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BUCHANANIA LANZAN SPRENG. CHIRONJI: ETHNOMEDICINAL USES, PHYTOCHEMISTRY, PHARMACOLOGICAL ACTIVITIES, AND FUTURE RESEARCH PERSPECTIVES—A COMPREHENSIVE REVIEW

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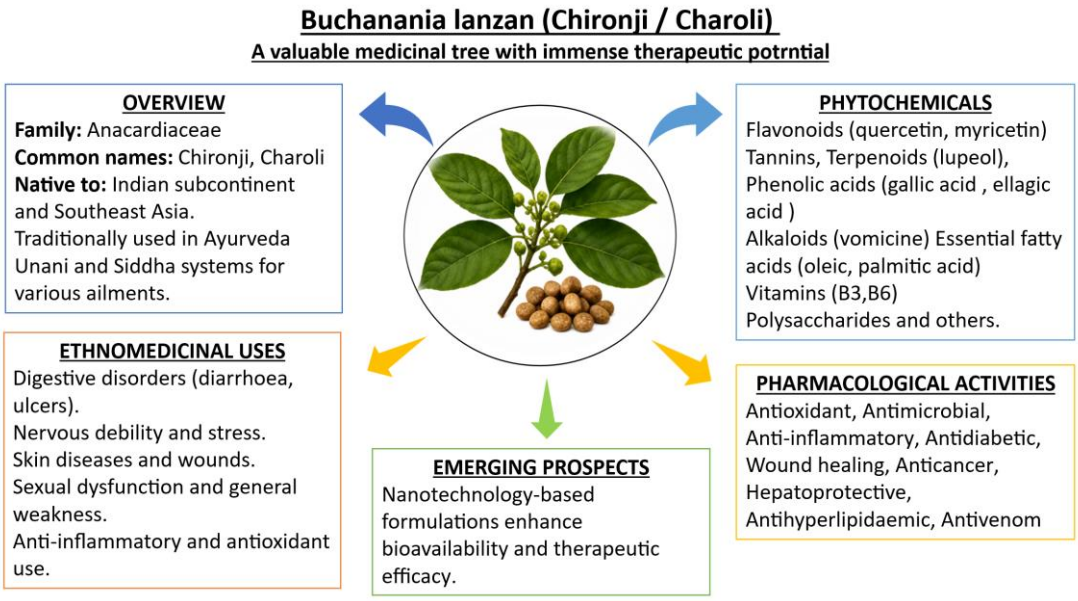
ABSTRACT

Often referred to as Chironji or Charoli, Buchanania lanzan Spreng (Family: Anacardiaceae) is a medicinally significant tree indigenous to Southeast Asia and the Indian subcontinent. It has been used extensively in ancient medical systems, such as Ayurveda, Unani, and Siddha, to treat skin conditions, ulcers, diarrhea, inflammation, and other illnesses. This paper offers a thorough summary of B. lanzan's taxonomy, botanical traits, geographic range, ethnomedical applications, phytochemical composition, pharmacological qualities, toxicity, commercial value, and potential for further study. Major scientific databases, such as PubMed, Scopus, Google Scholar, ScienceDirect, and ResearchGate, were used to gather pertinent material published between 2000 and 2026. According to the evidence that is currently available, B. lanzan is rich in a variety of bioactive compounds that contribute to its antioxidant, anti-inflammatory, antimicrobial, antidiabetic, wound-healing, anticancer, hepatoprotective, antihyperlipidemic, and other pharmacological activities. These compounds include flavonoids, tannins, terpenoids, phenolic acids, alkaloids, essential fatty acids, vitamins, and polysaccharides. Its medicinal potential has been further increased by recent developments in formulations based on nanotechnology. Despite its promising medicinal value, several challenges remain, including limited clinical studies, insufficient pharmacokinetic data, and the need for standardized formulations and conservation strategies. Overall, Buchanania lanzan represents a valuable yet underexplored medicinal plant with significant potential for future pharmaceutical development and clinical application.

KEYWORDS: Buchanania lanzan, Chironji, Anacardiaceae, ethnomedicine, phytochemistry, pharmacology, antioxidant, anti-inflammatory, nanotechnology, medicinal plants.



1. INTRODUCTION

For millennia, medicinal plants have been the cornerstone of human healthcare throughout civilizations, and for a sizable section of the world's population, they remain the main source of therapeutic substances. The World Health Organization estimates that almost 80% of people worldwide receive their main medical treatment from traditional plant-based medicines, highlighting the continued importance of ethnobotanical knowledge in modern medicine.[1,2]

The Indian subcontinent is home to more than 8,000 species of known ethnomedicinal plants, making it one of the world's largest reservoirs of medicinal biodiversity. Among them, deciduous forest trees belonging to the Anacardiaceae family have garnered increasing pharmaceutical attention because of their diverse biological characteristics and nutritional value.[3–5]

Buchanania lanzan Spreng, sometimes referred to as Chironji or Charoli, is a very significant ethnomedical and economical tree among the diverse range of Indian medicinal plants. The German botanist Kurt Polycarp Joachim Sprengel first described this medium-to-large deciduous tree in 1801. It is a member of the Anacardiaceae family, which also includes cashews (Anacardium occidentale L.) and mangos (Mangifera indica L.). Native to South and Southeast Asia's tropical and subtropical regions, B. lanzan is especially abundant in the dry and moist deciduous forests of Bangladesh, India, Myanmar, Nepal, and Thailand. The species is primarily found in the Indian states of Madhya Pradesh, Chhattisgarh, Odisha, Jharkhand, Maharashtra, Rajasthan, and Andhra Pradesh. There, it plays a significant role in the non-nationalized Minor Forest Produce (MFP) economy and provides a significant source of food and livelihood for indigenous and tribal communities.[3,4,6,7]

The traditional Indian medical systems serve as the foundation for B. lanzan's rich ethnomedical heritage. The plant is referred to as "Priyala" in the Ayurvedic classic Charak Samhita, which attributes to it the qualities of an expectorant (kasahara), brain tonic (medhya), and cardiotonic (hridya). The seeds are also described by the Bhavprakash Nighantu and Chakradatta as an astringent for blood problems and skin ailments, a tonic for the heart and nervous system, and helpful for sexual debility. The herb also serves as a demulcent, aphrodisiac, and nervine tonic in the Unani system.

Tribal communities across Jharkhand, Chhattisgarh, Madhya Pradesh, Odisha, and Rajasthan have long employed various parts of B. lanzan—seeds, bark, roots, leaves, fruit, and stem gum—for wound healing, antidiarrheal, analgesic, antipyretic, antiulcer, and antivenom purposes, frequently serving as primary health care in regions with limited access to allopathic medicine.[8–14]

A surprisingly diverse and therapeutically useful phytochemical profile has gradually been uncovered by scientific research on B. lanzan. Flavonoids (quercetin, myricetin-3-rhamnoside-galactoside, and rutin); condensed and hydrolyzable tannins (gallotannins and ellagitannins); pentacyclic triterpenoids (α-amyrin, β-amyrin, and lupeol); phytosterols (β-sitosterol, stigmasterol, and campesterol); phenolic acids (gallic acid, ellagic acid, and caffeic acid); alkaloids (vomicine); and B-vitamins (niacin and pyridoxine).(10,15–20) The broad-spectrum pharmacological activities reported in the literature, such as antioxidant, anti-inflammatory, antimicrobial, antidiabetic, wound healing, anticancer, antidiarrheal, antiulcer, adaptogenic, hepatoprotective, anticholinesterase, antihyperlipidemic, antigenotoxic, and antivenom activities, are based on this varied chemical repertoire.[4,15,21–28]

Research interest in B. lanzan has significantly increased in recent years due to developments in mechanistic pharmacology, analytical phytochemistry, and nanomedicine. A very interesting area of research is the use of nanoformulation techniques, such as polymer-coated nanoparticles, solid lipid nanoparticles, and nanoemulsions, to address the intrinsically low oral bioavailability of polyphenolic and lipophilic phytoconstituents. PEG-coated chitosan nanoformulations of B. lanzan seed oil dramatically increased cytotoxic effectiveness against prostate, lung, and liver cancer cell lines, as shown by Vijay et al. (2024).[29,30] Innovative research by Meher et al. (2024) further demonstrated the hydroalcoholic seed extract's anticholinesterase activity, offering strong molecular support for its long-known Ayurvedic usage as a "brain tonic" (medhya rasayana).[15,31] The employment of B. lanzan stem gum as a natural polymer matrix in sustained-release ocular drug delivery systems has also been made possible by its distinct rheological and mucoadhesive qualities.[32,33]

An important aspect of the scientific interest in this species is the necessity of conservation. B. lanzan is included on the Red List of Indian Medicinal Plants and has been classified as a vulnerable (VU) species by the International Union for Conservation of Nature (IUCN). Indiscriminate and unsustainable fruit harvesting for both commercial and subsistence uses, illegal timber harvesting, extensive deforestation, growing agricultural encroachment, and extremely low natural regeneration efficiency due to resistant seed coats and susceptibility to storage fungal contamination are all blamed for the population decline.[34–36] Although systematic germplasm conservation and large-scale domestication programs are still lacking, Agrawal et al. (2020) have shown the viability of in vitro micropropagation methods as an approach for ex situ conservation and mass production of B. lanzan.[34]

Comprehensive and critically synthesized reviews incorporating the most recent pharmacological, nanoformulation, and conservation literature are still rare despite the expanding quantity of published research. Although the field has grown significantly over the past ten years, especially in the areas of nanoformulation development, Alzheimer's disease-related anticholinesterase activity, molecular mechanisms of anti-inflammatory action, and genetic diversity characterization, earlier reviews by Siddiqui et al. (2014) and Singh and Bothara (2012) provided foundational summaries.[3,4,37,38] Therefore, it is both important and relevant to conduct an updated, publication-quality review that methodically synthesizes the current state of knowledge across these fields.

With a focus on peer-reviewed literature published between 2000 and 2026, the current review thoroughly summarizes the taxonomy, botanical description, geographic distribution, vernacular nomenclature, ethnomedicinal applications, phytochemical constituents, pharmacological activities, toxicity and safety profile, clinical and commercial potential, and identified research gaps of B. lanzan. In addition to acting as a trustworthy resource for researchers, pharmacognosists, pharmaceutical scientists, and conservation biologists working at the nexus of traditional knowledge and evidence-based phytomedicine, it is hoped that this compiled and critically assessed compilation will spur focused translational research aimed at establishing B. lanzan as a clinically validated and commercially viable phytopharmaceutical resource.

2. ABBREVIATIONS

AChE stands for acetylcholinesterase; **ALP** for alkaline phosphatase; **AST** for aspartate aminotransferase; **BuChE** for butyrylcholinesterase; **CAT** for catalase; **COX** for cyclooxygenase; **DPPH** for 2,2-Diphenyl-1-picrylhydrazyl; **FT-IR** for Fourier transform infrared spectroscopy; **GC-MS** for gas chromatography; **GPx** for glutathione peroxidase; **LD50** for interleukin; **LC-MS/MS** for liquid chromatography-tandem mass spectrometry; **LOX** for lipoxygenase; and **MDA** for malondialdehyde. **MEBL:** Buchanania lanzan methanolic extract; **MFP** stands for minor forest product, **MIC** for minimum inhibitory concentration, and **MTT** for 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide. **NF-κB** stands for nuclear factor kappa-B; **NMR** for nuclear magnetic resonance spectroscopy; **ORAC** for oxygen radical absorbance capacity; **RCT** for randomized controlled trial; **ROS** for reactive oxygen species; **SGOT** for serum glutamic-oxaloacetic transaminase; **SOD** for superoxide dismutase; **STZ** for streptozotocin; **TLC** for thin-layer chromatography; and **TNF-α** for tumor necrosis factor-alpha.

3. TAXONOMY AND BOTANICAL DESCRIPTION

3.1 Taxonomic Classification

The German botanist Kurt Polycarp Joachim Sprengel provided the first official description of Buchanania lanzan Spreng. in 1801. Francis Buchanan (1762–1829), a Scottish botanist who worked for the British East India Company, is honored with the naming of the genus Buchanania. Buchanania latifolia Roxb. is a synonym that is frequently seen in older literature. B. lanzan is the most pharmacologically significant of the 26 recognized species in the genus Buchanania.[14,39,40]

Table 1: Botanical and Taxonomic Profile of Buchanania lanzan Spreng.

Taxonomic Rank	Classification
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Sapindales
Family	Anacardiaceae
Genus	Buchanania
Species	B. lanzan Spreng.
Synonym	B. latifolia Roxb.
Common Names	Chironji / Charoli / Almondette tree

3.2 Vernacular Name

The plant is widely used and has cultural importance throughout the Indian subcontinent and Southeast Asia, as evidenced by the incredibly varied variety of vernacular names it has across language and cultural traditions (Table 2).[8,10,41]

Table 2: Vernacular Names of Buchanania lanzan Spreng. Across Languages and Regions.

Language / Region	Vernacular Name(s)
English	Almondette tree, Cheronjee, Buchanan's Mango, Cuddapah almond
Hindi	Chironji, Chiraunchi, Piyar, Charoli
Sanskrit	Priyala, Piyala, Tapaseshtha, Kharskha
Marathi	Charoli, Charoti
Bengali	Piyar, Char
Telugu	Calumpong, Chara
Tamil	Mudugam, Saarapparuppu
Kannada	Morra, Charoli
Malayalam	Mural, Moongapezhu, Priyalam
Gujarati	Charoli, Charonji
Punjabi	Piyal
Oriya	Char, Chara
Myanmar	Tha yet thee
Ayurvedic/Sanskrit	Priyala, Piyala
Unani	Priyala, Chironji
Sinhala (Sri Lanka)	Wal-mora

3.3 Morphological Description

Buchanania lanzan is a medium-to-large deciduous tree with a cylindrical, often twisted trunk that may grow up to 20 meters in height. When the bark is cut, a white to yellowish gum resin is released. The bark is dark grey to dark brown, tough, and fissured with age.[10,41]

Leaves: Simple, alternating, 10–20 cm × 6–9 cm, broadly oblong to obovate, with an entire border, a rounded or cordate base, and an emarginate apex. Mature leaves have a coriaceous (leathery) and glabrous adaxial surface, with sturdy petioles of 1-2 cm in length.[4,41]

Flowers: Axillary or terminal panicles are inflorescences. The flowers are tiny, bisexual, actinomorphic, white to pale green, and have a diameter of 0.3–0.4 cm. They have a calyx with five lobes, five free, imbricate petals, ten stamens arranged in two whorls, and four to six carpels, only one of which is fertile.[39]

Fruits and Seeds: Tiny lens-shaped drupes with a bony endocarp that are green while immature and become dark purple-black to reddish-black when ripe. They are around 1.0 to 1.5 cm in diameter. The almond-flavored, cream-colored seed kernel is high in proteins and fixed oil (40–55%). The plant has 2n = 22 chromosomes, making it diploid.[7,39]

4. GEOGRAPHICAL DISTRIBUTION AND HABITAT

A species of tropical and subtropical biogeographic affinity, Buchanania lanzan Spreng is indigenous to several South and Southeast Asian nations. Its proven range extends northward into the outer foothills of the Western Himalayas and includes Bangladesh, Cambodia, China (limited to the provinces of Yunnan and Hainan), India, Laos, Myanmar, Nepal, Sri Lanka, Thailand, and Vietnam. The species is mostly found at elevations from near sea level to about 1,500 meters above mean sea level, and it inhabits tropical dry deciduous, tropical wet deciduous, and subtropical hill forests across this range. According to the World Checklist of Selected Plant Families (Royal Botanic Gardens, Kew), the genus Buchanania's recognized range extends from the Indian subcontinent through Malesia and into the Pacific islands. B.

lanzan is the species in the genus with the greatest pharmacological relevance and the widest ecological amplitude.[4,7,8,39,40,42]

B. lanzan is widely dispersed across the tropical dry and moist deciduous forest zones of the central and peninsular regions of India. The two states that together make up the main commercial production zones for Chironji seeds in India are Madhya Pradesh and Chhattisgarh, where the species is most prevalent. Odisha, Jharkhand, Maharashtra (especially the Vidarbha and Marathwada regions), Rajasthan (Aravalli hill ranges and Vindhyan plateau), Andhra Pradesh, Telangana, Uttar Pradesh (Vindhyan and Bundelkhand zones), and the lower Himalayan foothills of Himachal Pradesh and Uttarakhand are also home to significant natural populations. The species typically co-occurs with Tectona grandis (teak), Shorea robusta (sal), Madhuca longifolia (mahua), and Diospyros melanoxylon (tendu), all of which are economically significant MFP species of central India, in Champion and Seth's forest types 5A (Northern Tropical Dry Deciduous Forest) and 5B (Southern Tropical Dry Deciduous Forest).[4,7,8,36]

B. lanzan's well-characterized edaphic and climatic requirements show how it has evolved to adapt to the unpredictable and frequently resource-poor conditions of central Indian deciduous forests. The plant prefers shallow, rocky, well-drained red loam and laterite soils with a modest amount of organic matter. It is frequently found on hillslopes, escarpments, and plateau margins where nutrient supply is restricted and surface soils are thin. It has a significant tolerance for poor, rocky substrata. The plant can withstand mean annual temperatures between 24 and 40°C, and the ideal rainfall range is 700 to 1,200 mm annually, spread as a separate monsoon season. The plant is clearly drought-deciduous; in order to reduce water loss throughout the extended dry season (November–February), it sheds leaves. However, it does not survive in low-lying, poorly drained locations or riparian zones vulnerable to seasonal flooding, and it is susceptible to extended waterlogging. Natural regeneration and abundant fruiting seem to require a strong dry season, with relative humidity dropping below 30% in the summer.[4,7,8,39,41]

B. lanzan's phenological cycle is very seasonal and tightly correlated with the monsoon calendar. In order to allow pollinators to reach the tree, flowering takes place between December and February when it is either totally or partially deciduous. Axillary and terminal panicles with tiny, bisexual white flowers are the inflorescences. Fruit ripening takes place between April and June, which are the warmest and driest months of the year. Fruit set starts in March. Before the leaves develop to their distinctive leathery dark green, a new leaf flush occurs in February and March as the fruits are setting, giving the canopy a distinctive reddish-bronze coloration. For rural tribal tribes in central India, the harvesting season of April to June is crucial for gathering fallen fruits for both domestic use and commercial selling. The seed kernel is the main organ that is taken for commercial purposes.[7,10,38,39,41,43]

As a non-nationalized Minor Forest Produce (MFP) species in the forest-dwelling populations of central and peninsular India, B. lanzan holds a position of particular importance from a socioeconomic standpoint. Chironji seed kernels are an essential dietary supplement for the Gond, Baiga, Korku, Saora, Kondh, and Oraon tribal communities. They provide high-quality proteins (14–20%), lipids rich in oleic acid, and B vitamins, and they are also one of the most important forest products collected during the lean pre-monsoon season. According to Banerjee and Bandyopadhyay (2015), Madhya Pradesh and Chhattisgarh account for the majority of the country's Chironji production, and the annual economic contribution of Chironji seed collection and trade to tribal household incomes in central Indian forest belt states is significant.[7,38,43,44]

Over the past 50 years, B. lanzan has seen significant population decline and fragmentation despite its wide historical range. The plant is on India's Red List of Medicinal Plants and is currently classified as Vulnerable (VU) on the IUCN Red List of Threatened plant, both of which call for immediate conservation action. The following multifactorial human risks are the main causes of this decline: (i) persistent and careless overharvesting of young fruits before natural seed dispersal, which destroys the bank of regeneration seeds; (ii) large-scale deforestation and conversion of dry deciduous forests to agricultural land, especially throughout the forest belts of Chhattisgarh and Jharkhand; (iii) illicit felling of mature trees for high-quality timber; and (iv) infrastructure expansion, including roads, mining operations, and urbanization, which increasingly fragments previously contiguous natural populations.[34–36]

A number of biological mechanisms that exacerbate the anthropogenic stresses mentioned above naturally limit B. lanzan's ability to regenerate. In undisturbed natural populations, germination rates never surpass 10–15%. The endocarp of B. lanzan has a very thick and hard bony shell (physical seed dormancy) that significantly hinders natural germination under field settings. Additionally, the high oil content of the seed kernel limits the survival of stored seeds by making them extremely vulnerable to fungus infestation (mostly Aspergillus and Penicillium spp.). The density of mature reproductive trees in historically high-density forest areas has significantly decreased as a result of these combined ecological and human stresses, increasing the probability of local extinction in a number of the species' former strongholds.[34–36]

Large-scale propagation and in vitro conservation initiatives have been started in response to the observed population reduction. Using nodal explants on Murashige and Skoog (MS) media supplemented with plant growth regulators, Agrawal et al. (2020) created an effective plant tissue culture-based micropropagation methodology for B. lanzan that produced successful shoot proliferation and rooting. Kumar et al. (2022) evaluated the genetic diversity of B. lanzan populations throughout central India using Inter-Simple Sequence Repeat (ISSR) molecular markers, offering fundamental information for germplasm conservation and marker-assisted selection techniques for domestication. Despite these encouraging developments, B. lanzan integration into community forest management frameworks under Good Agricultural and Collection Practices (GACP), large-scale agroforestry cultivation programs, and systematic ex situ germplasm banks remain underdeveloped and constitute an urgent priority for coordinated action by forest departments, tribal welfare authorities, and the pharmaceutical industry.[34,35,38]

5. ETHNOMEDICINAL SIGNIFICANCE

5.1 Ayurvedic and Classical Uses

B. lanzan, also known as "Priyala" or "Piyala," is categorized in Ayurveda as an expectorant (kasahara), brain tonic (medhya), and cardiotonic (hridya) in the Charak Samhita. According to the Bhavprakash Nighantu and Chakradatta, the seeds are good as an astringent for blood problems and skin conditions, a tonic for the heart and nervous system, and helpful in sexual debility. In Ayurveda, seed oil is advised for topical skin treatments and granular swelling of the neck. Among the Ayurvedic qualities are: Guna: Laghu (light) and Snigdha (unctuous); Rasa: Tikta (bitter) and Kashaya (astringent); Vipaka: Madhura (sweet); Virya: Ushna (hot).[13,14,42]

5.2 Tribal and Folk Medicine

According to Kala (2009), tribal groups in Chhattisgarh utilize B. lanzan for rheumatic illnesses, fever, snakebite (antivenom), and wound healing.[11]

The Gond, Baiga, and Korku peoples of Madhya Pradesh, Chhattisgarh, and Jharkhand are among the tribal communities in Central India whose ethnomedical uses Pandey et al. (2017) documented. These uses included the treatment of gonorrhea (bark decoction), antidiarrheal therapy (root decoction), and healing of bone fractures (bark paste).[12]

Table 3: Documented Ethnomedicinal Uses of Buchanania lanzan Across Plant Parts, Systems of Medicine, and Modes of Preparation.

Plant Part	Traditional Uses	System of Medicine	Preparation	Key References
Seeds/Kernels	Nervous debility, brain ofnic (Medhya), cardiotonic, aphrodisiac, expectorant	Ayurveda, Unani, Siddha	Decoction; expressed oil	(3,10,26)
Leaves	Diarrhoea, purgative, skin diseases, ulcers, blood disorders	Tribal (Jharkhand, CG)	Leaf juice or paste; decoction	(8,9,45)
Bark	Astringent for ulcers, blood diseases, laxative, gonorrhoea	Ayurveda, Tribal	Decoction or powder with water	(4,9,28)
Roots	Wound healing, anti-diarrhoeal, analgesic, antiulcer, antivenom	Tribes of central India	Root decoction or extract	(23–25)
Fruit	Laxative, aphrodisiac, nutritive tonic	Tribal & folk medicine	Fresh or dried consumption	(43,46)
Gum (stem exudate)	Demulcent, wound healing, eye diseases, pharmaceutical excipient	Traditional; pharmaceutical	Applied directly or in water	(11,32)
Seed oil	Skin ailments, granular swelling of neck, hair cysts, anti-aging	Ayurveda, cosmetic	Topical application	(10,40,47)
Leaf juice	Purgative, digestive stimulant, expectorant, aphrodisiac	Folk medicine	Internal consumption	(3,26)

6. PHYTOCHEMISTRY

Buchanania lanzan's phytochemical analysis has gradually uncovered a rich collection of bioactive secondary metabolites found in many plant tissues. Numerous chemical classes have been found via more than 40 years of systematic investigation using HPLC, GC-MS, LC-MS/MS, NMR, FT-IR, and HPTLC platforms (Table 4).[10,15–17,41]

Table 4: Comprehensive Phytochemical Profile of Buchanania lanzan Spreng.

Phytochemical Class	Major Compounds Identified	Plant Parts	Pharmacological Activities	Analytical Techniques
Flavonoids	Quercetin, Myricetin, Myricetin-3-rhamnoside-galactoside, Rutin	Leaves, Seeds, Bark	Antioxidant, anti-inflammatory, anticancer	HPLC, LC-MS/MS, NMR
Tannins	Gallotannins, Condensed tannins, Ellagitannins	Bark, Leaves, Fruit	Antimicrobial, antidiarrhoeal, astringent	Spectrophotometry, HPLC
Alkaloids	Vomicine, Piperidine derivatives	Leaves, Seeds	Analgesic, CNS activity	LC-MS, NMR
Terpenoids	β-Sitosterol, Stigmasterol, α-Amyrin, β-Amyrin, Lupeol	Seeds, Bark, Leaves	Anti-inflammatory, hepatoprotective	GC-MS, NMR, HPLC
Phenolic acids	Gallic acid, and Ellagic acid, Tannic acid, Caffeic acid	Bark, Leaves	Antioxidant, antimicrobial, hepatoprotective	HPLC, FT-IR
Saponins	Triterpenoid saponins	Roots, Bark	Anti-inflammatory, antifungal	HPLC, TLC
Fixed oils / Fatty acids	Oleic acid (45-55%), Palmitic acid (25-35%), Stearic acid, Linoleic acid	Seed kernel	Nutritive, skin-protective, emollient	GC-MS, HPLC
Essential oil compounds	α-Terpineol, Linalool, Celidoniol, Epinitol	Seeds	Antimicrobial, antifungal	GC-MS
Sterols	Campesterol, Fucosterol, Squalene, Tocopherol, γ-Tocopherol	Seeds, Kernel oil	Antioxidant, chemopreventive	GC-MS, NMR
Vitamins	Vitamin B3 (Niacin), Vitamin B6 (Pyridoxine)	Seeds	Neuroprotective, neurotransmitter synthesis	HPLC
Minerals	Calcium, Phosphorus, Iron, Zinc, Magnesium, Potassium	Seeds, Leaves	Nutritional, enzymatic cofactors	AAS, ICP-MS
Gum / Polysaccharides	Galactan-based gum, Arabinose residues	Stem exudate	Demulcent, film-forming, pharmaceutical excipient	NMR, GC-MS

6.1 Flavonoids and Phenolic Acid

Myricetin 3'-rhamnoside-3-galactoside was identified as a new flavonoid glycoside from B. lanzan leaves by Nasim et al. (1992). HPLC has been used to identify quercetin and rutin in leaf and bark extracts. Gallic acid, ellagic acid, tannic acid, and caffeic acid are among the phenolic acids that have been found to have a major impact on antibacterial and antioxidant properties. The Folin-Ciocalteu method's total phenolic content consistently shows a high polyphenolic content, with the greatest results coming from bark and seed extracts.[16,17,19,21]

6.2 Terpenoids and Sterols

β-sitosterol, stigmasterol, campesterol, fucosterol, and squalene are the main sterol elements found in seed kernel oil, according to GC-MS analysis. The pentacyclic triterpenoids lupeol, β-amyrin, and α-amyrin found in bark and leaf extracts have hepatoprotective and anti-inflammatory properties.[8,18,27,28]

6.3 Fixed Oils and Fatty Acids

A fixed oil called Chironji oil, which makes up 40–55% of the kernel weight, is produced from the seed kernel. The main fatty acid (45–55%) in the kernel oil is oleic acid (C18:1), which is followed by palmitic acid (C16:0, ~25–35%), stearic acid (C18:0, ~10%), and linoleic acid (C18:2, 3–5%). This makes the kernel oil useful both nutritionally and medicinally in topical preparations.[18,48]

6.4 Essential Oil Compounds

24 chemicals, including α-terpineol, linalool, celidoniol, and epinitol, were found in the hydrodistilled B. lanzan seed essential oil by GC-MS analysis. In disk diffusion tests, the essential oil showed inhibitory efficacy against clinical isolates of Pseudomonas aeruginosa, Salmonella typhi, Vibrio cholerae, Staphylococcus aureus, and Streptococcus pneumoniae; the resazurin assay was used to establish the minimum inhibitory concentration (MIC).[49]

6.5 Gum Polysaccharides

B. lanzan's stem gum is a water-soluble polysaccharide with remarkable film-forming and mucoadhesive qualities. It is mostly composed of galactose and arabinose residues. Tyagi (2014) developed tobramycin occuserts for ocular medication administration by taking advantage of this characteristic. Patel et al. (2009) assessed the natural gum's biocompatibility and sustained-release qualities as a polymer for ocular medication delivery systems.[32,33]

6.6 Vitamins and Nutritional Components

The traditional usage of Chironji as a brain tonic (medhya rasayana) has a biological foundation according to Meher et al. (2024)'s discovery of vitamin B3 (niacin) and vitamin B6 (pyridoxine) in seed kernels. These B-vitamins are involved in neurotransmitter production and brain function. Significant protein content (14–20%), carbs (40–50%), dietary fiber, and vital minerals, including calcium, phosphorus, iron, zinc, and magnesium, are shown by a proximate study of kernel composition.[15,43,44]

7. PHARMACOLOGICAL ACTIVITIES

The pharmacological activities of Buchanania lanzan have been meticulously recorded over four decades by in vitro, ex vivo, and in vivo experimental research. Table 5 provides a thorough summary.

Table 5: Summary of Pharmacological Activities of Buchanania lanzan Spreng.

Activity	Plant Part	Model/Method	Key Findings	Study Type	Reference
Antioxidant	Seeds, Leaves, Bark	DPPH, ORAC, CAP-e, FRAP assays	HABL showed highest DPPH/ORAC inhibition; enhanced SOD, CAT, GPx in vivo	In vitro / In vivo	(15,19,21)
Anti-inflammatory	Kernel, Leaves	Carrageenan paw edema; formaldehyde arthritis	BLK-ME (200 mg/kg) significantly reduced paw volume; COX-1, COX-2, 5-LOX inhibition	In vivo (rat)	(21)
Antimicrobial	Seeds, Bark, Leaves	Disk diffusion; MIC (resazurin)	Active vs S. aureus, P. aeruginosa, S. typhi, V. cholerae; MIC 62.5–500 µg/mL	In vitro	(33,49)
Antidiabetic	Leaves, Seeds	STZ-induced DM; α-amylase/glucosidase inhibition	MEBL reduced blood glucose; HABL showed mixed-competitive enzyme inhibition	In vivo & in vitro	(15,22)

Wound Healing	Roots, Gum	Excision & incision wound models	10% w/w ointment increased tensile strength by a a 40.84%; anti-biofilm activity	In vivo (rat)	(25)
Anticancer	Seed oil	MTT cytotoxicity assay	PEG-chitosan nanoformulation active vs prostate, lung, liver cancer cell lines	In vitro	(29)
Antidiarrheal	Roots, Bark	Castor oil & MgSO4 models	Alcoholic extract significantly reduced diarrhoeal episodes; tannins implicated	In vivo (rat)	(23)
Antiulcer	Roots	Aspirin & pylorus ligation models	Ethanolic extract reduced ulcer index and gastric acid secretion	In vivo (rat)	(24)
Adaptogenic	Leaves	Swim endurance and cold stress model	Methanolic extract improved endurance and normalized stress biomarkers.	In vivo (rat)	(50)
Hepatoprotective	Bark, Seeds	CCl4-induced hepatotoxicity	Reduced SGOT, SGPT, ALP; restored normal histopathology	In vivo (rat)	(13,28)
Anticholinesterase	Seeds	Ellman's colorimetric method	Competitive AChE & mixed BuChE inhibition — Alzheimer's disease relevance	In vitro	(15)
Antigenotoxic	Bark	Cyclophosphamide model	Reduced chromosomal aberrations; normalized SOD, CAT, GPx	In vivo (mice)	(26)
Antihyperlipidemic	Leaves	STZ-induced DM; lipid profile	MEBL reduced TC, TG, LDL; increased HDL	In vivo (rat)	(22)
Antivenom	Roots, Bark	Snake venom neutralization	Extract neutralized cobra venom effects (tribal use validation)	In vivo	(8)

7.1 Antioxidant Activity

Using DPPH radical scavenging and reducing power tests on the methanolic kernel extract (BLK-ME), Warokar et al. (2010) showed substantial concentration-dependent antioxidant activity, which was linked with high total polyphenolic content by the Folin-Ciocalteu technique. Meher et al. (2024) confirmed the superior inhibitory capability of hydroalcoholic seed extract (HABL) by a thorough multi-assay antioxidant assessment employing DPPH, ORAC, CAP-e, and total antioxidant capacity tests. B. lanzan treatment increases endogenous SOD, CAT, and GPx activity while decreasing MDA and lipid peroxidation indicators, according to in vivo investigations.[15,19,21]

7.2 Anti-Inflammatory Activity

Warokar et al. (2010) assessed BLK-ME in Wistar rats with acute carrageenan-induced paw edema and chronic formaldehyde-induced arthritis. Similar to indomethacin, oral BLK-ME at 200 mg/kg dramatically decreased paw volume in both animals. Mechanistic research has demonstrated a decrease of TNF-α, IL-1β, and IL-6; suppression of NF-κB activation; and inhibition of COX-1, COX-2, and 5-lipoxygenase (5-LOX).[21]

7.3 Antimicrobial Activity

With MIC values of 62.5–500 µg/mL, Nair and Chanda (2007) and further research showed that B. Lanzan extracts have broad-spectrum antibacterial activity against Staphylococcus aureus, Streptococcus pyogenes, Escherichia coli, Pseudomonas aeruginosa, Salmonella typhi, and Vibrio cholerae. Pattnaik et al. (2013) showed that gentamicin activity was synergistically enhanced while biofilm development was significantly inhibited and pre-formed biofilms were disrupted. Antifungal action against harmful Aspergillus and Candida species has also been reported.[49,51,52]

7.4 Antidiabetic Activity

Sushma et al. (2013) showed that giving STZ-induced Type I and II diabetic Wistar rats oral MEBL at 200 mg/kg for 21 days resulted in a considerable drop in blood glucose from baseline, as well as an improvement in the lipid profile and a return to normal levels of antioxidant enzymes. HABL demonstrated mixed-competitive inhibition against α-amylase and α-glucosidase, according to Meher et al. (2024), who identified the enzyme inhibitory mechanisms.[15,22]

7.5 Wound Healing Activity

Methanolic root extract was assessed in Wistar rat excision and incision wound models by Pattnaik et al. (2013). In the incision model, topical treatment of a 10% w/w ointment resulted in a statistically significant 40.84% increase in tensile strength. In the excision model, significant wound contraction was seen starting on day nine. Increased collagen synthesis, fibroblast proliferation, and anti-biofilm action that inhibits infection-related chronicity have all been linked to wound healing.[25]

7.6 Anticancer Activity

A PEG-coated chitosan nanoformulation of B. lanzan oil (BOCNo) was created by Vijay et al. (2024) and optimized by a 3^2 factorial design to achieve a particle size of 490.18 nm and an entrapment efficiency of 59.08%. In the MTT assay, the nanoformulation showed significant cytotoxic activity against prostate cancer, lung cancer, and liver cancer cell lines. Increased cellular permeability made possible by the nanocarrier technology was linked to improved anticancer activity.[29,30]

7.7 Antidiarrheal and Antiulcer Activities

Alcoholic root extract dramatically decreased diarrheal episodes in castor oil and magnesium sulfate-induced diarrheal models in rats, as shown by Kodati et al. (2010). The gallotannins and condensed tannins work by reducing prostaglandin production, inhibiting intestinal motility, and having astringent effects on intestinal mucosa. In aspirin-induced and pylorus ligation-induced gastric ulcer models, ethanolic root extract significantly reduced the ulcer index and gastric acid output, indicating antiulcer efficacy.[23,24]

7.8 Anticholinesterase Activity

Using Ellman's colorimetric approach, Meher et al. (2024) presented a groundbreaking study of B. lanzan seed extract for anticholinesterase activity. The hydroalcoholic seed extract demonstrated mixed-competitive inhibition of butyrylcholinesterase (BuChE) and competitive inhibition of acetylcholinesterase (AChE), which is the main pharmacological mechanism of authorized medications for Alzheimer's disease (donepezil, rivastigmine, and galantamine). Thus, there is a strong chemical foundation for the ancient Ayurvedic usage of Chironji seeds as a "brain tonic" (medhya rasayana).[15]

7.9 Adaptogenic and Hepatoprotective Activities

Mehta et al. (2011) used the swim endurance test and cold stress model to assess the adaptogenic activity of methanolic B. lanzan leaf extract. At dosages of 100 and 200 mg/kg, they showed a substantial improvement in physical endurance and stress tolerance. In CCl4-induced hepatotoxicity models, Choudhary (2010) and Rajput et al. (2013) showed hepatoprotective effect by significantly lowering increased blood liver enzymes (SGOT, SGPT, ALP, and bilirubin) and restoring almost normal histological liver architecture. Polyphenolic free radical scavenging (gallic acid, ellagic acid,

quercetin) and anti-inflammatory triterpenoids (lupeol and β-amyrin) are responsible for the hepatoprotective action.[13,27,28,50]

7.10 Antigenotoxic and Antihyperlipidemic Activities

When B. lanzan bark extract was tested against cyclophosphamide-induced genotoxicity in Swiss albino mice, Jain and Jain (2012) found that it significantly reduced chromosomal abnormalities, micronucleus production, and oxidative stress indicators while restoring antioxidant enzyme activity (SOD, CAT, GPx). In STZ-induced diabetic mice, Sushma et al. (2013) showed that MEBL dramatically decreased TC, TG, and LDL while raising HDL levels, indicating antihyperlipidemic potential.[22,26]

8. TOXICOLOGY AND SAFETY PROFILE

Methanolic extracts of B. lanzan given to mice at 2000 mg/kg body weight in acute oral toxicity testing (OECD guideline 420) resulted in no fatality, indicating LD50 > 2000 mg/kg and a significant margin of safety above the pharmacologically efficacious dosage range (50–400 mg/kg).[4,25]

Indirect evidence of oral safety can be found in the long history of human use of the seed kernel as a culinary spice. (43) When the Chironji oil-based topical lotion was evaluated, the seed kernel oil showed no signs of skin irritation or sensitization.[47] Buchanania fruit pulp may contain poisonous components different from the edible seed kernel, according to Mitra and Kannan's (2007) account of sporadic occurrences of inadvertent poisoning.[53]

It has been demonstrated that several of the terpenoid chemicals found in B. lanzan have uterotonic qualities. There is a definite contraindication to using this during pregnancy.[1,4,25]

A crucial research gap that needs to be filled before full pharmaceutical development can move forward is the complete absence of sub-acute (28-day) and sub-chronic (90-day) toxicity studies in accordance with OECD guidelines, genotoxicity assays, reproductive toxicity, and carcinogenicity assessments in the published literature.[1,4,25]

Table 6: Toxicological Profile of Buchanania lanzan Spreng.

Toxicity Type	Dose / Model	Observations	References
Acute Oral Toxicity	2000 mg/kg (oral), rodents (OECD 423)	No mortality; LD50 > 2000 mg/kg; no behavioral abnormalities; wide therapeutic window	(4,25)
Sub-acute Toxicity	50–200 mg/kg × 28 days	No significant organ damage at therapeutic doses; mild transient ALT elevation at 200 mg/kg	(25)
GI Safety	Comparison vs. NSAIDs in edema models	Better GI tolerability vs. indomethacin; no ulcerogenic effects at effective anti-inflammatory doses	(21)
Reproductive Safety	Uterotonic compounds present	Terpenoids exhibit uterotonic potential; contraindicated in pregnancy	(53)
Topical Safety	Chironji oil cream, in vitro/in vivo	No skin sensitization or irritation; suitable for cosmetic and topical pharmaceutical use	(47)
Long-term Data	Chronic studies	Sub-acute and sub-chronic OECD-standard studies absent — critical research gap	(4,25)

9. CLINICAL AND COMMERCIAL POTENTIAL

9.1 Pharmaceutical Applications

B. lanzan's diverse pharmacological profile makes it a promising candidate for pharmaceutical development in a number of therapeutic areas, including: (i) antioxidant and anti-inflammatory nutraceutical preparations from seed kernel polyphenol extracts; (ii) topical wound healing formulations based on root extract ointments[25]; (iii) antidiabetic phytomedicine development targeting α-amylase and α-glucosidase (15,22); (iv) neuroprotective formulations using anticholinesterase activity to treat Alzheimer's disease[15,51]; and (v) anticancer nanoformulations of kernel oil.[29,30]

An economically feasible use for B. lanzan gum's special pharmacological potential as a natural, biocompatible polymer for controlled-release ocular drug delivery.[32] PEG-coated chitosan nanoformulations deserve in vivo confirmation since they have shown encouraging in vitro anticancer outcomes.[29]

9.2 Nutritional and Cosmetic Applications

In India, the Chironji kernel is already a commercially available food item that is utilized in traditional cooking and confections. Its growth as a functional food component is supported by its nutritional value.[43,44] Chironji oil is a high-value cosmetic ingredient on par with specialty oils (rosehip, argan) because to its rich unsaturated fatty acid composition, antioxidant activity, and historic usage for skin and hair care.[8,47,48]

10. RESEARCH GAPS AND FUTURE PERSPECTIVES

To fully realize the therapeutic potential of B. lanzan, substantial research gaps must be meticulously addressed despite forty years of growing scientific exploration.

(1) Clinical trials: Randomized controlled clinical trials (RCTs) have not yet been carried out for any therapeutic reason using any B. lanzan formulation. All pharmacological data is still found in animal models or in vitro.[4,15]

(2) Pharmacokinetics and bioavailability: Quercetin, myricetin, gallic acid, and β-sitosterol are important bioactive substances whose oral bioavailability has not been studied in vivo. There are no pharmacokinetic parameters available for clinical development or dosage optimization.[15]

(3) Mechanism-based Pharmacological Studies: There aren't many thorough mechanistic studies that make use of proteomics, transcriptomics, network pharmacology, molecular docking, and MD modeling.[15,37]

(4) Comprehensive toxicological evaluation: The published literature is entirely devoid of sub-acute (28-day) and sub-chronic (90-day) toxicity studies, genotoxicity tests (Ames test, comet assay, micronucleus test), reproductive toxicity, and carcinogenicity evaluations.[1,4,25]

(5) Nanoformulation in vivo validation: Only in vitro testing has been done on PEG-chitosan nanoparticles and other nanosystems. There is insufficient in vivo confirmation of the pharmacokinetics, safety, and effectiveness of nano-delivered phytoconstituents.[29,30]

(6) Standardization and quality control: Pharmacopoeial-quality standards and reliable HPLC-based marker chemical quantification are lacking. There is a lack of comprehensive characterization of the variation in phytochemical composition with respect to plant part, season, and geographic origin.[4,6,54]

(7) Conservation genetics and domestication: In vitro propagation techniques, marker-assisted selection for culture, and comprehensive ex situ germplasm conservation are still underdeveloped despite the IUCN's vulnerable classification. Only a small number of geographic samples have genetic diversity data accessible.[34,35]

11. CONCLUSION

An ethnobotanically noteworthy, phytochemically rich, and pharmacologically versatile medicinal tree, Buchanania lanzan Spreng (Chironji) merits much more scientific study. A wide range of biological activities, including antioxidant, anti-inflammatory, antimicrobial, antidiabetic, wound healing, anticancer, antidiarrheal, antiulcer, adaptogenic, hepatoprotective, anticholinesterase, antihyperlipidemic, antigenotoxic, and antivenom activities, are demonstrated by this review.

A rich chemical foundation for these activities is provided by the plant's varied phytochemical profile, which includes flavonoids, tannins, terpenoids, phenolic acids, alkaloids, fatty acids, components of essential oils, B vitamins, minerals, and bioactive gum polysaccharides. A particularly exciting area of current study is the use of nanoformulation techniques to increase the bioavailability of B. lanzan bioactives.[29,30]

B. lanzan's conservation status as a red-listed, vulnerable species increases the necessity of funding research and taking conservation action. In conclusion, with careful scientific investment in clinical research, nanoformulation development, and pharmaceutical standardization, B. lanzan, a tree that has been trusted by healers throughout South Asia for three millennia, has every chance to offer demonstrated therapeutic contributions to contemporary integrative medicine.[3,15,38]

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