The Biology of Balochistan weeds: *Prosopis juliflora* (Swartz) DC

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Abstract:

Prosopis juliflora (Swartz) DC, belongs to leguminous family of Mimosaceae, is one of the most controversial exotic plant species that infests field crops, small grains, grasslands, and a variety of other habitats in central and southern Pakistan. P. juliflora is amongst the most invasive species in hot semiarid and arid regions of Pakistan, which showed negative impacts on local flora of Pakistan. At the same time it is also regarded as an economically and ecologically important tree species of arid zone, where it is used as fuel wood, timber, fodder (especially legume) for livestock including goats, sheep, and cattle. Similarly it can be used as shade in hot climates, as well as for stabilization of sand dunes in the coastal areas. P. juliflora is a perennial thorny shrub which under favorable conditions also reached a height of 5m tall but occasionally up to 12m. It is mostly grow through seeds which exhibited a high level of seed dormancy due to a hard seed coat that usually requires damage to germinate. High seed production, a persistent seed bank, an endozoochory seed-dispersing mechanism, and the ability to tolerate different mechanical, chemical and biological control methods contribute to the success of P. juliflora in these habitats. Similarly P. juliflora also exhibited allelochemical activities which negatively affect the growth and germination of competing native flora.

Key words: *Prosopis juliflora, mesquite, allelopathy, weed biology, native plant species*

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1. Name:

Prosopis juliflora (Swartz) DC, Mexican thorn, (Belton 2008), Mesquite' (English) and 'mezquite' (Spanish) are used in North America, and 'algarrobo' (Spanish) and 'algarobeira' (Portuguese) are used in Latin America (Pasiecznik, *et al*. 2001). It was suggested that word "mesquite" originated from the original Nahuatl Indian name from Mexico, 'misquitl' meaning 'bark that tans' (Pasiecznik, *et al*. 2001, Maldonado 1990). In Pakistan it is commonly known as "vilayati babul, vilayati jand, vilayati kikar (Punjabi)". Similarly Walaiti Babur, Devi, Shatan Babur are used in Balochi. Family: Mimosaceae.

2. Distribution:

P. juliflora is a major invasive species in different parts of the world including Saharan and southern Africa, the Middle East, Pakistan, India, and Hawaii (USA) (Pasiecznik, *et al*. 2001). In Pakistan, it is mostly distributed in Saharo-Sindian phyto-geographical region, which include vast tract of areas of Southern Balochistan, Sindh, and lower Punjab. In Balochistan, this weed mainly distributed in coastal areas of Gwadar and Lasbela districts where it was deliberately introduced by different governmental and non-governmental agencies during the last quarter of 20th century. A recent survey conducted by Faculty of Agricultural, Lasbela University (LUAWMS) under the supervision of first author of this paper, during this survey it was observed that *P. juliflora* penetrated into different parts of Lasbela district where previously it was unknown. Results of this survey are still under process.

3. History

Prosopis juliflora (Swartz) DC is biologically one of the most controversial leguminous plants in arid and semi-arid regions of the world. *P. juliflora* is a native to Mexico, South America and the Caribbean (Kaur *et al*. 2012). *P. juiflora*, like any other exotic plant, when introduced into

Indo-Pak subcontinent becomes far more abundant and noxious than in their native range.

According to Reddy (1978) the first introduction of *P. juliflora* in India took place in 1877.

The plant was propagated through seeds which were brought from Jamaica one year earlier. Similarly in 1877, *P. juliflora* was also introduced in Sindh province of Pakistan to check sand dunes movements and few years later, it was also introduced in plains of Pakistani Punjab (the arid areas of the Lahore, Sahiwal and Multan Districts) (Raizda and Chatterji 1954). However, Luna (1996) gives a compelling account of the introduction of *P. juliflora* in Indian subcontinent, and uses the date of 1857 as that of first introduced in Sindh province from Mexico. The introduction of *P. juliflora* in Balochistan was initiated by provincial Forest Department around 1970 in Pasni Tehsil, 1972 in Gwadar and 1981-82 in Pishukan coast areas of present districts of Gwadar (Khan 1987). Like any other parts of Indo-Pak Subcontinent this program was also initiated to protect roads and local abodes from shifting of sand dunes.

4. Description and Account of Variation

(a) Taxonomical description

A medium sized tree, thorns 0.7-5.0 cm long, axillary, stout. Perennial deciduous thorny shrub or small tree, to 12 m tall (under favorable conditions it reach a height of 20 cm Singh and Singh 1993); trunk to 1.2 m in diameter, bark thick, brown or blackish, shallowly fissured. Leaves bipinnate, alternate, rachis 2.5-12.5 cm long, prolonged beyond the last pinnae as a soft bristle, swollen and glandular at the base, pinnae 1-2 pairs, 7.5-12.5 cm long, sometimes glandular between the leaflets. Leaves compound, commonly many more than 9 pairs, the leaflets mostly 5–10 mm long, linear-oblong, glabrous, often hairy, commonly rounded at the apex; stipular spines, if any, yellowish, often stout (Online Flora of Pakistan 2014, Reed, 1970). Under natural condition plant started lowering at the age of 3-5 years and under certain experimental condition, begin flowering at 3-4 months after germination (Pasiecznik *et al.*, 2006).

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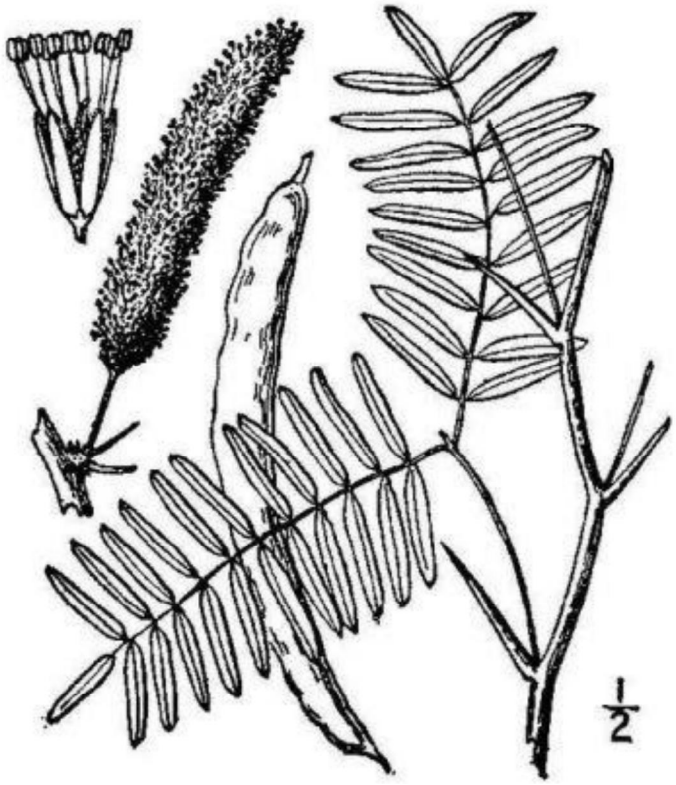
Flowers are perfect, greenish-yellow, sweet-scented, spikelike; corolla deeply lobate. Flowering period: March-September. Pods several-seeded, strongly compressed when young, thick at maturity, more or less constricted between the seeds, 10–25 cm long, brown or yellowish, 10–30-seeded. Seed compressed and oval or elliptic, 2.5–7 mm long, brown (Online Flora of Pakistan, Reed, 1970).



(b) Morphology

The plasticity is apparent in morphology of *P. juliflora* when grow in tree form, including erect tree, flat-topped trees and trees with decumbent branches that touching the ground. Similarly variation in morphology also observed when *P. juliflora* grown in shrub form, including erect sub-shrub to prostrate shrub form. In both shrubs and trees multi-stemmed was pronounced. According to Lee *et al*. (1992) and Kumar *et al*. (1998) differences in morphology and architecture in *P. juliflora* is due to genetic variations. However, environmental factors such as thin soils, presence of parental bedrock on soil surface and persistent wind pressure are also played an important role in morphological diversity in *P. juliflora* which induce the formation of smaller and prostate individuals.

(c) Reproductive characteristics:

Flowers are diminutive and 4-6 mm long which attached on spike-like inflorescences commonly known as racemes. Flowers are bisexual and yellow in colour. Flowering in *P.juliflora* take place throughout the year. *P. juliflora* mostly reproduces by seed, however, it is also propagated through cuttings of roots or stems. Pollination takes place with the help of insects. Seeds are found in a long narrow indehiscent pod with a high content of sticky, sugary material. Each legume contains up to 30 seeds per pod. Seeds are up to 6.5 mm long and weigh around 0.25-0.30 g (Pasiecznik *et al.*, 2001). The seed remain dormant for a specific period due to a hard outer layer (exocarp) which requires damage to stimulate germination. According to Pasiecznik and Felker (1992) when seeds remained in soil seed bank for a longer period of time the hard seed coats will also degrade over time and older seed that is still viable tends to germinate without pre-treatment. More than 90% of freshly harvest seed showed germinability, because at early stages of seed maturity the seed coat has not yet hardened (Ffolliot and Thames 1983).

Dispersal of seeds takes place through endozoochory when animals eat the pods and seeds are excreted through their droppings.

During the rainy season a large number of seeds germinate in the animal dung (Shiferaw 2004). Seed germination is depending upon available soil moisture and water quality, available nutrients, temperature and the depth in the soil (El-Sharkawi *et al* 1997). Therefore, availability of soil moisture has played an important role on germination, emergence and seedling survival (Pasiecznik *et al.*, 2001).

(d) Root system

P. juliflora is typical phreatophyte, and develop two different types of root systems i.e. surface lateral roots and deep tap roots (Jenkins *et al.* 1987, Pasiecznik *et al.*, 2001, Gallaber and Merlin, 2010). According to Raven *et al*. (2005) the deep tap root systems of *P. juliflora* were found growing at a depth of 53.3 meters (nearly 175 feet) at an open-pit mine near Tucson, Arizona. The extensive root system also plays an important role in survival of *P. juliflora* under harsh environmental conditions. It was suggested that roots in *P. juliflora* develop rapidly after germination of seeds and can reach a depth of 40 cm in eight weeks (Pasiecznik *et al.*, 2001). Therefore the extensive root system played an important role of hydraulic redistribution in *P. juliflora* (Hultine *et al.*, 2004), and helps the plant to survive under drier condition without adopting xerophytic alterations in morphology (Bristow, 1996). Recently, Yoda *et al.* (2012) reported that plastically in root architecture in *P. juliflora* was prominent according to different soil moisture conditions, and acquired water and nutrients in the soil effectively using horizontal surface roots and deep tap roots. In this study which was conducted in dry environmental conditions Eastern Africa, during the rainy months of July-September, the tap root systems of *P. juliflora* seedlings penetrated beyond 3 m depth in the soil and to grow vigorously with expending lateral root system.

This extensive root system during the rainy seasons helps the seedling to establish itself in acquiring water from subsurface-aquifer. Therefore the juvenile seedlings secure its establishment in new habitats during the dry season (Yoda *et al*. 2012).

5. Allelopathic effects

Allelopathy is defined as the negative effect of chemicals compounds produced by a plant species on the germination, growth of another plant species when grow together in a same habitat (Akobundu 1987). De Candolle (1832) was the first scientist who observed that some plants species exude chemical substances from their roots and aerial parts that are detrimental to the growth of other plants. However, it was Molisch (1937) who introduced the term allelopathy in reference to biochemical interactions between living organisms when shared the same environment. It has been reported that allelopathy helped some exotic plant species to become dominant in invaded plant communities (Callaway and Aschehoug, 2000). It is observed that *P. juliflora* inhibit germination and growth of neighbouring plant species through the release of allelopathic substances into the environment (Al Humaid and Warrag, 1998). It was also observed that the root system of *P. juliflora* has allelopathic effects that hinder the germination and growth of competing plant species (Elfadle and Luukkanen 2006). The negative effects of *P. juliflora* was mainly due to various chemicals including tannins, flavinoids, steroids, hydrocarbons, waxes and alkaloids which are leached down from green aerial parts (Pasiecznik *et al*. 2001). Getachew *et al*. (2012) reported that leaf, bark and root aqueous extract of *P. juliflora* at 0, 0.5, 0.8, 1, 2 and 6% inhibited seed germination of *Cenchrus ciliaris* and *Enteropogon rupestris,* however germination of *Acacia nilotica* and *A. tortilis* was not affected by all aqueous extracts of different organ parts of *P. juliflora.* From the results of this study it was concluded that the

allelopathic effect of *P. juliflora* is species specific and annuals

(*Cenchrus ciliaris* and *Enteropogon rupestris*) were affected more than perennials (*Acacia nilotica* and *A. tortilis)*. Similarly leaf extracts to contain greater amount of inhibitors chemical compounds compared with root and bark. However, effects of aqueous substances from bark showed least affect on germination of these plants. From these results it was concluded that heavy accumulation of toxic substances at under canopy soil of *P. juliflora* may be one of the reasons which made *P. juliflora* a successful invasive plant species in an exotic environment.

6. Tolerance to High pH

P. juliflora is an ideal plant in regeneration and afforestation of sodic wastelands, particularly in coastal area where soil salinity regime equivalent to seawater salinity (Garg, 1999). It is also helpful in reclaiming the agricultural fields which are affected by salinity. According to Yadav and Singh (1970) *P. juliflora* can withstand in a soil with 0.54% soluble salts and a pH below 9.5, however, *P. juliflora* saplings died within 3 years of planting at soil pH 10.1 to 10.6 and electrical conductivity (EC) 1.66 to 5.43 dS/m (Singh *et al*. 1990). Similarly, according to Rhodes and Felker (1988) *P. juliflora* can tolerate 12,000 mg/l salinity level. From these results it was concluded that *P. juliflora* grew adequately without the application of soil amendments in soils of pH 9.01 to 9.59 and at a low EC level (0.6 to 1.2 dS/m) (Rhodes and Felker, 1988).

7. Controversies relating with the status of *P. juliflora*: noxious weed or a blessed-tree?

P. juliflora is a fast growing, salt tolerant and drought tolerant shrubby species; therefore it is used for several purposes in arid and semi-arid regions of the world.

In Lasbela district, the Afghan nomads built inexpensive 'Casamance' mount kilns, which they used for making charcoal from woody stem of *P. juliflora*. Although the provincial government did not regularize this charcoal producing cottage industries but there is a potential for producing good quality charcoal from prosopis trees. Iqbal and Shafiq (1997) elaborated the benefits of *P. juliflora* in rural areas of Pakistan where it used as valuable resources in the form of firewood, timber, as well as fodder for livestock. Similarly in hot climates, it used as shelter and as wind breaks, as well as for the stabilisation of sand dunes which are always threatening to invade into local abodes. *P. juliflora* also fulfill the demand of local folks in rural areas regarding the procurement of natural resources, who are always facing the shortage of natural resources due to unchecked population pressure, drought and other climate hazards. For instance, in Lasbela district up to 80% of firewood comes from this plant (Forest Department, *personal communication*). In the said district one can notice the presence of several sawmills on both sides of national highway chopping lumbers acquired from *P. juliflora*. Moreover, *P.juliflora* is extremely tolerant towards a wide range of climatic, soil physical and chemical factors. *P. juliflora* can also be used for manufacture of furniture and agricultural tools. The sweet, nutritious pods rich in carbohydrate and vitamins are consumed by mammals, birds, insects and reptiles. The floral parts of *P. juliflora* are rich in nectar and pollen which also exhibit dazzling colours that can be manipulated in apiculture industry. There is a potential of obtaining high quality honey from these plants which is also helpful in enhancing the livelihood of local folks of the district. *P. juliflora* is used for acquiring gums (pseudo-gum Arabica) from the trunk and branches which can be used in various sectors i.e. food, pharmaceutical, chemical and manufacturing industries. On the basis of above mentioned reasons, particularly energy shortages of rural communities of southern Pakistan, the Forest Department of

Balochistan Government extensively establishing new plant stands of *P. juliflora* in different parts of Lasbela District (Forest Department, *personal communication*).

Like any other leguminous plant *P. juliflora* also possess the ability of fixing the atmospheric nitrogen through *Rhizobium* bacteria which grow in root nodules. Therefore, this plant is also used as a green manure in the wasteland and newly acquired agricultural field. Similarly, *P. juliflora* is also helpful in enhancing soil fertility and reducing the salinity.

Despite all these above-mentioned benefits, there are enormous scientific papers available which revealed the negative impacts of *P. juliflora* on ecosystem. These scientific sources regarded *P. juliflora* as an aggressive invader. Even the advocates of *P. juliflora* plantation, for instance, Forest Department, Government of Balochistan, personally admitted the negative impacts of this invasive plant on grazing land, native plant species and general biodiversity within the native ecosystems (Forest Department, *personal communication*). According to Sharma and Dakshini (1998) *P.juliflora* due to its aggressive and invading nature not only successfully invaded local ecosystems where it was introduced but also seriously involved in damaging of finer soil particles that resulted into increased salt content of soils in dry conditions.

Although *P. juliflora* first introduced in Indian subcontinent to stabilize the sand dunes in late 19th century, however, it is still in practice, especially in coastal areas of Balochistan (Forest Department, *personal communication*). Unfortunately, due to lack of natural enemies in introduced area and favourable environmental

conditions, *P. juliflora* soon became a noxious weed and spread in different ecosystem.

It is recorded as an aggressive invading plant in different ecosystems such as ravine forests and river banks, irrigated crop land, road sides, national parks and immediate settlement areas.

8. Management and control

P. juliflora is very hard to be eradicated and there are several methods are applied to control its widespread in native rangelands where it threatened the survival of local flora.

(a) Physical/mechanical methods

Once *P. juliflora* established in a newly acquired area, it is hard to be eradicated. The physical and mechanical methods are includes:

(i) Hand weeding- it is an old and effective method which selectively removed the unwanted plant species; however, it is laborious and time consuming method which need lots of manpower. This method is effective only when *P. juliflora* is at seedling stage and plants up to 20cm, or grows in light or sandy soils where the shallow root system can be completely removed.

(ii) Cutting – it can be applied before flowering stage; therefore it will prevent further seed dispersal. Cutting is only affective when plant is large enough to remove the above ground portion. Traditional tools can be used for cutting the mature plants such as chainsaw for large stemmed plants, or a clearing saw, handsaw, for smaller plants.

(iii) Hand-digging – this is laborious and time consuming method and effective only on small infestations of *P. juliflora*. It is important that all underground parts of mother plant should be removed.

(iv) Mechanical method-is expensive and showed negative impacts on surrounding environment (Belton, 2008).

(b) Chemical herbicides:

There are several chemical herbicides are available which can be used to control *P. juliflora*, such as glyphosate, metsulfuron-methyl, triclopyr, picloram, and 2-4-D (Belton, 2008). Unfortunately, these chemical are very expensive and poor country like Pakistan, where cheap labour is easily available, application of these chemical herbicides is not a common practice. However, in luxury resorts such as golf-courses and lawns of hotels, motels and villas, these chemical herbicides are affective, because they provided desirable results in a shorter period of time.

(c) Biological control:

When exotic plants are introduced in an alien environment, they grow faster and become a weed due to the absence of their natural enemies. Therefore, in biological control methods those natural enemies after several experiments in controlled environmental condition are introduced for the control of these plant species. In late 1990 two species of seed boring bruchids (insects) were introduced to Ascension Island for the biological control of *P. juliflora*. These were *Algarobius prosopis* and *Neltumius arizonensis.* Similarly an insect of the genus *Rhinocloa* has also been recorded as a natural enemy of *P. juliflora* (Belton, 2008).

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