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NOTES ON NEGLECTED AND UNDERUTILIZED CROPS

Traditional uses, phytochemistry and biological activities of *Parkia timoriana* (DC.) Merr., an underutilized multipurpose tree bean: a review

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Abstract Tree bean, *Parkia timoriana* (DC.) Merr. (Fabaceae) is an underutilized nutritious leguminous tree found in North-eastern states of India and other Southeast Asian countries. Ethnobotanically, tree bean has much importance among the ethnic groups in various states of Northeast India. Decoctions of bark, fruit and leaf parts are used to treat various diseases. Right from flowers and tender pods to mature seeds of this plant are edible, provide a good source of nutrients and fetch high market price during particular seasons. Cultivation of this tree will not compete with other legumes in an existing field and it could be a supplementary source of vegetable proteins if properly exploited. Anti-nutritional factors, total free phenols, tannins and lectins can be eliminated if the seeds are properly processed by heating or cooking since these factors are heat-labile. Only a few researchers worked on phyto-constituents of the plant with lacuna in nutritional studies and pharmacological activities. The plant has been reported to possess antioxidant, α-glucosidase and α-amylase inhibitory properties, antibacterial, antidiabetic, antiproliferative and insecticidal activities. Though it has much importance in commercial purposes, research and knowledge on this wonder plant is meagre and its utilization for human consumption has not yet been fully exploited. The present review is aimed to provide a botanical description and highlights ethnobotanical uses, nutritional value and biological activities along with its toxicity and future prospects.

Keywords Ethnopharmacology · Medicinal uses · *Parkia roxburghii* · Review · Toxicity

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Introduction

Legume family (Fabaceae/Leguminosae) is third largest family of angiosperms with about 730 genera and more than 19,400 species worldwide (Mabberley 1997) and second only to Poaceae (grass family) in view of agricultural and economic importance.

Fabaceae covers about 27% of the world's primary crop production with grain legumes and 33% of dietary protein nitrogen needs of mankind (Graham and Vance 2003). The number of economically important plants in Fabaceae is not larger than that of Poaceae, but they exceed them in range of uses (Doyle and Luckow 2003). The different species of Fabaceae provide food, pharmaceuticals, medicines, biodiesel fuel, commercially important enzymes, wood for building, construction, textiles, furniture and crafts, paper and pulp, mining, chemicals, fertilizers, waste recycling, horticulture, pest control and also ecotourism (Lewis et al. 2005).

Most species of Fabaceae have developed a number of chemical defence mechanisms with alkaloids, tannins, terpenoids and isoflavonoids, however the chemical mechanisms are relatively easy to de-toxify or to remove by breeding programmes (Hammer and Khoshbakht 2015). The general characteristic features of Fabaceae are distinctive in being trees, shrubs, vines or herbs, with stipulate, often compound leaves and typically pentamerous flowers, usually with a single, unicarpellous pistil, marginal placentation, the fruit a legume (Simpson 2006). Roots of many species have symbiotic association with N_2-fixing bacteria (*Rhizobium* spp.) which induce formation of root nodules (common in the Faboideae). The symbiosis with root bacteria which are able to bind nitrogen from air makes them vital in land improvement and used as green manuring (Hammer and Khoshbakht 2015).

The Fabaceae is classified into three subfamilies viz. Papilionoideae (Faboideae), Caesalpinioideae and Mimosoideae. The subfamily Mimosoideae (Mimosaceae) consists of 80 genera (3270 species) of trees, shrubs and lianas found mainly in tropical, subtropical and warm temperate regions of the world where they serve as important sources of forage and fuel (Luckow et al. 2003). Until recently, Bentham's (1875) classification was followed for Mimosoideae, who recognized five tribes based partly on aestivation of sepals and male reproductive parts. Recent phylogenetic studies based on molecular and morphological data have cast serious doubt on monophyly of these tribes in Mimosoideae and is revised into four tribes such as Acacieae, Ingeae, Mimoseae and Mimozygantheae (Wojciechowski et al. 2004).

Parkia: an Indo-Pacific genus

Parkia R. Br. is a genus of the tribe Mimoseae (family Fabaceae, sub-family Mimosoideae) with 31 species distributed throughout both the New World and the Old World tropics. It was named in memory of celebrated Scottish explorer of West Africa, Mungo Park (1771–1805). Some species of *Parkia* are known as "*African locust bean*". *Parkia* is taxonomically most diverse in rainforest of Amazon basin, four species are found in Africa and Madagascar and about 10 species in the Indo-Pacific region (Luckow and Hopkins 1995). *Parkia* is a major tree legume producing human food and condiment in savannah areas.

"*The Plant List*" includes 39 accepted names for the genus *Parkia* which are widely distributed in tropical regions of the World with six scientific names of infra-specific rank (www.theplantlist.org). Hooker (1879) reported four species of *Parkia* from India such as *Parkia biglandulosa* Wight et Arn., *P. insignis* Kurz, *P. leiophylla* Kurz and *P. roxburghii* G. Don with cosmopolitan in distribution in tropical areas. Hopkins (1994) revised the genus *Parkia* and described 12 species which occur from Northeast India to Fiji and they appear to be more closely related to the African species of this section than to the American ones. According to current taxonomic studies, available species of *Parkia* in India are *P. timoriana* (DC.) Merr., *P. biglandulosa* Wight et Arn., *P. filicoidea* Oliv., *P. speciosa* Hassk., *P. clappertoniana* Keay and *P. bicolor* A. Chev.

Botanical description and distribution of *Parkia timoriana*

Parkia timoriana (DC.) Merr. is the accepted botanical name of "*Tree Bean*" (www.theplantlist.org). The synonyms of *P. timoriana* are *Parkia roxburghii* G. Don, *Acacia niopo* Litv., *Inga timoriana* DC., *Mimosa peregrina* Blanco, *Parkia calcarata* Lecomte and *Parkia grandis* Hassk. The plant was sometimes misapplied as *Mimosa biglobosa* auct. non Jacq., *Parkia africana* auct. non R. Br., *Parkia biglobosa* auct. and *Parkia javanica* auct. (http://www.theplantlist.org/tpl1.1/record/ild-24964). *Parkia timoriana* is one of the most widespread species of *Parkia* in the Indo-Pacific region. It is quite similar to *P. biglandulosa* from which it can be distinguished by broader, rather sigmoid, not linear leaflets and to *P. speciosa* from which it differs by acute, not rounded apex of leaflets and lack of pubescence on outer side of corolla lobes (Hopkins 1994).

P. timoriana is a large tree with spreading branches having white to brown or light grey bark with white spots, generally found in lowland rainforests and often along streams (Fig. 1). It's height at maturity varies approximately from 6 to 20 m or even more and spreads around 6–17 m. Leaves are compound bipinnate i.e. the mid-rib produces secondary axes which bear the leaflets. There are 14–31 pairs of pinnae and 52–71 pairs of leaflets in each pinna.

The inflorescence is head or capitulum of racemose type with clusters of yellowish-white tiny flowers, hanging at top of long stalks from the branches and emerges during June–July. The young inflorescences are protected by foliaceous bracts which are free from each other. The axillary bud does not develop fully but persist till the development of secondary bud and forms new shoots of subsequent season. At the base of every flower there is a thin membranous structure called bracteole; it covers individual flowers in inflorescence during juvenile stages thereby imparting its brown greenish colour to the head (Hopkins 1994). The heads produce numerous flowers, the majority of which are fades and drops off.

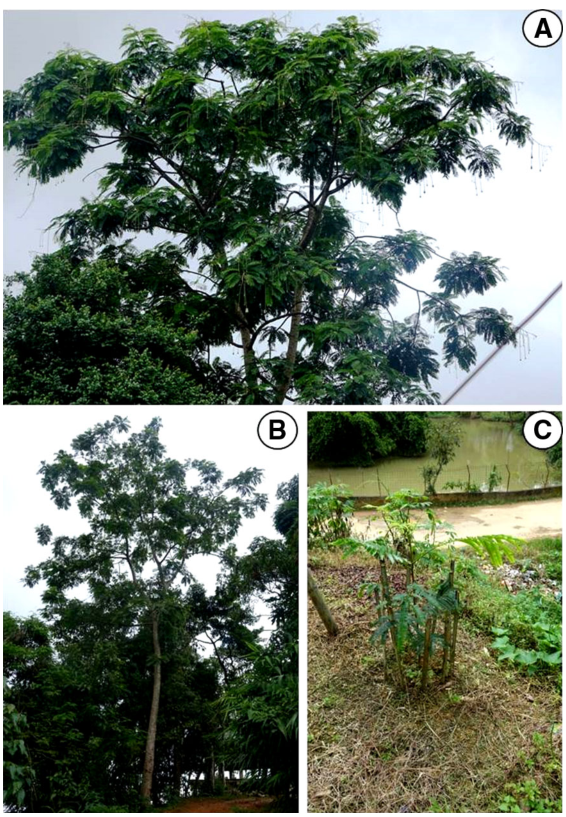


Fig. 1 *Parkia timoriana*, **A** A mature tree with drooping fruits, **B** tree beans planted on roadside near to ICAR Research Complex for NEH Region, Kolasib, Mizoram, India, **C** A seedling of tree bean, grown in the backyard of ethnic hamlet in Mizoram

Flowering starts by last week of July and fruit set starts after 10–15 days of flowering. The five calyx lobes are partially gamosepalous and petaloid and are persisting with the flower. Corolla lobes are five, membranous, polypetalous which are attached to the tubular structure of stamens about 2–2.5 mm above the calyx. There are 10 whitish stamens fused one another at the base and forms a tubular structure called staminal tube. The ovary is simple with single stigma and has marginal placentation (Hopkins 1994). The fruits in early stages are soft, tender and bright green in colour and comprises bunches of pods up to 50 cm in length. The fruits mature during March–April. Pods are formed in clusters of 10–15 and remain suspended on long peduncles. Depending on shape and size of pod, size and number of seeds also varies. Pods turn black on maturation and contain yellow dry powdery pulp in which several black seeds are embedded (Longvah and Deosthale 1998).

P. timoriana is a little known nutritious, leguminous tree which grows luxuriantly in north-eastern hilly regions of India and distributed in Southeast Asian countries like Burma, Bangladesh, Thailand and the Malaysian region. It is an important multipurpose leguminous tree having commercial and ecological significance. This tree is distributed in tropical and subtropical zones with an altitudinal variation from 40 to 820 m a.s.l. (Robert et al. 2003). *P. timoriana* is commonly grows in every house yard, jhums and forests in Northeast states in India such as Mizoram, Nagaland, Manipur, Meghalaya and Assam (Kanjilal et al. 1938). The tree is well adapted to grow in diverse agro-climatic regions from colder hilly regions to hotter plains without any special care (Thangjam 2014).

The plant has been locally recognized with different vernacular names (Table 1) in India (Firake et al. 2013) and other countries (Hopkins 1994). Wood of *Parkia* is classified as light hardwood, soft to moderately hard and light to moderately heavy (Hopkins

Table 1 Vernacular names of *Parkia timoriana* in India and other countries

Vernacular names in India (languages)	Vernacular names in other countries (languages)
Supota, Kharial—Hindi	Burma—Mai-Karien (Shan)
Urohi, Yongchak—Manipuri	Thailand—Riang, Karieng & spelling variants (Thai)
Manipuri seem—Bengali	Malay Peninsula—Kedawong, Kada-ong, Petai kerayong, Gudayong, Kuayong, Neneting, Tayur
Zawngtrah—Mizo	Sumatra—Alai, Alei (Indonesian)
Khorial—Assamese	Java—Kedawung, Peundeuj, Dawung, Petir (W Java)
Aoelgap—Garo	Sumbawa—Kopang (Indonesian)
Bire-phang—Kachari	Kalimantan—Koepang (Bandji)
Themuk-arang—Mikir	Sarawak—Buah batar (Kelabit)
Unkamn-pinching—Naga	Sabah—Timbarayong
Shivalingada mara—Kannada	Sulawesi—Olimbopo (Tolalaki)
Unkampinching—Marathi	Palawan—Amarang
	Luzon—Cupang or Kupang (Taf, Tagalog, Visayan)

1984). Approved vernacular name in timber trade for *P. timoriana* is *petai kerayong*. However problems associated with taxonomy of *Parkia* are caused by confusion of names, aggravated by cultivation, paucity of illustrations and incomplete or missing types (Thangjam et al. 2003). The present review highlights the nutritional, ethnomedicinal and pharmacological properties of *P. timoriana.*

Nutritional value

Tree bean can be a good source of various nutrients and supplements. Seeds of *P. timoriana* contain rich in protein (albumins and globulins), minerals (potassium, iron, magnesium, zinc, phosphorus and manganese), essential amino acids (isoleucine, leucine, phenylalanine and tyrosine) and fatty acids such as oleic and linoleic acids (Mohan and Janardhanan 1993). Processing method had a major role in determining nutritional and antinutritional components of this species. Sathya and Siddhuraju (2015) attempted some processing methods in kernels of *P. timoriana* and found that protein (15–36%) and lipid contents (11–69%) were enhanced after processing. All the methods attempted by them significantly reduced antinutrients such as tannins, phytate, saponins, trypsin and chymotrypsin inhibitors and lectins which led to an increase in protein and starch digestibility, whereas total phenolic content was increased.

Protein content of pods ranged from 12.1% in tender to 18.8% in mature pods, but protein content of kernels (28.8%) was much higher than pods, whereas maturity of pods led to an increase in protein and fat content accompanied by a decrease in ash and carbohydrate content (Longvah and Deosthale 1998). Fat content in seeds was less in tender stage and increased with age of pods (Salam 2011). Seeds and pods of *P. timoriana* have better mineral content than other grain legumes (Gopalan et al. 1989).

Composition of aspartic acid in tender pods of *P. timoriana* was exceptionally high, accounting for almost 26% of total amino acids (Longvah and Deosthale 1998). Level of essential amino acids is ranged from 33% in tender pods to 42% in kernels and increased with maturity of kernels. Development of pod from tender to mature stage led to a rapid decline in aspartic acid with an increase in glutamic acid content. Lysine in immature and mature pods and kernels were comparable to other legumes such as soybean (Gopalan et al. 1989) and *P. filicoidea* (Balogun and Odutuga 1982).

The essential amino acid content of *P. timoriana* kernel is comparable to the FAO/WHO/UNU (1985) pattern of essential amino acid requirement of preschool children (Longvah and Deosthale 1998). Fermented kernels recorded minor change in leucine, lysine and tyrosine content and 18.8% of trypsin loss was noticed which followed by cysteine (8.8%) and methionine (5%) when compare to raw kernels

(Sathya and Siddhuraju 2015). They also revealed that fatty acid content was increased in fermented kernels and it might be due to lipase/esterase activity. *P. timoriana* is reported to have a good source of ascorbic acid (26.0 mg 100 g^{-1}), fat (20.28%), proteins (32.82%) and minerals (4.45%), though it contains lesser amount of Na (51.0), Mg (34.7) and P (160 mg 100 g^{-1}) in seeds, Ca (97.47), K (2400), Cu (2.3) and Zn (2.77 mg 100 g^{-1}) which is at par with other legumes (Salam et al. 2009). *P. timoriana* was found to be a good source of Fe and Mn with 57.1 and 35.0 mg 100 g^{-1} in pod and 34.9 and 9.4 mg 100 g^{-1} in seeds, respectively.

Albumins and globulins derived from raw seeds showed haemagglutinating activity without any specificity against human ABO system (Mohan and Janardhanan 1993). Lectins purified from the pods mediate agglutination of red blood cells of rabbit and rat and no haemagglutination was recorded in human, sheep or goose red cells (Utarabhand and Akkayanont 1995). They also stated that, up to 64-fold increase in specific haemagglutinating activity of lectin was observed in trypsin treatment of rabbit RBC prior to haemagglutination test. The haemagglutinating activity was rapidly declined when the lectin was preheated to over 50 °C. The haemagglutinating activity was reduced to one half at 55 °C and completely lost at 70 °C (Utarabhand and Akkayanont 1995).

Devi et al. (2007) examined nutritional quality in leaf, seed and pods of *P. timoriana* in which crude protein was significantly high in seed (22.9%) than leaf and pods, whereas total carbohydrate was higher in pods (23.2%). Seeds have maximum fat (29.6%) whereas crude fibre was significantly higher in leaf (5.5%). Ascorbic acid and calcium are higher in leaf followed by seed and pod. Carbohydrate content in *P. timoriana* was ranged from 59.26 to 67.82% in different stages of pods (Salam 2011) and increase in carbohydrate content with maturity of pods was also noticed (Geervani and Devi 2006). It was reported that crude fibre content was ranged from 10.16% in tender pods and 19.28% in matured pods, while seeds has 9.03% of fibre (Salam, 2011). Different processing and cooking methods on seeds of *P. timoriana* led major increase in moisture, fat and carbohydrate content (Salam et al. 2010).

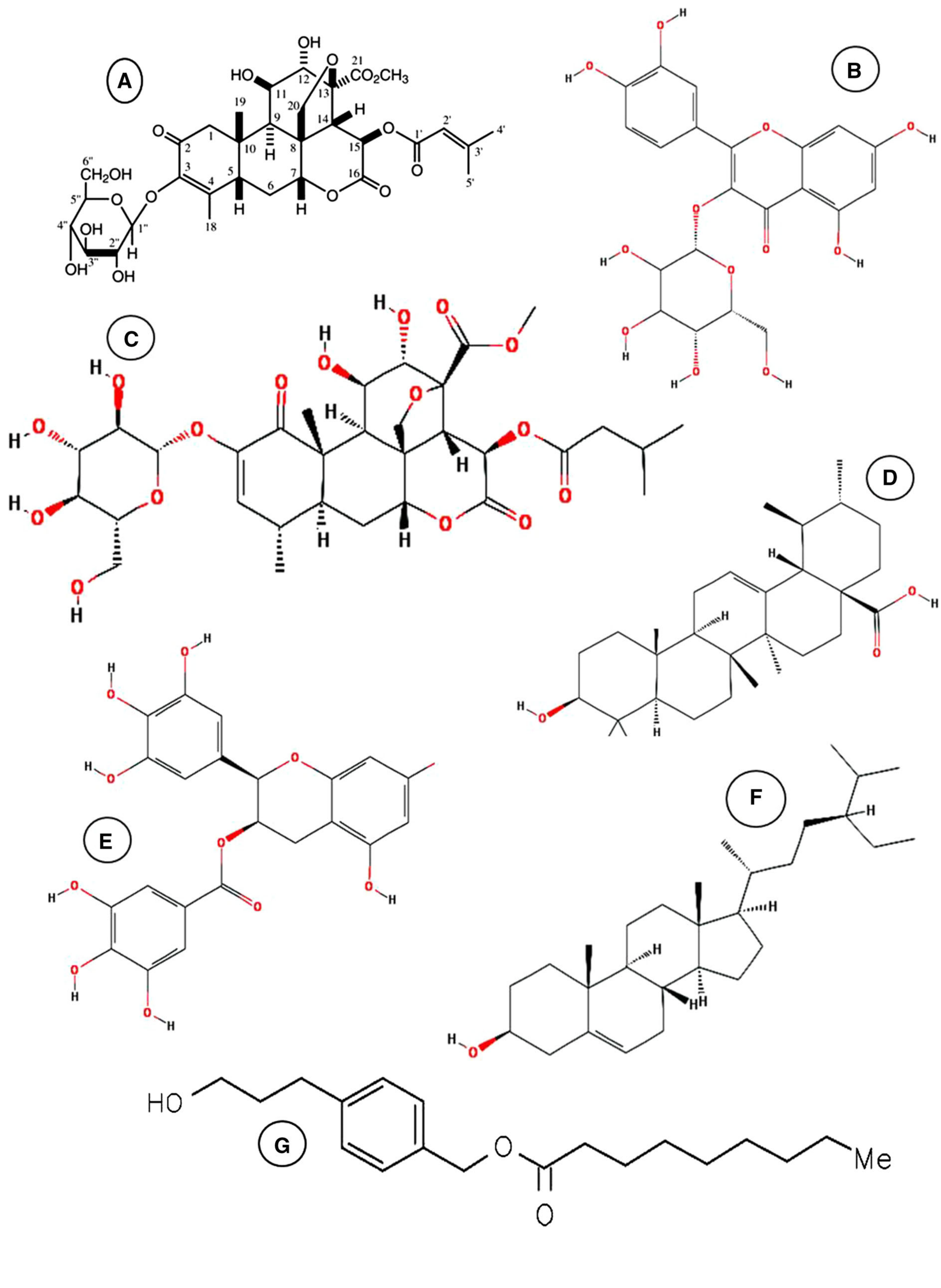
Phytochemical constituents

Parkia timoriana was investigated scarcely on phytochemistry point of view (Fig. 2) with lacuna in pharmacological actions of isolated compounds. Phytoconstituents present in pods was studied by Salam et al. (2009). Presence of anti-nutritional factors, total free phenols, tannins and lectins was reported by Mohan and Janardhanan (1993) and these anti-nutritional factors can be exterminated if the seeds are properly processed by heating or cooking. An appreciable amount of tannins, flavonoids, saponins, anthocyanins and leuco-anthocyanins are reported from pods of *P. timoriana* (Salam et al. 2009). L-DOPA, a non-protein amino acid was recorded with very low quantity in this plant when compared to other leguminous crops (Mohan and Janardhanan 1993) like *Mucuna*.

Hyperin and epigallocatechin gallate are two biomolecules isolated from ethyl acetate fraction of edible pods of *P. timoriana* (Sheikh et al. 2016). Javanicoside A, Javanicoside A pentaacetate, Javanicoside B and Javanicoside B hexaacetate along with known compounds like ursolic acid and β-sitosterol were isolated from methanol extract of leaf and stem bark of *P. timoriana* (Dinda et al. 2009). Kaur et al. (2005) isolated novel mannose/glucose specific lectins from seeds of *P. timoriana*. Parkinol, a new compound isolated from leaves of *P. timoriana* along with several other known compounds (Dinda et al. 2010).

Production technology

P. timoriana is commonly propagated by seeds and vegetatively through cuttings. Depending on age and growing condition, a mature tree bears 500–1500 pods $tree^{-1}$ (90–260 kg $plant^{-1}$) (Roy et al. 2014). Good emergence was obtained by mature seeds extracted from pods, dried for 10 days and soaked in water for 48 h. After soaking, seeds can be treated with Carbendazim 12% and Mancozeb 63% @ 2 g L^{-1} of water for 2 min. A mixture of sand, soil and farmyard manure (1:1:1) treated with Carbendazim @ 1 g 10 kg^{-1} provide good substrate for germination. The seeds can be sown in polybags are filled with the mixture. The ideal sowing time is the last week of April to first week of June.


A
B
C
D
E
F
G

◀**Fig. 2** Major phytoconstituents of *Parkia timoriana*, **A** Javanicoside A, **B** Hyperin, **C** Javanicoside B, **D** Ursolic acid, **E** Epigallocatechin gallate, **F** β-sitosterol, **G** Parkinol

Roy et al. (2014) suggested that pits of 2 × 2 × 2 ft should be dug at a spacing of 24–30 × 24–30 ft and filled with top soil thoroughly mixed with farmyard manure. Thongbam et al. (2012) reported that application of 10–15 kg compost annually along with chemical fertilizers at the time of mulching helps in growth and development in addition with application of 160 g urea, 300 g SSP and 80 g MOP plant^{-1} at the time of transplantation and increasing the dose to 325 g urea, 625 g SSP and 165 g MOP from 5th year onwards. One or two year old seedlings which are propagated through seeds can be transplanted in field (Firake et al. 2013), it also enrich soil by fixing atmospheric nitrogen. *P. timoriana* has higher diameter at breast height, canopy spread and timber production than its associated tree species like *Alnus nepalensis, Michelia oblonga* and *Pinus kesiya* in hilly areas of north east India (Saha et al. 2007).

Local people in Manipur state of India believe that narrow and uniform pods with light green colour are superior in flavour and accordingly thirteen genotypes were identified based on their morphological characters (Meitei and Singh 1990). Likewise, nine genotypes of *P. timoriana* were reported from different *Parkia* growing belts in Manipur based on their palatability and other eating qualities (Salam and Singh 1997). Germination percentage of *P. timoriana* was higher at constant temperature (25 °C) and among the pre-treatment methods, nicking of seed coat significantly increased the rate of germination (Sahoo et al. 2007) than seeds treated with chemicals or soaked in water either cold or hot. Germination of tree beans for 2–7 days resulted in a decrease in total protein indicating that proteins were utilized for germination and amount of total protein from extracted solution varied with age of tree beans used for extraction (Utarabhand and Akkayanont 1995).

Traditional uses

Ethnobotanically, tree bean is quite important and has high nutritional and medicinal values (Table 2 and Fig. 3). Since time immemorial, different ethnic groups in the state of Manipur have practiced the art of dying cloths and other items with fruit skin of *P. timoriana*. The plant is one of the costly vegetable (due to its vast ethnobotanical uses) fetching a market value of Rs. 70–120 kg^{-1} (Firake et al. 2013) in north east India. Nutritional value of *P. timoriana* is similar to that of apple (Chandrabalan 2011). Besides containing antioxidants that can ward off many diseases and also improves learning ability of children.

P. timoriana is of immense use among the local and indigenous people in northeast India, especially decoctions of bark, fruit skin and leaves are used to treat various diseases (Hopkins 1994). The pods and kernels have been traditionally used as a supplementary food source in Manipur (Longvah and Deosthale 1998) and to treat leprosy and hypertension. In Gambia, leaves and roots are used in preparing a lotion to cure sore eyes (Ajaiyeoba 2002). Food can be used as medicine and vice versa, while certain food crops are used because of their health benefits and hence called as medicinal foods. In case of *P. timoriana*, pods, leaves and other parts of the plant are consumed either raw or boiled with other ingredients to treat various diseases and pods are eaten raw as salads which contribute to health benefits among the ethnic people.

Bioactivities of *Parkia timoriana*

Comprehensive literature survey on *P. timoriana* revealed that only a few researchers have examined the biological activities of this tree. Various parts of the plant was reported to have antioxidant, α-glucosidase and α-amylase inhibitory properties, antibacterial, antidiabetic, antiproliferative and insecticidal activities along with toxicity its pods (Fig. 4 and Table 3).

Antioxidant properties

Methanol and acetone extracts of pods of *P. timoriana* recorded higher amount of total phenolic content with 49.39 and 79.63 GAE respectively and flavonoid content with 4.05 and 4.35 mg g^{-1} respectively (Tapan 2011). Acetone extract of pods of the plant has showed an appreciable quantity of flavonol (5.00 mg g^{-1}), high reducing power (32.25 mg g^{-1}) and strong inhibition (IC_{50} = 0.23 mg dry material)

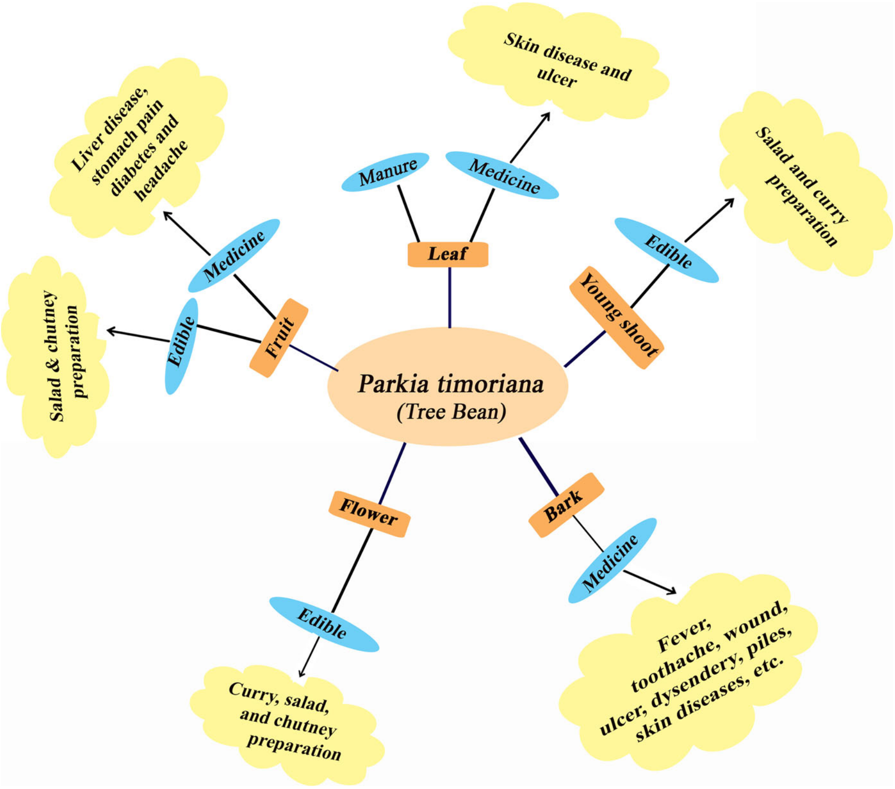
Table 2 Uses of *P. timoriana* among the different ethnic groups of India and nearby regions

Region and people	Traditional uses
Local people in Gambia	Decoction of bark is used as a bath to get relief from fever; hot mouthwash is used to get relief from toothache; pulped bark is taken orally with lemon to heal wound and ulcer (Irvine 1961)
Tribal people in Malaysia	Pods are consumed to treat kidney disorder, diabetes, urinary tract infection, hypertension and headache (Samuel et al. 2010; Ong et al. 2011)
Local people in Ghana, West Africa	Fruits are used to treat leprosy and hypertension (Badu et al. 2012)
Local people of Manipur and adjoining states, India	Young and mature pods and seeds are cooked and eaten as a delicious vegetable (Jain 1981; Salam et al. 1995)
Mizos, Garos, Kacharis, Nagas, Mikir tribals in northeast India	Pods are used as vegetables; pods pounded in water and used for washing head and face; lotion made from bark and leaves are used to treat skin diseases and ulcer (Bhuyan 1996)
Local people in northeast Indian states	Pods are consumed at different stages of maturity, either fresh or processed; beans, after scraping out the skin, sliced into pieces, prepared as chutnies; mature flowers and young shoots are used in preparation of curries and salads; leaves are used as fodder and green manure; decoction of bark, fruit skin and leaf is used to treat diarrhoea and dysentery (Rai et al. 2005)
	Inflorescence, tender pods and mature seeds are eaten; flowers are taken as salads whereas pods are used in preparation of salads, curries and chutnies (Salam et al. 2009)
	Seeds/tender pods are taken orally to treat stomach and liver disorders; pods are pounded in water and used for cleaning face and head (Paul et al. 2016)
Traditional healers from sacred groves of Manipur, India	Tender pods and bark is eaten to treat intestinal disorders, piles, dysentery and diarrhoea (Khumbongmayum et al. 2005)
Local people and ethnic communities of Mizoram, India	Fruit paste is applied to heal wounds and scabies; fruit and juvenile shoots are eaten to treat diarrhoea, dysentery and to get relief from food poisoning (Bhardwaj and Gakhar 2005)
	Pod is consumed as vegetable, to prepare salad and chutney; wood is used as firewood/timber (Thangjam and Sahoo 2012)
	Flowers and pods are eaten as vegetable, used in preparation of *singju*, a typical salad, this may be mixed with fish curry and used in preparation of local delicacy, *Iromba* (Roy et al. 2014)
	Pods/seeds are consumed as vegetable, used in salad/chutney preparations and sun dried for future use (Thangjam 2014)
	Fruit skin is soaked in water for 2–3 days and the liquid which shows dark brown colour is used as adhesive for different dye mainly for red colour (Akimpou et al. 2005)
Local people of Mizoram, Manipur and Nagaland, India	Pods, seeds, flowers and young shoots are taken raw or used in salads/curries; tree provides fuel wood (Sahoo et al. 2007)
Meitei communities in Assam	Leaves are used as green vegetable and grown in almost all home gardens (Devi and Das 2010)
Meitei communities in Manipur	Decoction obtained from bark is taken to treat diabetes (Devi 2011)
Dimasa and Kachari tribals, northeast India	Paste made from the bark is used as plaster to treat eczema (Rathi et al. 2012)

which shows that the tree has high radical scavenging property (Tapan 2011). Total antioxidant capacity of methanolic fruit extracts of *P. timoriana* was determined by DPPH and reducing power assays was ranged from 160.44 ± 2.26 to 157.31 ± 1.90 mg/g (Badu et al. 2012) which produced concentration-dependent values comparable to ascorbic acid control.

Antioxidant standards, BHA (Butylated Hydroxy Anisole) and rutin showed higher scavenging activity than raw and processed legume seed extracts on the radicals, DPPH and ABTS (Sathya and Siddhuraju 2013). Different processing methods steadily increased the radical-scavenging activity on both radicals (DPPH: 6–9%; ABTS: 24–80%) and it

Fig. 3 Traditional uses of *Parkia timoriana* among the different ethnic communities



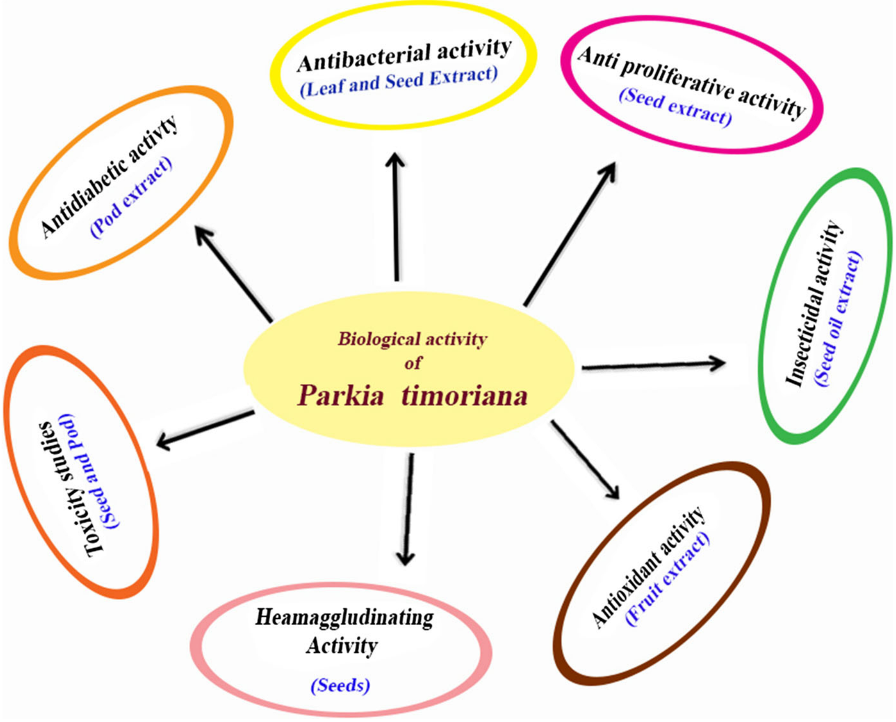


Fig. 4 Biological activities of different parts of *Parkia timoriana*

Table 3 Biological activities and toxicity studies in *Parkia timoriana*

Part of plant or extract used	Observation	Activity studied
Different parts of the plant	Inhibits the growth of *S. fecalis* and *B. cereus*	Antibacterial (Thongbam et al. 2012)
Leaf extract	Effective against *E. coli, V. cholerae, S. aureus* and *B. cereus*	Antibacterial (Zuhud et al. 2001)
Seed extract	Inhibits the growth of several microorganisms except *E. coli*	Antibacterial (Devi et al. 2007)
Gold and silver nano-particles synthesized from dried leaves	Effective against *S. aureus* and *E. coli*	Antibacterial (Paul et al. 2016)
Ethyl acetate sub-fraction of pods	Significant reduction in blood glucose levels and normalization of HbA1c, SGOT, SGPT, TG, TC and uric acid in STZ induced diabetic rats	Antidiabetic (Sheikh et al. 2016)
Lectins isolated from seed extracts	Inhibited proliferation of cancerous macrophage cell lines such as P388DI and J774	Anti-proliferative activity (Kaur et al. 2005)
Seed oil extract	100% of mortality was observed in 2.0% of oil extract after four days	Insecticidal activity (Salam et al. 1995)
Ethyl acetate fraction from pods	No mortality was observed and animals treated with the extract did not show any changes in their behavioural pattern	Toxicity (Sheikh et al. 2016)
Methanolic extract of plant	No acute cytotoxic effect on normal human cell lines	Toxicity study (Aisha et al. 2012)
Crude methanol extract of pods	Significant α-glucosidase and α-amylase inhibitory effects with IC_{50} values of 7.39 ± 0.04 and 9.11 ± 0.815 mg mL^{-1} respectively	α-glucosidase and α-amylase inhibitory potency (Sheikh et al. 2016)
Ethyl acetate fraction of pods	α-glucosidase inhibition with IC_{50} value of 0.39 ± 0.06 mg mL^{-1}	α-glucosidase inhibitory effect (Sheikh et al. 2016)
Epigallo-catechin gallate and hyperin isolated from ethyl acetate sub-fractions of pods	Showed significant α-glucosidase inhibition with IC_{50} values of 0.51 ± 0.09 mM for epigallo-catechin gallate and 0.71 ± 0.03 mM for hyperin	α-glucosidase inhibitory potency (Sheikh et al. 2016)
Raw seeds	Albumins and globulins derived from raw seeds showed haemagglutinating activity without any specificity against human ABO system	Haemagglutinating activity (Mohan and Janardhanan 1993)

indicates free radical scavenging activity was mostly depends on legume type, processing conditions and nature of microbes involved in fermentation. Though, processing methods had positive influence on scavenging activity of synthetic radicals like DPPH and ABTS, it is not reflected on biologically relevant radical species and this is due to variations in reaction kinetics between radicals and antioxidants during quenching process (Sathya and Siddhuraju 2013).

Antibacterial activity

Different parts of *P. timoriana* have the capacity to inhibit the growth of pathogenic bacteria (Table 3) like *Streptococcus fecalis* and *Bacillus cereus* (Thongbam et al. 2012). The leaf extract had significant growth controlling effect against pathogenic bacteria viz. *Escherichia coli, Vibrio cholerae, Staphylococcus aureus* and *B. cereus* (Zuhud et al. 2001). Seed extract had significant effect against all pathogenic bacteria except *E. coli* (Devi et al. 2007). Gold and silver nanoparticles synthesized from dried leaves of *P. timoriana* produced significant inhibition against *S. aureus* as compared to *E. coli* and it might be due to accumulation and absorption of Au and Ag NPs on cell wall of *S. aureus* (Paul et al. 2016).

Antidiabetic activity

Sheikh et al. (2016) revealed that significant reduction in blood glucose levels which was dependent on dose and duration of the treatment and ethyl acetate sub-fraction reduced blood glucose concentration to normal when administered with 10 mg/kg b.w. for 14 days after 48 h of streptozotocin (STZ) treatment. They also believed that anti-hyperglycemic and hepato-protective effects of enriched ethyl acetate sub-fraction of pods of *P. timoriana* could be due to the presence of hyperin and epigallocatechin gallate. Levels of plasma glucose, serum glutamic oxaloacetic transaminase, erum glutamic pyruvic transaminase, triglyceride, total cholesterol and uric acid were also elevated in STZ induced diabetic rats, which were brought to near normal following the effect of ethyl acetate sub-fractions at different doses (Table 3).

Anti-proliferative activity

Lectins isolated from the seed extracts of *P. timoriana* inhibited proliferation of cancerous macrophage cell lines such as P388DI and J774 with 48.13 and 67.93% respectively (Kaur et al. 2005) and it could be used for a range of other cancer cell lines including human needs which should be investigated for anti-proliferative response (Table 3).

Insecticidal activities

Seed oil extract of *P. timoriana* possesses insecticidal properties and holds promising agent in controlling a variety of insect pests. Percentage of mortality of aphids by seed oil extract was significantly increased with increase in time and concentration and vice versa under laboratory conditions (Salam et al. 1995). After four days, 100% of mortality was recorded in 2.0% of oil extract followed by 96.66, 86.66, 76.66, 63.33% of mortality in concentrations of 1.5, 1.0, 0.5 and 0.1% oil extract respectively (Table 3).

Toxicity studies

Local people in Manipur, India stated that consumption of one pod every day by a person (mostly after cooking) does not cause any adverse effects (Sheikh et al. 2016). But, eating raw pods causes bad breathe due to the presence of volatile disulphide compounds which are absorbed by blood and thus exhaled in breath so that odour persists for many hours (Meyer, 1987). Several toxic substances were isolated from seeds of *Parkia* including non-protein amino acids, lectins and alkaloids (Hopkins 1984). No mortality was observed with ethyl acetate fraction of pods of *P. timoriana* in acute toxicity study (Table 3) and animals treated with pod extract did not show any change in their behavioural pattern up to a dose of 2000 mg/kg (Sheikh et al. 2016). Methanolic extract of pods showed no cytotoxicity on normal human cell lines (Aisha et al. 2012). Seeds of *P. timoriana* contain fewer amounts of anti-nutritional factors, viz., phytate phosphorus, tannins, saponins, trypsin and amylase inhibitors which can be further removed by processing and cooking methods (Salam et al. 2010).

Significant α-glucosidase and α-amylase inhibitory potencies with methanol extract of *P. timoriana* pods showed IC_{50} values of 7.39 ± 0.04 and 9.11 ± 0.815 μg mL^{-1} respectively (Sheikh et al. 2016). Ethyl acetate (EA) fraction showed higher α-glucosidase inhibition (0.83 ± 0.01 μg mL^{-1}) followed by n-butanol (1.89 ± 0.01 μg mL^{-1}) and water (1.39 ± 0.60 μg mL^{-1}) fractions. Strong α-glucosidase inhibition with IC_{50} value of 0.39 ± 0.06 mg mL^{-1} was observed with EA sub-fraction. Hyperin and epigallocatechin gallate isolated from EA sub-fractions showed α-glucosidase inhibition with IC_{50} value of 0.51 ± 0.09 mM and 0.71 ± 0.03 respectively (Table 3). All the studied extracts of *P. timoriana* showed moderate α-amylase activity.

Need for domestication assessment for *P. timoriana*

Wild plants have major role in the life of indigenous people around the world and several comprehensive catalogues for edible plants are available in the literature. During the last few decades, collection and consumption of non-cultivated food plants has been highly focused. Also field studies aimed at documenting traditional knowledge through anthropological, ethnoecological and ethnobotanical perspective is also increasing nowadays (Hadjichambis et al. 2008). Cultivated plants differ from wild plants in the way they are reproduced and maintained (Zohary and Hopf 2000) and trait assessment studies on the basis of diversity of crop plants will provide their domestication values.

Domestication provides us vast arrays of morphological, anatomical, physiological and chemical changes which have evolved in crops in a very short span of evolutionary time in plants (Zohary and Hopf 2000). Also, selection under domestication moulded gene pools of major food crops to become backbone for production of food and other essential utilities for humankind. Domestication is generally considered to be the end-point of a continuum that starts with exploitation of wild plants, continues over cultivation of plants selected from wild but not yet genetically different from their wild progenitors (Pickersgill 2007). Further studies are suggested to explore genetic diversity in wild populations (especially for under-utilized and neglected crops of economic importance like *Parkia timoriana*) and traits of economic importance based on wider sampling across whole distribution range including transferred land races (Ekue et al. 2011).

Conclusion and future prospects

In recent years, unfortunately the tree is reported to be associated with various pests and infestations accompanied with die-back symptoms leading to mass decline in many locations in northeast India, especially in the valley of Manipur. This led to fear of being threat of extinction in wild in the region. The reasons could be due to changing climate, *Verticillium* wilt disease, mobile radiation, etc., but the real cause is still unknown (Ashem 2012). Thus there is an urgent need to address issues for decline in their population and further research for mass multiplication and conservation of this tree should be undertaken. Therefore it becomes important to prioritize the conservation of *P. timoriana* wild populations through both ex situ and in situ strategies and emergence of a regional tree bean breeding program using wild genetic resources appears promising.

In most of the hilly states of Northeast India, the forest lands are becoming barren due to practice of *Jhum* cultivation. The tree bean may act as an excellent crop in reducing shifting cultivation (*Jhum*) which is still a common practice in north eastern hills. Now it is time to rethink, introducing fast growing leguminous tree bean in large scale on priority basis, which can help in maintaining ecological balance, enrich and improve soil of *jhum* through nitrogen fixation and prevent soil erosion as well as uplift the socioeconomic status of the *jhumias* of the region.

The pods of P. *timoriana* are considered as a delicacy in north-eastern states in India and Southeast Asian countries. Owing to its nutritious pods, wide adaptability in different soils in varied altitudes, if properly exploited *P. timoriana* can be considered as a supplementary source of protein. Despite a presence of high amounts of saponin, flavonoid and tannin which are heat labile and which can be removed through processing methods (Salam et al. 2009). Besides its immense nutritional values, *P. timoriana* has reported to have anti-oxidant properties, antibacterial, antidiabetic, anti-proliferative and insecticidal properties. Although a very few studies have been available in literature on effect of specific compounds from tree bean, still many functions and interactions are yet to be investigated. Further studies needs to be done extensively to understand its potential for health promotion and potential drug discovery to enhance our knowledge and appreciation for the use of *P. timoriana* in daily diet.

Studies on optimizing various products of tree bean, its sustainable production in large scale and implementation in industrial scale would lead us to achieve food and nutritional security. Also, it is of outmost importance to obtain data about popular uses of wild food plants like *P. timoriana* before this knowledge disappears from the present day traditional healers and ethnic people. Hence, there is a need for collaboration among the scientists, institutions, private seed companies etc. to pay more attention towards research and improvement of the dying bounty *Parkia timoriana.*

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