis pallida* pods and its milling products

Code No.	Fraction	Moisture*	Dry matter	Organic matter	Minerals	Ether extrac-tives	Crude protein	Total CHO	Gross energy, kcal
PP-53	Pods un-ripened	48.47	51.53	95.50	4.50	6.55	12.40	76.55	449
PP-54	Pods Ripened	9.17	90.83	96.15	3.85	5.40	10.96	79.79	444
PP-41	Meso-carp >16 mesh	3.28	96.72	96.95	3.05	4.30	6.58	86.07	435
PP-40	Meso-carp 16-30 mesh	3.24	96.76	96.85	3.15	4.70	6.49	85.66	436
PP-39	Meso-carp 30-72 mesh	3.33	96.67	96.80	3.20	5.10	6.71	84.99	439
PP-04	Meso-carp <72 mesh	4.69	95.31	95.00	5.00	4.30	10.46	80.24	433

*on as such basis.

Table 3. Comparison of chemical constituents (% on dry matter basis) of various milling products of *Prosopis juliflora* (PJ) and *P. pallida* (PP) pods

Fraction	Code No.	Moisture*	Dry matter	Organic matter	Minerals	Ether extrac-tives	Crude protein	Total CHO	Gross energy, kcal
Pods Ripened	PJ-69	6.39	93.61	95.85	4.15	12.10	12.79	70.96	
	PP-54	9.17	90.83	96.15	3.85	5.40	10.96	79.79	444
Meso-carp >16 mesh	PJ-18	9.18	90.82	95.75	4.25	4.05	8.04	83.66	431
	PP-41	3.28	96.72	96.95	3.05	4.30	6.58	86.07	435
Meso-carp 16-30 mesh	PJ-19	8.52	91.48	94.90	5.10	5.35	8.79	80.76	435
	PP-40	3.24	96.76	96.85	3.15	4.70	6.49	85.66	436
Meso-carp 30-72 mesh	PJ-20	8.32	91.68	92.35	7.65	6.60	9.84	75.91	433
	PP-39	3.33	96.67	96.80	3.20	5.10	6.71	84.99	439
Meso-carp <72 mesh	PJ-21	7.86	92.14	91.90	8.10	6.65	10.37	74.88	432
	PP-04	4.69	95.31	95.00	5.00	4.30	10.46	80.24	433

*on as such basis.

Table. 4. Chemical composition (% on dry matter basis) of milling products of *Prosopis juliflora* pods

S. No.	Milling product	Moisture*	Ash	Organic matter	Crude protein	Ether extractives	Total Carbohydrates	Gross energy, kcal
1.	A	6.92	4.7	95.3	7.37	3.52	84.41	425
2.	B	7.08	4.2	95.8	10.70	4.24	80.86	436
3.	C	8.10	6.03	94.0	12.76	9.16	72.05	467

*As such basis.

Table. 5. Composition (%), chemical constitution (% on dry matter basis) and physical characteristics of Multi-nutrient feed blocks (MNB) prepared from *Prosopis juliflora* pod milling products

S. No.	Ingredient	Standard formulation	A	B	C
I. Composition					
1.	Molasses	44.5	34.90	35.4	33.7
2.	Urea	4.30	3.3	3.4	3.2
3.	Water	4.0	3.0	3.0	3.0
4.	Common salt	4.30	3.3	3.4	3.2
5.	Dolomite	4.30	3.3	3.4	3.2
6.	Vitamin Min mixture	4.30	3.3	3.4	3.2
7.	Wheat bran	32.10	21.7	20.4	24.3
8.	Milling product	-	25.10 (A)	25.5 (B)	24.3 (C)
9.	Guar meal	5.10	4.0	4.1	3.9
10.	Guar gum dust	1.0	1.0	1.0	1.0
II. Chemical Constitution					
1.	Moisture*	2.7	3.0	2.7	4.0
2.	Ash	21.7	17.4	17.2	15.9
3.	Organic matter	78.3	82.6	82.8	84.1
4.	Crude protein	22.9	20.7	22.2	20.9
5.	Ether extractives	4.1	7.0	6.04	6.0
6.	Total Carbohydrates	51.3	54.8	54.6	57.2
7.	Gross energy, kcal	381	411	409	412
III. Physical Characteristics					
1.	Fresh weight, kg		2.40	2.40	3.40
2.	Final weight, kg		2.22	2.10	3.23
3.	Loss on drying,%		12.7	12.4	5.0
4.	Volume, Cu cm		2457	2071	2792
5.	Bulk density, g/cu cm		0.9	1.02	1.16

*As such basis.

Table. 6. Composition (%), chemical constitution (% on dry matter basis and physical characteristics of Multi-nutrient mixture (MNM) prepared from *Prosopis juliflora* pod milling products

S. No.	Ingredient	Standard formulation	MNM-A	MNM-B	MNM-C
I. Composition					
1.	Molasses	46.14	38.90	37.0	34.90
2.	Urea	1.06	1.06	1.06	1.06
3.	Water	0.89	1.00	1.00	1.00
4.	Common salt	4.44	3.40	3.6	3.4
5.	Dolomite	4.44	3.40	3.6	3.4
6.	Vitamin Min mixture	4.44	3.40	3.6	3.4
7.	Wheat bran	33.27	22.40	20.80	25.2
8.	Milling product		25.70 (A)	26.70 (B)	25.2 (C)
9.	Guar meal	5.32	4.1	4.3	4.0
II. Chemical Constitution					
1.	Moisture*	3.1	3.1	3.2	3.6
2.	Ash	21.3	18.3	17.3	16.4
3.	Organic matter	78.7	81.7	82.7	83.6
4.	Crude protein	11.6	9.45	13.2	13.8
5.	Ether extractives	4.2	3.7	3.5	4.0
6.	Total Carbohydrates	62.9	68.6	65.9	65.8
7.	Gross energy, kcal	365	372	381	389

*As such basis.

Table 7. Composition (% on dry matter basis) of Guar meal vs *P. Juliflora* seed meal and wheat bran *vs* epi-carp and the meso-carp fraction of *Prosopis juliflora* pods

Code No.	Fraction	Moisture*	Dry matter	Organic matter	Minerals	Ether extrac-tives	Crude protein	Total CHO	Gross energy, kcal
PJ-32	Guar meal-	**6.18**	93.82	95.05	4.95	12.1	52.55	30.40	537
PJ-58	PJ- Seed meal	6.46	93.54	97.22	2.77	8.35	43.97	44.91	513
PJ-29	Wheat bran	6.28	93.72	96.00	4.00	8.25	14.12	73.63	463
PJ-03	PJ epi - carp	5.37	94.63	96.25	3.75	9.75	9.20	77.30	464
PJ-16	PJ-Meso-carp (>8 M)	18.55	81.45	96.05	3.95	3.95	7.15	84.95	430

*on as such basis

Table 8. Chemical composition (% on dry matter basis) of wheat-bran, whole *Prosopis juliflora* pods and its milling products (AC & AF)

S. No.	Feed ingredient	Preformed water*	Ash	Organic matter	Crude protein	Ether extrac-tives	Total Carbo - hydrates	Gross energy, kcal
1.	Wheat-bran	7.5	11.3	89.6	14.3	4.2	70.3	411
2.	*Prosopis juliflora* pods	4.2	6.7	93.3	14.0	4.9	74.5	434
3.	Milling product AC	5.4	6.8	93.2	13.5	2.1	77.7	418
4.	Milling product AF	6.3	7.6	92.4	13.9	2.4	76.1	417

*As such basis.

Table 9. Chemical composition (% on dry matter basis) of supplement-and complete-feed block comprised of *P. juliflora* pod milling products (AF)

S. No.	Milling product	Preformed water*	Ash	Organic matter	Crude protein	Ether extrac-tives	Total Carbo - hydrates	Gross energy, kcal
1.	Supplement block	8.1	9.9	92.4	22.3	2.0	67.9	415
2.	Complete feed block	7.5	8.5	91.7	11.7	1.6	78.3	406

*As such basis.

Table 10. Chemical composition (% on dry matter basis) of coffee beans, branded-coffee and processed meso-carp* of *Prosopis juliflora* pods

Code No.	Fraction	Moisture*	Dry matter	Organic matter	Minerals	Ether extractives	Crude protein	Total CHO	Gross energy, kcal
PJ-01	Coffee beans, Roasted	4.54	95.46	93.85	6.15	4.45	16.98	72.42	438
PJ-23	Nescafe classic	2.34	97.66	92.40	7.60	3.52	21.53	67.35	434
PJ-02	Meso-carp (MC) roasted	2.72	97.28	93.75	6.25	8.15	10.15	75.45	447
PJ-10	MC+ coffee essence	2.42	97.58	89.90	10.10	3.90	10.74	75.26	410
PJ-11	MC+ coffee essence	2.99	97.01	92.40	7.60	3.85	10.94	77.61	420
PJ-12	MC+ coffee essence	9.39	90.61	92.70	7.30	4.20	10.01	78.49	422
PJ-13	MC+ coffee essence	11.55	88.45	93.95	6.05	2.40	10.69	80.86	419
PJ-14	MC+ coffee essence	10.99	89.01	92.20	7.80	3.25	9.93	79.02	415
PJ-15	MC+ coffee essence	11.31	88.69	90.55	9.45	3.75	10.48	76.32	411
Mean	Mean of PJ-02 to PJ-15	**6.09 (2.42-11.55)**	**93.91**	**92.38**	**7.62**	**4.27**	**12.12**	**76.0**	**424**
PJ-22	Mesocarp dust + 30% chicory +coffee flavour	2.64	97.36	92.10	7.90	5.25	9.74	77.11	424

*on as such basis, **used for preparation of coffee like drink

Table 11. Seasonal variation in chemical constituents (% on dry matter basis) of *Prosopis juliflora* pods*

S. No.	Constituent	Winter	Summer	Monsoon	All Seasons mean
1.	Crude protein	12.32±0.10	12.84±0.30	13.96±0.26	13.04±0.48
2.	Ether extractives	3.61±0.09	2.22±0.13	2.57±0.09	2.80±0.42
3.	Crude fibre	25.41±0.50	24.79±0.73	34.10±0.37	28.10±3.01
4.	Nitrogen free extract	54.21±0.71	55.40±0.99	43.30±0.54	50.97±3.85
5.	Total sugars	16.20±0.32	16.18±0.35	14.53±0.32	15.64±0.39
6.	Ash	4.45±0.25	4.75±0.18	6.07±0.32	5.09±0.50
7.	Calcium	0.40±0.02	0.57±0.03	0.44±0.03	0.44±0.02
8.	Phosphorus	0.21±0.02	0.22±0.04	0.41±0.01	0.28±0.06
9.	Silica	0.16±0.01	0.26±0.04	1.30±0.23	0.57±0.36

*Adopted from Kanzaria and Varshney (1998).

Table 12. Essential Amino acid composition (% on dry matter basis) of *Prosopis juliflora* pod- and seed-protein, soybean- and whole egg-protein

S. No.	E. A. Acid	Pods*	Seed**	Soybean***	Whole Egg***
1.	Isoleucine	10.07	29.37	12.9	12.9
2.	Leucine	19.40		18.8	17.2
3.	Lysine	11.94	27.72	15.3	12.5
4.	Methionine+ Cystine	8.95	7.31	7.6	10.8
5.	Phenylalanine	12.31	12.41	12.0	11.4
6.	Threonine	10.44	5.65	9.6	9.9
7.	Tryptophan	-	traces	3.3	3.1
8.	Tyrosine	10.82	5.93	7.8	8.1
9.	Valine	16.04	11.58	12.7	14.1

Adopted from *Shukla *et al* (1986); Vimal and Tyagi (1986)**, and Pike and Brown (1970).

Fig.1. Schematic diagram of processing of *Prosopis juliflora* pods for production of various products for human food and livestock feed production

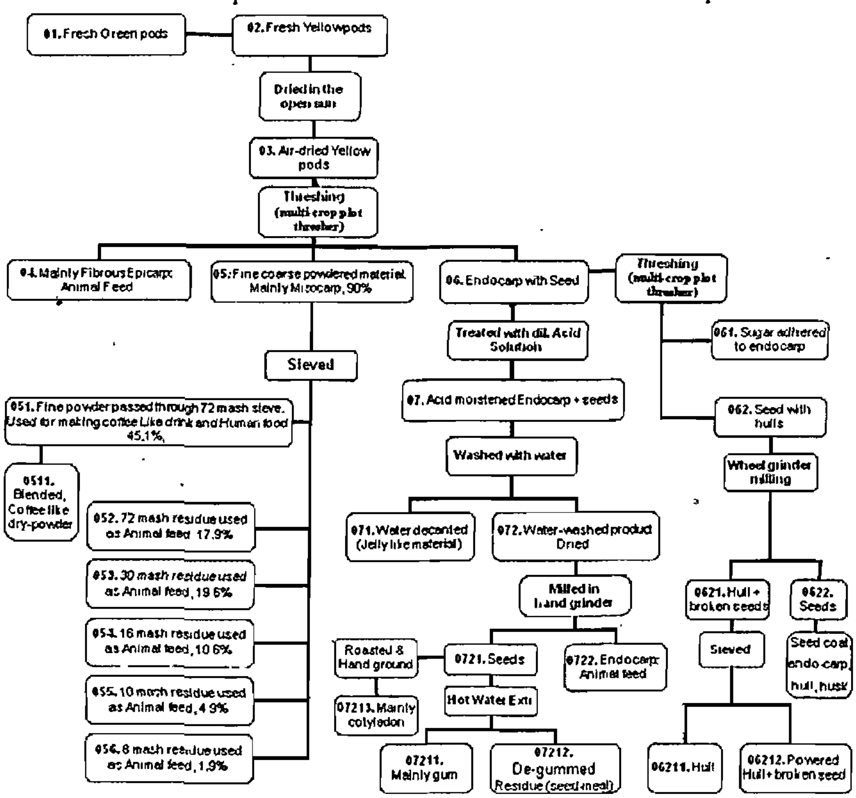


Photo. 1. Modified Multi-purpose plot-thresher; **2.** Hammer mill used for processing of *P. Juliflora* pods; **3.** *P. Juliflora* pods fractions obtained from Multi-purpose Plot

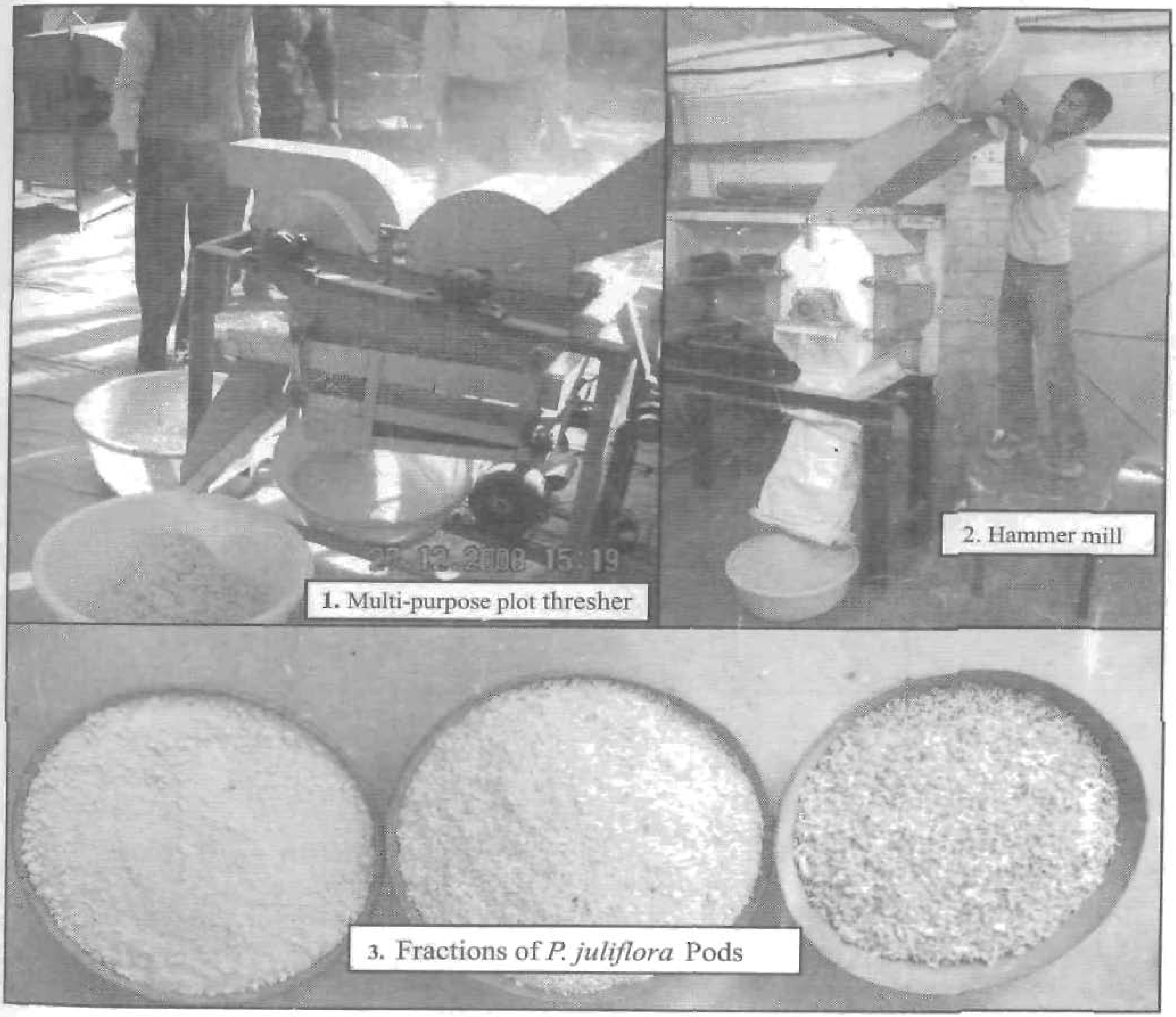
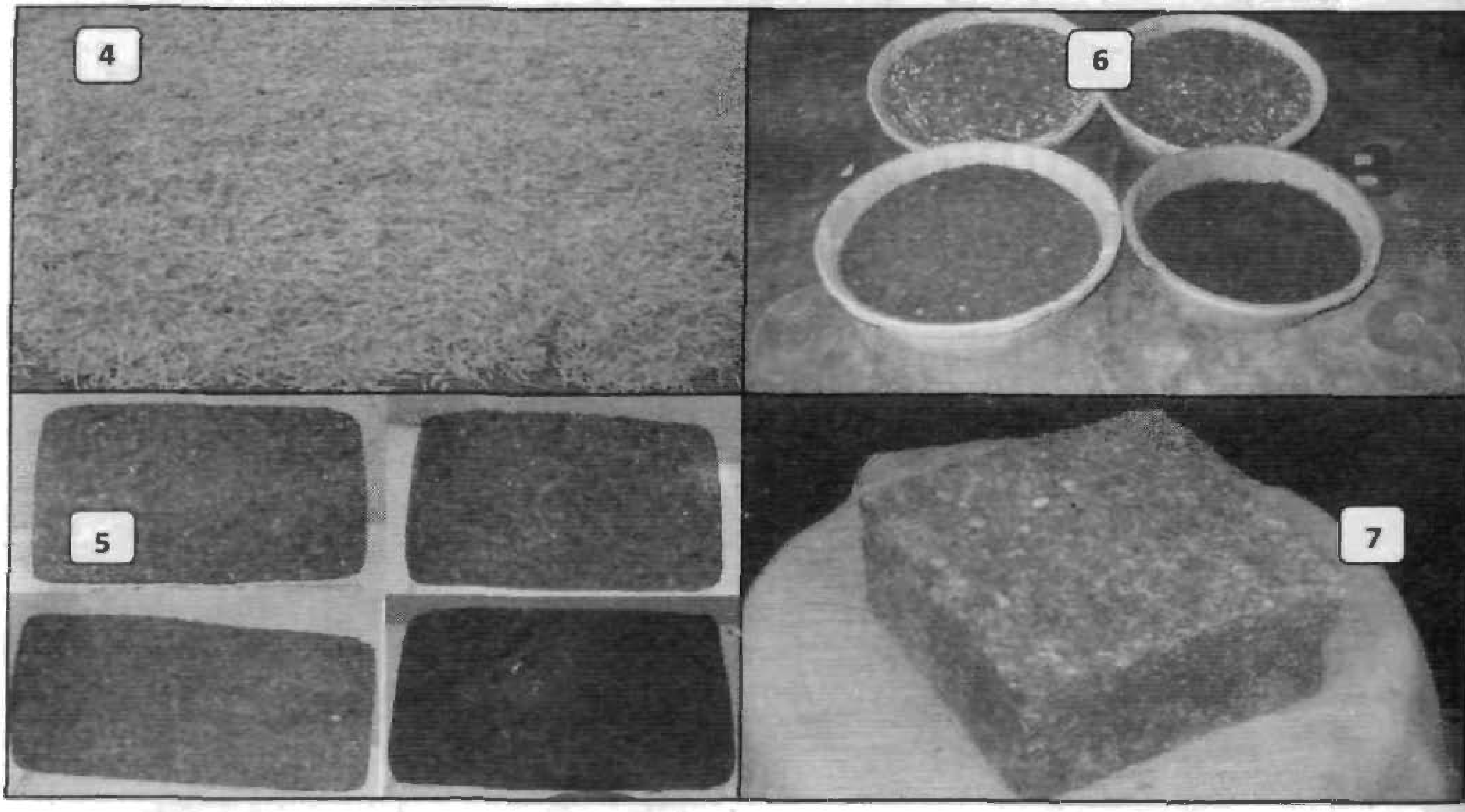


Photo. 4. *Prosopis juliflora* pods dried under sun; **5.** Multi-nutrient blocks prepared from various milling products of *P. juliflora* pods; **6.** Multi-nutrient mixture prepared from various milling products of *P. juliflora* pods; **7.** Fodder block prepared from *P. juliflora* pod milling products



Incorporation of *Prosopis juliflora* Pod Powder as Ingredient of Low Cost and Highly Nutritious Concentrate Mixture for Livestock feed

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Mesquite or Vilayati babool (*Prosopis juliflora*) trees are extensively grown in desert areas, especially to check the shifting of sand dunes. *Prosopis juliflora* provides highly palatable and nutritious pods in large quantities and the flowers produce good quality nectar for honey. Ripe pods which have fallen on the ground are widely consumed by domestic stock and wild ungulates. These are rich in protein and free sugar, which gives them a sweet taste. In Mexico, ripe pods of some Prosopis species are ground into coarse flour (Pinot) for human consumption and baked after removing the seeds and pods are also fermented and brewed into a weak beer, because of high carbohydrates and protein contents. The present study includes its palatability and its effect on dry matter intake (DMI), water intake, body weight changes, milk yield and blood constituents in goats, sheep and cattle. Chemical composition and cost of feed ingredients are given in Table 1.

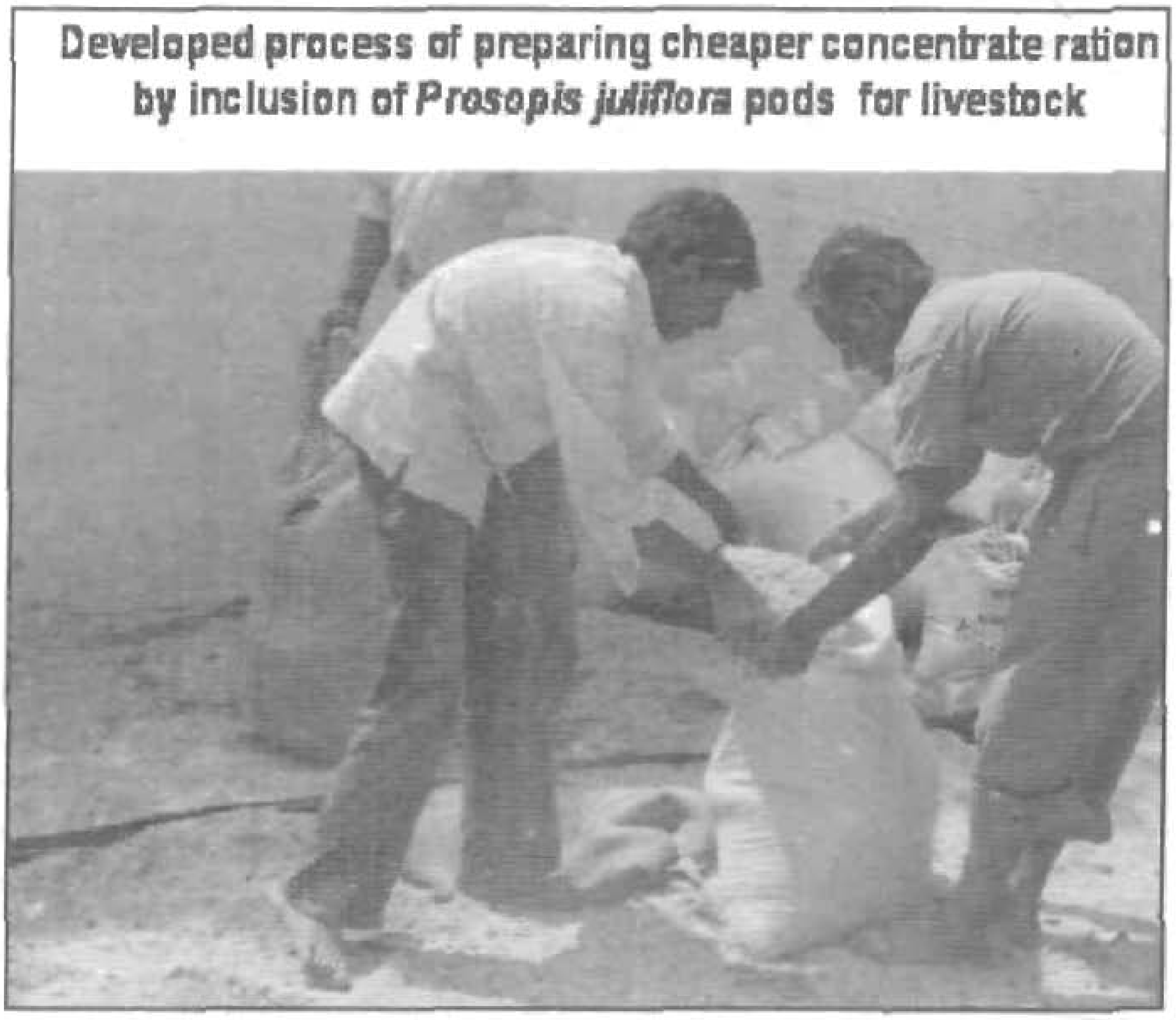
Goat

In this trial 10 Marwari goats were taken to study the acceptability and palatability of *Prosopis juliflora* pod powder (PJPP) during summer, for one month. These goats were divided into two equal groups of 5 each i.e. group I control and group II treatment. Animals of each group were offered weighed quantity of roughage 5.25 kg (3.750 kg masoor straw + 1.5 kg *Zyzyphus* spp. Leaves) and 1.25 kg concentrate on as such basis (consisting of 35% ground bajra, 40% Tumba seed cake and 25% groundnut cake). However, in treatment group 35% bajra in concentrate was replaced by PJPP making ration near about isonitrogenous and isochloric. Trial was carried out for 4 weeks. Milk yield was recorded daily during the trial to see the effect of PJPP on late lactation milk yield. Blood samples were taken during the period of pre and post experiment of goat for genetic characterization. The data were analysed statistically.

Table I. Chemical composition and cost of feed ingredients.

Feed ingredient	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	Approx cost /kg
Prosopis juliflora pod powder	7.92	3.0	19.63	61.56	7.87	62.0
Tumba (Citrullus colocynthis) seed cake	16.9	3.95	42.0	25.95	11.2	2.50
Masoor (*Lens esculenta)* straw	5.02	1.62	43.1	41.5	8.76	2.25
Bajra *(Pennisetum typhoides)* grain	9.4	5.5	1.7	78.9	3.5	5.25
Pala *(Zizyphus nummularia)*	14.20	4.30	15.70	57.10	8.60	2.50

*Ex-Principal Scientist



The effect of utilizing *Prosopis juliflora* pods powder at 35% level in concentrate mixture of late lactating goats on body weight, DMI, water intake, milk yield and certain blood constituents were studied on goats. Weekly body wt. data were recorded and body wt. gain or loss was assessed (Table 2). On an average, the animals of both groups of goats gained the body weight, however, the difference between both the groups were non significant.

Table 2. Average weekly live weight (kg), body weight gain DMI (kg) and water intake (L) /100 kg body weight/ day of Marwari goat.

Period (in weeks)	Control		Treatment		Control		Treatment	
	Average body wt. gain (kg)	% increase in body wt.	Average body wt. gain (kg)	% increase in body wt	DMI	Water intake	DMI	Water intake
0	30.82± 2.16	-	28.36± 2.29	-	2.93± 0.63	3.89± 0.21	3.26± 0.03	4.72± 0.29
1	30.92± 2.13	0.32	28.20± 2.44	-0.56	3.05± 0.02	6.09± 1.30	3.37± 0.018	6.99± 1.82
2	30.93± 1.73	0.33	29.40± 2.81	3.66	3.06± 0.03	5.95± 0.97	3.21± 0.024	6.70± 0.44
3	31.32± 1.12	1.62	29.24± 2.81	3.10	2.82± 0.02	5.74± 0.57	3.06± 0.03	5.26± 0.45
4	31.90± 1.83	3.50	29.48± 2.51	3.95				
Ave daily wt. gain	38.57		40.00					

Talpada and Shukla (1990) observed similar results in lactating cows, while Mathur *et al.*, 2004 also recorded non-significant difference in lactating goats. Periodical dry matter intake and water intake/100 kg body wt. per day of goat were presented (Table 3). The DMI and water intake in goat was high in treatment as compared to control group animals. However these differences were non significant. Similar results were observed by Talpada *et al.,* (1983) and Sukhla *et al.,* (1981) in lactating cows. The average milk yield did not show statistically significant differences between control and treatment group. Performance in terms of late lactating goats of treatment group compared to that of control was not affected by the presence of *Prosopis juliflora* pod powder in the concentrate supplementation.

The pre and post-experimental mean value ± SE of the blood parameters analyzed for goat (control and treatment group) are given in Table 4. The haemoglobin (Hb) values observed lower in pre-experiment in treatment group of goat than the post-experiment. The Hb value was observed high for goat in both groups than reported by Mathur *et al.,* (2000). However, the Hb value is in agreement with the values reported by Ghosal and Kataria (1995) for goats. Glucose and albumin were high at post-experiment. There was no significant difference in blood parameters between control and treatment group. Thus, it could be concluded that *Prosopis juliflora* pods could be used up to 35% in the concentrates of goats.

Table 3: Group wise per day milk yield (litre) of goats in late lactation (On weekly average basis)

Group	Week			
	1	2	3	4
Control	2.864±0.061	2.662±0.031	2.590±0.0325	2.202±0.0114
Treatment	2.934±0.057	2.58±0.092	2.405±0.0325	2.148±0.0158

Table 4: Mean ± SE values of different blood constituents of Marwari goat

Parameter	Whole blood	Plasma			
	Haemoglobin (g/dl)	Glucose (mg/dl)	Urea (mg/dl)	Total Protein (g/dl)	Albumin (g/dl)
Control group					
Pre experiment	9.00±0.84	29.73±2.96	45.18±2.44	7.61±0.96	2.79±0.83
Post experiment	9.88±0.51	26.25±2.45	32.26±1.55	8.74±0.81	4.92±0.65
Treatment group					
Pre experiment	9.00±0.61	32.94±3.93	50.51±2.55	8.02±0.84	3.33±1.17
Post experiment	10.12±0.73	27.28±2.78	36.56±1.75	8.57±0.72	4.73±0.69

Sheep

Eight ewes of Marwari breed maintained on grazing of similar age group and of comparable body weight were used in the experiment. The experimental animals were dewormed with albendazole before starting the feeding trial. The experimental animals were divided into 2 groups of 4 in each group, 4 animals were maintained on grazing termed as control and this group was sent out for four hours grazing on Cenchrus dominated pasture (Table 5), whereas remaining 4 were stall fed forming the treatment group.

Table 5. Grass/shrub/tree species and content of nutrients in the grazing area available to control group.

Species	Common name	CP	EE	CF	NFE	Total ash
Cenchrus ciliaris	Dhaman	4.90	1.20	31.30	53.81	8.79
Zizyphus nummularia	Bordi	14.20	4.30	15.70	57.10	8.60
Prosopis cineraria	Khejri	15.29	4.52	17.52	54.09	5.11
Tecomella unduleta flowers	Rohida	11.90	9.70	10.50	59.30	8.60
Corchorus spp	Cham kash	7.76	2.38	32.13	4.04	-
Prosopis juliflora pods	Vilayati babool	11.35	4.10	18.30	60.20	6.10
Acacia tortilis	Israili babool	12.3	1.80	22.40	57.90	5.60

The treatment group animals was offered concentrate mixture @ 250 g animal^{-1} day^{-1} comprised of PJPH and Tumba seed cake (TSC) in 1:1 ratio. Vitamin-mineral mixture @ 2% was added to the concentrate mixture. Treatment group was offered weighed quantity of lentil (*Lens esculenta)* straw *ad libitum* as roughage and left over was collected next day morning to estimate the daily feed intake of individual animals. Measured quantity of water was offered *ad libitum* to experimental animals and next day morning, water left out in the bucket was recorded. Feeding trial was conducted for a period of 30 days. Body weights of the animals of both groups are recorded at weekly interval. The chemical composition and cost of experimental feed ingredients are given in Table 6. The haematological studies of the cellular constituent viz., haemoglobin content (Hb) and the biochemical constituents of blood, viz., blood glucose, blood urea, total serum proteins, serum albumin and serum globulin were estimated before feeding and watering in the morning, at the beginning of the experiment and thereafter at the end of feeding trial. Blood was collected by jugular vein puncture and various constituents were analysed during pre experimental period and at the end of feeding trial to judge the effect of experimental ration on the physiological condition and the health of the animals.

Table 6. Chemical composition and cost of feed ingredients.

Feed ingredient	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	Approx cost /kg
Prosopis juliflora pod husk	7.92	3.0	19.63	61.56	7.87	62.0
Tumba (*Citrullus colocynthis*) seed cake	16.9	3.95	42.0	25.95	11.2	2.50
Lentil (*Lens esculenta*) straw	5.02	1.62	43.1	41.5	8.76	2.25

Effect of feeding *Prosopis juliflora* pod husk at 50%t level in concentrate mixture on live weight gain in sheep was worked out. (Table 7).

Table 7. Comparative body weight changes in sheep maintained on grazing v/s stall fed supplemented with *Prosopis juliflora* pod husk and Tumba seed cake concentrate.

Day	Control group		Treatment group	
	Body weight (kg)	% increase in body weight	Body weight (kg)	% increase in body weight
0	25.30±1.80	-	25.50±1.50	-
7	25.62±1.68	1.26	26.30±1.75	3.13
14	25.55±1.71	0.98	27.70±1.75	8.62
21	25.80±1.53	1.97	27.25±1.76	6.86
28	26.30±1.77	4.43	27.40±1.52	7.45
Average daily wt. gain (g)	43.48		67.90	

The average initial live weights of control and treatment groups were 25.30±1.80 and 25.50±1.50 kg, while the final weight of animals was 26.30±1.77 and 27.30±1.77 and 27.40±1.52 kg, respectively. Live weight gain was significantly higher (67.90 g) in the animals of treatment group than the control group (43.48 g). Average daily feed and water intakes /100 kg body weight (b.w.)/day in sheep of control group have been presented in Table 8.

Table 8. Feed and water intake in sheep maintained on grazing v/s stall fed alone andsupplemented with *Prosopis juliflora* pods husk and Tumba seed cake concentrate ration.

Weekly mean	Daily dry matter intake	Daily water intake	
	kg/100 kg b.w./day of treatment group	Lit./100 kg b.w./day of control group	Lit./100 kg b.w./day of treatment group
I	3.25±0.12	12.59±0.84	13.00±0.79
II	3.05±0.07	9.79±1.81	10.43±1.72
III	3.14±0.06	10.84±2.22	11.66±1.58
IV	3.15±0.03	11.01±1.20	11.61±0.68
Average	3.15±0.07	11.05±1.48	11.67±1.29

The DMI/day of treatment group on an average were 3.15±0.07 kg/100 kg live weight. However, Ranga Rao and Reddy (1983) added upto 40% of *Prosopis juliflora* pods in concentrate ration and obtained lower daily weight gain in Nellore lambs than reported in the present study. The water intake in sheep of both the group was more or less equal during experimental period, and there were 11.05±1.48 and 11.67±1.29 litre/100 kg body weight/ day of control and treatment group, respectively. However, these values were considerably high during first week of experiment. It may be attributed to relatively high ambient temperature during first week of the study conducted in arid zone. Concentration of different blood metabolized is presented in Table 9. The effect of treatment on Hb was statistically non significant. Blood glucose level in both the group ewes was on lower side but was within normal range. The results are in agreement with observations of Talpada and shukla (1988) feeding 30% *Prosopis juliflora* pods to lactating cows and Mathur (1996) feeding Tumba (*Citrullus colocynthis*) seed cake to sheep. All the blood parameters were in normal range as reported by Ghosal and Kataria (1995).

Table 9. Blood metabolites in sheep maintained on grazing v/s stall fed supplemented with *Prosopis juliflora* pods husk and Tumba seed cake concentrate

Parameter		Whole blood haemoglobin (g dl^{-1})	Plasma				
			Glucose (mg dl^{-1})	Urea (mg dl^{-1})	Total protein(g dl^{-1})	Albumin (g dl^{-1})	Globulin (g dl^{-1})
Control	Initial	9.52±0.64	31.92±2.05	41.80±1.11	8.39±0.71	3.61±0.55	4.789±0.16
	Final	9.98±0.25	34.45±2.87	31.42±0.77	8.45±0.22	5.76±0.56	2.69±0.36
Treatment	Initial	9.20±0.89	32.33±1.35	49.51±1.15	8.50±0.60	2.52±0.75	4.98±0.15
	Final	10.35±0.16	36.25±3.59	25.14±0.82	8.49±0.13	5.56±0.06	2.93±0.07

The major nitrogenous biochemical constituents of blood were closely associated with protein metaboloism viz.,. blood urea, total serum proteins, serum albumin and serum globulin estimated at zero days and last day of feeding trial. Blood urea was significantly ($P<0.05$) low in treatment group indicating early utilization of protein. Total serum protein level was statistically comparable in both groups, which is in agreement with Matras *et al.* (1992) feeding faba bean meal with grass hay to sheep. The albumin level increased significantly in the ewes of both groups at the end of the experiment, indicating better health of the animals.

Cattle

Prepared and evaluated cheaper concentrate mixture in lactating cattle with bare minimum processing and labour cost.

In India livestock keepers are feeding concentrate to their animals without engaging labour towards its preparation, which otherwise is practiced in developed countries having organized dairy farms. Since cost is involved with each step of feed preparation process and ultimately feed becomes highly costly, livestock owners in India do not follow it due to unaffordable labour cost involved and cost benefit ratio(B:C).

Keeping this in view, a simple technology was followed for the preparation of cheaper and balanced concentrate feed mixture utilizing ground feed ingredients available locally viz. *Prosopis juliflora* pods, Tumba *(Citrullus colocynthis)* seed cake, Guar *(Cyamopsis tetragonaloba)* Korma, Til *(Sesamum indicum)* seed cake, Wheat bran, Maize grain, common salt, mineral mixture, etc. as per requirement and mixing them properly with a spade and gunny bags were filled for storage. (Photograph 1). Farmers accept this process technology very easily and are possible at livestock owner's doorstep (Mathur *et al.*, 2009)

Photograph 1

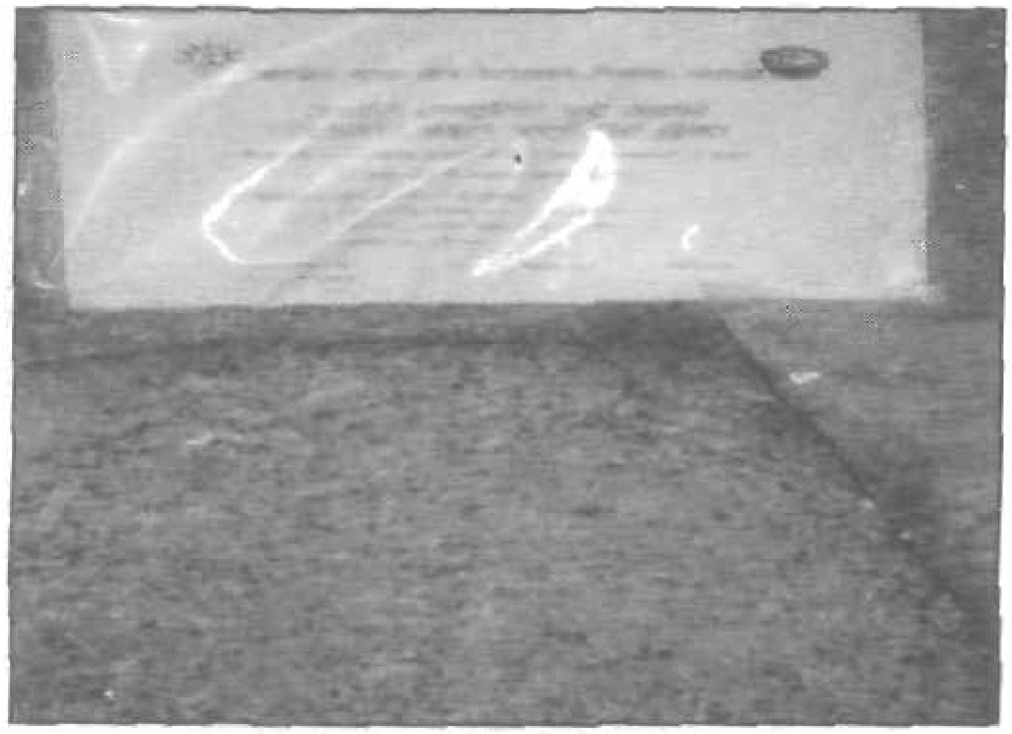


Photo 2: Feed block

To understand palatability, acceptability, digestibility and effect on production by feeding of *Prosopis juliflora* pods containing cheaper concentrate mixture, an experimental feeding trial was initiated on Tharparkar cattle, at Research cum Demonstration Unit, KVK, CAZRI, Jodhpur (Photo 2).

Twelve (12) lactating Tharparkar cattle were randomly divided into three groups of 4 each forming (T1); (T2) and (T3) groups. T1 group cattle were maintained on standard palleted concentrate feeding during morning and evening as per requirement with six (6) hours grazing on *Cenchrus ciliaris* dominated pasture and water ad libitum. T2 and T3 groups cattle were fed as per requirement with cheaper balanced concentrate mixture having 20% crude protein and 73% Total Digestible Nutrient (TDN), however, in T3 group concentrate mixture was partially replaced by ground *Prosopis juliflora* pods. The pods were grinded by using modified multipurpose plot thresher. Concentrate mixtures of T2 and T3 groups were isonitrogenous and isocaloric. These lactating animals were provided with concentrate as per their maintenance and production requirement (Photo 3).

Photo 3:

All the experimental animals were weighed in morning before feeding on day zero and thereafter at fortnightly interval, in addition to daily examination for health by veterinarian.

The initial live body weights (kg) of T1, T2 and T3 group were 330.6±15.318, 384.75±29.505, 352.75±16.452 and final were 315.58±10.96, 369.26±14.11, 344.0± 30.51, respectively Table 10 and 10 A. Most of the animals in all the three groups had parturition between November 2009 to March 2010; however, they maintained their live body weights and their body weights are comparable among the groups during the given period of time.

Table-10 and 10 (A). Monthly Body weight changes in experimental lactating Tharparkar cattle fed on Concentrate Mixture Containing *Prosopis juliflora* Pods

Table 10

Cattle Group		May	June	July	Aug	Sep	Oct
T-1	AV	330.6	320.4	330.9	310.71	302.98	323.43
	SE	15.32	15.05	18.60	24.63	21.65	18.24
T-2	AV	384.75	367.25	381	367.96	360.63	398.20
	SE	29.51	26.75	26.74	21.24	19.81	21.97
T-3	AV	351.00	347.06	369.25	369.85	360.45	385.67
	SE	13.77	15.36	16.12	13.54	11.77	10.63

Table-10 (A)

Cattle groups		Months				
		Nov	Dec	Jan	Feb	March
T -1	AV	319.43	324.67	345.86	317.51	315.58
	SE	19.58	23.70	26.99	20.56	10.96
T -2	AV	392.20	368.33	370.72	366.17	369.26
	SE	25.36	14.24	13.59	11.70	14.11
T-3	AV	370.67	378.33	398.63	382.8	344
	SE	13.67	20.32	11.97	18.19	30.51

The major observation recorded were monthly body weights, daily concentrate feed intake, blood parameters-haematological and biochemical, daily milk yield with quality analysis at weekly interval for fat and SNF and health check by veterinarian.

The fat and SNF% of milk of all the groups that is T1, T2 and T3 showed no significant difference in quality. The fat percentage in T1, T2 and T3 ranged from 3.13 ± 0.23 to 4.58±0.13; 3.4±0.01 to 5.8±0.97; 3.08±0.32 to 4.80±0.12, respectively. Whereas SNF% ranged from 7.96±0.15 to 9.76±0.19; 7.71±0.75 to 9.90±0.07; 7.93±0.15 to 9.73±0.14 in T1, T2 and T3 groups, respectively. They varied with the stages of production and season.

Blood Parameters

To study the effect of *Prosopis juliflora* feeding on the body function and health and diseases, quantitative estimation of blood parameters was done. During the feeding experiment, blood was collected at monthly intervals from all experimental animals in the morning before offering feed from the neck region by jugular vein puncture. Immediately blood was taken to laboratory for hematological i.e. haemoglobin (gm%) and then plasma was separated for biochemical parameters like glucose, total protein, albumin, blood urea nitrogen, cholesterol, creatinine, calcium and inorganic phosphorus. All this blood parameters were in normal range and showed non significant difference between T1, T2 and T3 groups. The result of the blood study showed that animals had normal body function with no change in blood chemistry and lactating Tharparkar cattle maintained normal health.

Production and Reproduction Status

Easily Processed, with minimum labour cost and energy utilization, a cheaper balanced concentrate animal feed mixture was prepared utilizing *Prosopis juliflora* pods powder (PJPP) to economize the cost of cattle production in arid region. Utilizing this cheaper concentrate mixture a long term feeding trial was conducted on lactating Tharparkar cattle. The milk yield of cattle fed on *Prosopis juliflora* pods containing concentrate mixture was significantly increased (Photo 4); however the calving interval of this group was also extended. The results showed that inclusion of *Prosopis juliflora* pods in concentrate mixture had no adverse effect on health reproduction and production.

Thus, cheaper concentrate ration reduces cost of milk production and showed comparable digestibility of these ration with fairly good nutritive value. Results revealed that this process technology of hand mixing feed ingredients involving minimum labour and energy inputs utilizing *Prosopis juliflora* pods is quite feasible at livestock owners' doorstep to economize cattle production

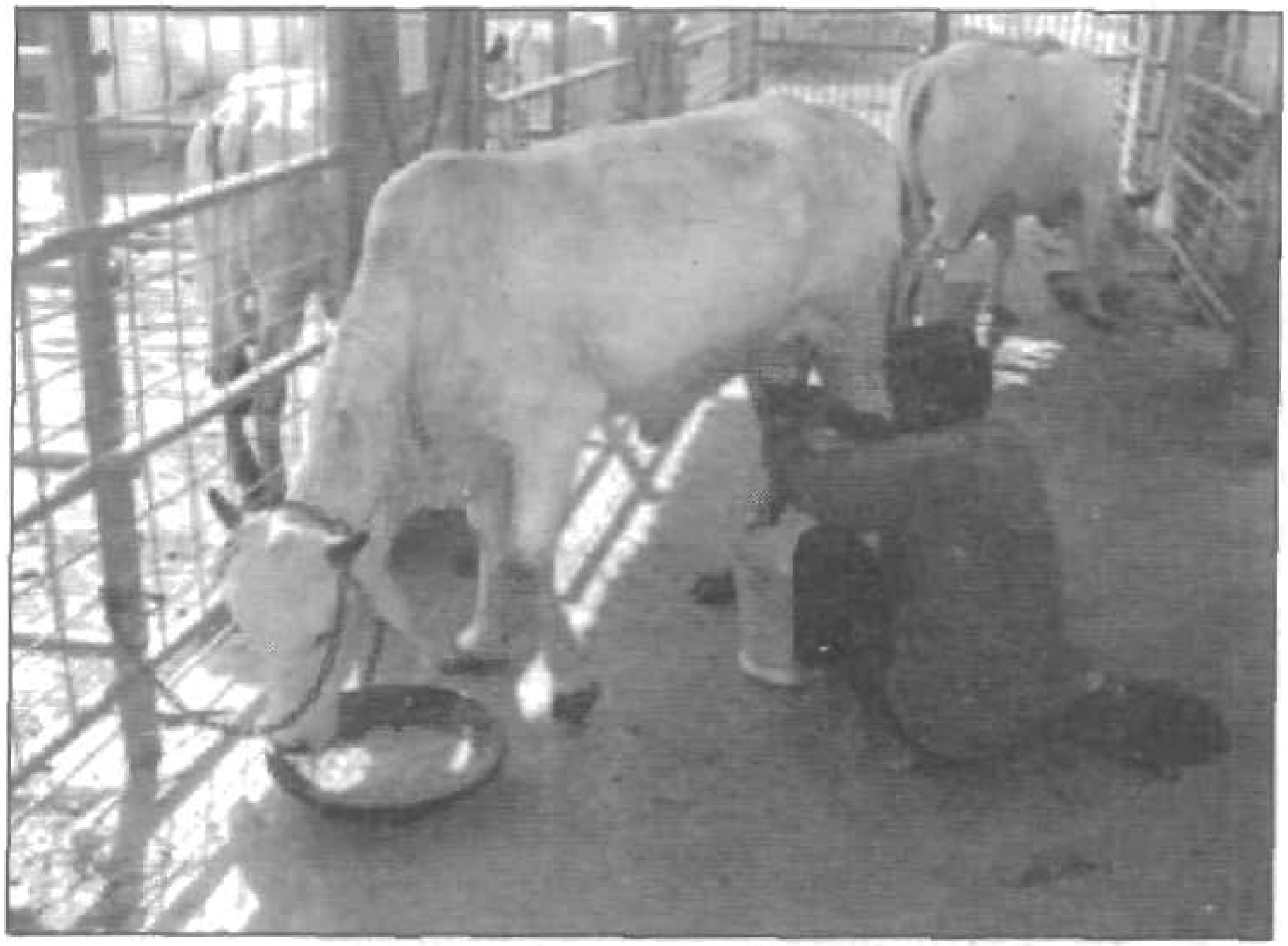


Photo 4: Measuring Milk of lactating Tharparkar cattle fed on concentrate Mixture Containing Prosopis juliflora Pods

Conclusion

Increased production [illegible] concentrate ration for arid region livestock:

Prosopis juliflora pods powder as energy source was effectively used along with another local resource for protein –Tumba (*Citrullus colocynthis*) seed cake for the formulation of low cost ration of the livestock in arid region. Feeding trials showed good animal health and increase in production.

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Prosopis juliflora: A Women Friendly Tree

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Introduction

Prosopis juliflora is a multi purpose tree spp. that serves several needs of farming community specially women. Feeding the family two square meals is a gigantic task for women as not only the food bowl should be full with grain but sufficient energy should also be available under the pot for cooking food. *Prosopis juliflora* provides both the alternatives for food and fuel wood. It is probably the most sought after species for fuel wood purposes due to its fast growing nature and tremendous coppicing capability.

Women as house makers has developed and nurtured knowledge to process *Prosopis juliflora* for various purposes from food to fuel wood. Women while collecting fuel wood from common property leave sufficient branches in place to keep the plant viable for future use. They also remove weeds near to plant so that natural habitat is enhanced for natural regeneration of new plants. Women also cultivate the roots with digging tools encouraging the faster growth of fuel wood and fodder. This system is sustaining since introduction of this magic tree into arid zones. Across the globe today food and fuel wood resources are declining rapidly. Population growth, market expansion and environmental degradation are increasing the time and labour invested by women in fuel wood collection and food preparation activities. The reduction in food resources is leading to poor diets and nutritional health of population and considerably increasing the reliance of poor people to market purchase or undergo cyclic food scarcity. The knowledge of women thus to nurture *Prosopis juliflora* and likewise plants for food, feed, fodder and fuel wood assumes greater importance.

Wood of *Prosopis juliflora* is a very important source of domestic fuel for millions of people in arid and semi-arid zone of India. It is a preferred fuel wood for many households, but the presence of thorns is a problem for cutting and processing. However it is the biggest source of energy under the rural pot. The wood does not spit, spark or smoke excessively and the smoke is never extremely unpleasant. Its popularity as fuel wood is related to its easy and ubiquitous availability. The tree is available in large number at common lands making it possible for poor women to collect it fearlessly. In rural setting women and children while collecting fuel wood often come in conflict with private/government land owners, *Prosopis juliflora* growing on common property serves a regular fuel wood resource and helps saving the modesty of women and children.

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It is not only rural societies that depend on this tree but recently a wide interest has been shown by the industrial sector to process this tree into animal feed. *Prosopis juliflora* provides fodder, fuel, medicine and multitude of materials for energy production.

A. *Prosopis juliflora* as Fuel Wood Resource

A survey on 150 farm women was conducted for collecting information on fuel energy use pattern in arid village 'Sar'. It is located on the Basni- Salawas Road at a distance of 29 km from Jodhpur city. The sample was selected through random sampling method comprising 150 house holds of the total population of the village 'Sar'. The data was collected through pre tested interview schedule, which was prepared after consultation with progressive farmers.

The results of the study revealed that maximum respondents had 5-8% members (medium family size) in their families (54.7%) followed by small size family i.e. 1-4 members per family (37.3%). Only 6-7% respondents had large family size i.e. 9-12 members per family and 1-3% had very large families i.e. 13-16 members per family. The caste wise representation in the sample was 61.3% for general caste, 21.3% scheduled caste and 17.4% for other backward classes. Maximum percentage of families i.e. 56% had land holding little less than 12 acres, followed by landless (31%). All families had one or the other type of domestic animals like cattle, sheep herd or goat. Women spend up to 2 hours in the morning as well as in evening on cooking related activities. Most of the families' burn 4-6 kg fuel wood in morning and evening. Women contribute 5-20 hours per week in collection of fuel wood, where maximum percentage of families spends 10-15 hrs per week, amounting to two man -days per week. About 14.7% families collect fuel wood up to 25 kg., 41.3% families around 25-50 kg and 29.3% families around 50-75 kg per week.

Besides fuel wood, cow dung is also burnt as fuel for which 28.7% women spend one hour, 9.3% women spend 2 hrs and 6.2% women spend 3 hrs per day for cow dung cake preparation. Other than fuel wood and cow dung, crop residue, kerosene and LPG are also used as fuel in some families. As far as fuel wood is concerned *Prosopis juliflora, Azadirachta indica, Salvadora* spp., *Prosopis cineraria, Capparis decidua, Accacia Senegal,* etc., wood are burnt in arid zone of Rajasthan. Women prioritized *Prosopis juliflora* for burning followed by *Prosopis cineraria, Azadirachta indica* and *Salvadora* spp. (Table 1).

Table 1. Fuel wood species used for burning (ranking as given by respondents)

Fuel wood species	Ranking				
	I	II	III	IV	V
Prosopis juliflora	84* (56.0)**	41 (27.3)	5 (3.3)	-	-
Azadirachta indica	9 (6.0)	5 (2.3)	2.2 (14.66)	-	-
Salvadora spp	4 (2.66)	8 (5.33)	23 (15.33)	-	-
Prosopis cineraria	42 (28.0)	54 (36.0)	6 (4.0)	6 (4.0)	-
Capparis deciduas	2 (1.33)	9 (6.0)	31 (20.66)	4 (2.66)	-
Acacia senegal	-	-	3 (2.0)	6 (4.0)	4 (2.66)
Calotropis	-	2 (1.33)	-	-	5 (3.3)

*Absolute values against each species are frequencies
**Values in parentheses indicate percentages.

The wood of *Prosopis juliflora* is found easily and collected abundantly by the women. This was followed by *Prosopis cineraria, Salvadora* spp, *Azadirachta indica* and *Capparis deciduas* (Table 2).

Table 2. Fuel wood species used by rural women (preference ranking)

Fuel wood species	Ranking	
	I	II
Prosopis juliflora	83* (55.33)**	12 (18.07)**
Azadirachta indica	3 (2.0)	2 (1.3)
Salvadora spp	6 (4.0)	3 (2.0)
Prosopis cineraria	52 (34.66)	26 (17.33)
Capparis deciduas	2 (1.33)	2 (1.33)

*Absolute values against each species are frequencies
**Values in parentheses indicate percentages

In the villages of hot arid zone of India two major sectors comprise fuelwood supply system: private collection from farmers' own agricultural fields, and collection from extra territorial areas which do not come under any landuse category of the village.

Both sectors do not have any formal organisation in terms of rural forestry management. The supply system of fuelwood is neither documented and monitored nor regulated in any part of the Indian hot arid zone. The woody vegetation composition and fuel- wood production in the private collection system (farmers' agricultural fields) is based on information gathered through questionnaires and field checks (Table 3). Not a single household purchased fuelwood from any source, though each household was primarily dependent on fuelwood for cooking human and animal food, and for heating.

Table 3. Woody vegetation and fuelwood production by lopping and partial cutting of trees in village 'Sar'.*

Species	Density (trees/ ha)	Fuelwood production (kg/ tree/ yr)	Fuelwood production (kg/ ha/ yr)	Calorific value (k. cal./ kg)
Prosopis cineraria(L) Druce	3.62	48.0	173.76	4560
Capparis decidua(Forsk.) Edgew	2.81	2.0	5.62	4650
Ziziphus nummularia (Burmt.)Wt.&Arn.	1.02	1.0	1.02	4800
Acacia Senegal Wild	0.30	9.0	2.70	4600
Tecomella undulata (Sm.)Seeman	0.19	16.0	3.04	3350
Salvadora oleoides Dence	0.12	17.0	2.04	4232
Azadirachta indica A.Juss	0.11	32.0	3.52	6000
Total	8.17	-	191.70	-

* Values are average across the farmers field and village common land i.e., private collection. Besides above mentioned species, *Prosopis juliflora* (Swatrz) DC wood is collected in very large quantity as fuel in the form of extra - territorial collection. A headload of collected dry wood of the species, on an average weigh 26.5 kg (calorific value = 4800 k cal/kg).

At the end of cropping season (November - December), villagers cut side branches and twigs (lopping) of available tree species on their agricultural field for fuelwood use and also for fencing. Our assessment revealed that on average 8.17 trees per ha are available on agricultural fields + village common land (grazing), of which 44.3% were trees of *Prosopis cineraria*, 34.4% bushes of *Capparis decidua* and 12.4% bushes of *Zizyphus nummularia.* The remaining 8.8% trees belong to other species.

During the annual lopping cycle of woody species, the maximum dry fuelwood, on an average per tree, was recorded for *P. cineraria,* followed by *Azadirachta indica* and *Tecomella undulata.* The minimum dry fuelwood per plant was available from bushes of *Z. nummularia.* These findings of dry fuelwood production from different woody species of hot arid zone of India through annual fuelwood lopping regime were in conformity with earlier findings, especially, in respect of per tree fuelwood production (Shankarnarayan 1984; Tewari *et al.,* 1989; Tewari *et al.,* 1999). As it was virtually impossible to quantify *P. juliflora* thickets through the field estimations and further more, participants also did not responded satisfactorily regarding the quantity of the wood of the species exploited for fuel purpose, therefore, fuelwood availability from *P. juliflora* thickets was quantified by repeated weighing the head loads carried by rural women folk as and when possible.

On the basis of available tree densities of different woody species, and fuelwood production estimates from the resources available on farmers' field and village common land (grazing), per hactare private dry fuelwood collection per year is 191.70 kg (Table 3). On an average per household level it was 1.16 t per year and for whole village it was 414.45 t/ year. The extra-territorial fuelwood collection was of much higher magnitude than that of private collection, because private collection is done during a particular period and stored for the use during other times, especially during winter. Extra-territorial fuelwood collection is as per requirement of household and without any systematic procedures which farmers follow for private collection.

B. *Prosopis juliflora* Pods as Food Resource

The idea held in rural societies that pods of *Prosopis juliflora* are harmful for human being is highly debated in arid zones. The pods are a reliable source of feed in countries like Brazil, Peru and Argentina. Literature published in 1943 (Algaroba: Estudios, Utilidades, aplicacao, 1960) on the uses of the *Prosopis juliflora* fruit, a leguminous tree, record its use as food for human consumption. In Argentina, several by products there of were consumed, the species most commonly used being *Prosopis nigra, Prosopis alba* and *Prosopis panta,* by people living in semi-arid areas (Table 4) at CAZRI under NAIP project Preclinical toxicological study has been initiated in non- pregnant, non-lactating mice in association with NIN.

Conclusion

Prosopis juliflora is providing a sustainable ecological balance that future generations will inherit as green cover. This tree is helping to reduce withdrawals of present generations on the stock of environmental capital of next generations. Future generations will be obligatory to present generations for tapping on indigenous source of feed, fodder and fuel wood. The world's poor will have enough to collect from common property that may fill the plate and energy below the pot. Rich people may hesitate to consume this food resource thus leaving it entirely for poor to be secure in food. Women will be collectively benefitted with option of *Prosopis juliflora* rather than individual search of food, feed and fuel wood. The tree of *Prosopis juliflora* thus stands for support of women on humanity ground.

Table 4. Food products from *Prosopis* used in different parts of the world

S.NO	PRODUCT	USAGE	PLACE OF USE	REFERENCE
1.	*Yupisin*	Obtained by water extraction of the sugars from the pod. Used to prepare desserts with sweet potato flour.	Rural zones of Northern Peru	Cruz 1986, Ochoa, 1996
2.	***Anapa- aloja/ chicha***	Fermented beverages as substitute of wine or beer.	Argentina	Cruz 1986, Ochoa, 1996
3.	***P.pallida – wheat composite flour***	Causes dough resistance to decrease & dough elasticity to increase resulting in softer leavened bread.	Peru	Cruz 1986
4.	***Sweet bread with 5% pallida flour***	Acceptable in texture and taste	Peru	Cruz 1999
5.	***Biscuits with 25% P.pallida flour***	Reduced the requirement of sugar to be added	Peru	Cruz 1999
6.	***Patay***	Flour from sugary pulp of several P species, used in bread, biscuits & cakes.	N. Argentina	Ochoa, 1996
7.	***Algarrobina***	As medicine, as a sweetener and natural flavouring in juices and milk.	Peru	Nora Grados and Gaston Cruz, 1996
8.	***Cocktail de Algarrobina***	Algorrobina + brandy + milk	Peru	Cruz 1999
9.	***Pinole***	Pod as sweet flour	Mexico	Galindo, 1983
10	***Quesco/ Piloncillo***	Dried candy	Mexico	Galindo, 1983
11.	***Atole***	Beverage boiled in water/ milk with corn meal	Mexico	Galindo, 1983
12.	***Alcoholic drink***	Drink	Mexico	Galindo, 1983
13.	***Garrofina***	Instant soluble powder made by fine grinding of whole fruit.	Peru	Nora Grados & Gaston Cruz, 1996
14.	***Café de algarroba***	Coffee substitutes from *P.pallida* pods which are caffeine free	Peru	Cruz 1999

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Products of Economic Importance from *Prosopis juliflora*

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Introduction

Prosopis juliflora (Wartz) DC, locally known as Vilayati babool, first introduced in 1877, has been well naturalized and spread over a large part of arid and semi-arid tropics of India and is thought to inhabit more than a million ha land. Prosopis plays an important role in the arid regions as it helps to retain and stabilize sand dunes, develop ground-carpet vegetation, stabilize water tables, retain moisture, fix nitrogen and improve soils.

In Mexico and Southern USA, each part of the plant is used as a source for human and animal food, wood and charcoal, building material, medicine, nectar for apiculture, and several other uses.

In India, *P. juliflora* is presently used as fuel wood or at some places for making charcoal. The utilization of *P. juliflora* as an alternative source of food gains increasing importance, envisaging it for replacing a number of traditional food items, such as coffee, bread and others. A variety of edible products may be prepared from different components of the pods. The pods are composed of mesocarp (56%), endocarp (35%) and seed (9%). Seed is further comprised of episperm (20%), cotyledon (48%) and endosperm (32%). Seed endosperm is the source of gum with functional properties that are similar to those of guar gum, thus could be used as an alternative gum for industrial applications. The wood is a potential source of an antioxidant which has economic potential. In this article, isolation and properties of gum, antioxidant compound and protein are discussed.

Prosopis Seed Gum

Prosopis seed gums are neutral water-soluble polysaccharides, chemically classified as a Galactomannan. They have a molecular mass of the order of 10 6 and consist of a linear β-(1-4)-D-mannopyranose backbone with branch points from their 6-positions linked to α-D - galactopyranose unit. The *Prosopis* seed gum has close similarity to guar and carob polysaccharides. They differ from each other in mannose: galactose ratio and fine structure regarding distribution of single galactose branches on the main chain, causing variations in solubility, rheology and other properties. Chemical analyses of *Prosopis* endosperm show that it is a galactomannan polysaccharide. The

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individual constituents of *Prosopis* seed polysaccharide is shown in Table 1. The main components, galactose and mannose, are present in a 1:1.36 ratio. This ratio is near that of guar gum (1:1.2) but is smaller than the ratio in carob gum (1:1.9).

Table 1. Composition of *Prosopis* Endosperm Polysaccharide

Component	g/100 g of dry matter
Rhamnose	0.00
Fructose	0.25
Arabinose	1.56
Xylose	0.19
Mannose	46.28
Galactose	33.97
Glucose	0.93

Extraction of Gum

Prosopis juliflora Seeds were mechanically separated and ground to a coarse particle- sized flour in an electric mill. Ground seeds were submitted to lipid extraction with toluene: ethyl alcohol (2:1) mixture in a Soxhlet, for 24 h. Defatted ground seeds were dispersed in water (1:20) and boiled for 10 min for enzyme inactivation. The system was cooled and allowed to rest for 24 h at room temperature. The crude mixture, containing pieces of hull, germ and the galactomannan solution, was filtered and centrifuged at 6500 rpm. The clarified supernatant was retained and mixed with ethyl alcohol (1.5 parts of alcohol for 1 part of supernatant) to obtain a mucilaginous precipitate. It was filtered, dried at 40°C and milled to produce powdered gum. The yield was 21%.

Properties and Uses

Galactomannan gums are capable of absorbing a great quantity of water that increases its volume several times to form a highly viscous solution. The Viscosity of 1% gum solutions is about 3000 mPa. The solution is stable over a range of pH. These gums are excellent stabilizing and thickening and gelifying agents and the absence of toxicity allow their use in many food systems like ice cream, sauces, cheese, yoghurt, sausages, and bakery products.

Gums are regarded as soluble fibre and have also been used as fat replacers in various low-calorie products. They act like a sponge and absorb water in the intestine, mix the food into gel and thereby, slow down the rate of digestion and absorption: Gums have been used to reduce blood cholesterol and to promote fermentation in the large bowel. The latter yields short-chain fatty acids, mainly acetate, propionate and butyrate, which have beneficial effects on the colon through stimulation of blood flow and enhancement of electrolyte and fluid absorption and muscular activity.

These seed gums play an important part in the facilitating slow absorption of glucose, hence may be used for control of diabetes. It reduces the rate of glucose absorption by slowing gastric emptying and nutrient absorption, thereby leading to a decrease in blood sugar spikes following a meal. Slowed gastric emptying causes a feeling of fullness and suppresses appetite, which can help reducing weight loss.

Economic Potential

There would be several benefits to accrue from the use of *Prosopis* for seed gum production. It would give an additional source of cash income from the same crop. Yields of *Prosopis* pods vary from 4-10 tonnes ha^{-1} y^{-1} equivalent to a yield of 0.4 to 1 tonne ha^{-1} of seeds or 40 to 300 kg ha^{-1} of gum (endosperm).

Antioxidant Compound

Beneficial effect of antioxidants/free-radical scavengers as antimutagenic, antiinflammatory, antiatherosclerotic, antidiabetic, antihepatotoxic, antiageing and in a variety of neurological disorders, are known. The search for new antioxidant principles is becoming therefore, essential to improve the pharmacological treatment of pathological conditions related either due to free radical/oxidative damage or due to imbalance between antioxidant/oxidant homeostasis such as cataract, rheumatic diseases, atherosclerosis, Alzheimer's disease and other neurodegenerative conditions. The pharmacological approaches therefore have focused the search for potential resources rich in antioxidant principles. The medicinal importance of plants bearing rich proportion of antioxidant principles is therefore becoming hot item.

Extraction and Isolation

Prosopis juliflora heartwood and sapwood were separated and collected. Air dried wood materials were ground to fine powder and dried at 60°C before extraction. Powdered wood materials were extracted with organic solvent using soxhlet extractor for 25 hours. After extraction, the solvent was evaporated under reduced pressure and the crude extract dried under vacuum. The heartwood and sapwood yielded 6-8% and 1-2% (-)-mesquitol, respectively.

Identification of the Antioxidant Compound

The antioxidant compound which is present in concentrated form (6-8%) in the heart wood of *P. juliflora*, has been identified as (-)-mesquitol ($C_{15}H_{14}O_6$). It has flavonol structure assigned as 2, 3-trans-3', 4', 7, 8-tetrahydroxyflavan-3-ol and has close similarity to (+) - Catechin and (-)-Epicatechin (Fig 1). It is brown to pale yellow in colour having melting point 81-83°C. Its silica gel TLC has Rf value of 0.45 with ethyl acetate.

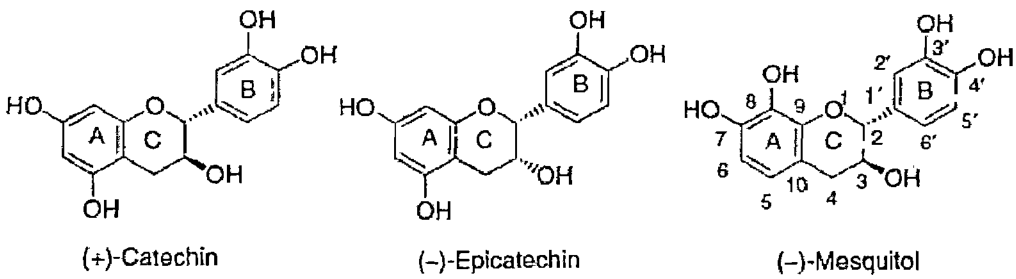

Fig.1. Structure of the different flavanols.

Antioxidant/free radical Scavenging activity of (-)-Mesquitol

(-)-Mesquitol has been compared with existing pharmacologically/ therapeutically accepted antioxidant probucol and α-tocopherol. It is found that (-)-mesquitol is better than the above mentioned reference drugs . In another experiment oxidation of methyl linoleate induced by AIBN, was carried out. Oxidation inhibition of (-)-Mesquitol was compared with (+)-catechin and BHT. (-)-Mesquitol performed better antioxidation properties than (+)-catechin and BHT .

Other source of (-)-mesquitol is the bark of Dichrostachys cinerea but the yield is only 1.5%. The unusual high yield and high purity of the crude extract of *P. juliflora* could therefore be of valuable interest as a potential source of this flavonol, which have been described as powerful antioxidants. It may be used with pharmaceutically/ therapeutically acceptable additives. It is proved to be useful and better antioxidant molecule than the presently used medicinally important lipophilic antioxidants probucol and .alpha.-tocopherol. It may have better therapeutic potential in inflammatory disease conditions, atherosclerosis, diabetic complications, cancer, hepatotoxicity and variety of disease conditions mediated through or fostered by oxidative stress and/or overt oxidative burden due to increased generation or under scavenging of free radicals.

Protein

Protein content in different fractions of *P. juliflora* seeds: Husk, cotyledon, gum portion of *P. juliflora* seeds were manually separated and analyzed for total protein, dry matter and moisture content and compared with those of guar seeds (Table 2). Protein content is better in juliflora seeds than in guar. The portion cotyledon of *P. juliflora* seed is the richest source of protein (63.81-71%) among all fractions followed by guar korma containing (49-52.31%).

Table 2. Protein content in different fraction of seeds

Fraction	Moisture content (%)	Dry mater content (%)	Crude protein content (%)
Whole seed(*P. Juliflor a*)	7.81	92.19	34.63
Whole seed defatted (*P. Juliflora*)	7.84	92.16	32.97
Husk(*P. Juliflora*)	8.05	91.95	25.32
Cotyledon(*P. Juliflora*)	6.37	93.63	6381
Whole seed residues after extraction with water (*P. Juliflora*)	8.36	91.64	49.72
Whole seed(Guar)	7.5	92.5	30.03
Korma (Guar)	7.09	92.91	52.31
Whole seed residues after extraction with water (Guar)	7.82	92.18	37.05

Optimum conditions for protein extractability was established by considering solid: solvent ratio, Extraction time, type of solvent, pH. Protein extractability of *p. juliflora* seeds is greatly affected by above conditions. Extractable protein increased from 19.8 to 26.4 mg/ml when solid to solvent ratio increased from 1:20 to 1:50. solid to solvent ratio in the range 1:50 to 1:100 did not give significantly different extractable protein. Maximum extractable protein was obtained at 3 h time. After 3 h there is decreasing trend in protein content. Isoelectric pint was observed at pH 5.5. Extractability is maximum (43.2 mg/ml) at pH 2.5 which decreases to 14.5 mg/ml at pH 5.5. Protein extractability in aqueous solvent is affected when the solution contains sodium chloride or sodium sulfate. Protein extractability is higher in aqueous sodium sulfate solution and it was maximum when the molar concentration of the salt was 0.1M.

Conclusion

Apart from traditional uses, *Prosopis juliflora* may also be exploited for seed gum, protein concentrate and antioxidant compound having pharmaceutical potential. These products may be proved as additional source of income.

Prosopis juliflora as Biomass Fuel for Green Power Generation

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Introduction

India has reached a point in its process of development where the focus has shifted back to building the basic infrastructure. This time however it is in close partnership with private investors as private industry in the country has reached a maturity level to undertake infrastructure projects both in terms of capital and expertise. The government on its part has in place statutory framework and an incentive mix that has made infrastructure development a low risk and high return investment opportunity. This has set the stage to support India's billion population as it embarks on an unprecedented growth. By 2030 India will sustain a population of 1.5 billion people on an infrastructure that will almost entirely be built between now and the next two decades.

Electrical power sector like any other infrastructure sector plays a critical role in a nation's development. It is difficult to imagine any real growth on "a unit a day" of electricity which is the current reality. Real improvement in Human Development Index – A holistic approach to evaluate human development will require nothing less than 5000 units of annual per capita electricity consumption by year 2030 - A clear 15 fold increase in electricity consumption between now and 2030. United States, one of the nations high on human development index, consumes 13,250 units of electricity per capita per year. India's current per capita consumption figure of 450 units speaks of the tasks ahead.

Conventional Thinking

At present more than half of the electricity that we consume comes from burning coal. The current focus is on setting up of Mega and Ultra Mega Thermal Power Plants feeding on imported and locally available coal. The chances that this solution can meet the envisaged demand are remote. The coal situation in one word is "Bad" and future is not promising either. Recently India became net importers of foreign coal. And very soon several super mega thermal power plants will start firing imported coal to make the situation even worse.

Oil is less said the better. India will need oil to drive its cars and also fuel World's largest diesel driven captive power generation capacity. Flattening production of fossil fuel and a huge and growing import bill will limit ability to provide energy to billions of tomorrows' India.

Energy is a important one because of the two reasons given below:

Reason 1- Energy Security

Reason 2- Global Warming

Energy Security

As a nation grows it must secure its energy sources to sustain development. This security is in terms of availability of the fuel at the right price and fluctuations at a predictable and reasonable velocity. Events in the last two decades have shown struggle of a major energy consumer to secure its energy needs and the recent economic recession triggered by unreal prices and its source from the politically most volatile regions of the world require Indian planners to look at alternatives.

Global Warming

Fossil fuel such as coal and oil are storehouses of carbon millions of years ago. Post renaissance industrial growth has forced us to burn them for our energy need and release the carbon that is no longer part of the present eco-system. This additional carbon is causing global warming and climate change and is threatening human existence. Various studies have tried to identify the components of human of global warming.

Electric Power is clearly the single largest source of Green House Gases. Its contribution is expected to increase over the years as more and more processes and systems including vehicles look towards electricity for fuel. It is clear that for India to grow, alternative sources of power must be explored and focus should shift towards greener fuel.

India already has a leadership position in the world in alternative sources. Already Ministry of Power and Ministry of New and Renewable Energy along with agencies such as IREDA, PFC, etc. have taken leadership position in developing policies for large scale exploitation of the new and renewable sources of energy and for facilitating power generation from them.

Alternative Solutions

The alternative to fossil fuel is the new and renewable sources such as wind, solar, biomass, small hydro, cogeneration and waste to energy. Wind Energy in India has been a success story. India has accumulated enough technological acumen to completely secure same time, it may also be noted that Wind is a non-dispatchable source and it also cannot be completely controlled. Too much of unpredictable wind energy can compromise the grid security. Besides, most of the wind sites with high wind density in India have already been used and further development of wind based power generation will have to be in relatively inferior wind sites.

Another important alternative is large solar thermal power plants. This is again a non-dispatchable source like wind. Grid security concerns will limit the overall% of energy from this important source that can be injected into the grid. Besides, solar based power plants require very high initial capital (4 to 5 times than that required for other renewable sources). Biomass, unlike wind or solar, is a firm and dispatchable source of renewable power. It is Renewable and Green because the biomass it consumes as fuel is regenerated periodically. More importantly the carbon that is released by its burning is absorbed by the plants as they grow again. Overall ecological balance is maintained as only the green house gasses that they accumulate during their life is released when they burn.

Biomass as an Alternative

Biomass can be exploited for generation of electricity using the thermal cycle common in coal fired thermal power plants. A biomass project therefore requires essentially the same technology and project management skills that are used in thermal power plants. The key difference is in making available the primary fuel which is "Biomass". Being agriculture based commodity there are certain challenges in the supply chain that requires elaborate procurement process. The availability of biomass over the life of the power plant needs to be assessed keeping in mind the long-term projections of availability of biomass and other competing pressure on its use.

About the Company

Transtech Green Power Pvt. Ltd. is a Special Purpose Vehicle dedicated for the development of Renewable Energy projects. Transtech Green inherits strategic advantage and benefits available from the others companies of the Promoters. This company has ambitious plans of becoming a leading Green Power company in the country and the present power plant planned is among the many more green power plants to come. The company has set up a 12 mw biomass based Power plant at Sanchore, from where commercial production has already commenced.

Apart from the existing 12 MW biomass based power plant at Sanchore, there are various Renewable Energy projects in the pipeline which are at different stages of development.

Plant Details

- Name: Transtech Green Power Pvt. Ltd.
- Address: Patwar Area, Kachela Bagasari, Tehsil Sanchore, District Jalore, Rajasthan
- Date of Commissioning of Plant: 25 June 2010

- Date of Commissioning of Plant: 25 June 2010
- Electricity generation: Energy generation started, first bill generated in end of July 2010
- Power Plant Capacity: 12 MW
- Require of *P. juliflora* per year: 1,28,000 tons
- ***Prosopis juliflora* as Biomass Fuel**

The area around the Biomass Power Plant has abundance plantation of *Prosopis juliflora.* The history of *P. juliflora* plantation goes back long time when, in order to green the environment and stop the spread of desert, extensive plantation was done by the Rajasthan Government. Jodhpur Region was one of the district where this plantation has been extensively carried out on government land, private land, along-side the roads and area under the Forest Department.

As per records of CAZRI, a central government organization for research and development of arid plants and located at Jodhpur, *P. juliflora* is a very hardy plant and requires very less water to grow. It can grow very fast and is ready for harvest in 2 to 3 years time. A grown up plant once harvested grows back to its original size in the next 16 to 18 months. Hence a safe harvest cycle of every two years can be followed with the existing *P. juliflora* plantation.

This area has rich source of *P. juliflora* which is having a caloric value close to 3400 to 3600 kcal kg^{-1} and is the most suitable biomass fuel. There is an extensive reserve of *P. juliflora* plantation in the region of Jodhpur. *P. juliflora* is planted on all type of land. As a drive to green the desert extensive plantation has been carried out in the district of Jalore on various types of land. There is *P. juliflora* plantation on

- Forest land
- Village Panchayat land
- Government Revenue land.
- Road side plantation
- Private land

These plants are more than 20-25 years old and fresh wind pollination has spread the plantation everywhere.

Prosopis juliflora is planted extensively on the forest land. All forest land is situated within 5 km to 100 km of the vicinity of the power plant. As per physical survey done and data collected from the forest department, *P. juliflora* plantation is extensively done on the forest land as under (Table 1).

Table 1. *Prosopis juliflora* assessment on forest land

S No.	Panchayat Samiti	Forest Land	Total Area (Hectares)	Juliflora planted area (Hectares)	% Density Juliflora	Category
1	Sanchor	a) Bhavatara	1200	1200	95%	Very dense
		b) Galifakhar	492.42	492.42	90%	Reasonable dense
		c) Rankhar	6227	4000	50%	Sparse planting
2	Raniwara	Kuri Sariana	3236.50	2335	55%	Sparse planting
3	Bhinmal	a) Jujani	1779	1200	90%	Reasonable dense
		b) Hatimtai	979	550	90%	Reasonable dense
4	Jalore	Jalore	300	225	98%	Dense
5	Sayla	a) Poshana	92.72	97.72	98%	Dense
		b) Detakhurd	472.72	472.72	95%	Dense

In the above mentioned Table the per hectare harvest figures of different categories of *P. juliflora* plantation is as under:

Very Dense : 70 to 80 t ha^{-1}

Dense : 60 to 70 t ha^{-1}

Reasonably Dense : 50 to 60 t ha^{-1}

Sparse planting : 30 to 40 t ha^{-1}

The forest department as a greening initiative of the Rajasthan Government has specifically done these entire plantations. These are plantation ranging from 25 years to the last 5 year planning and are reasonably developed on respective land.

The total biomass requirement for a 12 MW plant is in the range of 1 Lac tons per annum. This assessment is based on the caloric value of 3000 kCal kg^{-1}, where as *P. juliflora* has excellent burning value estimated in the range of 3000 to 3600 kCal kg^{-1} which is as good as Indian coal. Also, it would definitely require less weight of *P. juliflora* compared to other biomass fuels, but on a conservative note, same weight has been considered for *P. juliflora* as for other biomass, for the sake of biomass assessment study.

Fuel Supply Linkage Model

Harvesting	Collection	Transportation	Processing	Storage
•Harvesting of existing plantation. •Approval received from Rajasthan government to harvest Juliflora on Forest Panchayati land. •Development of captive biomass plantation. Supervised, advised & maintained by experienced Agricultural team.	•Creation of regional collection centre or biomass depot.	•Primarily on tractor trolleys from the field to the Project sites providing employment to the local rural people.	•Biomass cut from tree sized and stacked for maximum quantity transportation. •Juliflora biomass, chipped from chippers, would be fed into travelling grate boiler	•Onsite storage: Plant side capacity to store for 5 to 6 months •Offsite storage: Regional collection centers to hold temporary storage for 4 to 5 days

Scheme for Planting *Prosopis juliflora* through Channel Partners

- We are planting *Prosopis Juliflora* on barren land by encouraging a concept of Channel Partners. Planting material to be raised and given to local partners for planting.
- Motivating and encouraging land owners and local people having land resources within a radius of 50 km and lying barren; to plant *P. juliflora* under buy back agreement with us.
- Agriculture team within the company who looks after this development and organizes farmer camps and presentations. Extension team to provide cultivation assistance. Objective is to do commercial plantation of *P. juliflora* (different from exiting plantation, which is planted without any commercial intention)
- Raising plantation material in house, which would be planted in pot holes dig through tractor run post hole driller.
- Adequate use of fertilizers on the treated area for reclaiming the area
- We would be providing the seeds and saplings to farmers as incentive

Advantages of Growing *Prosopis juliflora*

Developing Rural economy of the state: Among the various RE options, biomass can play a significant role in rural development and economy of the state. Investments in biomass based generation will lead to employment in rural economy as well as higher income levels for the farmer community who would be directly associated with the biomass generation in the long run. This is evident from the fact that biomass fuel cost have increased over the last one decade. Farmers don't farming round the year. Farmers have the opportunity to plow their field twice a year only and that too depending on seasonal conditions, water conditions and market conditions. They spend roughly 5-7 months in farming if they own good fertile land and even then there is no guarantee of return. Remainder of the year they have relatively free time. If they use a part of their land for *P. juliflora* plantation, they will have guaranteed income. The power plant has such a huge requirement of *P. juliflora* that the farmers can bring their harvest any time of the year and increase their income. They can grow the plant on any kind of land whether it be saline land or water draught land.

- After an initial growth time of 3 years, the plant will grow in larger volume and at a quicker pace every time it is harvested.
- Also, the bud of the plant can be used to make coffee, jams, honey, pickles and used for other misc. purposes. That can act as another source of income for the farmers.
- *P. juliflora* plantation is a risk free investment. The plant has a life of 50-60 years, it is immune to any kind of disease, animals don't use it as a fodder and it grows in larger volume every time it is harvested.

Conclusion

Green power is imperative for a sustainable way to meet the energy demands of the country. In the green power segment, bio-mass plants have a very vital role to play not only in generation of environmentally clean and sustainable power but also in regenerating the rural economy. *P. juliflora* seems to be a promising potential as a bio-mass fuel. We need to encourage energy plantations of *P. juliflora* on arid lands which ensures the sustainability of bio-mass based power plants and also regenerates rural economy. New forms of thornless *P. juliflora* plantation need to be propagated so that the handling of *P. juliflora* becomes easy. The government must play an active role in propagation of *P. juliflora* through policies, research and awareness generation of the benefits of this plant. Our partnership with NAIP project on *P. juliflora* of CAZRI, Jodhpur is true example of research intitution - industry collaboration with win-win situation for all the stake holders.

An Economic and Environmental Evaluation of *Prosopis juliflora:* A Major Bio-energy and Livelihood Source in India

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Introduction

India is emerging as one of the fastest growing countries in the world with a GDP growth exceeding 8% consistently for the past couple of years and this trend is expected to continue. Energy being the driver of this growth its availability is of the utmost importance to sustain this level of growth. The official projections show that the energy demand is expected to be more than three to four times the current level in another 25 years (Planning commission, 2005). About 75% of rural households still depend on fuel wood (in traditional stoves) for their cooking energy needs (Census, 2001 and NSSO, 2005) with only 3% having access to kerosene for cooking. For this level of energy demand, CO_2 emissions are expected to rise from the current level of 1 billion tonnes to 5.9 billion tonnes per year by 2031-2032 (Planning Commission, 2005). India has a large biomass resource base, which is currently being utilized inefficiently. In addition, there are large tracts of wastelands that can be used for growing of biomass. An area of about 107 million hectares has been estimated to be degraded with 64 million hectares categorized as wasteland, which includes degraded forests (Committee Report, 2005). Potential for additional generation of woody biomass in the country has been estimated at 255 MT. It is estimated that about 83% of total household energy consumption is derived from biomass with fuel wood having a dominating share fuel wood consumption, estimated at about 205 MT a year, is the dominant bioenergy source used in India, followed by cattle dung (107 MT $year^{-1}$) and agro-waste (57 MT year) in 2003–2004.

Among the woody biomass in India, *Prosopis julifora* is one of the most popular and widely adapted species with a productivity of 15-40 t ha^{-1} yr^{-1}. It is a major fuel wood species for rural households in India and other south east Asian countries (Jagadish, 2003). This species is highly adapted to the agro climatic conditions prevalent in South India as a result of which it grows profusely well in unmanaged community and wastelands in this region. *Prosopis juliflora* is considered as poor man's fuel wood, as it is the only fast growing leguminous fuel wood tree species well adapted to warm and dry tropical climates and capable of growing in wide range of soils including problematic sites like eroded lands, riverbeds, degraded lands and salt affected soils. It has a deep to very deep stout taproot, well-meshed laterally spreading root system. It acquires bushy nature in the early stages, which provides shade and litter over a relatively large area so that its effect on soil attributes particularly on soil surface is significant even in young plantation. *P. juliflora* is well distributed in several states in India (Fig. 1) (Gurumurthi *et al.,* 1984). It is widely used as fuel wood and maximum number of poor people is depending on this tree for their day-to-day life through selling this wood as fuel wood as well as by preparation of charcoal for industries. The energy conversion from woody biomass is an economically viable option in areas where woody biomass is freely available in abundance. These potential economic benefits and commercial and industrial scope has attracted the attention of policymaker's worldwide.

In view of high economic potential and environmental benefits of *P. juliflora,* a study was conducted wherein the objectives were (i) to survey the geographical spread and estimate the production of *P. juliflora,* (ii) to determine the social costs and benefits of *P. juliflora* use for charcoal production and electricity generation and (iii) to assess the CO_2 emission reduction potential of this method of power generation as compared to power generation through thermal generators and other conventional means.

Study Area and Methodology

One-year study was taken up in two Indian states. Andhra Pradesh and Gujarat were selected for the study in view of the predominance of *P. juliflora* in these states. The survey work study was conducted in two districts in each of these states, with large area under *P. juliflora,* and four villages in each district were selected at random. The *Prosopis juliflora* distribution and use was studied in Chittoor and Prakasam districts of Andhra Pradesh and Kutch-Bhuj district of Gujrat. A census of each of these villages was done by adopting transect walks to locate the occurrence, density and total biomass production of *P. juliflora* in different land use classes. The impact on the biomass use in power generation on CO_2 emission saved was studied and impact of *P. juliflora* on the income and employment generated for the communities were also studied.

Biomass from Land Use Categories and Annual Power Generation Potential

Field level surveys in the study area were conducted to calculate the biomass productions from different land use categories, besides information from published literatures were also reviewed. In this study it is assumed that the heating value (Energy content) of air-dry wood is 15 GJ t^{-1}. The efficiency of biomass fired Rankine cycle power plant is assumed to be 24%, so that 1 t of wood would generate one MWh of electricity. Similarly, considering an efficiency of 42% (Richard *et al.*, 1996) of biomass integrated gasification combined cycle (BIGCC), 1 t of wood would generate 1.75 MWh of electricity.

Results and Discussion

Biomass Generation and Charcoal Production

The estimates made by the Forest Development Corporation, Gujarat on the *Prosopis juliflora* area in three districts of Gujarat viz. Bhuj, Patan and Surendranagar was 1,70,972 ha in the year 2005 with a potential of 1,52,600 t of charcoal production and employment generation of 18.55 lakh man days per rotation (Table-1). The primary use of *P. juliflora* is the firewood for the local people followed by charcoal production from the wood. As presented in Table 2, it has been estimated that annually about 87 t/ha/yr of dry biomass of *Prosopis* can be harvested from different land use categories in study area of Gujarat which possess 1309.5 GJ energy equivalents per year.

In Gujarat, the government forest department had undertaken a massive afforestation programme on the coast of Bhavnagar and Kutch districts with great success to ameliorate the adverse weather impact. In about 40 years after its introduction, these regions *have transformed into P. juliflora woodland. High plant densities are encountered in Kutch,* where it has fully infested almost all habitats including saline lands. Its value as a firewood is already realized in Kutch, where the fuel requirements of the entire rural population close to 1 million inhabitants is met by *P. juliflora* wood. Of course the ıecent state policy has encouraged massive conversion of wood to charcoal. The annual livelihood generation is estimated at 1.9 million person days in the process of charcoal making.

Large scale, close-spaced plantations (1.3 x 1.3 m) of *P. juliflora* planted in Gandhinagar, Gujarat (700 mm mean annual rainfall), has produced 113 t ha^{-1} of biomass dry matter after 4 years (28 t ha^{-1} yr^{-1}), and the total biomass (root + shoot) produced was 148 t ha^{-1} (Gurumurti *et al.*, 1984). A study carried out by the Forest Research Institute (Dehra Dun) in Gandhinagar, Gujarat, found that the utilizable dry matter biomass (stem and branches) of *P. juliflora* was 113 t ha^{-1} and the non-utilizable biomass (leaves and roots) was 35 t ha^{-1}, 4 years after out-planting. *Prosopis* produces double the biomass that eucalyptus does on similar soils (Banerjee, 1986), and yet is considered by the Gujarat Forest Department to be a low-value tree. Organized plantations done by the GFDC near Mundra in the forest area for supplying to power plants have estimated charcoal production of 1.18 t per ha with a rotation of 4-6 years.

In Prakasam district, charcoal making from the roots of *P. juliflora* is a common activity, especially in the summer seasons. The cost of charcoal production works out to Rs. 1500 per tonne, which is sold to the traders at the village level for Rs. 3500 per t. According to a field study (Ravindranath and Hall, 1995) in five villages of the semi-arid district of Anantpur (Andhra Pradesh) 86% of households met more than 75% of their cooking needs from *Prosopis* alone. Here gathering of fuel wood from degraded public lands has become a cottage industry, as much of it goes to the nearby metropolitan town, Bangalore. As much as 10% of the local population gets employment from this activity (Agarwal, 1990). Field studies in dry areas with low employment opportunities in the slack season, like Anantpur in Andhra Pradesh (CIDA,1988) and Mathura in UP (Saxena, 1989), show that *Prosopis* has on its own solved the fuel wood crisis, besides providing employment to many who prune the branches and sell them in urban areas.

As presented in Table 2, it has been estimated that annually about 27.59 t ha^{-1} yr^{-1} of dry biomass of *Prosopis* can be harvested from different land use categories in study area of Andhra Pradesh which possess 413.85 GJ energy equivalents per year.

Electricity Generation Potential from Sustainable Woody Biomass Production

Biomass power projects with an aggregate capacity of 703 MW through 102 projects have been installed in the country. Most of these projects have employed higher steam pressure and temperature viz., 65 ata and 485°C. Biomass power project designed with boiler configuration of 106 ata pressures 525°C and 87 ata 500°C have also been commissioned in Karnataka and Tamil Nadu. Fuels used in such projects are rice husk, *Prosopis juliflora* and agricultural residues. *P. juliflora* is a preferred over other species for power generation because of its higher calorific value of 5000 K Cal and its wide availability. Indian Renewable Energy Development Authority (IREDA) has approved many power plants for power generation based on biomass, which are being established in Andhra Pradesh and Karnataka. In two of the three states studied, the commissioned biomass based power plant was 266 MW with 46 power generation units in operation. Of the two states, the commissioned capacity in AP. was 208 MW as on 30/09/2005. *Prosopis juliflora* is the major source of fuel for the boilers of the power plants in AP, whereas for the power plants in Karnataka as of now, *P. juliflora* is a secondary fuel source (Table 3). All the three power plants studied in AP have developed their captive plantations of *P. juliflora.* As the captive plantations are young, the current needs are met from community/ private lands. About 1.4-2.0 kg of *P. juliflora* gives 1 kWh of power. A 50 kwe power plant costs Rs. 13.5 lakhs, which can save 125-250 t CO_2.$Year^{-1}$ with power charges of Rs. 3.5-4.5 per kwh (Desipower Pvt. Company Ltd., 2005). India can reduce green house gas emissions up to 14% by 2020 using renewable energy (Kroeze *et al.,* 2004). Five biomass based power plants are in operation in South India and another 15 in the processes getting commissioned, which primarily use woody biomass like *P. juliflora,* in addition to eucalyptus, coconut shell, etc. Status of Biomass Project Commissioned and under implementation in India as on 31.12.2007 is given in Table 4 (MNES, 2008).

Social and Economic Implications

Biomass power offers significant job creation and rural revitalization potential. Biomass offers energy security benefits as a domestic renewable fuel source; climate change benefits could be achieved from expanded biomass energy use (via recycling of atmospheric carbon in the biomass fuel cycle). It is important to consider the social implications of bioenergy developments, especially those in developing countries, from a broader perspective. These developments will make biomass derived energy available to rural populations that have limited access to other energy sources, and this can increase agricultural productivity and promote the development of local businesses. Indirect benefits should also be explored. Bioenergy developments can reduce the indoor air pollution that increases infant mortality and reduces life expectancy in many developing countries. The situation in poor households that currently depend on traditional biomass could be dramatically improved if bioenergy development considers such aspects as promoting the more efficient and sustainable use of traditional biomasses and enabling people to switch to modern cooking fuels and technologies .

The greatest potential for supply of fuel wood at little opportunity cost is from shrubby *Prosopis juliflora* on degraded lands. This is not favored species because of the presence of thorns. However, the lack of commercial interest means the poor have greater access to this shrub. In many semi-arid regions, the natural spread of *Prosopis* provides the poor with excellent fuel wood for both consumption and sale at almost zero opportunity cost. However, these positive developments (which are not connected with any government policy) still do not help a large proportion of the rural population. Wood fuel trade provides employment in rural and urban areas and for many landless and poor people it appears to be an important source, and sometimes the only source, of cash income. So, a power projects based on woody biomass open up new avenues for employment generation this would open up other choices of fuel to rural masses. Each 5 MW woody biomass power project could generate at least 100,000 man-days per year of employment in rural areas. Woody biomass requirement for generating electric power and employment generation potential of M/s Agri Gold Power Plant, Prakasam Dist was studied.

A case study of M/s Agri Gold Power Plant, Prakasam Dist.

- 6 MW capacity
- Monthly 23 lakh units of power generated
- Daily woody biomass required 120-150 t
- Manpower : regular: 35 persons (Employment)
- Casual (work contract): Rs. 45-50 per t of wood
- Power purchase price : 80% at Rs. 3.16 per unit and 20% at Rs.1.50
- Fuel: 4.03; salary, contract: 1.44; depreciation: 0.87; bank interest: 1.07: Total: 7.41
- Per unit cost : Rs. 2.48; Sale price: Rs. 2.35 per unit

Some of the observed case studies demonstrate that (a) charcoal production based on *Prosopis juliflora,* a species that generally concentrates in low-rainfall and high-risk ecological regions (where agriculture is not a major supporter of the household economy), can be economically viable; (b) charcoal making has the potential to generate gainful employment to poor families in regions where it was most needed; (c) the supply pattern of charcoal varied greatly but could be stabilized and improved with organizational innovations; (d) charcoal making is most suited to areas having sizeable wastelands; (e) charcoal making is based on local resources which have a value addition potential; (f) there is a need to promote the application of science and technology in *Prosopis* cultivation in problematic soils and in charcoal making practices; (g) charcoal making can support married women, as the help of all family members is instrumental; (h) charcoal making need not displace existing workers; (i) the economics of *Prosopis*-based charcoal production are more favorable than that of marketing *Prosopis* as fuel wood; (j) charcoal making does not have any competition from the established industries, as it is a decentralized rural activity; (k) it is sustainable, as *Prosopis juliflora* is renewable; and (l) the marketing of charcoal should not be difficult because industrial demand is expanding (IIM,1993). Comprehensive changes are needed in government policy on charcoal. Currently, charcoal policy lacks a broader perspective. *Prosopis* provides a good opportunity to make wealth out of wastelands, promote employment opportunities, improve land use pattern, and make available raw materials needed by industries.

Environmental Impact of Use Wood

Biomass is the third largest primary energy resource in the world, after coal and oil (Bapat *et al.,* 1997) In all its forms, biomass currently provides about 1250 million tonnes oil equivalent (mtoe) of primary energy which is about 14% of the world's annual energy consumption (Hall *et al.,* 1991 and Werther *et al.,* 2000). The use of woody biomass for the substitution of fossil fuel(s) has an additional importance from climate change considerations since biomass has the potential to be CO_2 neutral. Trees remove carbon dioxide from the air during growth. Though combusting wood emits CO_2 into the atmosphere, regrowth of wood captures CO_2 from the atmosphere. Thus, biomass combustion recycles atmospheric carbon, rather than contributing additional carbon, as occurs with combustion of fossil fuels. As a result, the use of woody biomass in substitution for fossil fuels offers an important option for reducing emissions of greenhouse gases which contribute to global warming. Wood fuels an environmentally sound energy option as the net addition of CO_2 and other greenhouse gases is zero if harvested on a sustainable basis. The total CO_2 emission reduction potential (as a consequence of not using the coal in thermal plants) of the biomass based power plants. (on account of 16000 MW potential per yr) is 35.3 million t/ year. Although many plants have *been commissioned in India, they are yet to be registered with the UNFCC. As on* March 6, 2006 only two plants from AP (18 MW) have registered with UNFCC for a saving of 39670 t of CO_2 per annum. At a moderate rate of $4 per t CO_2, the potential would be $ 140 million per year. Environmental considerations compel greater use of sustainable technologies. One of the major environmental threats is energy induced global warming and associated impacts. Modern Bioenergy Technologies (BETs) are uniquely placed in this context as they could mitigate the climate change impacts by preventing emissions and also absorb emissions by sequestering carbon through the photosynthesis process. A quick estimate of GHG reduction potential from BETs is shown in Table 5 (Ravindranath *et al.,* 2000).

Conclusions

Energy consumption will continue to grow, and fossil fuel will continue to be the main source of energy over the next few decades, in spite of concerns about climate change and energy security and the efforts to develop alternatives. Biomass is an important source for energy generation, but its use is normally limited to heating and cooking, with few developments in power generation and other applications. Large wood based bioenergy projects require extensive land areas and can affect food security, biodiversity, the wood processing industry and the availability of construction and other wood products on the market. To mitigate these eventual impacts, there is need to regulate land uses and take into consideration national interests and other policies, such as the involvement of all stakeholders, when implementing strategies to develop wood based bioenergy. In a national strategy, it is also important to consider the potential efficiency gains from using existing wood based energy development and to take advantage of the often extensive degraded lands available. Planting trees also helps to combat erosion and restore ecosystems.

Table-1: *Prosopis juliflora* coverage and potential for charcoal and employment in Gujarat

District	Estimated *Prosopis juliflora* area (ha)	Estimated charcoal production (tons)	Annual employment generated (Lakh man days)
Bhuj	88225	103800	4.4
Patan	23037	13800	3.95
Surendranagar	59710	35000	10.2

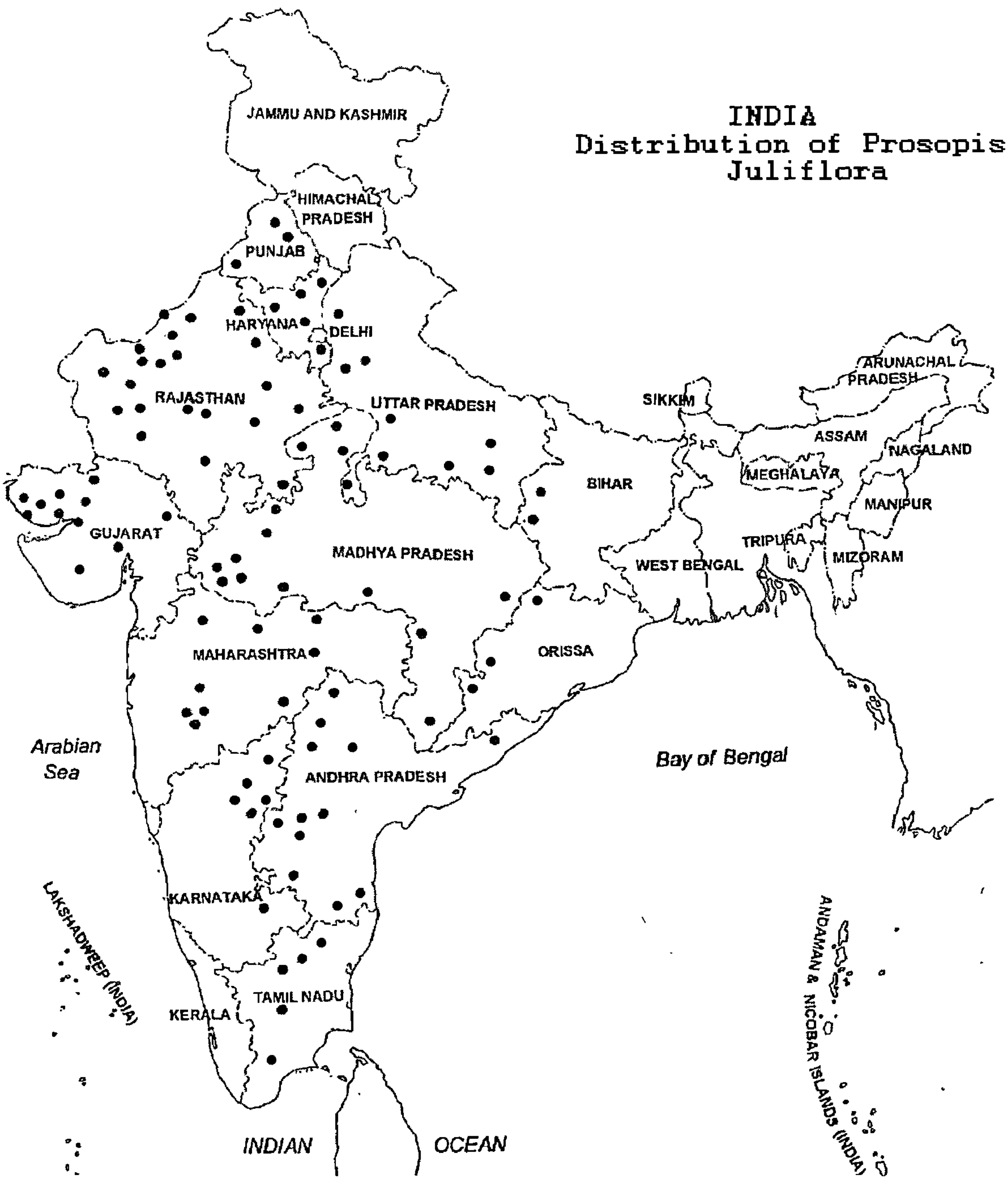

Figure 1 State wise distribution of *Prosopis juliflora*

Table 2. Biomass production potential for energy and the electricity generation in Gujarat and Andhra Pradesh under different land use categories in the study area.

State	Land use categories	Density per ha	Number of stems per plant	Height (m)	Girth (cm)	Dry Biomass (t/ha/yr)	Annual Power generation potential (TWh yr^{-1})		Energy equivalent (GJ/yr)
							Rankine cycle power plant	Biomass integrated gasification combined cycle (BIGCC)	
Gujarat	Road side	450	5.5	1.60	4.30	17.52	17.52	30.66	262.8
	Community wastelands	1711	8.5	2.90	11.70	18.91	18.91	33.09	283.65
	Pasture land	1300	7.0	2.49	13.00	20.93	20.93	36.63	313.95
	Farmers fallow land / Natural regeneration	1167	7.6	2.44	11.33	11.53	11.53	20.18	172.95
	Other waste lands	1770	8.0	2.69	11.27	18.41	18.41	32.22	276.15
	Total	**6398**				**87.3**	**87.3**	**152.78**	**1309.5**
Andhra Pradesh	Community wastelands	1414	5.29	4.51	7.16	9.72	9.72	17.01	145.8
	Farmers fallow land/Natural regeneration	1060	6.35	3.62	4.23	8.75	8.75	15.31	131.25
	Other wastelands	1205	6.5	3.62	6.68	9.12	9.12	15.96	136.8
	Total	**3679**				**27.59**	**27.59**	**48.28**	**413.85**

Table-3: Biomass source and use by sample power plants

State	Biomass based power plants visited	Major biomass	Procurement price of *Prosopis juliflora* (Rs./ t)	Captive plantations of *Prosopis juliflora* per MW (ha)	Status of power plants
Andhra Pradesh	3	*Prosopis juliflora*	1100-1300	75-500	Fully operational
Karnataka	2	Rice husk, *Prosopis juliflora*	700-800	Nil	Fully operational
Gujarat	2	*Prosopis juliflora*		Nil	One unit closed due to mismanagement & the other is a captive power plant

Table 4. Status of Project Commissioned and under implementation in India (as on 31.12.2007) (MNES , 2008)

Project Status in India	Biomass Power	
	No. of Project	Capacity (in MW)
Commissioned	90	605.80
Under implementation	59	525.30
States		
Gujarat		0.50
Andhra Pradesh		210.20

Table 5. BET's greenhouse gases reduction potential in India

Biomass Technology	Technical Potential	Global Environmental benefit (million T C year $^{-1}$)
Biogas	17 million	5
Community biogas	150000 villages	10.8
Improved stove	120 million	4
Biomass	57000MW	89
Cogeneration	3500MW	6
Urban wastes	1700MW	3

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Multi-dimensions of Mesquite on Production, Conservation and Value Addition Aspects

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Introduction and Botany

Prosopis is a native species of Central America which has its genetic center in South America (Burkart, 1976). This species has been successfully introduced in the arid tracts of Asia, Australia, Sudan and South Africa where the rainfall varies from 10 to 20 cm (Raizada and Chatterji, 1954). *Prosopis* was first introduced into India during 1870's for meeting the fuelwood demand and also for stabilizing sand dunes (Konda Reddy, 1978). There are about 44 species in *Prosopis*, of which three species are cultivated in India. In this one is indigenous *Prosopis cineraria* and the other two are exotics viz., *P. juliflora* DC var. horrida and *P. glandulosa* Torr. Among the three species *P. juliflora* (commonly called as mesquite) is widely adapted to the dry and poor soil conditions and is preferred for its fast growth and high biomass production. Now this species is most common in Punjab, Rajasthan, Gujarat, Harayana, Uttar Pradesh, Orissa, Tamil Nadu and West Bengal of India. At present, *P. juliflora* is thought to inhabit more than 500,000 ha, although plant densities vary with different areas and habitats.

Prosopis juliflora DC is a medium sized, semi evergreen to evergreen tree (Troup, 1983) attaining a height of about 9-12 meters and girth of 90 cm, main stem branched from the ground level, long, zig-zag armed with thorns of 1-5 cm long. Bark: is thick, dark reddish brown in colour divided by shallow fissures. Leaves: alternate on the branch lets 3-13 cm long with leaflets 8-46 pairs. Flowers: creamy white in axillary pedunculate, spikes 4-10 cm long. Pods: 12 to 25 cm long compressed, pale yellow or straw colored when ripe. Seeds: 8-24 oblong flattened.

This species is a light demander and hence comes up very well in open. It requires a hot dry climate with mild winters. The temperature requirement of the species is 15-46°C with an annual rainfall of 200-800 mm. It cannot withstand prolonged water logging. *P. juliflora* comes up very well on plains, on small hillocks and sometimes on stony ridges. This species could be seen from the sea level to about 1500m above sea level. Though this species comes up on a wide range of soils from salty coastal to fertile alluvial, it always prefers deep soils with a high water table. Soils of shallow depth with canker underneath are relatively unfavorable. The performance was poor on red lateritic soil but best on black cotton soil (Devaraj *et al.*, 1997).

How ever in the recent past, this species is being considered as noxious weed because of its invasiveness and negative allelopathic effects. The impact of this invasive species is a subject of debate due to its multidimensional roles. The first author has witnessed the livelihood support of this species in southern districts of Tamil Nadu, and the present position at CAZRI made him to attend this chapter to analyze the opportunities and gaps on its management towards better usage.

Opportunities with Mesquite

Fast growth and productivity: It is one of the fast growing exotics. Based on age, *P. juliflora* produces a total biomass of 19 t/ha in 18 months and about 167.2 t/ha at the end of 5 years (Gurumurti *et al.*, 1984) due to its higher solar energy conversion efficiency. Wide variation in the annual yield of this species may be due to the variation in management practices (Esbenshade, 1980) genetic materials (Felker *et al.*, 1981), soil fertility, rainfall and soil moisture (Wightman and Felker, 1990) variations. According to Mathur *et al.* (1984) out of the 114 t/ha of total biomass produced by this species, 88.87 t/ha was utilizable biomass.

Remarkably, the shifting sand dunes afforested by his species have produced a wood yield of 1-20 t ha^{-1} after 5 year of planting (Kaul, 1985) while, Bhimaya *et al.* (1967) have calculated that fuel production to the tune of 38.2 t ha^{-1} in 10 year felling cycle.

Saline tolerance and edapho-climatic adaptability: The growth and spread of *Prosopis* is tremendous in recent times. This is mainly due to the inbuilt adaptive mechanism in the plant to overcome adverse conditions. The small leaves and spines make it to behave like a xerophyte by reducing the surface area for transpiration. According to Sher-Mohammed *et al.* (1990) the proline content in *Prosopis* is high under stress conditions which help the plant to thrive under extremes of drought. Due to the halophytic nature of the plant it could also tolerate extreme saline condition. Sharma (1981) stated that the high sodium content in the leaves (3.94-4.51%) indicate the capacity of the plant to tolerate salinity. Jain (1995) also reported that the survival of this species was high even under high exchangeable sodium percentage. Srinivasu and Tokey (1996) opined that this species would germinate and grow in soils with a pH as high as 11.0. Being a phreatophyte, this species put forth deep roots (Meinzer, 1927) to draw water from deeper layers and thus could thrive adverse drought where other species die. It could also be called as a facultative phreatophyte for in sites with shallow water table it uses its lateral roots to absorb water. The lateral roots extended up to 48 m in a shelterbelt plantation of *P. juliflora* (Prajapati *et al.*, 1971). *P. juliflora* seeds gave 48% germination after being exposed to 90°C temperature. Thus *Prosopis* is considered highly adaptive to adverse conditions.

Multiple benefits: (i) Fuel wood and Charcoal- *Prosopis juliflora* was first used as domestic firewood (4350 K.cal.) for rural house holds. Later it spread as an industrial fuelwood and was used by the cottage industries like tile works, brick kilns, lime kilns, pottery works, blacksmithy, carpentry works, laundry works etc. This species is one of the most suitable species for short rotation fuelwood forestry on alkaline soil because of its high wood density, biomass yield, low ash and moisture content and good heat of combustion at the juvenile stage (Goel and Behl, 1996). The demand gradually increased in the early seventies when the process of making charcoal from *Prosopis* wood was invented. Now charcoal made from this species is exported. The small twigs and branches are also useful for making activated carbon. The charcoal from *Prosopis* is used for drying, raising steam and smelting metals in steel and polyfibre industries. It is also used in carbide and ferosilicon industries. The charcoal powder is used for agarbathi manufacturing (Kondas, 1992).

(ii) Timber and industrial usages - *Prosopis* wood obtained after the tree has attained an age of more than 10 years is considered as a loyal timber for the poor in India (Konda Reddy, 1978) and is used for making fence post and small pilings. According to Shukla *et al.* (1990) the timber from this species after 30 years falls into group 'C' timbers and from its strength point it could be used for construction purposes, tool handles and railway sleepers.

The mesquite gum of 2-12% concentration could be used in tablet formulation by direct compression and wet granulation method (Khanna *et al.,* 1997). *Prosopis* wood of 30-50 cm girth could be used for making papers. This apart several industrial products like alcohol, gums and sweetening agents could also be obtained from this species (Anderson and Wang, 1989). Piperidine alkaloids like juliprosinene and juliflorinine could be isolated from the leaves of it (Ahmad *et al.*, 1989).

Pods also contain about 12 ppm Cu, 22 ppm Mn, 18 ppm Zn and 300 ppm Fe (Talpada *et al.,* 1989). The sugar content of the pods varied from 13.33 to 19.86% (Talpada and Shukla, 1988). The mostly available amino acid in the pods were lysine 438 mg/g N for the pod protein (Marangoni and Ali, 1988). They also contain adequate amounts of valine, leusine, tyrosine and phenylalanine. Methionine was the most limiting amino acid. *Prosopis* flowers are a rich source of honey and apiary could be an ideal occupation in *Prosopis* belt (Ramanujam and Kalpana, 1993).

Due to the above, several value added products viz., pod floor as mixture for bread & biscuit making, roasted and grinded pod as coffee power, high sugary syrup of mesocarp as substitute of honey, high pretentious pod as non-conventional feed were prepared by CAZRI.

Unquantifiable services: (i) Soil fertility improvement- This species being a leguminous one helps in biological nitrogen fixation through its root nodules and thereby improve the fertility status of the soil. According to Rundel *et al.,* (1982) at full stocking this species fixes about 100 kg N ha^{-1} $year^{-1}$. Diagne and Baker (1994) reported that *P. juliflora* stand of 650 trees ha^{-1} could fix about 20 kg N ha^{-1} in the first year, while Ganry and Dommergues (1995) categorized this tree as an average-nitrogen fixing species.

P. juliflora adds about 3700 kg of leaf litter per hectare per year through which about 16.2 kg N, 6.2 kg P, 34.6 kg K, 72.8 kg Ca. and 29.6 kg Mg is added to the soil. Addition of leaf litter by this species has been reported by Gurubachan Singh and Singh (1993). Thus cultivation of *Prosopis* for a longer period helps to reduce soil pH (Yadav, 1975) and increases the status of organic matter (Verma, 1987) and nitrogen in the upper 15 cm soil layer (Shukla and Misra, 1993).

(ii) Soil reclamation and rehabilitation- The physicochemical properties of sodie wasteland was improved through *P. juliflora* cultivation for a period of 10 years (Jain and Garg, 1996). Intercropping Kamal grass *(Dipiachne fusca)* in this species on highly sodic soil was found the best biological means to reclaim such soil economically (Gurubachan Singh and Singh, 1993). Cultivation of this species improves hydraulic conductivity of the soil (Khanduja *et al.,* 1986) reduces bulk density and increases the water holding capacity (Pathak *et al.,* 1964). According to Shukla and Misra (1993) cultivation of this species on sodic soils in the long run reduced soil pH, salt content and exchangeable Ca, reduced the bulk density and increased the water holding capacity and hydraulic conductivity of these soils.

(iii) Bio-conservation- Under Bio-conservation *P. juliflora* seeds were the principal food for the quail *(Callipapla sqamata)* (Davis *et al.,* 1975). The leaves and pods in wilderness are a food for deer (Beason *et al.,* 1982). This besides, the leaves, flowers, pods and seeds serve as food for a variety of insects (Cates and Rhoades, 1977).

(iv) Microclimate improvement- Increased rainfall (20-40%) and reduction in temperature (4-7°C) reported under widespread thickets of *P. juliflora* relative to open fields (Sharma,1981).

Threats to/ Due to Mesquite

Invasiveness as weed: *Prosopis* is equipped with a number of biological characteristics that foster its rapid invasion of new areas. These include: (i) production of many, small and hard seeds capable of surviving passage through the digestive system of animals, entering into the soil to form soil seed banks and remaining viable until favorable conditions for germination and seedling establishment appear; (ii) attractive and rewarding pods for animals, containing fleshy and sweet mesocarp embodying the numerous small seeds, which is sought after by both domestic and wild animals, meant for long-distance dispersal; (iii) accumulation of dormant but long-lived viable seed reserves that would serve as sources of regeneration of new *Prosopis* plants in the event of disturbance that might eliminate the above-ground stands; (iv) production of a mixture of seeds, with a few capable of germinating immediately after dispersal to exploit the favorable conditions that might exist at the time of dispersal, while the majority remain dormant for spreading germination over time and space; and (v) great ability of resprouting and fast coppice growth from stumped/damaged trees, making it a very strong competitive invader combined with its sexual reproduction.

The very high adaptability of this species along with the combinations of all these characteristics make *Prosopis* a powerful noxious invader as can be evidenced from its rampant invasion in the study site and elsewhere in the tropics.

Bulk mortality due to frost sensitivity: In general *P. juliflora* is considered as frost sensitive. But the observation on frost damage from different parts of India indicated that there is some forms / ecotype with frost hardiness/resistance to frost. It was due to the reason that, during the introduction of *P. juliflora,* the other related *Prosopis* species seeds were also mixed with that. And it is also true that taxonomy of genus Prosopis is very complex and confusing (Tewari *et al.,* 2000). In *P. juliflora,* there are five forms in India, viz. (i) Argentine ii) Arid (iii) Mexican (iv) Peruvian and (v) Australian forms. Morphological characters of the different forms of *P. juliflora* were already published by Raizada and Chatterji (1954). The Argentine, Arid and Mexican forms are reported to be frost hardy but the Australian form is susceptible to frost, especially when young. The Peruvian form has been found to be more sensitive to frost than the Australian. So, identification of frost hardy / resistant *P. juliflora* is need of the hour.

Future Thrust Areas

It is well known and accepted that the invasiveness of this species has both positive and negative implications. It is the managers/scientist duty to manage and exploits the best with that species. It is also well understood that efforts on eradication of a well adapted species is not advisable and possible, while exploit it to the maximum is the way to use & manage this species.

The words of Jeff Cox "A person who loves his or her work is like a plant in the right spot; there growth is maximized and the yield is greatest" are exactly true with the case of *P. juliflora.*

In this context, following are the thrust areas to be looked in to augment the usage of Mesquite

a. To identify the best management practice to limit the invasive nature of *P. juliflora.*

b. To develop frost, saline, and other problem resistant *P. juliflora* ecotypes.

c. Develop and encourage successful value chains for better usage of *P. juliflora.*

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Socio-economic Impact of *Prospious Juliflora* in Arid zone of Rajasthan

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Prosopis juliflora was introduced during 1917 by former ruler of princely state Marwar, which played a leading role in the afforestation of arid lands. Growing the species on degraded lands have made them especially suitable for plantation purpose. Being a multipurpose tree, *Prosopis juliflora* by controlling soil erosion, stabilizing sand dunes, improving soil fertility, reducing soil salinity, providing fuel energy resources, supplying feed and forage for grazing animals, furnishing construction timber and furniture wood, supplementing food for humans, and promoting honey production plays vital role in life support in of desert dwellers arid zone. It also produces high quality charcoal and its heartwood is strong and durable. Its branches are widely used as fencing posts, while its pods, which are high in protein and sugars may be important fodder for livestock, and / or food for humans *Prosopis juliflora* has also been used to shelter agricultural crops from wind by reducing the movement of soil and sand. Its leaves contain various chemicals known to affect palatability to livestock, and also suppress the germination and growth of crops, weeds and other trees. The utilisation of *Prosopis juliflora* in different form of products and other related activities in arid region of Rajasthan, keeping this view, a socio-economic survey of farmers in certain village of Jalore district was purposefully conducted seeing the development in the neighbouring district of Gujarat where *Prosopis juliflora* is managed on commercial basis.

Material and Methods

The data collection were collected by a well tested questionnaires and information were collected from the selected farmers on various socio-economic indicators. 125 farmers who were using *Prosopis juliflora* in one or another way, were selected randomly from five villages namely, Khanpur, Golia, Gajipura, Kotra and Mandhara. The farmers were selected in such a way that they represented all the class of farmers, i.e., landless, marginal, small, middle and large farmers. The data were collected through well-structured questionnaire designed particularly for the purpose. The distribution of farmers in different socio-economic strata is presented in Table1.

Table 1: Distribution of farmers as per size of holding of land

Type of farmers	Khanpur	Gajipura	Kodita	Mandhar	Golia**	Total
Landless farmers*	6 (17.65)***	4 (16.00)	3 (14.29)	8 (29.63)	4 (22.22)	25 (20.00)
Marginal	15 (44.12)	5 (20.00)	2 (9.51)	4 (14.81)	7 (38.89)	33 (26.40)
Small	3 (8.82)	5 (20.00)	4 (19.05)	5 (18.52)	4 (22.22)	21 (16.80)
Semi medium	3 (8.82)	6 (24.00)	4 (19.05)	5 (18.51)	1 (5.56)	19 (15.20)
Medium	6 (17.65)	4 (16.00)	3 (14.29)	3 (11.11)	2 (11.11)	18 (14.40)
Large	1 (2.94)	1 (4.00)	5 (23.81)	2 (7.40)	0	9 (7.20)
Total	34 (100.00)	25 (100.00)	21 (100.00)	27 (100.00)	18 (100.00)	125 (100.00)

* Farmers having land less than 0.25 ha have been treated as landless for the study.

** Golia is not a revenue village, it included in Bhinmal Rural I

*** values in parenthesis indicated% of total.

Out of 125 selected farmers, 58 belonged to marginal and small farmers classes. Most of these farmers put the land fallow due to less area available for cultivation. The *Prosopis juliflora* was growing profusely around farmers field.

Results and Discussion

Family size

The family size distribution of farmers is presented in Table 2. The maximum farmers' had family size between 7 and 10, closely followed by family size of 4 to 6 persons in all the sample villages.

Table 2. Distribution of sample household according to size of family (in numbers)

Size of family	Khanpur	Gajipura	Kodita	Mandhar	Golia*
< 3 members	7 (20.59)**	4 (16.00)	4 (19.05)	4 (14.81)	4 (5.56)
4 - 6 members	11 (32.35)	8 (32.00)	8 (38.10)	10 (37.04)	11 (61.11)
7 - 10 members	14 (41.18)	11 (44.00)	6 (28.57)	9 (33.33)	4 (22.22)
>11 members	2 (5.88)	2 (8.00)	3 (14.28)	4 (14.82)	2 (11.11)
Total members.	34 (100.00)	25 (100.00)	21 (100.00)	27 (100.00)	18 (100.00)
Average	5.97	6.28	7.50	6.74	7.11

* Golia is not a revenue village, it included in Bhinmal Rural I

** values in parenthesis indicated% of total.

Types of Family

The family types of sample household is presented in Table 3. Joint family system prevailed in Khanpur, Kodita and Mandhar villages while separate families were in Gajipura and Golia.

Table 3 : Distribution of sample household according to types of family

Type of Family	Khanpur	Gajipura	Kodita	Mandhar	Golia*
Joint	22 (64.71)	11 (44.00)	12 (57.14)	17 (62.96)	8 (44.44)
Separate	10 (29.41)	14 (56.00)	9 (42.86)	10 (37.04)	10 (55.56)
Single	2 (5.88)	-	-	-	-
Total	34 (100.00)	25 (100.00)	21 (100.00)	27 (100.00)	18 (100.00)

* Golia is not a revenue village, it included in Bhinmal Rural I

** values in parenthesis indicated% of total.

Type of House

Mixed type of houses (i.e. having both kuccha and pucca construction) was dominated among the selected households in Khanpur and Gajipura followed by kuccha and pucca types of houses in Mandhar and Golia villages (Table 4). The roof of kuchcha and mixed household used *Prosopis juliflora* wood in substantial quantity and were aged more than 12 years.

Table 4: Distribution of sample household according to type of house owned

Type of Houses	Khanpur	Gajipura	Kodita	Mandhar	Golia
Kutcha	10 (29.11)*	5 (20.00)	4 (47.62)	12 (44.44)	12 (66.67)
Pucca	7 (20.59)	3 (12.00)	8 (38.10)	6 (22.22)	1 ((5.55)
Mixed	17 (50.00)	17 (68.00)	3(14.28)	9 (33.34)	5 (27.78)
Total	34 (100.00	25 (100.00)	21 (100.00)	27 (100.00)	18 (100.00)

* values in parenthesis indicated% of total.

Distribution of Livestock

It was found that buffalo population was more than that of cows in all the household sample respondents which might be due to availability of more fodder and sufficient material for stall feeding, as concentrate in the form of *P. juliflora* pods. The pods flour mixed with other concentrate improve its quality, which in turn increases the milk output. Buffalo gives more milk with more fats which resulted in higher returns in comparison to cow milk. The higher population of goats and sheep might be due to availability of open grazing facility in the study area (Table 5).

Table 5. Distribution of Livestock of sample farmers (in numbers)

Particulars	Khanpur	Gajipura	Kodita	Mandhar	Golia
Cows	35	38	26	56	14
Buffalo	57	84	44	77	42
Goats	137	203	118	210	64
Sheep	178	220	49	150	139

Type of Occupation

The type of occupations prevailed in sample households is presented in Table 6. Maximum percentage of population in the total selected households were working as agriculturalist and agricultural labourers engaged in different sorts of activities in Gajipura and Mandhar. The 34 households selected for the study were engaged in agriculture and animal husbandry and as agriculture labourers. Agriculture was prominent occupation of the farmers. The other occupation apart from agriculture among selected farmers were government and private service, and personal business.

Table 6: Distribution of sample household according to occupation (in numbers)

Type of Occupation	Khanpur	Gajipura	Kodita	Mandhar	Golia	Total
Labourer	6 (17.65)*	2 (8.00)	5 (23.81)	6 (22.23)	8 (44.44)	27 (21.60)
Agriculture + Labourer	7 (20.59)	9 (36.00)	4 (19.05)	8 (29.63)	2 (11.11)-	30 (24.00)
Agriculture + Animal Husbandry + Labourer	10 (29.41)	8 (32.00)	3 (14.29)	7 (25.93)	6 (33.33)	34 (27.20)
Agriculture + Anima 1 Husbandry + Business	3 (8.32)	4 (16.00)	5 (23.81)	5 (18.51)	1 (5.56)	18 (14.40)
Agriculture + Animal Husbandry + Service	8 (23.53)	2 (8.00)	4 (19.05)	1 (3.7.)	1 95.56)	16 (12.80)
Total	34 (100.00)	25 (100.00)	21 (100.00)	27 (100.00)	18 (100.00)	125 (100.00)

* values in parenthesis indicated% of total.

Family Household Income

The family income distribution among the selected households was grouped into four categories (Table 7). The maximum farmers (40 respondent) were having monthly income between Rs. 3000 and Rs. 5000. The 36-sample households were having monthly income less than Rs. 3000. Twenty respondent were having more than Rs. 10000/- monthly income, which might be due to business activities apart from agriculture.

Table 7. Distribution of sample household according to per household monthly income (in numbers)

Per Household Income (Rs.)	Khanpur	Gajipura	Kodita	Mandhar	Golia	Total
< 3000	10 (29.41)*	6 924.00)	4 (19.05)	9 (33.33)	7 (38.89)	36 (28.80)
3000 – 5000	11 (32.350	8 (32.00)	9 (42.86)	7 (25.93)	4 (22.22)	40 (32.00)
5000 – 10000	7 (20.59)	6 (24.00)	5 (23.81)	6 (22.23)	5 (27.78)	29 (23.20)
>10000	6 (17.65)	5 (20.00)	3 (14.28)	4 (14.81)	2 (11.11)	20 (16.00)
Total	34 (100.00)	25 (100.00)	21 (100.00)	27 (100.00)21	18 (100.00)	125 (100.00)

* values in parenthesis indicated% of total.

Prospect of Use of *Prosopis juliflora*

The different use of *Prosopis juliflora* products were estimated and presented in Table 8. The *Prosopis juliflora* was primarily used, for its pods and wood. The 40 sample households were grazing their dry animals on *P.juliflora* thickets. Pods of *P.juliflora* were basically used as a feeding source of livestock. Farmers also mixed the pods with dry fodder and also in concentrate for increasing in milk yield. The wood of *Prosopis juliflora* is the major source of fuel. The sample households were using wood for fuel purpose and also making charcoal, which is used during rainy season. The charcoal is prepared by traditional way and makes fair amount of income used for purchase of food items. The wood pole were was used for roofing purpose. The sample households were saving good amount of money by use of *Prosopis juliflora* in one way or other, which was estimated to the tune of Rs. 3500/- per year. The wood is also used for fencing of houses, farms, etc.

Table 8. Distribution of sample farmers according to use of *Prosopis juliflora* products (in numbers)

Type of Products	Khanpur	Gajipura	Kodita	Mandhar	Golia*	Total
Grazing by animals on *Prosopis* forest	21 (61.76)*	9 (36.00)	3 (14.29)	6 (22.22)	4 (22.22)	43 (34.40)
Only Pod feeding	10 (29.41)	5 (20.00)	2 (9.52)	3 (11.11)	5 (27.78)	25 (20.00)
Pod mixed with concentration	8 (23.53)	6 (24.00)	3 914.29)	4 (14.81)	7 (38.39)	28 (22.40)
Gum collection	3 (8.82)	2 (8.00)	2 (9.52)	3 (11.11)	4 (22.22)	14 (11.20)
Fuel wood	30 (88.23)	18 (72.00)	20 (95.24)	23 (85.19)	16 (88.88)	107 (85.60)
Construction (as pole and for roof)	15 (44.18)	13 (52.00)	10 (47.62)	20 (74.07)	15 (83.33)	73 (58.40)
Pod eating habits among children	20 (58.82)	12 (48.00)	9 (42.86)	21 (77.78)	5 (27.78)	67 (53.60)

values in parenthesis indicated% of total.

However, some respondent also reported itching due to injuries caused by its throne, specially in children and elderly persons. By over eating, some of animals are also facing the throat problem, especially in goats.

Environmental and Social Safety Issues

The most of the forest land is covered by *P. juliflora* which created favourable environment as it provide fodder, nutiterative concentrate for animals and wood for population of the study area. None of the farmers has reported any unsocial incidence. All the farmers have good relation as produce from *P. juliflora* is sufficient in amount.

In the target area, 1100 ha of land is under *Prosopis juliflora,* the population density is around 400 per ha. In other words, 440000 plants are in selected villages. These plants can produced 4400 t pods. The income generated from the collection of pods will be Rs. 8.8 m and generate nearly 56,000 mandays in the selected villages. The expected increase in per household is aroind Rs. 6,000/- per year. In the arid tropics lands of India have more than one million ha land area under *Prosopis juliflora.* If 50% of the pods are actually collected, the estimated pod yield would be about 5 million tons (density = 500 trees per ha), which can generate employment to the tune of 16 m man days and can provide income to stakeholders nearly 5000 million rupees per year.

Conclusion

Maximum number of households belonged to marginal and small farmers class. The family size was generally large (>7 members). In the entire study area joint family system was prominent, however, a shift towards separate family is evident from the information collected during the survey. The housing pattern at and around the project area exhibited dominance of mixed housing (i.e., household were having both kuchha and pacca structures). Interestingly, livestock rearing trend was quite different than other parts of arid zone, where cows are prominent wealth of the farmers. In the project site villages, buffalo population was higher than cows. The trend clearly indicated the availability of more fodder and material for the concentrate. Sheep and goats were fair numbers as also found in other parts of arid region. Intensive survey in the area revealed that maximum household were having family income between Rs. 3000-5000/- per month. Only 16% families belonged to higher income group i.e., having monthly income more than Rs. 10,000/-. *P. juliflora* is used by almost all the household for firewood purpose However, farmers allow their livestock to graze on fallen pods of the species. Some times, they also collect the pods for stall feeding of the animals with other fodders. Many farmers are engaged in preparation of charcoal by using wood of the species. The log of the species was widely used in kachha house in roof portion. Thus, the species is indirectly benefited the farmers and on and average, across different income groups every year Rs. 3500/- per year were being contributed by the species. The lack of awareness is the main factor, which was not allowing farmers to initiate the species up to its full potential.

In the study area, 1100 ha of land is under *Prosopis juliflora*, the plant density is around 400 stems per ha. These plants with little management can produced 4400 t pods. In the arid tropics of India more than one million ha land area is under *Prosopis juliflora.* If 50% of the pods are actually collected, the estimated pod yield would be about 5 million tons (density= 500 trees/ ha), which can generate employment to the tune of 16 m man days and can provide substantial income to stakeholders.

Occurrence of Triacontanol in *Prosopis juliflora*

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Introduction

A number of compounds have been reported from *Prosopis juliflora,* an important plant of the genus *Prosopis* (leguminosae). Amino acids, steroids, tannins, leucoanthocyanidin and ellagic acid glycosides have been reported from*P. juliflora.* Chemical investigation of waxy part of the extracts of this plant has led to the isolation of triacontanol from leaves (Khan *et al.*, 1992). Pods and bark of *Prosopis juliflora* have also been investigated for triacontanol (Khan, 1998) and the triacontanol content compared.

Materials and Methods

Samples of different parts of the plant such as leaves, pods and bark were collected, dried and crushed and an extract of each was prepared using petroleum ether (60-80°C). The TLC of the extracts indicated the presence of triacontanol. The identity of triacontanol was confirmed by m.p. m.m.p. and co-TLC.

Results and Discussion

The triacontanol content from various parts *Prosopis juliflora* is given in Table 1. It was found that the level of triacontanol content was more in leaves as compared to other parts. It was in 1977 (Ries *et al.*, 1977) when the growth promoting activity of triacontanol was first discovered. Triacontanol was found effective in increasing growth and water uptake of rice seedlings and also growth of corn and barley. It has also been found effective in promoting germination and stubble sprouting. The presence of such a plant growth regulator in the leaves of *Prosopis juliflora* may increase the growth of the plants under canopy of the tree that is affected by the leaf litter fall. Such increase in the yield of grass under *P. juliflora* (J.C. Tewari, pers. comm.) were postulated to be due to increased land fertility around the tree. However, in view of occurrence of triacontanol in the leaves of *Prosopis juliflora,* the effect of plant growth substance on the growth of understory vegetation cannot now be discounted. In viiew of plant growth activity of triacontanol, its occurrence in the leaves of *P. cineraria*, another species of the genus, partly explains the observation (Shanker *et al.*, 1976) that the dry grass yield under Khejri was more as than under other tree tree species like *Tecomella undulata*, *Albezzia lebbek*, *Prosopis juliflora* and *Acacia senegal*. Lesser dry grass yield under *P. juliflora* despite the fact that it contains more tiacontanol is, however, partly attributable to its drooping type branches and aggressive growing nature which obstructs growth of vegetation under this tree.

Table 1. Triacontanol content in different parts of *Prosopis juliflora*

Triacontanol (%)	
Leaves	Upto 0.68
Pods	0.009
Bark	0.012

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Prosopis juliflora: Weed or Wealth – A Review

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Prosopis juliflora (Sw.) DC (Vilyati Babool), an evergreen tree is native to south America, central America and the Caribbean. The history of the first introduction of *Prosopis juliflora* into India is about 130 years old (Tewari, 2006). Introduction of species was first seriously attempted in 1870s and different people have different views about its introduction in India. It was first introduced in Punjab during 1875 (Rawat *et al.*, 1992); in Cuddaph district of old Madras Presidency during 1876 (Reddy, 1978); in Sind during 1877 (Kaul, 1956), whereas, Gupta and Blara (1972) reported that *Prosopis juliflora* was introduced to India in 1857 from Mexico. These reports indicate that the tree was introduced somewhere during 1870s. Literature revealed that it was declared "Royal Plant" in 1940 by the Former King of Jodhpur state and placed under government protection (Muthana and Arora, 1983). Large scale aerial seeding of this tree was undertaken to establish sand dunes and sand storms in Rajasthan (Harsh *et al.*, 1996). The most abundant distribution of this species is found in the Kuchh 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 (Tewari *et al.*, 2000). Because of natural inter species hybridization over the years different morphological and physiological variations are found among the natural stand of *Prosopis juliflora* in different parts of the country and attributed reason is the existence of different forms of the species in different places. 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.

Prosopis juliflora as a Weed

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 (Tewari *et al.*, 2000). Because of its deep rooting system that consumes much moisture and thick canopies which has shading effect on it's under vegetation, *Prosopis juliflora* has survived where other tree species have failed and in many cases become a major nuisance. It is an aggressive and invading species that has spread rapidly due to its great tolerance to the extremely refractory conditions of the most parts of arid zone. *Prosopis juliflora* has invaded, and continues to invade, millions of hectares of rangeland in south Africa, east Africa, Australia

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and coastal Asia (Pasiecznik, 1999). In 2004, *Prosopis* was rated one of the world's top 100 least wanted species (Invasive Species Specialist Group of the IUCN, 2004). In the native region of *Prosopis juliflora* (from Mexico to Peru) where, the people have developed local economies based on this tree and its products. Vilayati babool is a foreigner in India, the tree has been introduced long back, but the knowledge of multipurpose use of this tree has not been so far known to all. The prolific growth of *Prosopis juliflora* invaded communal grazing lands discourages grass growth and hence leaving there little or no grass for livestock. In fact, it ranks first in term of distribution, abundance and aggressive encroachment of rangelands. The incidence of malaria associated with the expansion of *Prosopis* thickets is also the frequently mentioned problem. Associated all the problems has kept *Prosopis juliflora* in category of a weed.

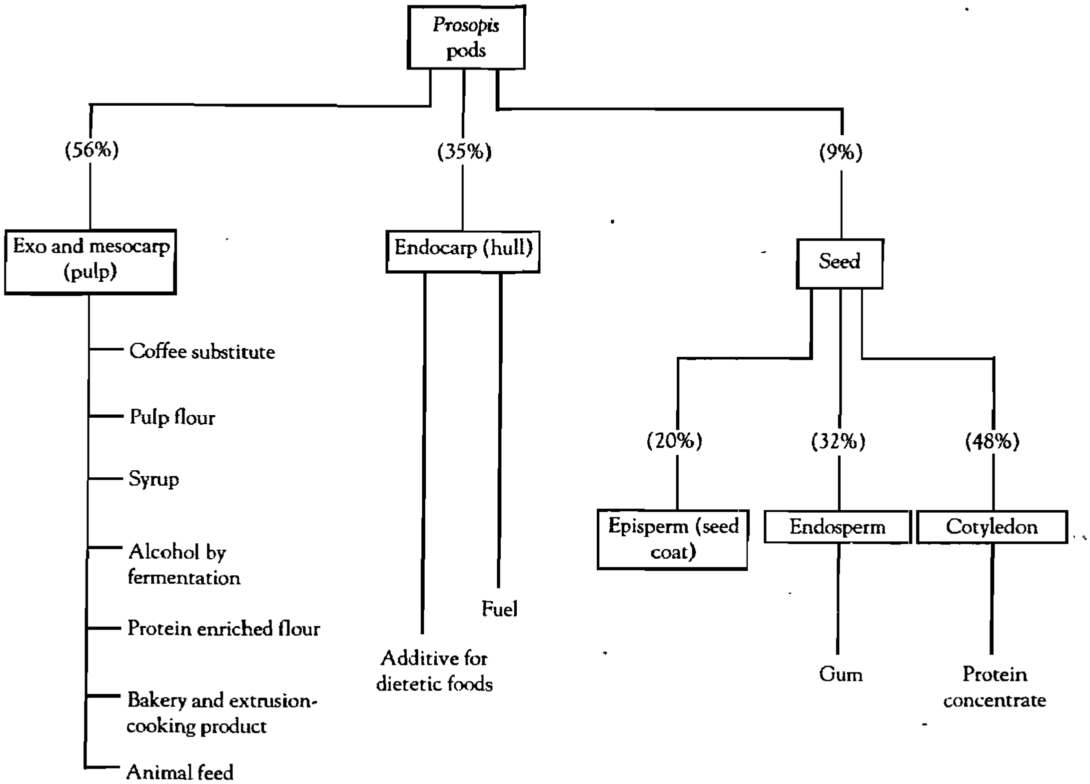
Prosopis juliflora Turned into Wealth

Invasion of *Prosopis juliflora* can be turned into a significant resource for the local population, if the usefulness of this species is recognized from the angle of diverged products from it. The usefulness of *Prosopis juliflora* has long been recognized (Muthana and Arora, 1983; Silva, 1988; Silva, *et al.*, 1988). It is considered to be a valuable tree species of the desert ecosystem. Its multiple use possibilities have attracted growing interest in this species, especially in arid zone. This species is one of the most efficient species to convert energy into biomass as a primary producer. It produces biomass about 25 to 30 t ha^{-1} $year^{-1}$ at the short rotation age of 4 to 5 years (Patel, 1986), It is therefore, necessary to improve the management of this natural resource through scientific and technical studies to obtain various raw materials in perpetuity for agro-industrial utilization. Let us discuss the wealthiest products derived from this species.

Pod Production and its Uses

Prosopis juliflora trees have a tremendous potential for pod production. Pod production is estimated to be about 20 kg $tree^{-1}$ $year^{-1}$ (Shukla *et al.*, 1984), thus, about 10 metric tons/ha (500 trees/ha). The pods are collected twice a year (winter and summer). The maximum pod production is between March and June. Regarding the composition of dried pods, it has been reported that the pods contain: protein, 16.5%; fat, 4.2%; carbohydrate, 57%; fibre, 16.8%; ash, 5.4%; calcium, 0.33%; phosphorus, 0.44% (Vimal and Tyagi, 1986) and 12.46 to 15.51 ppm copper, 22.11 to 22.30 ppm manganese, 18.30 to 28.01 ppm zinc, and 203 to 638.8 ppm iron (Shukla, *et al.*, 1984). Considering arid & semi-arid that contribute 40% (131.6 mha) of total geographical area (329 mha) under *Prosopis juliflora*, and that of 40% (52.64 mha) actually under *Prosopis juliflora*, it is estimated that about 52.64 million tons of pods could be collected from an estimated area of about 52.64 mha in the entire arid zone of India. If 50% of the pods were actually collected, the estimated yield would be about 26.32 million tons, which could provide employment to millions of people and earn hundreds of millions of Rupees as country income.

Fractions and potential uses from processing and separation of *P. juliflora - P. pallida* pods (Adopted from Pasiecznik *et al.*, 2001)



Use of Pod in Animal Feed

Ripe pods are said to have high nutritive value, i.e., rich in sugar and nitrogen and are greedily eaten by most of the herbivorous animals and livestock. Studies on palatability and nutritive value of pods and their source on productive and reproductive status of milking cattle have been conducted by Central Arid Zone Research Institute, Jodhpur under National Agricultural Innovation Project. Crushed or ground *Prosopis juliflora* pods provided good fodder without causing any digestive adverse effect on cattle resulting good animal performance. Further, it can also be mixed with wheat and rice-straw, tumba (*Citrullus colosynthesis*) seed cake, guar (*Cyamopsis tetragonaloba*) korma, til (*Sesamum indicum*) seed cake, ground-nut cake, wheat bran, maize grain and molasses, etc., to make it more nutritious, palatable, and valuable. The Institute has succeeded in preparing highly nutritive livestock feeds from these pods after seed separation. The whole project provides employment to the rural poor through collection of pods. The project also provides a highly nutritive cattle feed that is cheaper than other available cattle feeds.

Use of Pod in Human Food

Prosopis pods were eaten by humans in the Tehuacan valley in Mexico as long ago as 6500 BC (Smith, 1967), and there are other reports relating to the use of pods over one thousand years ago (Towle, 1961). It can be assumed that the use of pods for food and wood for fuel was widespread amongst early man in the Americas. The powder from *Prosopis juliflora* (thorn less) pods contains 13% glucose which can be utilized in making biscuits after adding to it 50% wheat fine flour. During drought and scarcity, the pods are even used as food items by poor people. Because of the high carbohydrate content and good amount of protein, the spongy walls of ripe pods are highly nutritive and used in making meal for humans. Coffee substitute has been made from *P. juliflora* in Brazil (Rocha, 1990), with the roasting of just the coarse pulp flour. Flour is roasted at 120°C until it becomes dark brown, during which time it agglomerates into larger granules requiring further grinding. The final product is used in the same way as filter coffee granules. *Prosopis* coffee substitutes are caffeine free (Vieira *et al.*, 1995). Work at Central Arid Zone Research Institute revealed that 20% coffee powder can be obtained from *Prosopis* pods which have been seen as a cheaper source of coffee than other coffee. A syrup, or concentrated sugary extract from *Prosopis* pods, called 'algarrobina', is commonly made from *P. pallida* in rural areas of northern Peru. This syrup is made from whole or crushed pods which are soaked in water for two hours before pressing and filtering the resulting liquid, and finally concentrating the liquid by evaporation. The dark brown syrup obtained is more viscous than honey and exhibits a peculiar brightness. The process is carried out on a household level in rural Peru using very simple kitchen equipment, and the 'algarrobina' produced is sold in reusable glass bottles (Estrada, 1974; Alza *et al.*, 1998).

Use of *Prosopis juliflora* Wood

Prosopis juliflora can be classified as hard and heavy woods due to their high density (more than 300 kg m^3) and specific gravity (0.70). It is excellent firewood (calorific value is 4800 k cal kg^{-1}) that burns slowly and evenly and holds heat well. Because of its superior quality, it is considered to be one of the best charcoals (Vimal and Tyagi, 1986). Dry wood, on destructive distillation gives 33.9% charcoal, 1.24 methanol and 124.8 litre kg^{-1} of gas (Varshney, 1996). These materials in general have low ash content and high heating value and produce hard and stable charcoal on combustion. *Prosopis juliflora* is hardest of the hard woods and most suitable for charcoal making and electricity generation (Singh, 2008). The traders opined that charcoal from *Prosopis* is preferred than other sources due to its high carbon content and calorific value. Varshney (1996) assumed that 500 trees ha^{-1} produce 24 kg dry biomass at end of five years (12 dry metric tons per 5 years = 2.4 tons $year^{-1}$) and 16.6% wood-to-charcoal yield for 0.4 tons of charcoal per ha-year. Based on this assumption, if 20% of the total area actually covered by *Prosopis* in India is harvested and processed into charcoal each year then, the approximately about 4.21 million tons of charcoal per year is yielded in perpetuity on a five-year cycle. Thus, annually thousands of million bags of charcoal would be available. In this way, thousands of millions man-days of labour could be generated for employment. Rural women in arid and semi-arid areas mostly use wood as fuel. It is estimated that more than 50% of the total fuel wood requirement in arid and semi arid areas is met by *Prosopis juliflora* trees. Larger branches and trunks yield a high quality timber, comparable in colour, finish and physical attributes to Indian rosewood and other commercial hardwoods. 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 (Singh, 2008). In India use of *Prosopis* wood in furniture industries is very limited because of non-availability of straight bole trees and also 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 of *P. juliflora* is soluble to varying degrees in water, sodium hydroxide, alcohol and benzene, which means that it can be successfully pulped for the production of writing and printing papers, textile fibres, tyre cord or cellophane. Tests have indicated that writing and printing papers could be produced from *Prosopis juliflora* logs having 30 to 50 cm in girth with 50% cellulose and 30% lignin (Madan and Tandon, 1991).

Medicinal Value of *Prosopis*

In India, boiling wood chips, a bark extract is used as an antiseptic on wounds, and gum is used to treat eye infections (Vimal and Tyagi, 1986). Research done at Central Arid Zone Research Institute, Jodhpur (Azam *et al.*, 2011) resulted in identification of antioxidant compound which is present in concentrated form (6-8%) in the heart wood of *P. juliflora*. The compound was identified as (-)-mesquitol ($C_{15}H_{14}O_6$) which was compared with existing pharmacologically/therapeutically accepted antioxidant probucol and α-tocopherol and found that (-)-mesquitol is better than probucol and α-tocopherol drugs. *Prosopis* wood is reported to have medicinal value for treatment of rheumatism and against miscarriage. Some of the alkaloids of *Prosopis* species are reported to be antifungal and antibacterial. In Brazil, *P. juliflora* flour is used as an aphrodisiac, syrup as an expectorant and tea infusion against digestive disturbances and skin lesions (Rocha, 1990).

Use of *Prosopis juliflora* Biomass

Prosopis juliflora is 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. It was reported that total biomass from *Prosopis juliflora* ranked first amongst the high biomass producing native trees of arid and semi arid regions of India (Singh, 2008). It provide livelihood security to the rural population, settled in arid and semi arid drought prone regions. *Prosopis juliflora* trees maintain their greenery and continue to grow even during severest of the severe droughts in desert states like Rajasthan. 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. Kuchh region of Gujarat has ample scope for electricity production as *Prosopis* thickets are naturally growing in this tract. Singh (2008) has made tentative calculations 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 per unit. *Prosopis juliflora* biomass is reported to be better for electricity generation because of higher heating value of its biomass.

Use of *Prosopis juliflora* Gum

Prosopis juliflora exudes gum from the sap wood. On average, about 40 g of gum is produced from one plant. However, under drought conditions more gum is exuded. A single person has been estimated to be able to collect 1-2 kg of *P. juliflora* gum/day in India (Tewari, 1998). The trade in exudate gum has been increasing in India, with *P. juliflora* gum estimated to make up approximately 80% of that total gum production in Gujarat (Tewari, 1998). *P. juliflora* gum exudation increased at higher temperatures and ceased completely at the beginning of the rainy season (Tewari, 1998). The gum forms adhesive mucilage, with favourable physical and chemical properties, that can be used as an emulsifying agent. *Prosopis* gum also finds use in confectionery, mending pottery, and as an adulterant and substitute for gum arabic. (Krochmal *et al.*, 1954). Owing to the high content of arabinose, which is easily separable, the gum has proved to be an excellent source of this sugar. Furthermore, the gum contains: D-galactose, 45%; L-arabinose, 24%; L-rhamnose, 13%; and glucuromic acid, 13.7%. It possesses fairly good adhesive strength and can be used as paper adhesive for brown paper and wall paper (Vimal and Tyagi, 1986).

Role of *Prosopis* in Carbon Sequestration

Prosopis trees and woodlands world-wide may account for a significant amount of sequestered carbon, though tree species in arid and semi-arid zones are not considered when calculating carbon balances at present. Felker *et al.* (1990) estimated that carbon stored as woody biomass was equivalent to 2-20 t C ha^{-1} in *P. glandulosa* stands in the USA, with an additional 1.4-18.4 t C ha^{-1} sequestered as reserves of soil carbon, assuming 25% canopy cover (Geesing *et al.*, 2000). While such data is expected to vary greatly between sites and species, they indicate the considerable quantities of carbon stored in woody biomass and soil reserves. Even a single rotation of *P. juliflora* would lead to significant amounts of total carbon sequestered. Using the figures above, it may be estimated that *Prosopis* plantations could sequester carbon in excess of 1000 kg ha^{-1} yr^{-1}, with a yet unseen value in the emerging global market for 'carbon credits'. Arid zones presently contain the lowest levels of carbon in the world on a per hectare basis, and it is necessary to consider the role of arid zone forests in carbon sequestration on a regional and global level.

Soil Reclamation by *Prosopis juliflora*

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 calcium, which exchanges with sodium on the exchange complex. Being highly tolerant to soil sodicity, the *Prosopis* roots open up otherwise impermeable sodic soil and thus facilitate 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 acid facilitate dissolution of precipitated calcium carbonate already present in sodic soils. Thus, help in reclamation of the sodic soil. It reclaims the soil to such an extent that agricultural crops can be grown without amendments.

Prosopis juliflora Combating Desertification

Desertification is an international problem and *P. juliflora* is solution to this. No single species should ever be seen as the sole answer but rather as a tool in the continuing fight against desertification, land degradation and resource depletion. Shelterbelts of *P. juliflora* and *P. pallida* are planted around fields in many semi-arid regions to reduce wind speed. This reduces wind-induced soil erosion, decreases desiccation by reducing transpiration and consequently increases plant and animal production. Shelterbelts can comprise one or more rows of trees, commonly three but up to ten. In India, shelterbelts of *P. juliflora* were found to have a positive effect in reducing soil erosion compared with other species and control plots. Gupta *et al.* (1983) noted a 36% reduction in the magnitude of wind erosion behind *P. juliflora* shelterbelts. Shankarnarayan and Kumar (1986) noted a decrease in area wind speeds of 33-38%, 17-26% and 12-21% at distances of 2, 5 and 10 times the height of the trees, with consequent reduction in the quantities of soil removed by erosive forces. In Sudan, wind speed was reduced by an average of 14% inside *P. juliflora* plantations, and with reductions up to 36% at high wind speeds (El Fadl, 1997). Seed disposal of this species on vast areas has helped natural regeneration and produced significant results in creating green belts and windbreaks to check the rapidly spreading problem of desertification.

Conclusion

Gone are the days when *Prosopis juliflora* was considered to be a weed. Due to its multiple uses, it has gained public acceptance as a plant of recognized economic value. Today it is the tree species utilized for its each and every part in various ways on a commercial basis. *Prosopis* pods are a good source of livestock fodder feed in drought prone areas which is cheaper, more nutritious and locally available fodder resource. Its larger branches and trunks yield a high quality timber, comparable in colour, finish and physical attributes to Indian rosewood and other commercial hardwoods. Fruit pods are high in sugar and protein and are a rich food source for man and beast. *Prosopis* exudate gum is comparable to gum arabic. *Prosopis juliflora* is hardest of the hard woods and most suitable for charcoal making and electricity generation. The tree has played a pivotal role in combating desertification and drought through its intensive plantation on refractory areas to enhance their eco-stability. Their importance is positive, in terms of the provision of raw materials, but also negative, in terms of weediness reducing agricultural productivity. Hence, time has come to pool the scientific and research findings for multiple agro-industrial uses of *Prosopis juliflora*. The inherent capacity and potentiality of *Prosopis* can be converted into an even greater asset besides generating tremendous local employment opportunities and numerous benefits through application of scientific and technical methods.

Future Possibilities

It is necessary to explore the feasibility of obtaining new products from *Prosopis juliflora* such as activated carbon, gas, organic acids, acetic acids, methanol, acetone, etc. through wood distillation. There is also a possibility of extracting carotene from its green leaves. The foliage, along with other organic matter, could be used as a green manure or compost.

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