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Pharmacology and Therapeutic Application of *Prosopis juliflora*: A Review

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Abstract: *Prosopis juliflora* is locally known as vilayati babul one of the most common tree of the Indian desert belonging to family Mimosacea. It has been reported that the plant contains anti bacterial, antifungal, anticancer, antioxidant, antimicrobial activity. It's a wonderful tree for fuel, charcoal, firewood, and Timber. It serves as one of the main sources of fuel for the rural people due to its excellent burning qualities. The extract of leaves shows very high antimicrobial activity. *Prosopis juliflora* is a deep rooted, sand dune stabilizers, multipurpose tree endemic to the hot deserts of India. Despite of number of uses it is known as serious invasive weed in most of the parts of world.

Keywords: *Prosopis juliflora*, Vilayati Babul, Antimicrobial Activity

1. Introduction

Medicinal plants have been used in virtually all cultures as a source of medicine. Assurance of the safety, quality, and efficacy of medicinal plants and herbal products has now become a key issue in industrialized and in developing countries. The widespread use of herbal remedies and healthcare preparations is described in the Vedas and the Bible. Medicinal Plants have been used for thousands of years to flavor and conserve food, to treat health disorders and to prevent diseases including epidemics.[1]

The genus *Prosopis* L. belongs to the family Leguminosae (Fabaceae), sub-family Mimosoideae. *Prosopis* contains 44 species, of which 40 are native to the Americas, three to Asia and one to Africa. In the Americas, Argentina has 28 native species, of which 13 are endemic. The tropical Andean region is home to six species and eight species are found in the Texas area, seven of them being endemic[2]

This is said to have been introduced to Sri Lanka in the 19th century, where it is now known as vanni-andara, or katuandara in Sinhala. The tree is believed to have existed in the Vanni and Mannar regions for a long time. *Prosopis juliflora* is a shrub or small tree, a kind of mesquite. Within *Prosopis* spices there are trees and shrubs of varying size, mainly characterized by the presence of thorns and prickles.[3]. The term "mesquite" includes all leguminous trees of the genus *Prosopis*, of which nine species are found in the highly arid environments of Mexico. These species are highly recognized for their properties as windbreakers, soil binders, and sand stabilizers, as well as their ability to grow in the poorest soils and to survive in areas where others trees cannot survive.[4] The nitrogen fixing trees of the *Prosopis juliflora*/P. Pallid complex are among the most adaptable and fastest growing trees in the truly tropical arid regions and have become naturalized in semi-arid tropics.[5]

1.1. Local Names

Arabic (mesquite); Creole (bayawonn, bayawonnfran);

English (ironwood, algarroba, honey mesquite, mesquite, mesquite bean);

Filipino (aroma); French (bayahonda, chambron, bayarone, bayahonde francais);

German (mesquitebaum); Hindi (vilayatikhejra, vilayatibabul, gandababul, vilayatikikar);

Swahili (kikwajukwaju)[6]

P.juliflora can grow as a shrub or tree, it can reach up to 12 metres, but it is usually much smaller than that. It is predominantly xerophilous, aculeate, spiny or rarely unarmed .[7]

It is used for feed of livestock, shade, windbreak, charcoal,

live fence, and firewood as well as house construction. However, it is jeopardizing the daily activities of the nomadic pastoralist and agriculturalists, on the other hand.[8]

1.2. Positive Impacts

It serves as one of the main sources of fuel for the rural and urban poor in the country. It provides more then 90% of the fuel wood in some Indian villages because *P. juliflora* wood has excellent burning qualities. The wood does not spit, spark, or emit much smoke and burn slowly with hot and even heat with specific gravity 0.70 or higher. Thus, it is called wooden anthracite. It has high calorific value. The wood does not require long periods of storage and drying. It burns well even when it is freshly cut. The rural people often cut it on a day to day basis and use directly in their traditional mud stoves[9].

P. juliflora provides monetary support to the rural community. If its stands are maintained properly in the form of plantations and the charcoal are produced using effective kilns, wood weight and charcoal quality can be enhanced and the economic status of rural people can definitely be uplifted and products are properly marketed through common agencies. It is an excellent source for income generation in the absence of any investment and maintenance.[9]

It improves soil physiochemical and biological properties, generating "fertility islands" or "resource islands" beneath its canopy .[10] its pods can be used as a livestock feed and for making human foods; and environmental services provided by nitrogen fixation, shade, shelter, live and dead fencing, erosion control, soil improvement and reclamation are remarkable. Secondary products from this tree includes honey, edible exudates gums, fibres, tannins, foliage for fodder, mulch, biopesticides and medicines, and other uses for wood and pods such as particle board, wood chips for energy generation, pods for ethanol production, galactomannan gums from the seeds and other specialist products[11]. *Prosopis juliflora* pods can replace concentrate mixture up to 40% in sheep feeding without any adverse effect on nutrient intake and utilization as well as rumen fermentation characteristics[12].

These pods were extensively consumed by indigenous peoples in the native ranges of *Prosopis* in Peru, North America and Argentina, the *Prosopis* pods in both sub-Saharan Africa and India have bitter astringent tastes and are occasionally consumed by livestock but not humans. There is considerable variability in the sweetness of the pods in the native range, some pods being very sweet and highly palatable while others area stringent, bitter and acidic. [13] The seeds are potential source of seed gum. Free ranging animals can eat pods directly from the tree. Alternatively, the pods can be collected and ground to produce course flour which can be included in the animal's diet. The percentage of the flour in the mix should be kept below 50% in order to avoid digestion disorders among the livestock[14] It has been used as a folk remedy for catarrh, cold, diarrhea, dysentery, excrescences, flu, hoarseness, inflammation, measles, sore throat and in healing of wounds. Decoction prepared from leaf and seed extracts are used in wound healing, as disinfectant and also to treat scury.[15] *P. juliflora* syrup prepared from ground pods is given to children showing weight deficiency or retardation in motor development, the syrup is believed to increase lactation. Tea made from *P. juliflora* is thought to be good for digestive disturbances and skin lesions[15]. It has soothing, astringent, antiseptic, antibacterial and antifungal properties.[16]. It has been used to treat eye problems, open wounds, dermatological ailments and digestive problems by the native tribes of many countries. The flavonoid, patulitrin isolated from its flowers and fruits showed significant activity against lung carcinoma in vivo.[17]. Leaves and pods are to be the richest source of plant metabolite, followed by flower, root and stem. Phytochemical analysis of the extracts revealed the presence of tannins, phenolics, flavonoids, alkaloids, terpenes and steroids in most parts of *P.juliflora*. Alkaloids are pharmaceutically significant and are used as analgesic, antimalarial, antiarrythmic, antispasmodic, in the treatment of coughs and pain, in the treatment of gout, and as pupil dilatin. [15]

Its wood is extremely hard and durable. It also has an appealing coloration that makes it ideal to make furniture with. The wood matures quickly and stems become dark inside when the plant is trained as a tree. The mature timber is resistant to pest attack and weathering and thus can be used for furniture making and other useful purposes especially housing. It is also used as parquet flooring wood. However particularly in stressful conditions of dry areas, *Prosopis juliflora* trees remain craggy, crooked and small, which makes using them to make furniture or charcoal less attractive.[14]

Very high flavonoids content (16%) of Propsopis *juliflora* makes it a potential candidate bearing antioxidant and anticancer properties. Tannins and Phenols although found in low concentrations, (0.33 and0.66% respectively) can synergize the antioxidant and anticancer potential of flavonoids. Phenols are reported to prevent the platelets from clumping and have the ability to block specific enzymes that cause inflammation. These also act as immune enhancers, anticlotting and hormone modulators. Tannins in the plant cell inhibit hydrolytic enzymes like proteolytic macerating enzymes used by plant pathogens.[18]. The tree has been regarded as a valuable resource for firewood and dune stabilization.[19]

The charcoal obtained from this wood is also of very high quality and can be produced as easily from green wood as from dried wood. For instance 10 kg of green wood will make 1 to 2 kg of charcoal using traditional earth kilns normally in 2 to 4 days. The wood does not produce sparks while burning nor does it emit much smoke. It burns with a hot and even heat giving high heating value.[20]

By spreading charcoal and using it as bio-char, acidic degraded land can be rehabilitated and yields can be increased. Charcoal improves the physical, biological and chemical properties of the soil by releasing and storing nutrients, increasing the bulk density, improving the overall

porosity and creating favourable conditions formicro-biological activity. It can be applied in conjunction with farmyard manure and soil microbes. Wooden residues from *Prosopis juliflora* can be chipped off and used as mulch in gardens and little vegetable gardens. The mulch is effective in reducing evapo transpiration. Consequently, it also reduces the plant water consumption. The chips have also been successfully proceeded into wooden pulp, which is the primary raw material for paper production. The biomass of *Prosopis juliflora* can be used to generate power in Kenya, the private electricity producer. The new plant will be fed by the *Prosopis juliflora* tree. The project is set to transform the tree from a noxious weed to a cash crop when about 2,000 households begin supplying the company with the tree stems. It is known to produce high amount of pollen that can be transformed into high-quality honey. The only constraint in dry-lands is the lack of water sources for the bees. The gum that exudates from *Prosopis juliflora* is comparable to gum Arabic and can be used in the food-cosmetic industry. Its use is constrained by the absence of toxicological tests necessary for it to enter the industrial market.[14]

P. juliflora pods are characterized by elevated sugar content, about 300 g/kg of dry matter. With 120 g/kg of crude protein on a DM basis. Once concentrated, the aqueous extract obtained from these beans becomes dark and dense and can be used in beverages and jellies. Roasted and ground, the beans can be used to make a coffee-like beverage[21].

Due to health and economic considerations, the efficacy of the plant extracts may provide an alternative method to protect field or stored grains from fungal and mycotoxin contamination. Therefore there is an absolute need for bioactivity guided fractionation and isolation of the active components from the plant extracts found to be effective.[22]

1.3. Nutritional Analysis

The pods are rich in carbohydrates (46-52%); and the main soluble sugar present is sucrose. The pods and seeds contain 10–18% and 35% protein respectively with lysine as a predominant amino acid 18.8%. The pods are rich in minerals, Ca, P, Mg, K, Na, Cu, Zn, Fe and Mn as well as in vitamins. However the fibre content of pods is high (26-32%); they contain antinutritional factors such as tannins, phenolic compounds, phytic acid and trypsin inhibitor; and also contain galactomannan as a major non-starch polysaccharide. Thus improvement of the nutritional quality and removal of antinutritional factors in pods are important for their effective use as feed in animal diet, especially as a dietary source for fishes.[23]

In India and countries of its origin *P. juliflora* was called a “poor man’s tree” or a valuable tree. But people’s perception about the costs and benefits of P. *juliflora* depend on their livelihood strategy. Rural poor who cannot afford alternative energy sources value the tree for fuel and fodder production. Similarly, ranchers, pastoralists and agropastoralists whose main livelihood strategy is keeping livestock and farming view it negatively because it invades pastures and farm lands .[23]

1.4. Plant Profile

Mesquite or Vilayati babul (*Prosopis juliflora*) is a xerophytic evergreen tree; it thrives on all soil types under variable climatic conditions (Anonymous, 1969) [24] *Prosopis* species are all trees or shrubs of varying size (rarely sub-shrubs), predominantly xerophilous, aculeate, spiny or rarely unarmed[25]

P. juliflora has a large crown and an open canopy and can grow to a height of 14 meters. Its stem is green-brown, sinuous and twisted with axial and strong thorns . It has a thick rough grey-green bark that becomes scaly with age. *Prosopis juliflora* is a thorny shrub 3-5 m or tree growing up to 15 m height. The plants are often multi-stemmed and furnished with abundant large and very sharp thorns measuring up to 5 cm. The tree is deeply rooted. The stems are shaped in a "mild zigzag" way with one or two stout thorns at each turn of the stem. [26]

The leaves are twice-compound (bipinnate) with mostly two, sometimes more pairs of pinnae, 6-8 cm long, 12-25 pairs of oblong leaflets per pinna, 6-16 mm long, 1.5-3.2 mm wide, dark bluish-green and have high tannin content. The foliage is unpalatable for livestock, except for very tender new shoots. *P.juliflora* flowers throughout the year with yellow flowers hanging from the branches. Its fruits are pods, which are green when immature and turn yellow when they mature. A mature *P. juliflora* tree can produce 40 kg of pods per year, from which 60 000 seeds can be obtained [27].

The root system of *Prosopis* consists of a deep tap root, sometimes reaching to the unusual depth of 35 m, combined with extensive lateral roots. *Prosopis* is especially suitable for dry sites with annual rainfall between 150 –700 mm. Tap roots contribute to a stable anchoring of the tree and expand towards ground water reserves. They are essential during periods of drought when only deep water sources are available. The depth of the roots depends on the quality and structure of the soil and the availability of soil water; it is also determined by the density of the stand. Once the water source is reached, the roots extend horizontally in the direction of the water flow. *Prosopis* species are adapted to areas with low rainfall and long periods of drought once they are established and are able to tap groundwater or any other water source during the first years. The lateral roots play an important role during rainy seasons or periods of abundant water, for instance, in irrigated areas. The trees are also able to absorb moisture through their foliage during light rains or from dew or other atmospheric sources of moisture [2]

1.5. Negative Impacts

The fact that there are clear economic uses to this species but on the other hand severe negative consequences of *P. juliflora* invasion makes this a conflict of interest species.[28] It invades the farmlands, rangelands, irrigation canals, narrowing roads , and the spine attacks the livestock when they collect the pods[6]. In Africa and Asia, however, it remains under-used and is often regarded as an invasive weed and calls it a “devil tree”.[23]

Prosopis juliflora can be a very aggressive invader and replaces native vegetation and takes\-over rangelands. Negative effects include complete loss of pasture and rangelands for both domestic and wild ruminants, losses due to access to water and the destruction of fishing nets by the thorns, and illness and death of livestock due to eating *P. Juliflora* pods and being pierced by the sharp and stout thorns. Other impacts are loss of cropland, the costs of repairing tyres punctured or destroyed by thorns, and doctor's bills for treating thorn wounds. Dense stands of *P. juliflora* can block irrigation channels, obstruct roads and block smaller trails completely affecting access to pasture, croplands, water sources and fishing areas.

Animals do not eat the grass found under these tree. This tree contain more acidic ph value and due to this the soil becomes unfit for agriculture use. The abundance growth of this tree is responsible for pushing ground water table down and drying up surface soil killing vegetation in Rajasthan.[29]

It is sometimes said to dry out the soil and compete with grasses, particularly in dry areas; hence, in some areas it is considered a weed. Invasive, exotic *Prosopis* species have been

declared noxious weeds in Australia, South Africa, Sudan and Pakistan. The impact of *P. Juliflora* in the UAE has been studied by Essa*et al*., (2006) that showed a great depressive effect on the number, density and frequency of the associated species, particularly its invasion to native vegetation. *Prosopis cineraria*. It is being combated by many municipalities including the municipality of Dubai. The allelopathic effects of the organic extracts of its green and dried leaves on growth of different Gram- positive and Gram-negative antibiotic resistant bacteria, which become a major clinical and public health problem within the lifetime of most people living today.[30]

It invaded grasslands are transformed to woodland and forests. Loss of grass cover under canopies may also promote soil erosion. It has massive impacts upon water resources. Crop farmers from Chemonke village, Kenya, had to seek alternative settlement elsewhere because they have lost their land to P. *juliflora* invasions, often resulting in conflict with established communities, respectively, said that life would be better without *Prosopis*. Over 90% of livestock owners in eastern Sudan regard invasive *Prosopis* as a liability and pastoralists in Ethiopia refer to *Prosopis* as the "Devil Tree". P. *juliflora* has been included in the Global Invasive Species Database (GISD 2010). It has been listed as a noxious weed in all Australia states , Kenya and in Hawaii.[26]

Invasion of woody perennials in grazing lands has been viewed both positively and negatively. positively as a source of browse and shelter to grazing animals, and negatively as competitors for nutrients, water, and space with existing vegetation (Inderjit 2005). [30]

Prosopis juliflora (Sw.) contains many alkaloids such as juliflorine, julifloricine and julifloridine ,juliprosine juliprosinine and juliflorinine, are found to beresponsible for the biological activity. Recently ,*juliflora*vizole a novel alkaloid with broad spectrum antifungal activity against species of *Fusarium* ,*Drechslera* and *Alternaria* was reported from the leaves of *P. juliflora*[19]

2. Allelopathic Effect

Allelopathy is the detrimental effect of chemicals or exudates produced by one living plant species on the germination, growth or development of another plant species or microorganism sharing the same habitat. The leaves of *P. juliflora* contain various chemicals including tannins, flavinoids, steroids, hydrocarbons, waxes and alkaloids (Pasiecznik et al.2001). These are known to have effects on the germination and growth of other plant species. As a result of this, the plant diversity (both the number of individual plants of a species and the number of species around P. *juliflora*) will be affected by the allele-chemicals. Low light under *P. juliflora* canopy also make other plant species' survival difficult.[31]

In addition, several studies reported the presence of allelopathic compounds in *P. juliflora*. For example, Kaur*et al*.[13] detected the L-tryptophanin leaf leachates of *P. juliflora*. Nakano *et al*. (2001) suggested that L-tryptophan may play an important role in allelopathy of *P.juliflora* leaves. The negative impact of the plant could be through light deprivation, competition for water and nutrient, or leaching of allelopathic compounds. [32]

The high germination nature of the seed, mechanisms of seed dispersal, and its wide-range ecological adaptability are the main drivers for the high invasion rate. By the year 2020, [33]

3. Controlling of Mesquite

Mesquite may be controlled in at least 2 ways-

1. by removing the whole plant deep root enough to destroy all the buds. This can be accomplished either by hand grubbing or by power machinery.

2. by applying chemicals that will kill dormant buds on the underground stem without removing it.[34]

4. Pharmacological Activities

4.1. Antagonistic Effect

Well-diffusion test for *P. Juliflora* methanolic crude extract on two tested Gram negative bacteria (*E. coli* and Klebsiella sp.) and three Gram positive bacteria (*Staphylococcus aureus*, Bacillus sp and Streptococcus sp.) indicated inhibition of all tested bacteria . Green leaves showed the widest zone of inhibition on all tested bacteria with 22 and 19 mm zone of inhibition against Streptococcus sp., and Bacillus sp., respectively, whereas dry leaves revealed intermediate inhibition. The tests on Gram positive bacteria (*S. aureus*, Streptococcus sp., and Bacillus sp.) had higher sensitivity than Gram negative bacteria (*E. coli* and Klebsiella sp.) Overall, P. *juliflora* methanolic crude extract of green leaves succeeded to inhibit growth of all tested bacteria.[13]

4.2. Antibacterial Activity

The alkaloid rich fraction obtained from various parts of *Prosopis juliflora* were assessed for their antibacterial property using disc diffusion method on several Gram-negative and Gram-positive bacterial strains like *E.coli, Staphylococcus aureus, Bacillus cereus, Psuedomonas putida, Klebsiella, Salmonella, Acinetobacter and Alcaligen.*

Strong antibacterial effect was shown by leaf, pod and flower extract, with MIC [Minimum inhibitory concentration] value ranging between 25µg/ml-100µg/ml. The extracts of leaves showed highest activity among all the plant parts. *Klebsiella* was found to be the most susceptible bacteria, whereas *Acinetobacter* and *Alcaligen* were the least susceptible.

Growth of *Acinetobacter* and *Alcaligen* which were not inhibited by antibiotics, showed inhibition by the alkaloidal extracts, similarly a known ampicillin resistant *E.coli* strain was found to be inhibited by the plant extracts. DART-MS analysis of the alkaloid rich fractions showed the presence of piperidine alkaloids.[21]

The basic chloroformic extract (BCE), whose main constituents were juliprosopine (juliflorine), prosoflorine and juliprosine, showed Gram-positive antibacterial activity against Micrococcus luteus (MIC = 25 µg/mL), Staphylococcus aureus (MIC = 50 µg/mL) and Streptococcus mutans (MIC = 50 µg/mL).[21]

4.3. Antifungal Activity

To evaluate the antifungal potential of *P. juliflora* against *Alternariaalternata*, phytopathogenic fungi of tobacco plant. Aqueous extract of the leaves was tested in keeping view of developing management strategies in combination with synthetic fungicides or the aqueous extract alone. The further toxicological studies at the dosage tested is warranted as the pooled alkaloids recorded several neurological disorders in test animals. Hence the use of this alkaloid fraction in combination with already available fungicides which will reduce the concentration of both will be suitable choice. Aqueous extract recorded highly significant antifungal activity at 24% concentration. Among different solvent extracts tested, methanol and ethanol extract recorded highly significant antifungal activity[13].

Prosopis juliflora(Sw.) is known to contain pool of alkaloids with various biological activities including broad spectrum antifungal activity against a wide range of seed-borne fungi. Alkaloid extract of *Prosopis juliflora* (Sw.) DC was amended with all the chemical fungicides at 1.5 g L-1 and 1 g L-1. The combination of chemical fungicides amended with alkaloid extract showed highly significant antifungal activity compared to chemical fungicides alone tested at the recommended dosage. The study strongly recommends the idea of amending the plant extracts with chemical fungicides which are generally used for seed treatment, so as to reduce the dosage of the chemical fungicides during the seed treatment strategies and to achieve significant inhibition of the seed mycoflora in general and toxigenic fungi in particular.[35]

4.4. Anti –Tumor Activity

The total alkaloid extract from *Prosopis juliflora* DC. leaves was obtained using acid/base modified extraction method. The in vitro anti-tumor potential of the extract was evaluated using MTT (3-(4,5- dimethythiazol-2yl)2,5-diphenyl tetrazolium bromide) based cytotoxicity monitoring after 24, 48 and 72 h exposure of the MOLT-4 cells (1×10^6 cells/ml medium) to different concentration of the extract ranging from 10 to 100 µg/ml medium. The genotoxic potential of the extract was also tested using cytokines is block in vitro micronucleus assay. Simultaneously, the cytotoxic and genotoxic potential of the extract were compared with mitogen stimulated T-lymphocyte cultures derived from peripheral blood of healthy volunteers. The MTT test revealed that, the extract exhibited comparatively higher toxicity towards the cancer cells than the normal cells at all the tested concentrations and at all the time points studied. The results of the present investigation demonstrate that, P. *juliflora* leaf alkaloids are preferentially cytotoxic to human T-cell leukemia (Molt-4) cells in a dose and time dependent manner with the absence of genotoxicity.[36]

Prosopis juliflora (Sw.) DC contains many alkaloids such as juliflorine, julifloricine and julifloridine, juliprosine, juliprosinine and juliflorinine are found to be responsible for the biological activity. Recently, *julifloravizole* a novel alkaloid with broad spectrum antifungal activity against species of *Fusarium, Drechslera* and *Alternaria* was reported from theleaves of *P. juliflora*[20]

4.5. Ethanol Production

Zymomonas mobilis has been considered a promising alternative to Saccharomyces cerevisiae in the synthesis of ethanol. Regarding the high amount of carbohydrates present in mesquite pods and their high production in different countries, they could arise as a feasible alternative source for ethanol production. *Prosopis juliflora* is an underestimated source of sugars that can be converted into ethanol. Trials in the USA have shown that up to 80% of the pods carbohydrates can be converted in the process.[37]

5. Conclusion

From the above review, it can be concluded that *Prosopis juliflora*is used traditionally since many years as reported in various literature. However, after detected of various newer compounds from the plant, several new activities were reported by the researchers and hence the plant is now gaining importance to develop some more new search for the future development by understanding the gene level study. Therefore, considering its versatile medicinal uses, there is an ample scope for future research on *Prosopis juliflora* and hence further pharmacological investigations are warranted.

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