

A Comprehensive Review on the Endemic Plant *Docynia indica*: Its Ethnobotanical, Phytochemical, and Ethnomedicinal Perspective

Joy Biswas^{1,*}, Pranjan Barman², Mehzabin Rahman², Rajgourab Ghosh³

¹S. N. Pradhan Centre for Neurosciences, Taraknath Palit Siksha Prangan (Ballygunge Campus), University of Calcutta, Kolkata, West Bengal, INDIA.

²Department of Biotechnology, Gauhati University, Gopinath Bordoloi Nagar, Jalukbari, Guwahati, Assam, INDIA.

³Amity Institute of Biotechnology, Amity University, Kadampukur, Rajarhat, Kolkata, West Bengal, INDIA.

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ABSTRACT

Ethnobotanical knowledge and ethnomedicinal methodologies from different parts of the world are of comprehensive significance and documentation of ethnobotanical, and ethnomedicinal data is a key prerequisite for further research in the domain of herbal medicine and its implementation in modern clinical research. The important sources of beneficial natural products and ethnomedicinal elements are majorly contributed by the wild edible fruits. The *Docynia indica* is a wild edible fruit that belongs to the Rosaceae family and mainly disseminates in the eastern region of the Himalayas. Since immemorial time *Docynia indica* is an integral part of ethnomedicine and traditionally implemented for treating innumerable health diseases. It is a valuable ethnomedicinal plant with important sources of minerals and vitamins and is conventionally used for treating common ailments. In the traditional system of medicine, it is regarded as a wonderful prophylactic for combating enteric diseases. The natural compounds extracted from the fruits of *Docynia indica* contain polyphenol especially alkaloids and flavonoids which significantly have an anti-hyperglycemic and anti-hyperlipidemic property. The wild edible fruits are underemphasized despite their fascinating ethnobotanical and ethnomedicinal characteristics. Similarly, *Docynia indica* is a less explored endemic fruit that contains eminent natural compounds and ethnomedicinal importance. Though it is less popular in urban regions but in ethnic groups it is a key component in indigenous traditional medicine system. This article mainly discusses the morphological features and phytochemical constituents of *Docynia indica* and ethnobotanical characteristics highlighting the ethnomedicinal perspective.

Key words: *Docynia indica*, Endemic Fruits, Ethnobotany, Ethnomedicine, Wild apple, Wild edible fruit.

Correspondence:

Mr. Joy Biswas,
S. N. Pradhan Centre for Neurosciences, Taraknath Palit Siksha Prangan (Ballygunge Campus), University of Calcutta, 35, Ballygunge Circular Road, Kolkata, West Bengal-700019, INDIA.
Phone no: +91 8240436181

Email: joybiswasofficial97@gmail.com

INTRODUCTION

Docynia indica is a wild edible fruit commonly known as Indian Crab Apple or Assam Apple and taxonomically it belongs to the Rosaceae family.^[3,37,39,44] Wild fruits are characteristically fascinating and majorly they are

edible, safe for human consumption, and can be utilized in medicinal purposes but are undervalued since their knowledge is less explored. High levels of phytochemicals like flavonoids and anthocyanins are present in wild fruits due to favourable distinct genotype and environmental factors. Apart from consumption, they are antioxidant and antimicrobial in nature along with other remarkable bioactivities (Figure 1).^[9,11,22,42,43] *D. indica* is a deciduous tree that mainly disseminates in the eastern region of the Himalayas and generally propagates between 900 m to 1800 m above mean sea level (msl). The round pear-shaped fruits are pale green colour in matured state and are usually consumed either

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fresh or in pickle form.^[44] The fruit extract obtained from mature fresh fruits are processed as a semi-solid gel locally called 'chuk', it act as a satisfactory indigenous medicine for digestive disorder.^[37] Significantly in the north-east region of India, this plant is quite popular for its nutritive property and medicinal aspect. The fruits are acetic in flavour and usually contain phosphorus, sugar, organic acid, and iron. Ethnomedicinally the fruits of *D. indica* act as a prophylactic of digestive aid, infectious diseases, and reported with hypolipidemic and hypoglycemic effect.^[22,23,44,53]

GEOGRAPHICAL DISTRIBUTION

The *D. indica* mainly distributed to the lower temperate forest and community forest and proliferates between 1200-1800 m. The deciduous evergreen plant mainly disseminates in the eastern region of Himalayas, basically the eastern part of Bhutan, Darjeeling, Nepal, and Sikkim.^[37] *D. indica* proliferates smoothly in the thicket, streamside, and slopes since it is characteristically a temperate plant. The hardy temperate plant generally tolerates the temperature about -0.5°C to 10°C and with a proper drainage system it can be proliferated in sandy – loam to clay soils. Usually, the cultivation of the plant is carried by the means of seeds.^[19,49] The species usually favours moist soil and it is an inhabitant of the Eastern Himalayas. The species is widely spread from East Asia to Bhutan, China, Nepal, and North-East region of India encompassing Khasi and Jaintia hills of Meghalaya where it is raised in the backyard and also naturally

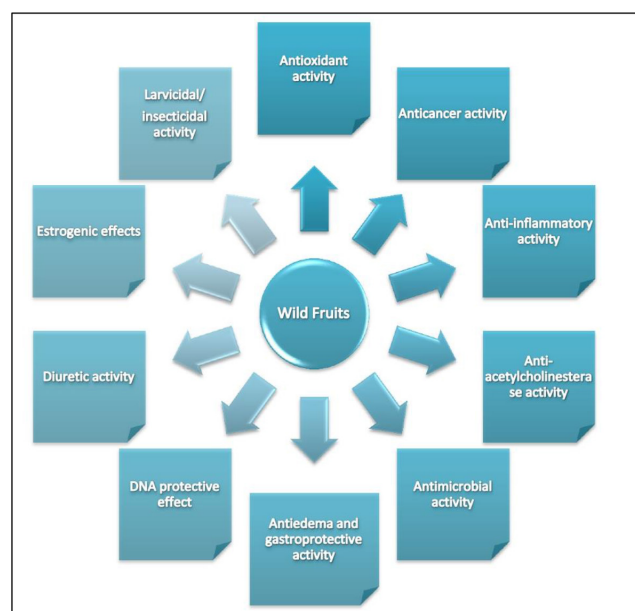


Figure 1: Different types of bioactivities observed in wild fruits.^[22]

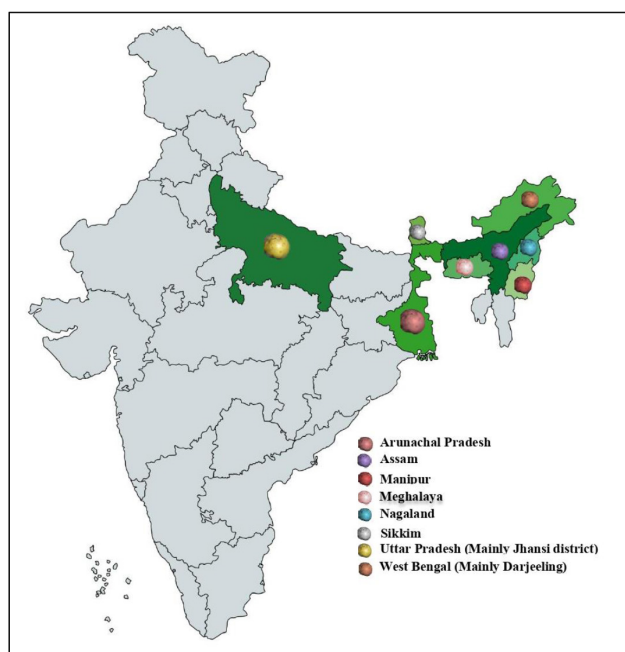


Figure 2: Geographical distribution within India where *Docynia indica* are generally distributed.^[2,19,36,37,49]

prevails in the forest areas^[36] (Figure 2). In recent years due to extensive deforestation and urbanization, the density of *D. indica* is drastically deteriorating.^[49]

MORPHOLOGICAL AND PHENOLOGICAL CHARACTERIZATION

The deciduous tree *D. indica* is medium to tall (up to 12 m) and the leaves are acuminate, glabrous, lanceolate, ovate to oblong, and serrate. In terms of inflorescence, the flowers are organized in fascicles of 2-3 or either solitary which flowers during the month of March and April. The fruits are mature during the month of August to November depending on the altitude where the plants are developed.^[21,36,37] Fruits are structurally spherical or ellipsoidal and acidic in nature and also slightly pubescent when young. The sepals are interminable, erect and are greenish or yellowish colour with a red tint.^[36,46] The elongated papery leaves are green in colour with simple lamina and are significantly compound leaves. The small-sized albuminous seeds are observed in *D. indica* measuring approximately 0.08 cm.^[37,39,49] The important morphological characteristics of *D. indica* are summarized in Table 1.

Plant phenology is the pre-arranged episodes of life-cycle which includes rupture of leaf bud, flowering, and fruiting and has a surging consequence on the diverse extent of the biological organization, from individuals to ecosystems. Phenology significantly plays a dominant role in the vitality of individual plants; it also influences

the proficiency of organisms in terrestrial ecosystems which depends on them.^[48] Vital phenological episodes of *D. indica* such as leaf falling and flushing, flowering, fruiting, and seed dispersal are discussed elaborately in **Table 1**. The reiteration for the active leaf proliferation period is nearly 8 weeks. Generally in *D. indica* flowering is occurs for a limited period of time that is for 3 weeks and it is preceded by the fruit development phase which lasts for 16-20 weeks.^[39]

PROXIMATE COMPOSITION AND ANTIOXIDANT PROPERTY

Wild edible fruits contain biologically active elements and are present in high amount which provides health benefits along with its fundamental nutritional value.^[28,41] Among the biologically vital constituents, natural antioxidants are more captivating due to their protective and potential therapeutic effect.^[18,35,41] In recent times, lesser known endemic fruits attract a huge public interest because of their organoleptic characteristics and numerous favourable effects on human health.^[41] Generally, the wild fruits play an important role in complementing the nourishment of the rural people.^[52] The indigenous fruit *D. indica* generally contains 85.1% moisture, 06% ash and approximately contains 202.8 mg potassium, 15.3 mg sodium, and 200.5 mg calcium per 100 g of fruit. Considering the nutritive value, the fruit contains 62.2 Kcal per 100 g.^[41] The proximate composition of *D. indica*, (**Table 2**) such as the moisture content in the fruit is approximately 74.60%, the minimal crude fat and protein content is 0.17% and 1.94% respectively. The proximate ash content is 2.64% and the resultant free N₂ extract is 13.48% whereas the energy value observed is 63.23 KJ per 100 g of the fruit.^[14,21,41] Fresh fruits diets substantially reduce cancer, hyperglycemia and cardiovascular diseases. Usually, the fruits of *D. indica* content phenolic compounds along with other constituents of secondary metabolites and act as an eminent source of antioxidants.^[13,14,23,39,41] The characteristic antioxidant property in *D. indica* is accountable due to several phenolic groups and their presence in high proportion elevates the antioxidant capacity.^[1,23,41]

PHYTOCHEMICAL, MINERAL AND NUTRITIONAL COMPOSITION

Secondary metabolites are generally organic compounds that are not directly involved in the normal physical functioning of plants such as reproduction, development or progression of an organism rather involved in the plant defence mechanism.^[4,15,30]

Table 1: Morphological characteristics and phenological series of *Docynia indica*.

	Morphological Features					Phenological Features				References		
	Pigment	Quantity	Type	Appearance	Size (cm)	Vigour	Active proliferation period	Termination of development	Opening of flower bud		Termination of flowering	Development of fruits
Stem	Brown	Dichotomous	Semi-hard	Cylindrical	Large (300)	Semi-wood	-	-	-	-	-	-
Leaves	Green	Numerous	Simple	Elongated	Medium (06)	Soft	April - May	July	-	-	-	-
Flowers	White	Few	Open	Round	Medium (02)	Soft	-	-	3 rd week of March – 2 nd week of April	3 rd week of April	-	-
Fruits	Green	Few	Single	Ovate	Medium (05)	Semi-hard	-	-	-	-	May	October – November
Seeds	Black	Few	Albuminous	Flat	Small (0.08)	Hardy	-	-	-	-	-	-

Alkaloids, anthocyanin, cyanogenic glycosides, carotenoids, flavonoids, phytic acid, and terpenoids are the important secondary metabolites present in the plant which possesses anti-oxidant, anti-proliferative, anti-microbial, anti-inflammatory, anti-carcinogenic, U-V light absorbing proceedings as the plant protect against micro-organisms.^[4,15,21,30] The Rosaceae family consists of moderate size angiosperms of over 100 genera and 3,000 species and contributes prominent phytochemicals in human dietary providing extortionate standard nutritional value.^[8] Ascorbic Acid (Vitamin C) is the primary vitamin; nearly 50 mg of Vitamin C per day is a basic requirement for a standard adult human being for its development. Nearly 90% of the dietary ascorbic acid is contributed by the fresh fruits. Ascorbic Acid acts as a powerful reducing agent which associates with free radicals and protects the body from their detrimental consequences. In *D. indica* the amount of ascorbic acid is approximately 14.84 mg per 100 g of the fruit.^[4,8,15,21]

In plants, specific categories of flavones are present which are predominately utilized in therapeutic purposes both in Allopathic and Ayurvedic medicine.^[24] Similarly different parts of *D. indica* contain different phytochemical constituents which make the deciduous temperate plant ethnomedicinally beneficial.^[14,16,33,41] The highest concentration of cyanide is reported in the mature seeds as compared to the immature ones and whereas it is absent in flowers and leaves. The phytic acid is approximately 2.25 mg per 100 g of premature *D. indica* fruits whereas it is 1.81 mg in 100 g of mature fruits and 1.85 mg in 100 g of *D. indica* seeds (**Table 2**).^[17,33]

A significant source of fibers, minerals, and vitamins are contributed by the wild fruits which imparts indispensable nutrients for human health and also considerably reduces the chronic diseases such as cardiovascular problems, cancer and other age affiliated disorders.^[32,38] Carotenoids (Pro-vitamin A), Vitamin A and E (Tocopherol) are the innumerable compounds that are present in wild fruits having antioxidant property and free radical scavenging activity and play an important role in intercepting various diseases.^[32,51] The different research work proposed that the pH of *D. indica* fruits is 3.25.^[33] The moisture contains in the fruits is approximately 80.32% – 85.14% and per 100 g pulp contains 14.8 – 17.5 mg Vitamin C. The protein contains is approximately 1.81 – 2.76 mg along with 1.05 – 4.31 mg reducing sugar, magnesium (2060 mg / 100 g), and potassium (140 mg / 100 g). The mineral and nutritional constituents such as cobalt, copper, iron,

Table 2: Proximate composition and phytochemical contents in fruits and seeds of *Docynia indica*.

	Proximate Composition										Phytochemical Contents							References
	Moisture content (%)	Crude fat content (%)	Ash content (%)	Crude fibre content (%)	Crude protein (%)	N ₂ free extract (%)	Energy value (KJ/100 g)	Total Phenol (mg GAE/g)	Total Flavonoids (mg QE/g)	Anthocyanin (mg/ 100g)	Ascorbic Acid (mg/100 g)	Total carotenoids (mg/100 g)	Cyanide (mg/100g)	Phytic Acid (mg/100g)	Saponin (mg/100g)			
Fruits	74.60 ± 1.81	0.17 ± 0.01	2.64 ± 0.12	7.16 ± 0.81	1.94 ± 0.18	13.48 ± 2.3	63.23 ± 9.77	29.13 ± 1.03	2.10 ± 0.07	1.33 ± 0.73	9.7 ± 0.59	0.99 ± 0.09	-	1.81 ± 0.033	6.11 ± 0.360			
Seeds	-	-	-	-	-	-	-	-	-	-	-	-	1.54 ± 0.081	1.85 ± 0.113	4.64 ± 0.066			

Note: N₂ – Nitrogen; g – Gram; mg – Milligram; KJ –Kilojoule; GAE – Gallic acid equivalent; QE – Quercetin equivalents.

Table 3: Mineral contents and nutritional composition of *Docynia indica*.

Mineral contents		Nutritional composition		References
Copper ($\mu\text{g/L}$)	4.16 \pm 0.9	Ash %	2.90 \pm 0.49	[14,33,40,41,44,49]
Calcium ($\mu\text{g/L}$)	1.98 \pm 0.02	Crude fat %	0.87 \pm 0.02	
Iron ($\mu\text{g/L}$)	23.29 \pm 2.1	Crude protein %	2.61 \pm 0.58	
Magnesium ($\mu\text{g/L}$)	6.88 \pm 0.8	Dry matter %	13.91 \pm 0.11	
Manganese ($\mu\text{g/L}$)	3.09 \pm 0.18	Fiber %	4.57 \pm 0.06	
Molybdenum ($\mu\text{g/L}$)	0.79 \pm 0.05	Energy value (Kcal/100 g)	393.14 \pm 1.96	
Potassium ($\mu\text{g/L}$)	111.37 \pm 4.38	Total carbohydrate %	89.06 \pm 0.52	
Sodium ($\mu\text{g/L}$)	7.05 \pm 1.4			
Zinc ($\mu\text{g/L}$)	0.16 \pm 0.2			

Note: μg – Microgram; L – Litre; Kcal – Kilocalorie.

manganese, and zinc are present as the micro-elements in the fruits of *D. indica* (Table 3).^[33]

ETHNOBOTANICAL AND REVENUE ASPECT IN INDIGENOUS CULTURE

Fruits of the Rosaceae family portray a prominent role in the Manipuri diet in terms of supplement and nutritional value.^[21] Manipur, north-eastern state of India is bestowed with immeasurable regional genetic diversity as well as in indigenous fruits. Manipur is mainly occupied by various indigenous communities and the usage of *D. indica* is quite popular in the 'Kom' tribe which belongs to the ancient 'Kuki' tribe.^[16] Socio-economic circumstances are very impoverished they generally consume various wild edible fruits. Similarly, *D. indica* are consumed in the ripe and unripe state and colloquially it is known as 'Theitup'.^[16,33] In Arunachal Pradesh *D. indica* is called 'Pecha' in Apatani language. Similarly, with respect to the region the name varies colloquially such as 'Chipfoshi', 'Phosi', 'Mel' and 'Kipho'.^[5,6,31] In 'Apatani' tribe, women generally use the fruits for making candies that are sold in the local market of Arunachal Pradesh.^[45] In Nagaland *D. indica* is associated with specific tribes or communities like 'Nagas' and 'Kukis'.^[19] In the Southern Shan state of Myanmar, particularly in Myin Ka village the wild edible plant *D. indica* apart from the ethnomedicinal application it is also used as fuel wood.^[47] Sometimes, it is used as rootstock for grafting of apple and the products are semi-dwarf apple.^[34,36] In Vietnam the fruits are commonly called 'Son tra' apart from ethnomedicinal purposes it is also used to manufacture wine, vinegar and syrups in commercial terms.^[50] The rigid woods of *D. indica* stem are utilized in the processing of household furniture, drum, tool handles and walking stick.^[49,50]



Figure 3: Indigenous processing of 'Mel-ko-chuk' from the fruits of *Docynia indica* (Picture Courtesy: [49]).

- Collected mature fruits are washed
- Fruits are sliced using 'dhiki'
- The sliced fruits are macerated
- The macerated fruits are squeezed using 'col'
- Continuous boil was done in 'khadkudo'
- Reddish dark colour extracts 'chuk'

In the month of October and November *D. indica* is harvested, the collected matured fruits are washed and crushed in small slices with the help of a traditional wooden crusher called 'dhiki' or 'okbli' (Figure 3).^[49] The crushed slices are then transferred into a woven bamboo basket known as 'pecha' and then squeezed by a wooden plank, to liberate the extract which is accumulated in a container and drained through the wooden flat collector 'col'. Then in 'khadkudo' the extract is instantly boiled for 4 to 5 hr along with small iron pieces. After continuous boiling, a thick reddish dark coloured 'chuk' is achieved

(Figure 3). In an air-tight container, the obtained lukewarm 'chuk' is stored and it is locally consumed or sold in the market.^[49] The pickle plays an essential role in the nourishment of the tribal people residing especially in the Himalayan region. Fruits of *D. indica* are cleaned and sliced, dried in direct sun, assorted with oil along with other essential species and then seasoned under sun by which the pickle is processed. In Sikkim Himalayas different types of pickles such as 'Adumwa-achaar', 'Bhatmas-ko-achaar', 'Til-ko-achaar' etc. are made using 'Mel-ko-chuk' as a main ingredient. These types of pickles are quite popular among the indigenous communities for utilizing daily in their staple diet.^[27,49] Since immemorial time *D. indica* have indigenous implementation for treating innumerable health diseases and consumption which enhances the economical perspective of the plant.^[40,49] The market price differs from locality to locality, season to season collection and accessibility of the plants and products of the plant in the local market.^[19] A fully mature *D. indica* tree on per annum basis can exchange revenue of Rs. 12,000. Generally 4.5 kg of 'Mel-ko-chuk' is sold in the local market at the rate of Rs. 1500.^[49] In Samthan city in Jhansi district of Uttar Pradesh the fruits are sold in Rs. 60 – 80 / kg whereas Rs. 100 per 200 ml bottle is the market price for the decoction. Similarly in Kalimpong district of West Bengal, the fruits are sold at Rs. 100 – 150 / kg and the decoction at Rs. 200 per 200 ml bottle which are only available in the month of November and December.^[2,7] In Nagaland *D. indica* plays a significant role in the source of revenue, the fruits are sold at approximately Rs 20 – 50 per 500 gm in the local market of Kohima, Phek and Tuensang district.^[11,19]

ENTHNO-MEDICINAL PERSPECTIVE

The medicinal plant comprises a prominent portion in the drug substances. There are more than 1250 Ayurvedic medicinal plants that are implemented for therapeutic application. If ethno-medicinal plants, are adjoined with the traditional Ayurvedic plants for the medicinal application, all over India the number of this plants will exceed 2000, for this reason, India recurrently designated as 'Medicinal Garden' of the world. Ethnomedicine are regarded as quite safe, readily available, and affordable in indigenous culture.^[9,10,24,28,41] In indigenous communities, the fruits of *D. indica* are popularly utilized for combating enteric diseases.^[40] Pulverized bark of *D. indica* is acquired twice a day by mixing one teaspoon in a hot glass of water and it is a productive ethno-medicine against piles and dysentery. The *D. indica* fruits are cut into small fragments and are

immersed in sugar syrup and then dehydrated in sun. The syrup acquired after boiling and soaking of the fruits is an excellent nausea and headache relaxing indigenous remedy.^[5] In Nagaland, the fruit is indigenously used to treat cough and cold and the leaves are used for dysentery and diarrhea.^[19]

Urolithiasis is a common scenario in Manipur; it is presumed that almost every family has a member exasperated with this disease.^[26] A survey by Marak et al.^[25] on a sample of 875 individuals with urolithiasis, revealed that the disease commonly affected 56.7% individual belonging to the age group of 25 to 44 years and the rest 93.7% were affected due to regular consumption of fish and lack of proper consumption of water.^[25] The fruits of *D. indica* are soaked in sugar and kept aside for 2 weeks and then consumed orally which act as anti-urolithiasis remedy in indigenous systems of medicine.^[29] The *D. indica* fruit plays a vital role in treating the digestive disorder in traditional therapeutic application. Apart from the ethnomedicinal aspect *D. indica* have anti-hyperlipidemic property and cytotoxic activity against HeLa and HepG-2 cancer cell lines.^[12,20,23,53] Different ethnomedicinal and traditional uses of *D. indica* are summarized in **Table 4**.

CONCLUSION

India is one of the mega-diverse countries rich in biodiversity and associated indigenous knowledge but unfortunately, only 50% of the ethno-medicinal plants have been officially implemented in medicinal application. In recent times lesser known wild edible fruits attract a huge public interest because of the presence of significant sources of fiber, minerals, and vitamins which impart vital nutrients for human health. The natural compounds extracted from the *D. indica* fruits contain the polyphenol especially alkaloids and flavonoids which significantly have an anti-hyperglycemic and anti-hyperlipidemic effect and makes the plant more special in the domain of traditional medicine. The different part of this deciduous plant from ancient times plays a vital role in treating innumerable diseases by using indigenous system of medicine. In the future, for full utilization of wild fruit resources, more indigenous plant should be identified and must be explored to enrich the traditional system of medicine with modern therapeutic approach.

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Table 4: Different ethnomedicinal and traditional uses of *Docynia indica*.

Plant Parts	Used For	Description	References
Pulverized Bark	Piles and Dysentery	Consumed twice a day by mixing one teaspoon in a hot glass of water.	[5,12,19,20,22,29,34,36,44,47,49,53]
Fruits	Nausea and Headache	The syrup acquired after boiling and soaking of the fruits is consumed.	
Fruits	Cough and Cold	Significant indigenous remedy.	
Fruits	Anti-Urolithiasis	The fruits are soaked in sugar and kept aside for 2 weeks and then consumed orally.	
Fruits	Digestive disorder	Act as a prophylactic of digestive aid and also observed with hypolipidemic and hypoglycemic effects.	
Leaves	Dysentery And Diarrhea	Productive ethno-medicine.	
Rootstock	Grafting of Apple	To produce semi-dwarf apple.	
Fruits	Wine, Vinegar and Syrups	To manufacture various products for commercial uses.	
Rigid Wood	Furniture, Drums, Tool Handles and Walking Stick	Utilized in the processing of different household items.	

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

Authors' Contributions

JB and PB conceptualized the article. The literature search, data collection, data analysis, design and preparation of the initial draft and final version of the manuscript and preparation of the Figures were carried out by JB. The resources and financial assistance were supported by PB. Supporting data analysis were carried out by MR and RG. All the authors have read and approved the final version of the manuscript.

Consent for Publication

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ABBREVIATIONS

D. indica: *Docynia indica*; **m:** Meter; **g:** Gram; **Kcal:** Kilo-calorie; **KJ:** Kilojoule; **mg:** Milligram; **ml:** millilitre.

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