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Review on *Hardwickia binata* Roxb: A Leguminous Tree Species with Multifaceted Importance in Forestry and Phytomedicine

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ABSTRACT
Hardwickia binata Roxb. or Indian blackwood belonging to family fabaceae represented by a single species is a multipurpose tree species of high ecological, medicinal, and economic importance. This review compiles and synthesizes existing knowledge focused on different aspects of *H. binata*. The species thrives in harsh climatic conditions, showcasing morphological and cytological features that support its ecological stability. Wood of this tree is highly valued for its exceptional strength and making it important for various commercial applications. Moreover, parts of this tree hold ethnobotanical significance, being traditionally used for medicinal purposes. Beyond its physical utility, the plant has demonstrated significant phytochemical richness with growing pharmacological relevance. The historical utilization of this species further highlights its longstanding importance in local livelihoods. This review aims to underline the biological and utilitarian significance of *H. binata*, offering future research and conservation strategies.
KEYWORDS: *Hardwickia binata*, *Climatic adaptation, Ethnobotany, Historical importance*

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HARDWICKIA BINATA ROXB.: AN OVERVIEW

Hardwickia binata Roxb. is an important indigenous multipurpose tree species of great economic value. It is commonly referred as Anjan and is considered near threatened in Madhya Pradesh (Singh et al., 2013) and is classified as an endemic species of India (Shankar et al., 2008). The genus *Hardwickia* is monotypic, represented by a single species, i.e., *H. binata* Roxb. (Luna, 1996; Seetharam and Kotresha, 1998). This genus was named by William Roxburgh in honor of Thomas Hardwicke (Roxburgh W, 1819).

Taxonomy:
According to botanical scheme the plant is classified as follows:

Kingdom:	Plantae
Phylum:	Streptophyta
Order:	Fabales
Class:	Magnoliopsida
Family:	Fabaceae/Caesalpiniaceae
Genus:	*Hardwickia*
Species:	*binata*

Vernacular name:
There are many vernacular names of *Hardwickia binata* Roxb. in different languages.

Nepalese:	Papri
Malayalam:	Aacha

Marathi: Kamara
Hindi: Anjan
Tamil: Acha
Telugu: Yepi

Distribution

In Central India, it grows naturally in Madhya Pradesh and Chhattisgarh, while in Western and Southern India, it is distributed across Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu (Luna, 1996). The species also inhabits the dry savanna forests of the Deccan Peninsula in Central India (FSI, 2003). In Southern India, it grows in shallow, hard, gravelly soils of trap rock, forming dense patches. In the Belllary Forest division of Karnataka, it grows in dense, gregarious stands, which has led to the area being referred to as *Hardwickia binata* division (Kumar and Joshi, 2018). Certain concentrated patches of this species, known as *Hardwickia* forest, occur in Maharashtra, Madhya Pradesh, Karnataka and Andhra Pradesh, typically on shallow, hard, gravelly soils overlaying trap rock. It is also found in the Satpuda mountain ranges and adjoining regions of Dhule, Jalgaon and Nandurbar districts in Maharashtra. Beyond India, *H. binata* has been reported in Pakistan, Bangladesh, Cambodia, Indonesia, Laos, Myanmar, Malaysia, Nepal, Philippines, Thailand, and Vietnam (Kundu, 2011). It is also believed to have originated in Southeast Asia and tropical South Asia (Luna, 1996).

CLIMATIC CONDITIONS FOR *HARDWICKIA BINATA* ROXB.

The habitat of *Hardwickia binata*, commonly known as Anjan, is characterised by hot, dry summers with prolonged droughts and intense sunlight. *Hardwickia binata* Roxb. Occurs naturally in the semiarid and arid zones of Western, Southern and Central India, where it appears either as a scattered stand or in localised patches (Luna, 1996). The species is adapted to hot, dry climates, characterized by a prolonged drought and low to moderate rainfall (Prabakaran et al., 2014). This tree species is found at altitudes ranging from sea level to 760 meters above mean sea level. It thrives on diverse soil types, including sandstone, quartzite, schist, gneiss and soils underlain by gravels or deep rock layers. In its natural habitat, temperature may reach as high as 47°C-48°C, while temperature may drop to 1°C - 10°C in winter. Annual rainfall is typically very low, averaging around 250 mm, though in some areas it may rise to 1000 mm. The species is noted for its capability to persist on rocky, shallow soils in arid regions where many other forest tree species struggle to thrive and fail to survive. It can tolerate soils that are acidic to neutral. Regarding soil conditions, *Hardwickia binata* thrives on various substrates, including quartzite, sandstone, schist, gneiss, and gravelly red sandy soils. However, the species exhibits optimal growth on deep, porous soils with underlying fissured rock (Luna, 2006).

MORPHOLOGY

The Anjan tree grows to a height of 25 to 30 meters with a cylindrical, straight bole measuring between 7 to 15 meters in length. (Seetharam and Kotresha, 1998). During its initial growth phase, the tree crown is conical, later spreading out laterally as the tree matures. The branches are slender and bear lush green, pendulous foliage. Leaves are small, leathery, grayish-green, reniform, compound, bifoliolate, paripinnate, measuring 2-6 cm in length and 2-3 cm in width, and exhibit an actinodromous venation pattern. The inflorescence occur an axillary or terminal panicle racemes bearing small yellowish green hermaphrodite flowers (Luna, 1996). Leaves of this tree are alternate, bifoliate, small, 6 cm long, 2-3 cm wide, kidney shaped, sessile, obliquely ovate, greyish-green, and coriaceous. (Deshmukh and Ghanawat, 2020). Leaves of this tree are leafless for a brief period toward the end of winter season and leaf start renewals subsequently in april and during hot summer the tree is completely with leaves (Kundu, 2011), the new leaves emerge in early May. The compound leaf bears two leaflets joined at the base (Krishen, Pradip 2006).

Bark of this tree is dark grey, rough, marked with irregular vertical fissures, 1.2-2.5 cm thick, exfoliating in narrow flakes. Young bark is silvery white and smooth, gradually becoming darker and rough with age. The flowers are minute white to greenish-yellow, inconspicuous and are easily overlooked (Krishen P, 2006). The fruit is flat, samaroid, oblong lanceolate pod that

is coriaceous, tapered at both ends, and contains a single seed near the apex. Pods mature by November and ripen in April or May. Seeds are exaibuminous, flat, approximately 2 cm long and 0.75 cm wide, straight to slightly curved, pointed at one end and rounded at the other, with a hard testa (Gunaselvi et al., 2010). Wood of this plant is extremely hard, with narrow white sapwood and a reddish-brown heartwood. 4800-5200 seeds per kg will be weighted and trees begin producing seeds at 20-25 years of age, whereas coppice regenerated individuals may begin seedling as early as seven years (Kundu, 2011).

Cytological Study

Cytological investigations of *H. binata* were first initiated by Bir and his colleagues in the early 1970s as part of their broader karyotype analysis of Indian legumes. Sareen and Kumari (1973) initially reported a somatic chromosome number of 2n = 34 for this species. Subsequent investigations by Bir and Kumari (1977) and later by Kumari and Bir (1989) expanded upon this study by examining the karyomorphology of this species collected from Pachmarhi hills in Central India. In contrast to these findings, Watson and Dallwitz (1993) reported a chromosome number of 2n = 68, suggesting the presence of a tetraploid cytotype within the species. However, Doyle (2012) again reported 2n = 34, corroborating the earlier observation of Kumari and Bir (1989). From these studies, it is evident that *Hardwickia binata* occurs in both diploid (2n = 34) and tetraploid (2n = 68) forms, necessitating extensive population studies. Karyotypic analysis confirmed a diploid chromosome number of 2n = 34, with somatic chromosome lengths ranging between 1.33 to 2.75 μm and an average length of 1.93 μm. The haploid complement was 32.89 μm in length. All chromosomes were metacentric, and the karyotype was classified as symmetric, belonging to the 1A type. (Deshmukh and Ghanawat, 2021).

IMPORTANCE OF *HARDWICKIA BINATA* ROXB.

Hardwickia binata Roxb. is a deciduous and multipurpose tree. Different parts of this plant had various important factors. Wood of this tree is extensively utilized in the fabrication of agricultural implements, wooden wheels, and in bridge and residential constructions (Prabakaran et al., 2014). The bioactive constituents of *H. binata* exhibit antimicrobial properties effective against various bacterial and fungal pathogens associated with illnesses such as gonorrhea, pneumonia, eye infections, and mycotic infections. Traditionally, tannins extract from the species have been used to treat catarrh, wounds, hemorrhoids, diarrhea, and as a remedy for heavy metal toxicity. Different parts of tree contain flavonoids that exhibit anti-inflammatory, anti-allergic, antithrombotic, anti-microbial and vasoprotective properties (Gunaselvi et al., 2010). Leaf extract showed efficacy against both gram-positive and gram-negative bacteria, as well as against fungi (Gunaselvi et al., 2010) Leaves contain crude protein (Orwa et al., 2009; Mohamed et al., 2018) used as fodder and manure (Chand and Singh, 2001; Prabakaran et al., 2014), and also used for headache and treatment of constipation (Gunaselvi et al., 2010). Leaf combined with grasses enhances the nutrient value of fodder (Singh et al., 1994). The leaves, tender stems, and twigs serve as an important source of fodder for livestock (Singh N and Sharad, 1996). The natives of the Chhattisgarh region used leaves for headache, purgative and constipation (Pankaj O., 2003). Roots exudates have been reported to possess anti-cancerous properties (Prabakaran et al., 2014; Deshmukh and Ghanawat, 2020).

Bark of this tree contains tannins that are utilized in the production of medicines used for treating diarrhoea, worms, indigestion, leprosy and are also known to possess appetizer properties (Ranganathan et al., 2012). Additionally, bark serves as a source of resins and gums (Basha et al., 2011). As a source of medicine for rheumatism, leaf and bark are used (Rajesham et al. 2013). Bark exhibits notable mercury sorption capacity, enabling effective removal of most of the mercury from water under specific conditions (Deshkar et al, 1990). Extracts of root bark reported anticancer properties in *H. binata* (Prabakaran et al., 2014). A Balsam combined with sandalwood and cubebs, has been used in traditional medicine

for the treatment of leukorrhea, sexually transmitted diseases, chronic cystitis and gonorrhea (Khare, 2007). The species also provides excellent firewood, manure, good charcoal, contributes to nitrogen fixation, improves soil fertility, timber production and bark yield a strong fibre, widely employed for making ropes (Orwa et al., 2009).

Pharmacological Importance

Numerous studies have demonstrated that the phytochemicals present in *H. binata* possess a wide range of biological activities. The antioxidant potential of different extracts was strongly supported by DPPH radical scavenging assays, with aqueous bark and ethanolic leaf extracts showing significant free radical scavenging ability (Hutke and Rathod, 2021; Tamada et al., 2022). The phenolic content was found to be higher in stem extracts, indicating a strong antioxidant efficiency. Rageeb et al. (2022) demonstrated that methanolic extracts of *H. binata* bark exhibited pronounced antimicrobial activity, producing large zones of inhibition against Gram-positive bacteria (*Staphylococcus aureus*, *Bacillus subtilis*) and Gram-negative bacteria (*E. coli*, *Pseudomonas aeruginosa*), along with antifungal efficacy against *Candida albicans* and *Aspergillus niger*. Shingade and Kakde (2021) reported that ethanolic extracts of *H. binata* leaves had broad-spectrum antibacterial activity such as analgesic, cardioprotective, anti-inflammatory, antifungal, and antitumor effects. In vivo studies on animal models have demonstrated anti-inflammatory and analgesic properties of bark extracts, attributed to the flavonoid-rich fraction that possibly inhibits prostaglandin synthesis (Ramesh et al., 2015). These findings highlight *H. binata*'s potential as a versatile medicinal plant capable of addressing oxidative stress, infections, and inflammation through natural mechanisms.

Historical Importance

In ancient history, it was indicated that ropes fabricated from *Hardwickia* fibers, often included with coconut fibers, were traditionally employed to capture elephants, as documented in the encyclopedic text "Manasollasa" (also known as *Abhilashitarthachintamani*). This encyclopedia is attributed to the Western Chalukya Ruler, Someshvara III, who reigned during the twelfth century AD. In the Sangam literature, poets mentioned *Hardwickia* as Yaa, which means the elephants are fond of the bark and aromatic oil of *Hardwickia* (Asher et al., 1971). Additionally, *Hardwickia* is also cited in *Sundara Kaandam* of *Valmiki Ramayana* and *Kamba Ramayana* as one of the trees in Asokavanam, the grove where Sitadevi was held captive beneath a *Simpsupa* tree (*Amherstia nobilis*)

Properties of wood and uses

Hardwickia binata Roxb. yield heavy and hard timber, which is traditionally utilized for manufacturing cart wheels, oil mill components, pestles and ploughs (Reddy, 2007; Saxena, 2010). It is also recognised as an efficient nitrogen-fixing fodder-yielding tree suitable for the semi-arid conditions of India. The tree yields extremely hard, very heavy and durable timber along with high-quality fuelwood (Roy, 1996), nutrient-rich fodder with substantial crude protein content (Singh, 1982) and demonstrates notable resistance to termites (Krishen and Pradip, 2006; Saxena, 2010). Its timber is classified as class I timber due to its hardness and density (Janka Hardness: 6490 Newton; density: 0.73; dried weight 745kg/m3 @ 12 % moisture content); moderate durability and strength. The branches serve as an excellent source of fuel wood and are utilized by local communities. Its wood exhibits a calorific value of approximately 4952 Kcal/kg, making it highly suitable for charcoal production (Luna, 1996). The tree is nitrogen-fixing, contributes to soil fertility, and is highly suitable for agroforestry systems due to its drought tolerance, minimal canopy cover, and responsiveness to pruning, coppicing, and pollarding. The species responds well to pruning interventions and exhibits good coppicing and pollarding ability.

Hardwickia binata is extensively employed as a key arboreal species in silvipastoral systems (Hazra, 1995) as well as in agrosilviculturual feamework (Khadse and Bharad, 1996). In sustainable agricultural systems, it improves farmer livelihoods, ecological resilience, and production because of its exceptional coppicing capacity, drought tolerance, and low maintenance requirements (Kumar and Joshi,

2018; Kamini et al., 2020). The wood of tree of *H. binata* is suitable for indoor and outdoor construction. Planks from them are used in flooring and decking and small diameter roundworm and branch wood is cut for firewood, charcoal and shaping into tool handles. Resin yield from heartwood is utilized to heal the wounds in elephants and Oleo-resin from heartwood is used in manufacture of varnishes (Rao and Rao, 1914)

CONCLUSION

The present review on *H. binata* provides a comprehensive overview of its botanical characteristics, ecological preferences, and traditional significance. The species, native to arid and semi-arid regions of India, is well-adapted to dry climatic conditions, exhibiting unique morphological and cytological traits that contribute to its resilience. Its wood, renowned for exceptional durability and strength, holds significant economic value. The presence of diverse secondary metabolites especially flavonoids, tannins, phenols, and saponins contributes to its strong antioxidant, antimicrobial, anti-inflammatory, and possibly antitumor potential. Additionally, local practices also underscores its ethnobotanical importance. Because of its high commercial value, flexibility, and ecological relevance, *Hardwickia binata* is a priority species for biodiversity conservation, agroforestry development, and sustainable forestry in India.

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