ISSN: 2321-4902
Volume 1 Issue 3

Online Available at www.chemijournal.com

International Journal of Chemical Studies

Prosopis julifera: A review

Pragnesh N. Dave [1]*, Jaya Bhandari [2]

1. Department of Chemistry, K.S.K.V. Kachchh University, Bhuj (INDIA). [E-mail: pragnesh7@yahoo.com]
2. Department of Chemistry, K.S.K.V. Kachchh University, Bhuj (INDIA) [E-mail: jaya_delhi@rediffmail.com]

Prosopis juliflora is one of the most economically and ecologically important tree species in arid and semi-arid zones of the world. *Prosopis* species are all trees or shrubs of varying sizes, predominantly xerophilous, aculeate, spiny or rarely unarmed. The chemistry of *P. juliflora* is well established having alkaloids, flavonoids and tannins. All parts of *P. juliflora* have a wide range of uses. In view of the immense importance of the plant, this review is an effort to compile information reported on the plant. The present review is an attempt to generate interest regarding the immense potential that is present in *Prosopis juliflora.*

Keyword: Prosopis juliflora, Tree Structure, Biology, Carbon Sequestration, Uses

1. Introduction

Prosopis juliflora is one of the most economically and ecologically important tree species in arid and semi-arid zones of the world. It is an important species because of its high nitrogen fixing potential in very dry areas and in drought seasons and also because of it provides shelter and food to many species of animals on its nectar, pollen, leaves and fruits [1, 2]. The shrubs of *Prosopis juliflora* (Fig. 1) are highly esteemed for windbreaks, soil binders, sand stabilizers, living fences, fuel wood, bee plants and animal feed [3]. These uses, together with fast growth [4], drought resistance [5] and salt tolerance [6] have lead to its introduction in many arid zones [4, 6, 7, 8]. The genera *Prosopis* and *Acacia* contain some of the most widespread and important tree species in the arid and semi-arid zones of the tropical and subtropical world. Species of these two genera have been estimated to occupy some 3.1 million square kilometres [9]. *Prosopis julifera* grows abundantly in Indian sub-continent [2, 10, 11, 12, 13, 14] and commonly it is known as Mesquite (English), Algarroba (Spanish), Vilayati babul, Vilayati khejra, Gando baval, Vilayati kikar (India).

Fig 1: Tree Canopy of *Prosopis juliflora*

The genus *Prosopis* is thought to be evolved approximately 70 million years ago, before the African and South-American continents separated [15]. *Prosopis* genus cropped up in the American sub-continent with two centers of diversity, the Texan-Mexican and the Argentinean center [16] having a large number of sympatric species.

Studies using morphological characters [17], isoenzymes [18, 19], seed protein electrophoresis [20] and molecular markers [21] have shown the occurrence of intra- as well as inter-series hybrids in populations of both sections of Algarobia and Strombocarpa. Pasiecznik *et al*.[22] suggested the grouping of species of section Algarobia into 'complexes' or 'species groups' principally according to their genetic similarity and geographic distribution, but also to their habit and resource characters.

In India, original introductions are thought to have been *P.juliflora* from Mexico or Jamaica [23, 24]. Differences in plant morphology may be due to further introductions of seed material of various origins and possible hybridisation between them. Five forms of *P. juliflora* have been identified in India [25].

Considerable amount of literature is present on *Prosopis juliflora* however, a synthesis of this information into comprehensive, concise and authoritative review is rare. Here is an attempt to synthesize the information available on *Prosopis juliflora*.

2. General Tree Structure

Prosopis species are all trees or shrubs of varying size (rarely sub-shrubs) (Fig.1), predominantly xerophilous, aculeate, spiny or rarely unarmed [16].

2.1 Tree size and form

Tree size and form vary considerably between species, populations and individuals both due to genetic and environmental influences. *P. juliflora* normally reaches a maximum height of 12 m [16, 26], but can also reach upto 20 m favourable conditions (e.g. Singh and Singh [27]). Some also exist as shrubs as low as 3 m high. The trunk is short and often crooked or twisted, reaching a diameter of ~65 cm. The bark is grey-brown, rough and fibrous, varying from finely fissured to furrowed. Tree forms vary from erect trees to flat-topped trees and also trees with decumbent branches touching the ground. The shrub form can also vary from erect sub-shrub to prostrate shrub form. Both trees and shrubs are generally multistemmed, with much forking beginning low on the trunk, although more erect and less branched land races are known. In decumbent tree forms, branches are upright at first but take a horizontal form before becoming pendulous at distal ends, occasionally touching the ground. Prostrate forms are more common in younger trees, which develop more upright stems as they mature. Smaller branches are green or greenish-brown and take on a zigzag appearance [28]. Nevertheless, environmental variables such as thin soils, presence of hard pan or persistent wind are also observed to induce the formation of *Prosopis juliflora*.

2.2 Seedling

Fig 2: Seeds of *Prosopis juliflora*

Seeds of *P. juliflora* are epigeous in germination. The fleshy cotyledons are the first seed leaves, persisting after the first true leaves have formed, being green or somewhat pale-green in colour (Fig. 2). Once germinated, most energy is expended on rapidly developing a root system and locating a water source as soon as possible. In the first months, root length and biomass increases are much greater than shoot biomass leading to a high root: shoot ratio [22].

2.3 Root system

Roots develop rapidly following germination and can reach a depth of upto 40 cm in eight weeks.

There are two distinct root systems formed under normal conditions of unimpeded root development. These are, characteristically, a deep root system and a superficial root system, both having different functions during different seasons. The deep root system is made up of one, two or three (rarely more) main tap roots, which may divide at lower depths. They have the function of anchoring the tree but are primarily for sourcing ground water reserves, whether watertable or other subterranean supply. They can become very thick and tens of metres long until a permanent water source are found[22]. The young roots of *P. juliflora* are cream coloured with a translucent cortex, while old roots are pale brown with a semi-opaque cortex. Root density of *P. juliflora* is 3 cm of root/cm^3 of soil in the upper 15 cm of the soil profile, dropping to less than 0.5 cm root/cm^3 of soil at below 45 cm depth, and less than 0.2 cm root/cm^3 of soil at 1.8 m depth.

2.4 Wood structure

The total volume of wood in *P. juliflora* is divided between its microscopic constituents into: fibres 48%, vessels 18%, rays 18% and axial parenchyma 16%. The anatomical description of *P. juliflora* wood mostly comprises of two descriptions one by Gomes and de Muñiz [29] (Fig. 3) based on samples from Brazil and by Kazmi and Singh [30](1992), based on samples from India. The wood of *P. juliflora* is diffusely porous in its gross structure [29, 30].

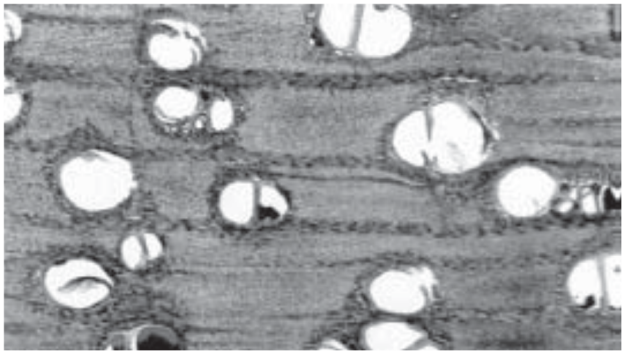

Fig 3: Section of Prosopis juliflora wood (x30) [29].

Growth rings of *P. juliflora* are occasionally demarcated by darker and denser zones of fibrous tissues, visible to the naked eye, and also by a fine interrupted line of parenchyma cells visible only under a magnifying glass [30]. Medium sized vessels are formed at the beginning of the growth ring, coinciding with the beginning of the rainy season in Brazil [29]. Vessels are small to moderately large, visible to the naked eye or with a 10X lens. They are mostly solitary but sometimes in radial multiples of two to four vessels or in short clusters. Vessels are moderately few to numerous (2-12/mm^2), with vascular lines irregular to slightly tortuous in tangential view, somewhat unevenly distributed, and with a circular or oval cross section, polygonal in multiples, usually open and occasionally filled with organic deposits [29, 30]. Vessel elements are very short to short (approximately 0.2 mm long), small to large in diameter (0.1-0.2 mm wide), with or without short appendages. The perforation plate is exclusively simple, transverse in larger vessels to slightly oblique in smaller ones [29].

Fig 4: Thorns of *Prosopis juliflora*

Intervascular pitting is alternate, circular to elliptic with a narrow aperture and distinctly vestured, similar to vessel-parenchyma pits and ray-parenchyma pits. Parenchyma cells are often abundant, visible to the naked eye and distinct

under a hand lens as lighter coloured patches or thick sheaths around vessels, sometimes connected obliquely or tangentially. They also appear as fine interrupted lines delimiting growth rings, both abundant and visible to the naked eye [30], or not abundant and visible only with difficulty with a 10X lens [29]. Parenchyma cells are paratracheal, vasicentric and mostly aliform to fluent, enclosing several vessels, particularly in late wood and delimiting growth rings, also with apotracheal parenchyma present. Parenchyma cells are fusiform and seriate, in strands of 2-4 cells (0.2 mm long), frequent and often subdivided into locules with solitary rhomboidal crystals [29, 30].

2.5 Thorns

Armature consists of cauline, axillary spines which are geminate and divergent. Spines are straight, multi or uninodal, solitary, paired or solitary and paired on the same branch. Spines are produced on new growth, and tend to be largest on strong basal shoots and prominent on young branches. They become shorter on older stems due to incorporation of spines during wood growth and diameter increments in the stem and branches, and may become absent on older wood. Trees vary in the number and size of thorns, which may be absent or not on all branches. Thorns can be rare or profuse, long or short, thin or stout, 0.5-7.5 cm long and 2-5 mm in thorn base diameter (Fig 4) [22].

2.6 Leaves and Flowers

Leaves are bipinnate, with 1-10 leaves per node and petiole plus rachis 5-20 cm long [31]. Trees are aphyllous or sub-aphyllous, with a rapid turn-over of leaves. Pubescence varies from entirely glabrous or ciliolate to somewhat pubescent or pubescent [16, 28]. Leaflets are linear-oblong, elliptic-oblong or ovate in shape, with an obtuse to mucronulate or minutely pointed apex, nerved below. Leaflets vary greatly in size, 2.5-23 mm long and 1-7 mm wide (Fig. 5). Glands are cupuliform, sessile with an apical pore, present at the junction of the pinnae, sometimes also at the junction of the leaflets [16,26,31]. While trees are generally evergreen, *P. juliflora* is occasionally deciduous, possibly due to drought or cold temperature [32].

Fig 5: Leaves and Flow ers of *Prosopis juliflora* (After Francisco Manuel Blanco (O.S.A.) 1880-1883[Atlas II]).

Flowers are small, 4-6 mm long, gathered densely together on cylindrical, spike-like inflorescences known as racemes. They are generally yellow, straw yellow or yellow-white in colour. Flowers are hermaphrodite, sometimes sterile, actinomorphic and pentamorous[16]. The calyx is campanulate, green or greenish-yellow, bell-shaped and ciliolate outside, 0.5-1.5 mm long. The corolla is 3.0-3.2 mm long, styles 2.0-3.0 mm long, petals 2.5-3.0 mm long, free and villous within[26].The five stamens are 4-7 mm long, pistils 4-5 mm long, and the stipitate, villous ovaries are light green in colour and 1.5-1.8 mm long[26]. Anthers have a glandular appendage [33]. The pedicel is short, 0.5-3.0 mm long [22].

2.7 Fruit and seed

The fruit is an indehiscent legume, straight with an incurved apex, sometimes falcate or sub-falcate, with or without parallel margins. Pods are stipitate and acuminate, compressed to sub-compressed and sub-moniliform. They are flattened, rectangular to sub-quadrate in section. Immature pods are green in colour, becoming

commonly straw yellow when fully mature [22]. The number of pods produced per inflorescence varies greatly, with 1-16 fruit per inflorescence. Pods also vary greatly in size, 8-40 cm long, 9-18 mm wide and 4-10 mm thick [16,26,31]. Pods are made up of an exocarp, a fleshy mesocarp, and endocarp segments each containing a single seed, with up to 30 seeds per pod. Exocarps vary in their thickness, external colour and ease of separation from the mesocarp but are generally consistent. The relative proportion of mesocarp in the pod varies greatly, affecting pod thickness and chemical composition, of particular note being the content of sugars and proteins. The fibrous endocarps each contain a single compressed, ovoid or oblong seed. Seeds are brown in colour, shiny and with a horseshoe-shaped fissural line on both surfaces of the testa, with the arms pointing towards the hilar end. Seeds are up to 6.5 mm long and weigh approximately 0.25-0.30 g (25000-30000 seeds/kg). Inside the tegmen is the endosperm, which is hard, mucilaginous, corny or vitreous, which surrounds the yellow cotyledons. The cotyledons are round or elliptical, with a sagitate base and frequently do not cover the upper part of the radicle [22].

3. Biology

3.1 Species

The genus *Prosopis* Linnaeus emend. Burkart is in the family Leguminosae (Fabaceae), sub-family Mimosoideae. The placing of *Prosopis* in the wider taxonomic classification system based on Elias [34] and Lewis and Elias [35]:

Family:	Leguminosae	650 genera, 18,000 species
Sub-family:	Mimosoideae	50-60 genera, 650-725 species
Tribe:	Mimoseae	5 tribes
Group:	*Prosopis*	9 groups
Genus:	*Prosopis*	4 genera

The name *juliflora*, comes from *julus*, meaning 'whip-like', referring to the long inflorescences, and *flora* being the flower. *Prosopis juliflora* (Swartz) DC. has had an array of synonymy since its first description in 1788. Originally known as *Mimosa juliflora* Swartz, it became both *Algarobia juliflora* (Swartz) Bentham ex Heynh. and *Neltuma juliflora* (Swartz) Rafinesque during the last two centuries. *P. juliflora* is used here in its original, restricted and certainly biological sense, re-established by Burkart[36] and accepted by Johnston[32].

3.2 Chromosome number

Leguminosae have a base chromosome number of n=7, with n=14 established early in their evolutionary history, followed by descending aneuploidy to n=13 or lower [37]. Only seven genera within the Mimosoideae, including *Prosopis* have n=14 showing their relative antiquity [37]. Bukhari [38] had found no aneuploidy or B-chromosomes and concluded that the direction of chromosome evolution was towards increasing chromosome number. The chromosome numbers of most recognized species of *Prosopis* have been determined, where all taxa are having diploid with a haploid number of n=14 (2n=28), with the exception of *P. juliflora* which also has tetraploid forms (2n=56) [39, 40]. False tetraploidy interpretations have been explained by the fact that polysomaty is common in the root tip squashes used for analysis[16], or due to inaccurate counting procedures[41]. *P. juliflora* has diploid and tetraploid forms (x=14, 28, 56, 2n=28, 56, 112) but are rarely diploid.

4. Ecology

The natural distribution of the genus *Prosopis* includes arid and semi-arid zones of the Americas, Africa and Asia. The native range of *Prosopis* species can be approximately divided into five regions, simply defined as Asia, Africa, North America, Central America and South America. Although there is some overlap on to neighbouring continents, each of the five regions are geographically distinct. Asian species of section *Prosopis* are native to the Middle East, stretching east to India, north to Georgia and Turkmenistan and west to Algeria along the North African coast.

5. Chemistry of *Prosopis juliflora*

Prosopis commonly called mesquite is a prominent member of the flora. *Prosopis juliflora* complex been investigated taxonomically [32, 36, 42, 43] but it has also been the subject of ecological studies [44, 45]. The flavonoids, one of the most bioactive compounds naturally existing in the plant kingdom [46]. A total of 21 flavonoids were found in populations representing the five species of *Prosopis*, two varieties and a putative hybrid. Twelve of the flavonoids have been identified: 6 flavones--apigenin, luteolin, apigenin 6,8-di-C-glycosides, chrysoeriol 7-O-glucoside, luteolin 7-O- glucoside, and 6 flavonols--kaempferol 3-O-methyl ether, quercetin 3-O-methyl ether, isorhamnetin 3-O-glucoside, isorhamnetin 3-O-rutinoside, quercetin 3-O-rutinoside, and quercetin 3-O-diglycoside (glucose, arabinose) (Table 1).

Table 1: Percentage of occurrence of Flavonoids in *Prosopis juliflora* (Bragg et al., 1978)

S.N		*Prosopis juliflora*
1.	Apigenin	100
2.	Luteolin	75
3.	Apigenin 6,8-di-*C*-glycosides	100
4.	Apigenin 6,8-di-*C*-glycosides	100
5.	Chrysoeriol 7-*O*-glucoside	100
6.	Luteolin 7-*O*- glucoside	50
7.	Kaempferol 3-O-methyl ether	100
8.	Quercetin 3-O-methyl ether	75
9.	Isorhamnetin 3-O-glucoside	100
10.	Isorhamnetin 3-O-rutinoside	100
11.	Quercetin 3-O-rutinoside	100
12.	Quercetin 3-O-diglycoside (glucose, arabinose	25

Nine additional compounds are also present but only in trace quantities [47]. Members of the *P. juliflora* population exhibit a total of 14 flavonoids. In contrast to their considerable morphological variation [32, 36, 42, 43], all members of the *P. julilora* complex exhibit similar flavonoid patterns. The relatively stable flavonoid chemistry also contrasts with the ecotypic differentiation within the complex [44, 45, 46].

Sucrose-phosphate synthase (UDP glucose: D-fructose-6-phosphate-2-glucosyltransferase; EC 2.4.1.14) is one of the key enzymes of the sucrose biosynthesis pathway [48]. The enzyme catalyses the formation of uridine-diphosphate (UDP) and sucrose-6-phosphate from uridine-diphosphate glucose (UDPG) and fructose- 6-phosphate (F6P). Sucrose-phosphate synthase (SPS) had been purified 4200-fold from the leaves of *Prosopis juliflora* and resulted in a final specific activity of 467 nkat mg-1 protein [49]. The Mr of the native enzyme was 443 by gel filtration. The enzyme showed marginal sensitivity to –SH reagents, and the activity could be restored with DTT [49].

Seed galactomannans, commonly known as seed gums [50], have widespread industrial applications in food paper, textile, petroleum, pharmaceuticals and cosmetics [51]. They are mostly found in the endosperm of leguminous seeds as cell wall storage components and energy reserves. *P. juliflora* seed gum was identified as a galactomannan with a Gal:Man (1:4.2) [52] and with a close similarity to guar and carob polysaccharides. Galactomannans have the fundamental structure consisting of a main chain of b-(1-4)-D-mannopyranose units substituted by single a-D-galactopyranose units at O-6, although there are few deviations from this basic structure. 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. Determination of the distribution of (1-6)-linked, a-D-galactopyranosyl side groups along the (1-4)-linked b-D-mannan chains in legume seed galactomannans has so far been attempted by X-ray diffraction analysis [53,54], degradation by purified 3-D-mannanases [55], specific methods of chemical degradation [56, 57, 58], methylation analysis after periodate oxidation [59, 60] and theoretical analysis of periodate-oxidation kinetics [61, 62, 63]. Purify *P. juliflora* galactomannan obtained by separation of the endosperm from the embryo and seed coating followed by extraction of endosperm with hot water to evaluate their structure by NMR [64]. The extraction procedure used resulted in a pure gum and well-defined spectra. The NMR study, in spite

of the low accuracy of the assay (±5% to 10%), allowed to establish for *P. juliflora* seed polysaccharide a Gal:Man ratio of 1.0:1.1, as determined by the relative areas of the anomeric substituted and non-substituted signals of the ^{1}H (Fig. 6)and ^{13}C (Fig. 7 and Table 2) NMR[64].

Comprehensive investigations on *P. juliflora* have been carried out. In regard to the same Monocyclic diketone, prosopidione, has been isolated from the leaves of *Prosopis juliflora* [65]. Its structure was determined by spectral methods. Prosopidione was isolated as a white amorphous powder. The EI and FD mass spectra, IR spectrum, UV spectrum, NMR spectrum and APT spectrum has showed the presence of four methyl, two methylene, four methane and three quarter carbon [65]. In view of the theraupeutic importance attributed to *P. juliflora*, bounteous investigations have been carried out by Siddiqui and Murthi [66], Ahmed *et al*. [67], Ahmed and Qazi [68]. From the studies on fresh leaves Ahmad *et al*. [67], and Ahmad and Qazi[68] reported the isolation and structure elucidation of alkaloids juliflorine, julifloricine and julifloridine. Further Ahmed *et al*. [69] isolated two new alkaloids juliprosinene and juliflorinine. The alkaloid juliprosinene has showed antibacterial activity against *E. coli* strains, *K. pnemoniae, P. aeruginosa, S. aureus* and *S. sonnei* [69].

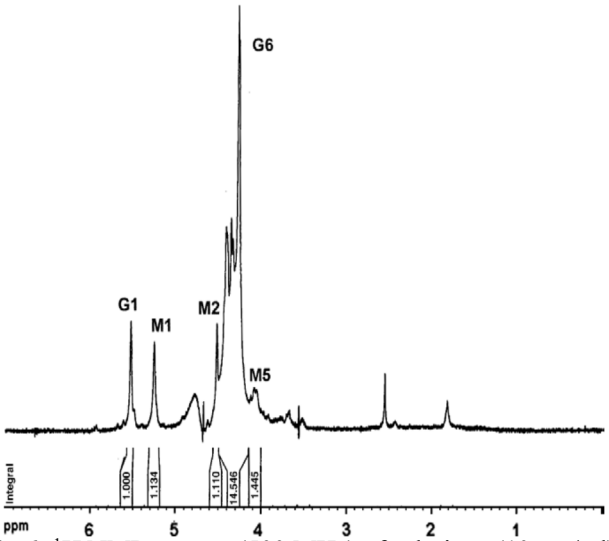

Fig 6: ^{1}H NMR spectra (500 MHz) of solutions (10 mg/ml) in D2O of the galactomannans from *Prosopis juliflora*[64].`

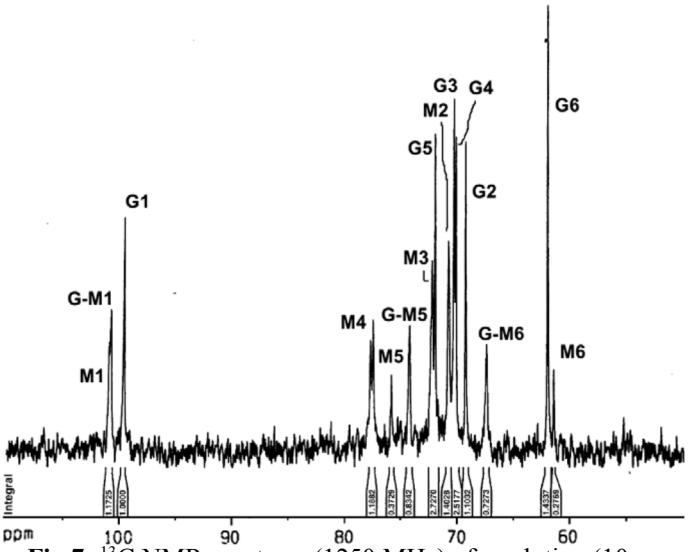

Fig 7: ^{13}C NMR spectrum (1250 MHz) of a solution (10 mg/ml) in D2O of the galactomannans from Prosopis juliflora [64].

Table 2: Peaks in ^{13}C NMR spectra of *Prosopis juliflora* seed galactomannans[a] [64]

Type of unit	C-1	C-2	C-3	C-4	C-5	C-6
α-D-Galactopyranosyl	99.63	69.25	70.29	70.12	71.96	61.94
β-D-Mannopyranosyl, unbranched at HO-6	100.77	70.75	72.21	77.47	75.84	61.40
β-D-Mannopyranosyl, branched at HO-6	100.77	70.75	72.21	77.69	75.84	67.39

[a] Shifts ppm downfield from internal sodium 3-(trimethylsilyl)-propionate

P.juliflora leaves have been used as feeding cattles and humans. Intoxication with plant has been reported and is characterized by neuromuscular alterations and gliosis. Silva et al. [70] study demonstrated that some alkaloids from *P.juliflora* leaves act directly on glial cells,

including either their activation or cytotoxicity. Chromatographic analyses have disclosed that the F32 fraction can be a pure substance and is the most toxic fraction. Therefore, Silva *et al*.[70] suggested that among the active components present in the *P. juliflora* total alkaloidal extract, the F32 fraction would be more effective in inducing cytotoxicity and reactivity in glial cells. The characterisation of its chemical structure contribute to a better understanding of its mechanism of action in glial cells and of its impact on the viability of neurons associated with alkaloids from *P. juliflora*.

Plant growth and productivity are adversely affected by various abiotic stress factors. *Prosopis juliflora* is a hardy plant reported to be tolerant to drought, salinity, extremes of soil pH, and heavy metal stress. George and Parida [71] reported the characterization of a cDNA clone for a putative nonspecific lipid transfer protein (*P.juliflora* LTP1) found abundantly in a drought stressed leaf cDNA library of *P. juliflora* and its promoter. A multiple sequence analysis of *P.juliflora* LTP1 revealed high similarity at the amino acid level. Northern analysis of *P. juliflora* LTP1 in *P. juliflora* leaves under oxidative stress revealed steady upregulation at the time points analyzed. A 929-bp fragment was isolated from the 5′ end of *P.juliflora* LTP1, and transient reporter gene expression studies revealed it to be a functional promoter. Several cis-acting elements previously reported to function in stress response were found in this promoter [71].

6. Carbon Sequestration by *Prosopis julifera*

Carbon (C) sequestration, transfer of atmospheric CO_2 into other long-lived pools (geologic, oceanic, terrestrial), is an important strategy to mitigate climate change caused by increasing concentration of radiatively-active gases in the atmosphere. In contrast to the engineering techniques of geologic and oceanic sequestration and of chemical transformations through mineralization of CO_2 into stable compounds, C sequestration in terrestrial ecosystems (i.e. soils, trees and other vegetation) is a natural process based on photosynthesis and humification of biomass[72, 73, 74, 75, 76]. Dryland ecosystems which cover about 47.2% of the earth's land area[73] are defined as regions in which the ratio of total annual precipitation to potential evapotranspiration (P:ET or the Aridity Index, AI) ranges from 0.05 to 0.65, and include dry sub-humid regions (AI = 0.50–0.65) covering 9.9%; semi-arid regions (AI = 0.20–0.50) covering 17.7%; arid regions (AI = 0.05–0.20) covering 12.0%; and hyperarid regions (AI = <0.05) covering 7.5% of the earth's land area[73, 77, 78, 79].

Tree-based land-use systems sequester carbon in soil and vegetation and improve nutrient cycling within the systems. Tree and grass species sequester carbon and nitrogen cycling in silvopastrol systems in highly sodic soils [80]. Saline and sodic soils are of widespread occurrence in the arid and semiarid regions. As afforestation and reclamation agroforestry systems have been reported to improve the biological production of sodic soils[81, 82], *Prosopis juliflora*, growing on sodic soils, shows increase soil organic matter content and bioavailability of inorganic nitrogen [83, 84].

The genus *Prosopis* contains many N-fixing species throughout the world's semi-arid regions. The high percentages of Nitrogen fixation (Ndfa) in wood and leaves indicates that *Prosopis* is actively fixing N. Furthermore, the levels of N and C are present in quantities that are very significant in economic and ecological terms. As the trees become larger, the percent of both N and P in the leaves increases, so does the level of soil N and P [85].

In the semiarid and arid part, mesquite (*Prosopis juliflora* (SW.) DC.), huisache (Acacia farnesiana (L.) Willd.) and catclaw (Mimosa biuncifera Benth.), N_2-fixing trees or shrubs, dominate the landscape. It is unknown, however, how much the leaves of those shrubs contribute to dynamics of carbon (C) and nitrogen (N) in soil. Arreola et al.[86] investigated leaves of each species to soil sampled under the canopy of mesquite, huisache, and catclaw and outside their canopy while monitoring production of carbon dioxide (CO_2),

and dynamics of inorganic N (ammonium (NH_4^+) and nitrate (NO_3^-)) in aerobic incubation. The lignin and polyphenol content was observed to be larger in the mesquite leaves. 49% of C was added with *P.juliflora* leaves mineralized in 42 days [86]. In addition only 6% of organic N of the mesquite leaves were mineralized which confirms a positive effect on the arid and semi-arid ecosystems as they increased soil organic matter and soil N content. They increase soil organic matter and soil N content through symbiosis with N_2 fixing bacteria, prevent erosion and runoff, improve water infiltration and soil structure, and their deep rooting system can take up nutrients and water from the subsoil. The microbial activity as witnessed by the emission of CO_2 was larger for soil sampled under canopy of the N_2 fixing shrubs than outside it, and higher for the taller shrubs. Addition of leaves increased production of CO_2 and between 40% and 50% of the organic C of the leaves was mineralized, but the amount of inorganic N released from them was minimal [86].

7. *P. juliflora* as a resource

P. juliflora, a member of Mimosaceae family which grows abundantly in Indian sub-continent is known for its various properties which have been widely used in various fields.

7.1 Wood

The constituents of woody biomass can be divided into cellulose, hemi-cellulose, lignin, extractives, ash and water. Levels of hemi-cellulose in *P. juliflora* have been estimated at 25-30%, cellulose 40-45%, lignin 11-28% and extractives 3-15% [87]. Rajput and Tewari [88] found 54% cellulose and 31% lignin, while Madan and Tandon [89] found 70% holocellulose and cellulose combined and 20% lignin. Ash levels of *P. juliflora* wood were found to be low, at 0.5- 0.6% by Patel and Safaya [87], Rajput and Tewari [88] and Madan and Tandon [89]. Goel and Behl [90] reported a higher ash content of 1.6%, with even higher contents of 1.8-4.8% reported by Khan *et al.* [91] and 7.1% in wood and 11.8% in *P. juliflora* bark by Sharma [92]. Sharma [92] worked on the chemical constituents of the wood of *P. julifera* and found N (0.39%), P (0.02%), K (0.70%), Ca (1.85%), Mg (0.38%), Na (4.17%).

7.2 Fruit (Pod)

The fruits of the *P. juliflora* are indehiscent pods, generally pale yellow in colour. A pod consists of three separable components: exo- and mesocarp (pulp), endocarp (fibrous hulls) and seeds. The seeds are enclosed in the endocarp, which can be opened by hand only with difficulty. There is an average of 25 seeds per pod [93, 94]. The seeds are small and very hard, approximately 5 mm in diameter, ovoid in shape and weigh about 40 mg. Seeds are made up of three parts, an episperm being the thin, brown seed coat, the endosperm which is adhered to the seed coat, and the cotyledon. The pulp represents 56% of the total weight of the fruit. The main soluble component of the pulp is sucrose (46%), representing over 90% of total soluble sugars, while the reducing sugars, glucose, fructose and xylose, are present in very small amounts [22, 95, 96]. Talpada [97] found that sugar content of *P. juliflora* pods varied from 13% to 20% in different seasons and years showing a strong environmental effect on pod compositions. Soluble sugars from the pericarp of *P. juliflora* comprises of 75% sucrose, 12% being fructose, 5% glucose, 5% inositol and 1% raffinose [98].

7.3 Leaves

The composition of the leaves of *P. juliflora* can be divided into basic extractives (Protien (26.3%), Fibre (24.8%), Extract (8.5%), Ash (1.4%), Nitrogen free extract (31.8%)[99] and mineral elements (macronutrients and micronutrients) (N, P, K, Ca, Mg, Na [92, 100, 101, 102]. Leaves are composed principally of lignin and cellulose in the cell walls to give rigidity to the leaf structure. Comparison of the proximate analysis of various authors show high levels of crude protein (14-26%) and crude fibre (21-25%), with ether extract (fat) of 3-9%, nitrogen free extract (carbohydrate) at 30-46% and highly variable levels of ash (1-16%). Elemental mineral content assessed by

different authors is in approximate agreement. Nitrogen content is generally high, ranging from 3.1% to 5.6%, as is potassium (1.2-3.1%). Levels of phosphorus are generally low, 0.1-0.3%, with a single value of 0.9%. Calcium levels are 0.4-4.2% and magnesium content is 0.3-0.8% [22]. Drumond [103] found that *P. juliflora* had lower levels of macronutrients than six other *Prosopis* species tested. Leaf contents of Na, Cu, Fe, Zn and Mn have also been assessed but comparison of data derived using differing methods of analysis is not possible. Leaves are rich in essential amino acids but low in sulphur containing amino acids [104]. Tannins, flavonoids and polyphenols are present in leaves of *P. juliflora* and *P. pallida* [47, 105, 106]. Leaf tannin content is generally high, at 0.8% [100] or 1.9-2.0% [106]. Alkaloids and other chemical compounds are also present.

7.4 Gum

The exudate gum from *P. juliflora* appears as a viscous liquid exuding from the trunk or branches of the tree, before drying and becoming solid. The colour can vary from translucent to yellowish, generally amber, becoming darker with age. *Prosopis* gums are soluble in water with a low viscosity. They are odourless and have little taste, are non-crystalline and non-soluble in alcohol or ether [106]. The intrinsic viscosity of *P. juliflora* was assessed as 14 ml/g [107]. The sample of *P. juliflora* analysed by Anderson and Farquhar [107] was found to be having a lower methoxyl content, a negative optical rotation, smaller nitrogen and arabinose contents and a higher proportion of rhamnose. The work by Azero and Andrade[108] have revealed that *P. julifora* seeds possess properties of gum that are similar to those of guar gum and can be used as alternative gum for commercial purposes.

7.5 Tannins

The tannins of *P. juliflora* and *P. pallida* are complex organic structures, comprising of phytogallotannins and pyrocatecollic tannins [109]. Alves *et al.*[110] reported new tannin in *P. juliflora* roots. Tannin content of the pods and leaves of *P. juliflora* but it is the bark, stem wood and root wood With *P. juliflora*, Kazmi and Singh [30] found 3-8% tannin in bark and root wood, Patel [87] found 3-8% tannin in bark and up to 9% in wood, while Vimal and Tyagi [99] found 6-7% tannin tannin in root wood. Tan extract from all plant parts of *P. juliflora* is yellowish. Tannin in *P. juliflora* roots was found to be unsuitable for tanning purposes by Vimal and Tyagi [99]. Tannins are also used in the petroleum industry, mixed with sodium hydroxide, to reduce the viscosity of drill mud, and also for making ink.

7.6 Allelopathy

Allelopathy has been defined as any direct or indirect beneficial or detrimental effect of one plant on another (including microorganisms) via release of chemical compounds to the environment [111]. Mesquite inhibits the germination or growth of many plant species growing in its vicinity through the release of allelochemicals in exudates from leaves, roots or fruits [10, 12, 112]. There are many bioactive alkaloids [113]. Julifloridine, which contains a piperidine ring, and its N-methyl derivative N-methyljulifloridine, isolated from the extracts of mesquite leaves [58, 114, 115]. Juliflorine (juliprosopine) which has two piperidine rings and a hexahydroindolizine ring, and its stereoisomers julifloricine and juliflorinine were isolated from the extracts of leaves of both mesquite and Prosopis glandulosa [116, 117, 118, 119]. Juliflorine (juliprosopine) possesses antidermatophytic, antibacterial, and DNA binding activities [67, 119, 120, 121], and julifloricine has antidermatophytic and antibacterial activities [122]. Juliprosine, which contains two piperidine rings and a dihydroindolizine ring, and its stereoisomer isojuliprosine, were isolated from the extracts of mesquite leaves [119, 123]. Juliprosine was found to possess DNA-binding activity [121]. Juliprosinene, which has two piperidine rings and an indolizine ring, was isolated from the extracts of mesquite leaves [119].

L-Tryptophan, syringin and (–)-lariciresinol were isolated from the aqueous exudates of mesquite

leaves as plant growth inhibitors, as determined by lettuce and barnyard grass root assays [124, 125, 126]. The chemical structures of L-Tryptophan [127, 128, 129, 130, 131], syringin[132, 133], and (–)-lariciresinol [134, 135] were elucidated from spectroscopic analyses. 3````-Oxojuliflorine (3````-oxojuliprosopine), secojuliprosopinal, a 1:1 mixture of 3`-oxo- and 3-oxo-juliprosine, juliprosine and juliflorine (juliprosopine) were isolated from the methanol extracts of mesquite leaves and investigated for their activity as plant growth inhibitors[136, 137]. All of these alkaloids generally inhibited growth of seedlings of both monocots and dicots. All alkaloids inhibited root growth more than shoot growth of all plant species. Thus, the active sites in these alkaloids are the functional groups at C-3 and C-30 of the piperidine and indolizine skeletons [124].

7.7 Medicines

With time there has been a shift from synthetic to herbal medicines, which we say 'Return to Nature' [138]. In traditional and ancient therapy various parts of plants are used therapeutically like its fruits, flowers, leaves, barks and roots [139, 140]. Extracts of *P. juliflora* seeds and leaves have several in vitro pharmacological effects such as antibacterial [67, 122, 141, 142, 143, 144], antifungal [69, 119, 145], and anti-inflammatory properties [69, 119]. These properties have been attributed to piperidine alkaloids [67, 146]. It is also known for its ethno-medicinal properties, mainly used for boils, rheumatic pain, digestive disturbances [147].

All parts of *P. juliflora* are used in the preparation of medicinal products to treat human ailments. An astringent decoction is made from boiling wood chips, a bark extract is used as an antiseptic on wounds and gum is used to treat eye infections [99]. *P. juliflora* flour is used as an aphrodisiac, syrup as an expectorant and tea infusion against digestive disturbances and skin lesions [109]. *P. juliflora* is also used to treat sexually transmitted diseases [142]. Anticarcinogenic effects have also been reported. Of the many chemicals with effects on human health that have been isolated from *P. juliflora*, most work has concentrated on alkaloids, flavonoids and tannins. Several groups of piperidine alkaloids have been isolated from *Prosopis* species. The alkaloids juliflorine, juliprosine, juliprosopine, julifloricine and julifloridine have been isolated from *P. juliflora* [99]. Diketone, prosopidione and cytotoxin patulitrin have been isolated from *P. juliflora* leaves by Ahmad and Sultana [65]. Many flavonoids and tannins have also been isolated [109]. Chemical compounds have also been isolated from *P. juliflora* bark, pods and roots by Vimal and Tyagi [99]. A mixture of alkaloids from *P. juliflora* has significant inhibitory effects on gram positive bacteria [122, 148, 149]. A water-soluble mixture of alkaloids from *P. juliflora* leaves has found to be more active against gram-positive bacteria than three commercial antibiotics bacitracin, chlormycetin, gentamicin or trimethoprim [148]. The antifungal, antibacterial and general antimicrobial activity of plant extracts of *P. juliflora* is well established, but there are concerns as to their toxic effects [22]. Cytotoxic effects were also observed with extracts of *P. juliflora* [65] and alkaloids were reported to cause haemolysis of rat and human erythrocytes [150]. Rocha [109] also identified the presence of the toxic chemical furfural. Tannins present are irritants of internal organs and can also bind proteins making them indigestible [109].

Roots and Shoot samples of *P.juliflora* have been assessed for their heavy metal content by Varun *et al*. [151] to evaluate the species as a green solution to decontaminate soils contaminated by lead and cadmium. *P. juliflora* has a good phytoremediation potential. It is an effective heavy metal remediator coupled with environmental stress. The impact of metal nanoparticles (NPs) on biological systems, especially plants, is still not well understood. Viezcas *et al*. [152] assessed the effects of zinc oxide (ZnO) NPs in velvet mesquite (*Prosopis juliflora*-velutina). Zinc concentrations in roots, stems and leaves were determined by inductively coupled plasma optical emission spectroscopy (ICP-OES). Plant stress was examined by the specific activity of catalase (CAT) and ascorbate

peroxidase (APOX); while the biotransformation of ZnO NPs and Zn distribution in tissues was determined by X-ray absorption spectroscopy (XAS) and micro X-ray fluorescence (μXRF), respectively. ICP-OES results showed that Zn concentrations in tissues (2102±87, 1135±56, and 628±130 mgkg−1 d wt in roots, stems and leaves, respectively) were found at 2000 mg ZnONPsL−1. Stress tests showed that ZnO NPs increased CAT in roots, stems, and leaves, while APOX increased only in stems and leaves. XANES spectra demonstrated that ZnO NPs were not present in mesquite tissues, while Zn was found as Zn(II), resembling the spectra of Zn(NO3)2. The μXRF analysis confirmed the presence of Zn in the vascular system of roots and leaves in ZnO NP treated plants [152].

7.8 Bio-Pesticidal

Stored food grains face severe damage due to infestation by insects. The insect damages are ranging from 5-30% of the world's total agricultural production. Pests are capable of decreasing crop production causing severe economical and social losses. Work by various groups have established that plant extracts have potential in managing and controlling pests [153,154]. *P. juliflora* has been used for its pesticidal properties. Extract from *P. juliflora* and some other plants has shown its antifungal potential against *Aspergillus* isolated from sorghum, maize and paddy samples [155]. Aqueous extracts from *P. juliflora* have also been known for its antibacterial activity against different pathovars of the phytopathogenic bacterium [144]. Late leaf spot (*Phaeoisariopsis personata*) and rust (*Puccinia arachidis*) are the two major biotic constraints of groundnut (*Arachis hypogaea L.*) of global importance. For economic and eco-friendly disease management aqueous leaf extracts of *P. juliflora* and *L. esculentum* were used, which completely inhibited the *in vitro* germination of *P. personata* and *P. arachidis*[156]. The aqueous leaf extracts from *P. julifora* and some other plants were directly sprayed on mulberry varieties to prevent tukra disease. The spray of the extracts did not control the disease but prevented further spread [157]. Biochemical analyses of leaf samples collected from pot culture studies showed that treatment with *Prosophis juliflora* caused enhanced activities of the defence enzymes viz. peroxidase, polyphenol oxidase and phenylalanine ammonia lyase which may account for their antifungal activities [158]. The antifungal activity of aqueous, petroleum ether, benzene, chloroform, methanol and ethanol extracts and alkaloid extract of *Prosopis juliflora* (Sw.) DC. leaves (Mimosaceae) was evaluated for antifungal activity by poisoned food technique against *Alternaria alternata* a causal organism of brown spot of tobacco[159]. Aqueous extracts from leaves of *P. juliflora* have also shown antibacterial activity against three phytopathogenic *Xanthomonas pathovars viz. Xanthomonas axonopodis pv. Malvacearum, X. a. pv. Phaseoli, X. campestris pv*. Vesicatoria associated with anular leaf spot of cotton, common blight of bean and bacterial spot of tomato [159]. Hence, the alkaloid fraction of P. juliflora is an important source of antimicrobials. Medicinal activity of *Prosopis juliflora* is also reported [160]. *P. juliflora* extract as a significant component for the integrated management of groundnut foliar diseases [156] Pugazhvendan *et al*. [161] worked on powders of various plants (*A. mexicana, P. juliflora* and *T. purpurea*) as biopesticides. All the plants showed pesticidal nature except *P. juliflora* which showed mild activity in high concentration. The seeds of *Prosopis julifora* act as proteinaceous inhibitor against papain [162]. Oliveira *et al*.[162] studies suggest that the proteins present in *P. julifora* seeds is involved with defense responses against insects. Franco *et al*., [163] have also worked on the proteinase inhibitors. Kunitz trypsin inhibitor from *P. julifora* has shown to possess cysteine proteinase inhibitory activity.

8. Conclusion

Prosopis juliflora plays an important role in the ecological setup and economy of arid and semiarid environs as they play a vital role in

sustainable development of the areas. It is known of reversal of desertification and has been suggested as a miracle plant. Besides it use as a fuel plant, it has varied properties which are useful to the human kind. Every part of *P.juliflora* is abundantly being used in various fields. Research in developing *P. juliflora* for its alleopathy, medicinal and bio-pesticide is going to have a great impact on development of new drugs and pesticides. The detailed understanding of the chemistry of *P. juliflora* and the ability of growing in extreme conditions will ensure a rational and cost effective development.

9. References:

1. Golubov J, Mandujano M, Eguiarte L, *Boleti´N De La Sociedad Bota´ Nica De Me´ Xico*, 2001, 69, 23.
2. Almaraz-Abarca N, Campos MG, Avila-Reyes JA, Naranjo-Jimenez N, Corral JH, Gonzalez-Valdez LS, Journal of Food Composition and Analysis 2007; 20:119.
3. Allen ON, Allen EK. The Leguminosae: A Source Book for Characteristics, Uses, and Nodulation. The University of Wisconsin Press, Madison, USA, 1981.
4. Wunder WG, Prosopis Juliflora (P. Africana) In the Arid Zone of Sudan. Pamphlet of the Forest Research Educaction Project, Forest Department of Sudan No. 26. Forest Department and Undp, Khartoum, Sudan, 1966.
5. Evans J. Planetary Forestary in the Tropics. Oxford: Clarendon Press, 1982, 394.
6. Goyal SP, Bohra HC, Ghosh PK, Parakash I. Journal of Arid Environments 1988; 14:285.
7. Chaudary SA. Acacia and Other Genera of Mimosoideae. In. Saudi Arabia. Riyad: El-Khalid Offset Press, 1983, 76.
8. Warag MAO. Journal of Arid Environments. 1994, 27, 79-84.
9. Griffith AL. Acacia and Prosopis in the Dry Forest of the Tropics. Fao, Rome, Italy, 1961.
10. Sankhla N, Baxi D, Chatterji UN. Current Science 1965; 34:612-614.
11. Nasir E, Ali SI. Flora of West Pakistan. Fakhri, Karachi, 1972.
12. Al-Hamid AI, Warrag Moa, J. Arid Environ., 1998, 38, 237.
13. Tabosa IM, Souza JCD, Graca DL, Barbosa-Filho JM, Almeida RN, Riet-Correa F. Vet. Human Toxicol 2000; 42:155.
14. Ei-Keblawy A, Ai-Rawai A, Plant Ecol., 2007, 190, 23.
15. Raven PH, Polhill RM. In: Polhill RM, Raven PH, Advances In Legume Systematics. Royal Botanic Gardens, Kew, UK, 1981, 27.
16. Burkart A. Journal of the Arnold Arboretum 1976 57, 219-249, 450-525.
17. Solbrig OT, Bawa K, Carman NJ, Hunziker JH, Naranjo CA, Palacios RA, Poggio L, Simpson BB. In: Simpson BB (ed.) Mesquite, Its Biology in Two Desert Ecosystems. Dowden, Hutchinson and Ross, Stroudsburg, Pennsylvania, USA, 1977, 44.
18. Saidman, B. O., *Silvae Genetica*, 1986, 35, 3.
19. Saidman, B. O., *Silvae Genetica*, 1990, 39, 5.
20. Burghardt AD, Palacios RA, Bulletin of the International Group for the Study of Mimosoideae, 1997, 20, 71.
21. Ramirez L, De LVA, Razkin N, Luna V, Harris PJC. Agronomie 1999; 19:31-43.
22. Pasiecznik NM, Felker P, Harris PJC, Harsh LN, Cruz G, Tewari JC, Cadoret K, Maldonado LJ. The Prosopis Juliflora-Prosopis Pallid Complex: A Monograph. HDRA, Coventry, UK, 2001, 172.
23. Reddy CVK, Indian Forester, 1978, 104, 14.
24. Muthana KD, Arora GD. Central Arid Zone Research Institute, Jodhpur, India, Cazri Monograph No. 22, 1983.
25. Raizada MB, Chatterji RN, Indian Forester, 1954, 80, 675.
26. Ferreyra R. Estudio Systemático De Los Algarrobos De La Costanorte Del Perú. Direccion De Investigacion Forestal Y De Fauna, Min. De Agricultura, Lima, Peru. Figueiredo & Price, 1987.
27. Singh G, Singh NT. *Bulletin No.18*, 1993, Central Soil Salinity Research Institute, Karnal, Haryana, India.
28. Perry, G., *Flora of Australia*, 1998, 12, 7.
29. Gomes AV, De-Muñiz GIB. In. Habit, M.A., Saavedra, J. C. (eds.), In: The Current State Of Knowledge On Prosopis Juliflora. (Eds.) Fao, Rome, Italy. 1990, 195.
30. Kazmi, S. M. H., Singh, R., *Journal of the Timber Development Association of India*, 1992, 38, 39.
31. Díaz Celis, A., Los Algarrobos. Concytec, Lima, Peru. 1995.
32. Johnston, M. C., *Brittonia*, 1962, 14, 72.
33. Chaudhry, B., Vijayaraghavan, M. R., *Phyton-Annales Rei Botanicae*, 1992, 32, 1.
34. Elias, T. S., In. Polhill R. M. And Raven P. H. (eds.) Advances In Legume Systematics. Royal Botanic Gardens, Kew, UK, 1981, 143.
35. Lewis, G. P., Elias, T. S., In. Polhill R. M., Raven, P. H. (eds.) Advances In Legume Systematics. Royal Botanic Gardens, Kew, UK. 1981, 155.
36. Burkart, A., *Darwiniana*, 1940, 4, 57.
37. Goldblatt, P., Polhill, R. M., Raven P. H., (Eds.) In: Advances In Legume Systematics. Royal Botanic Gardens, Kew, UK, 1981, 427.
38. Bukhari, Y. M., *Australian Journal of Botany*, 1997, 45, 879.
39. Hunziker, J. H., Saidman, B. O., Naranjo, C. A., Palacios, R. A., Poggio, L., Burghardt, A. D., *Forest Ecology And Management*, 1986, 16, 301.

40. Solbrig, O. T., Bawa, K., Carman, N. J., Hunziker, J. H., Naranjo, C. A., Palacios, R. A., Poggio, L., Simpson, B. B., In: Simpson, B. B. (ed.) Mesquite, Its Biology In Two Desert Ecosystems. Dowden, Hutchinson and Ross, Stroudsburg, Pennsylvania, USA, 1977, 44.
41. Bukhari, Y. M., (Dissertation) Department Of Plant Biology, Faculty Of Agriculture And Forestry, University Of Helsinki, Helsinki, Finland. 1998.
42. Benson, L., *American Journal of Botany,* 1941, 28, 748.
43. Carman, N. J., (Ph.D. Thesis), The University of Texas at Austin, Austin, Texas. 1973.
44. Mcmillan, C., Peacock, J. T., *Southwest. Nat.*, 1964, 9, 181.
45. Peacock, J. T., Mcmillan, C., *Ecology*, 1965, 46, 35.
46. Okwu, D.E, Ukanwa, N., *Der Chemica Sinica*, 2010, 1(2), 21.
47. Bragg, L. H., Bacon, J. D., McMillan, C., Mabry, T. J., *Biochemical Systematics and Ecology,* 1978, 6, 113.
48. Huber, S. C., Huber, J. L. A., Nielsen, T. H., Archives In Biochemistry And Biophysics, 1989, 681.
49. Sinha, A. K., Shirke, P. A., Pathre, U., Sane, P. V., *Biochemistry and Molecular Biology International,* 1997, 43, 421.
50. Dea, I. C. M., Morrison, A., *Advances in Carbohydrate Chemistry and Biochemistry*, 1975, 31, 241.
51. Whistler, R. L., Industrial Gums (2nd Ed.). New York: Academic Press, 1973.
52. Figueiredo, A. A., *Cie´Ncia E Tecnologia De Alimentos*, 1983, 3(1), 82.
53. Dey, P. M., *Advances Carbohydrate Chemistry Biochemistry*, 1978, 35, 341.
54. Mccleary, B. V., Clarck, A. H., Dea, I. C. M., Rees, A. D., *Carbohydrate Research*, 1985, 139, 237.
55. Palmer, K. J., Ballantyne, M., *Journal of the American Chemical Society*, 1950, 72, 736.
56. Courtois, J. E., Le Dizet, P., *Bulletin De La Societe De Chimie Biologique*, 1970, 52, 15.
57. Mccleary, B. V., Matheson, N. K., *Phytochemistry*, 1975, 14, 1187.
58. Mccleary, B. V., *Carbohydrate Research*, 1978, 67, 213.
59. Baker, C. W., Whistler, R. L., *Carbohydrate Research*, 1975, 45, 237.
60. Hoffman, J., Svensson, S., *Carbohydrate Research*, 1978, 65, 65.
61. Gonza´Lez, J. J., *Macromolecules*, 1978, 11, 1074.
62. Hoffman, J., Lindberg, B., Painter, T. J., *Acta Chemica Scandinavica Series B*, 1976, 30, 365.
63. Painter, T. J., Gonzalez, J. J., Hemmer, P. C., *Carbohydrate Research*, 1979, 69, 217.
64. Vieira, I.G.P., Mendes, F.N.P., Gallao, M.I., Sousa De Brito, E., *Food Chemistry*, 2007, 101, 70.
65. Ahmad, V. U., Sultana, A., *Phytochemistry*, 1989, 28, 278.
66. Siddiqui, S., Murthi, S., *J. Sci. Znd. Res.*, 1948, 7b, 188.
67. Ahmad, A., Khan, K. A., Ahmad, V. U., Qazi, S., *Planta Med.*, 1986, 4, 285.
68. Ahmad, V. U., Qazi, S., *J. Chem. Soc. Pak.*, 1985, 7(4), 347.
69. Ahmad, A., Kursheed, A. K., Sabiha, Q., Viqaruddin, A., Aqueel-Ahmad, *Fitoterapia*, 1989, 60, 86.
70. Silva, A.M.M., Silva, A.R., Pinheiro, A.M., Freitas, S.R.V.B., Silva, V.D.A., Souza, C.S., Hughes, J.B., El-Bacha, R.S., Costa, M.F.D., Velozo, E.S., Tardy, M. And Costa, S.L., *Toxicon*, 2007, 49, 601.
71. George, S., Parida, A., *Plant Mol. Biol. Rep.*, 2010, 28, 32.
72. Lal, R., *Climatic Change*, 2001, 51, 35.
73. Lal, R., *Climate Change,* 2004a, 65, 277.
74. Lal, R., *Environmental Management*, 2004b, 33(4), 528.
75. Lal, R., *Phil. Trans. R. Soc. B*, 2008, 363, 815.
76. Lal, R., *Journal of Soil Salinity and Water Quality*, 2009, 1(1-2), 30.
77. Dregne, H., Advances in Desert and Arid Lands, Harwood Academic, New York, 1983.
78. Glenn, E., Squires, V., Olson, M., Frye, R., *Water, Air And Soil Pollution,* 1993, 70, 341.
79. Reynolds, J. F., Smith, D. M. S., In. Reynolds, J. F., Stafford Smith, D. M., (Eds.) Global Desertification: Do Humans Cause Deserts? Dahlem Univ. Press, Berlin, 2002, 1.
80. Kaur, B., Gupta, S.R., Singh, G., *Agroforestry Systems,* 2002, 54, 21.
81. Singh, B., *Arid Soil Res. Rehab*., 1996, 10, 201.
82. Singh, G., Singh, N. T. In: Lal, R., Kimble, J., Follett, R. (Eds.) Soil Properties and their Management for Carbon Sequestration. USDA-Natural Resources Conservation Service, National Soil Survey Centre. 1997, 89.
83. Singh, G., *Agrofor. Syst.*, 1995, 29, 61.
84. Bhojvaid, P. P., Timmer, V. R., Singh, G., *Agrofor. Syst.*, 1996, 39, 139.
85. Geesing, D., P. Felker, A., Bingham, R. L., *Journal of Arid Environments*, 2000, 46, 1.
86. Herrera-Arreola, G., Herrera, Y., Reyes-Reyes, B.G., Dendooven, L., *Journal of Arid Environments*, 2007, 69, 583.
87. Patel, R. R., Safaya, V., In. Patel, V.J. (ed.) In: The Role of Prosopis in Wasteland Development. Javrajbhai Patel Agroforestry Center, Surendrabag, Gujarat, India, 1986.
88. Rajput, S. S., Tewari, M. C., In. Patel, V.J. (ed.) The Role Of Prosopis In Wasteland Development. (Ed.) V. J. Patel. Javrajbhai Agroforestry Center, Surendrabag,Gujarat, India, 1986.
89. Madan, R. N., Tandon, B., *Indian Forester*, 1991, 117, 29- 36.
90. Goel, V., Behl, H. M., Wood Quality For Fuel Wood Rotation Cycles. In: IUFRO Conference, August 1992, Nancy, France. 1992, 23.

91. Khan, D., Ahmad, R., Ismail, S., Case History of Prosopis Juliflora Plantation at Makran Coast through Saline Water Irrigation. Department of Botany, University of Karachi, Karachi, Pakistan, Proceeding of US-Pakistan Biosaline Research Workshop, Karachi, Pakistan. 1986.
92. Sharma, B. M., In: Proceedings of the Symposium on Recent Advances in Tropical Ecology. Varanasi, India, 1968, 248.
93. Solano, L., (B.Sc. Thesis), Universidad De Piura, Peru, 1989.
94. Bravo, L., Grados, N., Saura-Calixto, F., *Journal of the Science of Food and Agriculture,* 1994, 65, 303.
95. Cruz, G., B. Del Re, Amadò, R., *Abstracts of Iii Jornadas Peruanas De Fitoquímica. Soc. Química Del Peru*, 1987, 3, 122.
96. Sáenz, G., Serra, J. A., Escriche, I., In: Fito, P., Mulet, A., (eds.) Proceedings Of The Second International Carob Symposium. Generalitat Valenciana, Valencia, Spain, 1987, 419.
97. Talpada, P.M., (PhD thesis), Gujarat Agricultural University, Anand, India, 1985.
98. Marangoni, A., Alli, I., *Journal of the Science of Food and Agriculture,* 1988, 44, 99.
99. Vimal, O. P., Tyagi, P. D., In: Patel, V.J. (ed.) The Role of Prosopis in Wasteland Development. Javrajbhai Patel Agroforestry Center, Surendrabag, Gujarat,India, 1986.
100. Singh, G., Abrol, I. P., Cheema, S. S., Central Soil Salinity Research Institute, Karnal, Haryana, India, 1988.
101. Singh, G., Abrol, I. P., Cheema, S. S. *International Tree Crops Journal*, 1990, 6, 81.
102. Patel, V. J. (Ed.). The Role Of Prosopis In Wasteland Development. Jivrajbhai Patel Agroforestry Center, Surendrabag, Gujarat, India, 1986.
103. Drumond, M. A., Habit, M. A. and Saavedra, J. C.(eds.), The Current State Of Knowledge On Prosopis Juliflora. Fao, Rome, Italy, 1990, 307.
104. Sankhla, A. K., Sankhla, N., *Transactions of Indian Society of Desert Technology and University Centre of Desert Studies*, 1979, 4, 35.
105. Pancholy, A., Jindal, S. K., Singh, M., Kackar, N. L., Solanki, K. R., *Annals of Arid Zone,* 1989, 28, 299.
106. Lima, P. C. F., (Ph.D. Thesis) Universidade Federal Do Parana, Brazil. 1994.
107. Anderson, D. M. W., Farquhar, J. G. K., *International Tree Crops Journal*, 1982, 2, 15.
108. Azero, E. G., Andrade, C.T., *Jour. Braz. Chem. Soc.*, 2006, 17(5), 844.
109. Rocha, R. G. A., In: Habit, M. A., Saavedra, J. C. (eds.) The Current State Of Knowledge On Prosopis Juliflora. Fao, Rome, Italy, 1990, 397.
110. Alves, J. L. H., Melo, M. S. A., Alves, G. D., M. A. Habit And J. C. Saavedra (Eds.) The Current State Of Knowledge On Prosopis Juliflora. Fao, Rome, Italy, 1990, 187.
111. Molisch, H., Der Einfluss Einer Pflanze Auf Die Andere Allelopathie. Fischer, Jena, 1937.
112. Pandit, B. R., Mahesh, K.R., Kotiwar, O.S., *Geobios*, 1995, 22, 145
113. Toyooka, N., *Yakugaku Zasshi*, 2001, 121, 467.
114. Ahmad, V.U., Basha, A., Haque, W., *Z. Natur-Forsch*, 1978, 33b, 347.
115. Ahmad, V.U., Sultana, A., *Sci. Pham.*, 1990, 58, 409.
116. Ahmad, V. U., Mohammad, *Z. G., J Chem Soc Pak.*, 1979, 1, 137.
117. Ott-Longoni, R., Viswanathan, N., Hesse, M., *Helv Chim Acta*, 1980, 63, 2119.
118. Ahmad, V. U., Qazi, S., *J. Chem. Soc. Pak.*, 1985, 7(4), 347.
119. Ahmad, V.U., Sultana, A., Qazi, S., *J. Nat. Prod.*, 1989, 52 (3), 497.
120. Khursheed, A. K., Arshad, H. F., Viqaruddin, A., Sabiha, Q., Sheikh, A. R., Tahir, S. H., *Arzneim-Forsch/Drug Res*., 1986, 36, 17.
121. Tapia, A., Feresin, G. E., Bustos, D., Astudillo, L., Theoduloz, C., Schmeda-Hirschmann, G., *J Ethnopharmacol*, 2000, 71, 241.
122. Aqeel, A., Khursheed, A. K., Viqaruddin, A., Sabiha, Q., *Arzneimittel Forschung/Drug Research*, 1989, 39, 652.
123. Da¨Twyler P, Ott-Longoni R, Scho¨P. P. E, Hesse, M., *Helv Chim Acta*, 1981, 64, 1959.
124. Nakano, H.,. In. Ramawat, K.G. (Ed.) Desert Plants. Springer-Verlag Berlin Heidelberg Publ., 2010, 341.
125. Nakano, H., Fujii, Y., Suzuki, T., Yamada, K., Kosemura, S., Yamamura, S., Suzuki, T., Hasegawa, K., *Plant Growth Regul*., 2001, 33, 165.
126. Nakano, H., Fujii, Y., Yamada, K., Kosemura, S., Yamamura, S., Hasegawa, K., Suzuki, T., *Plant Growth Regul*., 2002, 37, 113.
127. Kato-Noguchi, H., Kosemura, S., Yamamura, S., Mizutani, J., Hasegawa, K., *J. Chem. Ecol.*, 1994a, 20, 315.
128. Kato-Noguchi, H., Mizutani, J., Hasegawa, K., *J. Chem. Ecol.*, 1994b, 20,309.
129. Nakano, H., Morita, S., Shigemori, H., Hasegawa, K., *Plant Growth Regul*., 2006, 48, 215.
130. Nakano, H., *Allelopathy J.*, 2007a, 19, 461.
131. Nakano, H., *Allelopathy J*., 2007b, 19, 487.
132. Ahmad, M., Aftab, K., *Phytother Res.*, 1995, 9, 452.
133. Nakayama, R., Kikuzaki, H., Nakatani, N., Horiuchi, H., *J Home Econ Jpn*, 1996, 47, 1193.
134. Badawi M. M., Handa, S. S., Kinghorn, A. D., Cordell, G. A., Farnsworth, N. R., *J. Pharm. Sci.*, 1983, 72, 1285.
135. Duh, C. Y., Phoebe, C. H., Pezzuto, J. M.,, Kinghorn, A. D., Farnsworth, N. R., *J. Nat. Prod.*, 1986 49:704.

136. Nakano, H., Nakajima, E., Hiradate, S., Fujii, Y., Yamada, K., Shigemori, H., Hasegawa, K., *Phytochemistry*, 2004a, 65, 587.
137. Nakano, H., Nakajima, E., Fujii, Y., Shigemori, H., Hasegawa, K., *Plant Growth Regul.*, 2004b, 44, 207.
138. Pal, A., Jadon, M., Katare, Y.K., Singour, P.K., Rajak, H., Chaurasiya, P.K., Patil, U.K., Pawar, R.S., *Der Pharmicia Sinica*, 2011, 2(2), 1.
139. Funde, P.E., *Der Chemica Sinica*, 2011, 2(1), 8.
140. Sivakumar, N. T., Venkataraman, R., *Der Pharmacia Sinica*, 2010, 1(1), 1.
141. Kanthasamy, A., Subramanian, S., Govindasamy, S., *Indian Drugs*, 1989, 26 (8), 390.
142. Caceres, A., Menendez, H., Mendez, E., Cohobon, E., Samayoa, B. E., Jauregui, E., Peralta, E., Carrillo, G., *Journal of Ethnopharmacology*, 1995, 48, 85.
143. Al-Shakh-Hamed, W.M.A., Al-Jammas, M.A., *Iraqi J. Vet. Sci.*, 1999, 12 (2), 281.
144. Satish, S., Raveesha, K. A., Janardhana, G. R., *Letters in Applied Microbiology*, 1999, 28, 145.
145. Kaushik, J.C., Sanjay, A., Tripathi, N.N., *Indian J. For.*, 2002, 25 (3&4), 359.
146. Batatinha, M.J.M., (Ph.D. Thesis). Hannover: Veterinary Medicine University. 1997.
147. Vyas, S. P., *Indian Journal of Environmental Science*, 2002, 6(1), 91.
148. Ahmad, A., Khan, K. A., Ahmad, V. U., Qazi, S., *Fitoterapia*, 1988, 59, 481.
149. Zainal, A. S., Abdel-Rahim, A. M., Abu-Ali R. M., Radwan, S. S., *Zentralblatt Für Mikrobiologie*, 1988, 143, 375.
150. Kandasamy, A., William, S., Govindasamy, S., *Current Science*, 1989, 58, 142.
151. Varun, M., D'souza, R., Pratas, J., Paul, M. S., *Bull. Environ., Contam., Toxicol.*, 2011, DOI 10.1007/S00128-011-0305-0
152. Viezcas, J.A.H., Castillo-Michel, H., Servin, A.D., Peralta-Videa, J.R., Gardea-Torresdey, J.L., Chemical Engineering Journal. 2011.
153. Singh, R., *Advances in Applied Science Research*, 2011, 2(2), 295.
154. Upadhyay, R.K., Yadav, N., Ahmad, S., *Advances in Applied Science Research*, 2011, 2(2), 367.
155. Satish, S., Mohana, D.C., Ranhavendra, M.P., Raveesha, K.A., *Journal of Agricultural Technology*, 2007, 3(1), 109.
156. Kishore, G. K., Pande, S., *International Journal of Pest Management*, 2005, 51(4), 325.
157. Babu, R. S.; Dorcus, D., Vivekanandan, M., *Journal of Sericultural Science of Japan*, 1994, 63 (3), 175.
158. Kamalakannan, A., Shanmugam, V., Surendran, M., *Z.F. Pflanzenkrankheiten & Pflanzenschutz*, 2001, 108 (5), 536.
159. Raghavendra, M. P., Satish, S., Raveesha, K.A., *Journal of Biopesticides*, 2009, 2(1), 56.
160. Sekar, M., Ayyanar, M., Gopalakrishnan, M., *Current Science*, 2010, 98(12), 1158.
161. Pugazhvendan, S.R., Elumalai, K., Ross, P.R., Soundararajan, M., *World Journal of Zoology*, 2009, 4(3), 188.
162. Oliveira, A. S., Pereira, R. A., Lima, L. M., Morais, A. H. A., Melo, F. R., Franco, O. L., Bloch Jr., C., Grossi-De-Sa, M. F., Sales, M. P., *Pesticide Biochemistry and Physiology*, 2002, 72, 122.
163. Franco, O. L., Grossi De Sa, M. F., Sales, M. P., Mello, L. V., Oliveira, A. S., Rigden, D. J., *Proteins: Structure, Function And Genetics*, 2002, 49: 335.