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REVIEW ARTICLE

Exploring the hidden treasures of *Coptis teeta* Wall.: Ethnomedicinal claims, traditional wisdom, and promising avenues for research

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Abstract

Coptis teeta Wall., commonly known as *Mishmi teeta*, is a perennial herbaceous plant belonging to the Ranunculaceae family and is rich in various bioactive compounds. It is classified as endangered on the Red List and is endemic to the Eastern Himalayas in Northeast India, representing a valuable repository of traditional wisdom and ethno medicinal practices. This article compiles available data on *C. teeta* for the first time, drawing from classical Ayurveda texts, botanical floras and research databases. Since 3000 B.C., this "Goldthread" has been an integral part of Traditional Chinese Medicine (TCM) as *Rhizoma coptidis*. Through an extensive literature search, including online published reviews, research articles and ethnomedicinal survey reports, it has been found that various tribes in Arunachal Pradesh, India, have utilized its potent therapeutic benefits for centuries to treat ailments such as gastrointestinal disorders, malaria, diabetes, eye disorders, infectious diseases and more. The vivid pharmacological activities of *C. teeta* are primarily attributed to its alkaloids and other non-alkaloidal components, although limited preclinical work has been reported to date. The roots and rhizomes of *C. teeta* are rich in alkaloids such as berberine, jatrorrhizine, columbamine, epiberberine, coptisine and palmatine. These compounds play a significant therapeutic role in managing various ailments, including diabetes and cardiovascular diseases. They possess anti-inflammatory and analgesic properties, offer neuroprotective effects, aid in metabolic regulation and exhibit antimicrobial activity. Additionally, this review discusses the extensive trade benefits of *C. teeta*, the reasons for its threatened status and various practical approaches for its conservation and cultivation. By bridging ethnomedicinal knowledge with scientific modernization through a multidisciplinary research approach, this review aims to unlock the hidden treasures of *C. teeta* and encourage further pharmacological research and standardization.

Keywords

ayurveda; *Coptis teeta* Wall; ethanomedicine*; Mamira; Rhizoma coptidis*

Introduction

India is renowned for its diverse and ancient systems of traditional medicine, with Ayurveda being the oldest and most widely recognized and practiced (1). The integration of this system opens new avenues for research by facilitating knowledge exchange, combining principles, enhancing research through collaboration, strengthening commonalities and promoting the global acceptance of herbal medicines with improved safety and efficacy (2, 3). India is recognized as one of the 12 mega-diversity countries, attributed to its vast climatic and altitudinal diversity and boasts over 8,000 herbal species, with 1800 used therapeutically. A 2019 survey by the WHO revealed that approximately 80-99% of the global population relies on traditional medicines and indigenous healing systems (4). In India, around 6000 plant species are utilized in traditional and herbal medicine, meeting about 75% of the healthcare needs in developing countries, with 23% of these species being native to India. Of these, 3000 plants have been officially recognized for their medicinal properties. Globally, the WHO recognizes over 21000 plant species for medicinal use, with India contributing around 2500 species (5, 6).

The Northeast states of India boast a diverse landscape, featuring mountains, plains and rivers, making the region highly favourable for the growth of valuable medicinal plants (7). In the culturally and biologically rich states of Northeast India, particularly Arunachal Pradesh, the inhabitants of 26 primary tribes and over 110 sub-tribes collectively use around 1963 plant species to treat various ailments (8, 9). The migration of Palaeoarctic biota from Tibet and Malayan species from the Southeast has contributed to the region's immense ecological and floristic diversity, which includes approximately 5000 plant species (10). Unfortunately, this invaluable ethnomedicinal knowledge is at risk due to overexploitation, deforestation and inadequate conservation and documentation efforts. Accurate plant records are essential for preserving the biodiversity and therapeutic potential of these valuable species before they are lost to extinction (11).

One of the notable medicinal plants from the Eastern Himalayas is *Coptis teeta* Wall., a stemless perennial from the Ranunculaceae family. It is extensively used by Indigenous tribes, particularly the *Mishmi* tribes of Arunachal Pradesh, for treating ailments such as diarrhoea, stomach aches and malaria. The plant is widely used in Bengal and other regions, where its roots are harvested toward the end of the rainy season. These roots are transported in small wicker baskets to Sadiya, Assam, where traders from different provinces purchased them (12-14). *C. teeta* is also a traditional remedy in Burma, Yunnan and Tibet, where the plant thrives in the shaded, cold and damp mountainous areas at altitudes ranging from 1500-2300 m, making the geographical conditions ideal for its growth (15).

In Traditional Chinese Medicine (TCM), several formulations include *Rhizoma coptidis*, which consists of the dried rhizomes of *Coptis chinensis* Franch., *Coptis deltoidea* C.Y.Cheng & P.K.Hsiao and *C. teeta* Wall. Commonly referred to as "Yunnan goldthread", *C. teeta* is therapeutically used both as a single drug and as a key component of *R. coptidis*. Formulations such as Jiu-Huang Lian, San-Huang-Xie-Xin-Tang and Jiao-Tai-Wan, which contain *R. coptidis*, are traditionally used to manage type-II diabetes (16) and dyslipidemia (17). The 2015 edition of the Chinese Pharmacopoeia Commission lists 18 different formulations containing *R. coptidis*. The rhizomes are rich in various phytoconstituents, including alkaloids, simple phenylpropanoids, flavonoids and other compounds (18). These compounds give *R. coptidis* its therapeutic properties, including heat-cleansing, moisture-dissipating and fire poison -draining actions, as well as antimicrobial and anti-inflammatory effects, making it an essential component of natural healthcare worldwide (19).

The significance of this review article lies in addressing a critical gap in research. While numerous reviews and articles have provided comprehensive descriptions of *C. teeta*, much of the work remains incomplete. To date, research has primarily focused on isolating key bioactive compounds from various parts of *C. teeta* using advanced instrumentation, highlighting its evidence-based pharmacological effects against conditions such as hypertension, arrhythmias, diabetes, diarrhoea, hyperlipidaemia, inflammation, pain, depression and microbial infections through preclinical investigations. However, no efforts have been made to compile and explore information on *C. teeta* from ancient Ayurvedic texts and floras. This review represents the first systematic attempt to bridge that gap. By linking the documented ethnomedicinal uses of *C. teeta* with traditional Ayurvedic wisdom and providing a scientific basis for its therapeutic potential, this work not only enriches the current body of knowledge but also enhances its therapeutic application and preserves this valuable information for future generations and further research.

Materials and Methods

A comprehensive search strategy was employed across various online platforms to gather relevant data. Information was collected from a wide range of review articles, research papers, databases and online search engines, including PubMed, Google Scholar, ScienceDirect, Web of Science, the Digital Library of Traditional Chinese Medicine and India's Traditional Knowledge Digital Library. Keywords such as '*Coptis teeta*', '*Rhizoma Coptidis*', '*Ayurveda*', 'Ranunculaceae', 'ethnomedicine', 'endangered species' and 'pharmacological activities' were used, along with their combinations.

The search was further expanded by examining traditional Ayurvedic texts (in both print and digital formats), botanical floras and authoritative references like the *Chinese Pharmacopoeia* and *Indian Medicinal Plants: An Illustrated Dictionary*. The review focused on inclusion criteria such as ethnomedicinal surveys, phytochemistry and pharmacology-related research, with particular emphasis on extracting data concerning the ethnomedicinal use of *C. teeta* by tribal communities in India. Sources that did not directly contribute to understanding the identified research gap were excluded from the search. This structured approach ensured a thorough exploration of available resources, allowing for a deeper understanding of *C. teeta*'s role in traditional medicine and identifying areas requiring further scholarly investigation.

C. teeta in Ayurvedic literature

Among the various texts of Ayurveda, *C. teeta* is first mentioned in *Bhavprakash Nighantu* (Indian Materia Medica), written by *Acharya Bhavmishra* between 1500-1600 A.D. The medicinal properties of its rhizomes or roots hold high therapeutic value, particularly in the upper regions of the

Mishmi hills. *Acharya Bhavmishra* highlights its significance in China, where it is known as "*Chini Mamira*" and is primarily used to manage *Madhumeha* (Diabetes mellitus). It is characterized by its *tikta rasa* (bitter taste). Internally, it acts as *Poushtika* (nourishing), *Deepana* (appetite stimulant) and *Pachana* (digestive aid), making it effective for treating conditions such as *Dourbalya* (general debility), *Vishama jwara* (malarial fever) and *Pachana vikara* (digestive issues). Externally, it inhibits *Netrya guna* (beneficial for the eyes) and is often used as an adulterant for medicinal herbs like *Katuki* and *Piyaranga*. *Thalictrum foliolosum* DC. (Family: Ranunculaceae) shares the Hindi name *Mamira* due to its similar phytoconstituents, such as 8.5% berberine and thalictrine, despite being a different plant from the original *C. teeta* (20).

Another Ayurvedic text, *Nighantu Adarsha,* written by Bapalal Vaidya, provides detailed information about *Mamira* under the *Vatsanabhadi varga* (Rananculaceae, Crowfoot family). The description of *C. teeta* in this text aligns with *Bhavprakash Nighantu*. The *Mishmi* tribes of Assam, Northeast India, commercially trade this plant, hence the name "*Mishmi teeta*". Its berberine-rich roots are well-known for their *Katupoushtika* (bitter tonic) and *Amapachaka* (detoxifying) properties and are typically prescribed in doses of 1 to 2 *masha* (g). *M. teeta* effectively alleviates *dourbalya* caused by *Jwara roga* and other ailments*,* such as *Ajeerna* (chronic indigestion), *Kosthavata* (gastrointestinal *Vata* disorders) and *Mutra vikara* (urinary disorders). In the case of *Vishama jwara*, it is administered in doses of 2-3 *masha* (g) every 3 h before the onset of fever, yielding positive outcomes.

Externally, a mixture of *Mamira* with rose water or pure honey is used to treat *netra-abhishyanda* (conjunctivitis). Eye drops prepared by mixing 20 parts of *Gulabarka* (rose petals) and 1 part of *Mamira* alleviates symptoms like *raktata* (redness), *daha* (burning sensation) and *sotha* (inflammation) of the eyes. Additionally, for the treatment of *Switra* (leukoderma), it is applied after being thorough ground with *madhu* (honey). Its action is comparable to *Daruharidra* (*Berberis aristate* DC) and its constituents. According to Unani practitioners, *Mamira* combination with *Anisuna* cures is used to treat obstructive jaundice. *Pili Jadi (Thalictrum foliolosum* DC*)*, with roots as yellow as *Haridra* (*Curcuma longa* L.), shares similar medicinal properties i.e. *rechaka* (purgative) and *mutral* (diuretic), as that of *Mamira.* Both the terms *Mamiro* and *Mamiri* are the same (21).

Saraswati Nighantu describes *Mamira* as a *Netraushadham*, under the classification of *Pittarohini.* However, *Gentiana kurroa* Royle (Family: Gentianaceae) could be considered a genuine source of *Pittarohini* based on identification inconsistencies (22). These referenced texts elaborate on the medicinal qualities of substances, including their *Rasa* (taste), *Guna* (properties), *Veerya* (potency), *Vipaka* (post-digestive effect), *Dosha karma* (impact on the three doshas: *Vata, Pitta* and *Kapha*), along with other therapeutic benefits. A summary of Sanskrit and vernacular names of *C. teeta* in classical Ayurveda texts are shown in Table 1.

Botanical floras

The *Flora of British India* provides the most detailed botanical description of *C. teeta*, particularly highlighting its perennial herbaceous nature, pinnatisect leaves and small white flowers borne on slender scapes. The text notably emphasizes the plant's golden yellow, woody and densely fibrous rootstock, which is distinctly bitter (23). The *Compendium of Indian Medicinal Plants* (24), *Glossary of Indian Medicinal Plants* (25) and *Indian Medicinal Plants* (26) collectively offer a comprehensive overview of the plant's medicinal importance and characteristics, including detailed descriptions of its rootstock, leaves, flowers and seeds, as well as its Ayurvedic and Unani names. These texts extensively cover its therapeutic properties, which include stomachic, antiperiodic, antibacterial, antifungal, hypoglycemic and hypotensive activities. *C. teeta* is used as a tonic and in the treatment of conditions such as debility, dyspepsia, fevers and various diseases, mainly due to its potent chemical constituents, such as palmatine, berberine and coptine. A special mention is made of its habitat in the *Mishmi* hills.

Three additional texts: *Forest Flora of the Bombay Presidency and Sind*, *Flora of Orissa* (27) and *Taxonomy of Vascular Plants* (28) provide a broad overview of the Ranunculaceae family, focusing on general botanical characteristics rather than specific details about *C. teeta*. These texts describe the diverse forms of the Ranunculaceae family, including herbs, tendril-climbing shrubs, vines, and trees and highlight common features such as leaf arrangement, flower structure and the distinctive fruit type, described as a head of many one-seeded plumose achenes. While offering valuable insights into the botanical context and classification of the family, these sources lack specific information on *C. teeta*'s unique attributes, habitat, or medicinal uses, underscoring the need for specialized texts to explore the species in depth.

The *Central Council for Research in Ayurvedic Sciences* (CCRAS) (29) and *Wealth of India* (30) both highlight *C. teeta*'s significance as an endangered medicinal plant in India, though from different perspectives. CCRAS emphasizes its medicinal importance in Indian systems of medicine, notes its threatened status due to commercial exploitation and discusses efforts to cultivate the plant for conservation. The

Table 1. Sanskrit and vernacular names of *C. teeta* in classical Ayurveda texts.

Name of text	Names of *C.teeta* in different languages					
	Sanskrit	English	*Hindi*	*Gujarati*	*Marathi*	*Assam*
Bhavprakash Nighantu	*Mahatikta, Pittamoolaa, Hematantu*	Gold thread	*Mamira, Mamiri*	-	-	*Mishmititta*
Nighantu Adarsha	*Mamir and Pittamoola*	*Coptis* or Gold thread	*Mamaira, Mamiri*	*Mamiro, Mimiri*	*Mamaira, Mamiri*	*Mishmiteeta*
Dravyaguna Vigyan	*Tiktamoola*	Gold thread root	*Mamaira, Mamiri, Haldiya bachanaga*	*Mamiro*, Mimiri	--	*Mishmiteeta*

text also covers the plant's appearance, habitat and medicinal uses, underscoring the urgent need to protect this species. Conversely, *Wealth of India* provides a detailed botanical description, discusses its alkaloid content and pharmacological properties and examines conservation issues. It also offers insights into the plant's commercial significance, trade names and cultivation practices, alongside applications of key constituents like berberine.

Overall, while the *Flora of British India* provides the most detailed description of *C. teeta,* other texts contribute to a broader understanding of the plant's family, classification and general botanical characteristics. Additionally, the *Flora of British India* and *the Flora of China* (15) offer detailed descriptions of a closely related species, *C. teeta*, which differs slightly in its botanical features, further enhancing the comparative study of the species.

Rhizoma Coptidis: part of Traditional Chinese Medicine (TCM)

Coptis plants were first recorded in the earliest monograph on Chinese Material Medica, *Sheng Nong's Herbal Classic*, during the Eastern Han dynasty (25-220 AD). From the 18th century onward, *Coptis chinensis* has been widely cultivated in China, with its rhizomes being exported to various countries. In Korea and Japan, the rhizomes of *Coptis japonica* are sometimes used as a substitute for *C. chinensis* (31, 32). For over 2000 years, Chinese medicine practitioners have incorporated *R. coptidis* both as a dietary supplement and a therapeutic herb, owing to its multi-targeted therapeutic effects, which include anti-bacterial, anti-viral, anti-inflammatory, antihyperglycemic and hypolipidemic activities (33), as well as its use in psoriasis (34). *R. coptidis* is rich in berberine, coptisine, palmatine, epiberberine, jatorrhizine, magnoflorine, columbamine and epiberberine, which are responsible for its diverse therapeutic activities (35, 36). It is featured in over 32,000 formulas in Chinese medicine, commonly in the forms of powders, pills, decoctions, or tablets (37).

New research avenues in *C. teeta* cultivation

Research in cultivation techniques is essential to meet the growing demand for plant-based medicines, as it reduces pressure on wild populations and prevents overharvesting, which can lead to biodiversity loss (38). Cultivation research also ensures consistent quality and availability of medicinal plants by optimizing growth conditions, phytochemical content and pharmacological and therapeutic actions (39). *C. teeta* is a slow-growing herb, typically cultivated at altitudes ranging from 1700 - 2800 m (40). In North India, the ideal planting time for *Coptis* is between September and October. Germplasm is collected using a small iron rod in forested areas from the start of the rainy season to the onset of winter when the plant is in its most vigorous condition. Immediate transplantation is done into earthen pots with a mix of leaf mold and garden soil, followed by light watering. Daughter plants appear after six months and the rhizomes, which reach a diameter of around 1.5 cm, typically take 4 to 10 years to mature. The plant's lifecycle lasts 8 to 10 years. For transportation, rhizomes are packed with Sphagnum moss to retain moisture and humidity for better survival (41).

The cultivation of *C. teeta* in the Darjeeling hills through ex-situ conservation has provided insights into ideal growing conditions. Rhizome and seed propagation require optimal conditions such as sandy loam soil with high organic carbon content, essential nutrients (N, $P2O_5$, K_2O) and a pH range of 4.5 - 5.6. The plant also thrives in well-drained, muddy soil. Flowering and lifecycle variation depend on the topography of the land, improving survival rates and commercial viability while reducing the threat of extinction in its natural habitat (42). In Arunachal Pradesh, a state-supported initiative by the Forest Department promotes the cultivation of *M. teeta* across 5 districts. The plant, propagated from seeds or wild-gathered specimens (spaced 30 × 30 cm apart), is cultivated during colder months. Cultivating this climate-sensitive plant is crucial, with around 124 kg of dry rhizomes fetching a market price of approximately Rs. 2000 per kg, providing a net profit of Rs. 16800 per ha. Governmental agencies and local communities play a pivotal role in ensuring the sustainable cultivation of *M. teeta*, a practice that has extended to Nagaland, though on a smaller scale (43, 44).

Lisu farmers, part of the Tibeto-Burman ethnic group inhabiting mountainous regions, cultivate *C. teeta* using minimal pesticides and fertilizers derived from burned shrubs and grasses. This agroforestry system enables efficient plant growth within three years (43). A study on *C. teeta's* flowering, breeding, and pollination biology provides insight into its endangered status and resource protection. Key findings include a 4-month floral longevity, a 45-60 day flowering period and pleiochasium inflorescences with numerous stamens and carpels. The plant is xenogamous and self-compatible, requiring pollinators for seed production, with agamospermy also playing a role (45).

In 2007, Tandon and colleagues successfully demonstrated *C. teeta's* rapid clonal multiplication through micropropagation, using axillary buds and rhizome parts from mature plants. They created multiple shoots by providing favourable growth conditions, including hormonal treatments, nutrient media and optimal environments for efficient regeneration (40). Commercial cultivation of *C. teeta* is also possible through improved agro-technology, such as selecting suitable cultivars, optimizing growing conditions, enhancing propagation techniques and implementing proper crop management and harvesting practices (42).

One major limitation to large-scale cultivation is *C. teeta's* slow growth, taking years to fully mature. Additionally, the plant is soil-specific, requiring well-drained acidic soil and high humidity. Farmers face challenges due to limited knowledge of cultivation techniques, leading to an imbalance between demand and cultivation, which increases reliance on wild harvesting (40).

Pharmacognosy and phylogeny of *C. teeta*

The taxonomic classifications of *C. teeta* are as follows: Kingdom: Plantae; Clade: Tracheophytes; Clade: Angiosperms; Clade: Eudicots; Order: Ranunculales; Family: Ranunculaceae; Genus: *Coptis;* Species: *C. teeta;* Synonyms: *Coptis teetoides*.

The first phylogenetic analysis of the *Coptis* genus identified two strongly supported clades. The first clade includes subgenus *Coptis* and section *Japonocoptis* of subgenus *Metacoptis*, supported by morphological traits such as the characteristics of the central leaflet base, petal color, and petal shape. The second clade consists of section *Japonocoptis* from subgenus *Metacoptis*. *Coptis morii* is not grouped with *C. quinquefolia*, contradicting the view that *C. morii* is a synonym of *C. quinquefolia.* Additionally, the two varieties of *C. chinensis* do not cluster together. *Coptis groenlandica* and *C. lutescens* have been reclassified as *C. trifolia* and *C. japonica*, respectively. The phylogeny of the *Coptis* genus is significant for several reasons, i.e., the evolution of its morphological characters, classification and taxonomy, important research, understanding the evolutionary relationships within the genus and developing conservation and management strategies for *Coptis* species (46).

This perennial herb features rhizomatous and densely fibrous roots. The leaves are ovate-lanceolate, measuring 5-20 cm or 6-12 cm in length and 5-9 cm in width, characterized by a distinctive triple fissure pattern (17), pinnatifid structure and a three-lobed glabrous lamina, with petioles measuring 10-20 cm long. The flowers are arranged in panicled inflorescence and display a small blue-green hue featuring 3-5 flowers that are either white or yellowish. The calyx is yellow-green and oval-shaped, measuring 7.5-8 mm in length and 2.5-3 mm in width. The anther measures approximately 0.8 mm in length, while the filament extends to 2-2.5 mm. The flowering period occurs from February to April. The most medicinally significant part of the plant is rhizome, which is horizontal to oblique. The fresh or live rhizome appears golden, while the dried form is brownish, measuring 5-15 cm in length and exhibiting an uneven shape along with fibrous roots. The prominent leaf scar gives the rhizome a pungent and bitter taste with cooling properties. The external skin is yellowish-brown, with yellow-orange pith that contains numerous nodes and rootlets, primarily consisting of fibrous roots. The rootstock originates profusely from the points where the leaves develop, while it is less abundant on the underground rhizome. The length of rhizome varies from 2.1 to 4.9 cm depending on the duration of the crop, with weights ranging from 4.3 to 8.9 g. During the fruiting period, *C. teeta* typically reaches a height of 15-25 cm and exhibits one or two scapes. The fruit is a multi-seeded follicle containing black seed, with fruiting occurring from May to July (47, 48, 14, 43, 35, 45).

The transverse section of *C. teeta* rhizome reveals that the outermost surface is covered with a multi-layered cork, with well-differentiated tissues comprising the cortex, vascular bundles and pith. Alkaloids are primarily deposited at the cortex and vascular bundles, where parenchymatous and conducting tissues are rich in yellowish alkaloids, while there is minimal alkaloid deposition in the pith (49, 14).

Phytochemical studies

The chemical components of the Ranunculaceae family include several representative groups such as benzylisoquinoline alkaloids, ranunculin, triterpenoid saponins and diterpene alkaloids (50). The phytoconstituents identified in the rhizome of *C. teeta* are listed in Table 2. Investigations into the phytoconstituents of *Rhizoma Coptidis* began in 1862, with the initial isolation of berberine sourced from *C. teeta* rhizomes (57). The primary active ingredient in the roots of *C. teeta* is berberine (6-8.5%), along with other alkaloids such as coptisine, palmatine, jateorrhizine, epiberberine, columbamine and various non-alkaloidal

Table 2. List of compounds identified from *C. teeta* rhizome.

Phytoconstituents identified in *C. teeta* rhizome	Total number of compounds
1,2,3, Propanetriol, 1-ethyl-2-pyroolidinone, 8-nonenoic-8,9-D2 acid, methyl ester, DL-Valine, N-acetyl-, methyl ester, Benzenepropanoic acid, methyl ester, 4,6-heptadecenoic acid,3,3,6-trimethyl -, methyl ester, Bicyclo(5.2.0)Nonane, 4,8,8-trimethyl -2-methylene, 2-methoxy-4-venylphenol, Cysteamine Sulfonic Acid, 2-propenoic acid, 3-phenyl, methyl ester, (Z), 7-isopropophenyl-4A-Methyl-1-methylenedecahydronphthalene, 1,3-benzenedicarboxylic acid, dimethyl ester, Nonanoic acid Methyl ester, Benzoic acid, 4 Hydroxy-3-methoxy-, methyl ester, Benzene, 1,2,3- Trrimethoxy-5-Methyl, 4-Methyl-2,5-Dimethoxy benzaldehyde, Octane,3-5- dimethyl, Heptadecanoic acid Methyl Ester,4-(1E)-3-hydroxyl-1-Propenyl)-2-methoxyphenol, Cyclopentanetridecanoic acid, Methyl ester, 2-methyltetracosane, Dichloroacetic Acid, undec-2-enyl ester, Octadecanoic Acid, Methyl Ester, 6-Octadecenoic Acid, Methyl Ester, (Z)-, 9-Hexadecenoic Acid, Methyl Ester, (Z)-, 9-Octadecenoic Acid, (Z)- Methyl Ester, Hexadecanoic Acid, Methyl Ester, Pentadecanoic Acid, Cyclopropanenonanoic acid, 2 -[(2-butylcyclopropyl) Methyl], Hexadecanoic acid, 15-Methyl-, Methyl Ester, Hexadecane-1, 16-diol, Noroxyhydrastinine, n-Nonadecanol-1, 9,12-Octadecadienoic acid (Z,Z)-, Methyl Ester, 9,12,15-Octadecatrienoic acid, Methyl Ester(Z,Z,Z)-, Methyl Streate, (9E,12E)-9,12 Octadecadienoyl Chloride, Eicosanoic Acid, Methyl Ester, Trans-2-Pinanol, 7-hydroxy, 6-methyl-bicyclo[4.3.0] nona-3-one, Tetracosanoic acid, Methyl Ester, Methyl Lignocerate, Lignoceric Acid Methyl Ester, 1,2-Dimethoxy-4-[(1E)-1-Prophenyl]Benzene, Canadine, 1,1'-Biphenyl, 3,3',4,4',5,5'-hexamethoxy-alpha.-Tocopherol-.beta.-D-mannoside, 3,4-Quinolinedicarboxylic acid, 6-Methoxy-2-Phenyl-, Dimethyl ester, N-(2,5-Di-Tertbutylphenyl)Phthalimide, Berbine, 13,13a-didehydro-9,10-dimethoxy-2,3-(methylenedioxy)-, Indeno[1,2-b]quinoxalin-11-one, 2-methyl-, C-Chloro-N-[2-(6,7-Dimethoxy-Isoquinolin-1-YLMethyl)-4,5-Dimethoxy-Phenyl]- Methanesulfonamide, Stigmast-5-EN-3-OL, (3.BETA.)-, Deoxyaniflorine, Cholest-4-en-3-one, Phenol,2,6-dimethoxy (14).	56
Berberine, Palmatine, Citric acid, Acetic acid, Columbamine, Jatrorrhizine, Coptisine, 3,4-Dihydroxyphenethyl alcohol, 3,5-Dihydroxyphenethyl alcohol-3-O-β-D-glucopyranoside, Epiberberine, Ferulic acid, Groenlandicine, (+)-Lariciresinol, Longifolroside A, Malic acid, Magnoflorine, Methyl-3,4-dihydroxyphenyl lactate, Oxalic acid, *Z*-Octadecyl caffeate, Protocatechuic acid, Quinic acid, Succinic acid, (+)-Syringaresinol-4-O-β-D-glucopyranoside, 3,5,7-Trihydroxy-6,8-dimethylflavone, Tartaric acid, 3,5,7-Trihydroxy-6,8-dimethylflavone, Woorenoside I, Woorenoside II (51).	27
Magnoflorine, nor oxyhydrastinine, jatrorrhizine, columbamine, epiberberine, coptisine, berberubine, worenine, palmatine, berberine and oxyberberine (52).	11
Alkaloids, carbohydrates, flavonoids, glycosides, organic acid, phenolic compounds, reducing sugars, saponin, starch, terpenoids and tannins (53).	11
Alkaloid, saponin, carbohydrates, phenols, flavonoids, tannin, terpenoids, cardiac glycoside, coumarin, starch, quinone, steroids (54).	12
Organic acids like Quinic acid, Acetic acid, Malic acid, Tartaric acid, Oxalic acid, Citric acid (55)	06
Lignans and flavonoids like 3, 5, 7-trihydroxy-6, 8-dimethylflavone, ferulic acid, Z-octadecyl caffeate, protocatechuic acid, methyl-3, 4-dihydroxyphenyl lactate, 3, 4-dihydroxyphenethyl alcohol, 3, 5-dihydroxyphenethyl alcohol-3-O β-D-glucopyranoside, (+)-Lariciresinol, Woorenoside I, Woorenoside II Longifolroside A (+)-Syringaresinol-4-O-β-D glucopyranoside (56)	14
Other compounds like Limonin, β-sitosterol, fixed oil, lignin, and sugar (44, 18)	05

components including lignans, phenylpropanoids, carbohydrates, fixed oil, albumin, coloring compounds, phenolic acids, lignin, extractives, flavonoids and sugars (48, 58). Additionally, the plant also contains starch, quinones, phlobatannins, steroids, glycosides, coumarin, tannins, saponins, phenols, terpenoids and cardiac glycosides (54, 59). In both crude and wine-processed *R. Coptidis*, 11 major alkaloids-including berberine, coptisine, epiberberine, berberubine, oxyberberine, worenine, magnoflorine, nor oxy hydrastinine, jatrorrhizine, columbamine and palmatine-were reported using a validated HPLC-PAD method (52).

The high polarity of the protoberberine alkaloids found in *C. teeta* posed challenges in their quantification. Consequently, a study was conducted to develop and validate a method using high-performance thin-layer chromatography (HPTLC) with densitometry for the precise quantification of berberine in a methanol extract of *C. teeta*, which provided an accurate measurement of berberine content. Another study developed and validated a reproducible TLC densitometric method for quantifying protoberberine alkaloids in a methanolic extract of *C. teeta*, with the highest amount of berberine quantified at 30.97%. This study also reported a high recovery percentage (90.74-96.47%) following ICH guidelines (60).

Preliminary qualitative analysis of the major secondary metabolites in the ethanolic extract of *C. teeta* roots indicated the presence of alkaloids, glycosides, anthraquinones, carbohydrates, flavonoids, tannins, saponins, terpenoids, amino acids, fixed oils and fats (60). A similar study that utilized various solvent extracts, including water, methanol, acetone, chloroform and n-hexane, also identified alkaloids, along with additional non-alkaloidal components such as phenols, cardiac glycosides, coumarins, starch, quinones, phlorotannins and steroids. The acetone extract exhibited the highest total phenolic content (100.24 ± 0.00 mg GAE/g) and flavonoid content (269.13 ± 0.05 mg QE/g) compared to standards gallic acid and quercetin, respectively.

Using the RP-HPLC-UV-DAD method, a relatively high concentration of berberine was assessed in a water-alcohol mixture (1:1) from *C. teeta* roots, compared to standard berberine (61). HPLC-based fingerprint analysis showed that *C. chinensis* rhizomes contained higher levels of epiberberine, palmatine, coptisine and columbamine, while *C. deltoidea* and *C. teeta* rhizomes exhibited the highest concentrations of jatrorrhizine and berberine, respectively (18).

Ethnomedicinal claims and traditional uses

The Mishmi and local tribes are known for their extensive ethnopharmacological knowledge of traditional medicine, relying on the region's rich biodiversity to meet their healthcare needs. *C. teeta,* locally known as *M. teeta*, is used to treat various conditions such as cough, diabetes, hypertension, malarial fever and jaundice. A small quantity of the pounded rhizome is taken twice daily with water as a remedy for fever, gastric problems and headaches (62). The residents of Arunachal Pradesh utilize the rhizome of *M. teeta* for various ailments based on traditional knowledge (44). A detailed screening of numerous researches related to the traditional medicinal practices of the tribal populations in Arunachal Pradesh's has yielded insights on *C. teeta,* as mentioned in Table 3.

Additionally, DeFilipps and Krupnick in 2018 highlighted the significance of *C. teeta* in Myanmar, where its roots are used to relieve constipation, regulate bowel movements, promote digestion, reduce fever and increase vitality. The roots can be soaked in liquor for use in treating malaria. The roots are also crushed and ground together with *Piper longum* Linn., forming pea-sized pellets; one pellet is taken each morning and evening to address excessive phlegm, asthma, bronchitis and coughs. A mixture of crushed roots, ground *P. longum* and juice from *Abutilon indica* Linn. leaves is shaped into pellets the size of peppercorns, with two pellets swallowed twice daily to reduce edema, promote digestion, and alleviate diarrhoea and other intestinal problems. A paste made from the root, one *Syzygium aromaticum* Linn., and one *Piper nigrum* Linn. is mixed with mother's milk and given to children for pneumonia.

Equal amounts of the root bark, the bark from *Shwe tataing* (the scientific name of this plant could not be ascertained per Thi Ta, *personal communication*) and the bark from *A. indica* are powdered and inhaled to alleviate asthma, bronchitis and coughs. Externally, a thick paste formed from ground roots is applied around the eyes to treat sore eyes and other eye problems. A mixture of the roots, crushed together with a bit of sap from *Aloe vera* Linn., and leaves or sap from *Mayoe* (*Calotropis procera*), is applied topically to snakebites. Crushed roots combined with *P. longum*. and a bit of the tuberous roots from *Maaye Chintaung* (a grass species with a triangular stem) are used to neutralize venom. The roots, when soaked in liquor, can also relieve constipation, regulate bowel movements, promote digestion, reduce fever, treat malaria and increase vitality (81).

Pharmacological study

Despite its multi-targeted efficacy in biological systems, it's important to note that preclinical research data on *C. teeta* are very limited. This limitation highlights the need for extensive scientific investigations using well-established models to generate authenticate data that can help the scientific community fully understand its bioactive components, mechanisms of action and potential health benefits.

Analgesic and anti-inflammatory activity

The analgesic activity of the methanolic extract of *C. teeta* was tested at three dose levels (30, 100 and 300 mg/kg in a 0.3% (w/v) CMC solution, p.o.) against acetic acid-induced writhing reflex in albino mice. A dose-dependent effect was observed, with maximum inhibition (43.62%) noted at the 300 mg/kg dose, although this was not greater than the effect of diclofenac potassium (10 mg/kg, p.o.). Additionally, the hot plate method was employed to assess analgesic activity, following the same dosing schedule for the *C. teeta* methanolic extract in albino mice. The results indicated a significant increase in percentage analgesia, ranging from 32.41% at 30 mg/kg to 65.04% at 300 mg/kg in a dose-dependent manner, with the most significant result achieved at 300 mg/kg, although it was comparatively lower than that of tramadol (15 mg/kg, p.o.), which showed 80.12% analgesia. Furthermore, the anti-inflammatory activity was evaluated using the carrageenan-induced rat paw edema method. The

Table 3. List of tribes utilizing *C. teeta* for various therapeutic purposes.

Tribal community of Arunachal Pradesh	Local name of *C. teeta*	Part used	Dosage, route of administration and uses
Adi tribe	*Ringka*	Dried rhizome	Infusion of dried rhizome soaked overnight in water is used as antidysenteric, antidiarrhoeic, antipyretic and antimalarial (63). Rhizome with water is utilized as a tonic, for fever, headache and gastric trouble (64). It is widely used in ailments such as fever, headache, gastric trouble, dysentery, ulcer, insomnia, and vomiting, is stimulant to the heart, and possesses anti-bacterial activities (65).
Adis and *Idus* tribe of Upper Singa Valley district	*Mishmi tita, Manbai*	Dried roots	**i.** The dried roots of *C. teeta* and rhizome of *Z. officinale* are ground into a paste with water, if taken orally as well as (with or without *Kasturi* and the skin of *Mithun*) ointment is used to cure snake-bite. **ii.** One spoonful of dried root yellow extract (boiled in water in an aluminium pot) if taken twice a day, cures fever. For better results mixture of the root extract with a few drops of latex of *Opuntia* spp. and juice of *R. communis* fruits (young) may be used. **iii.** One spoonful of dried root yellow extract taken twice a day to cure malaria. **iv.** The boiled water of root extract mixed with boiled juice of bear liver if taken, reduces piles problem (66).
Adi-Memba tribes	-	Rhizome	Decoction of dried rhizome is given twice daily for infective hepatitis as very effective remedy. Also given in cough and cold, malarial fever, and dyspepsia. Rhizomes are tonic and stomachic (67).
Adi-Minyong *Adi*, *Memba* and *Khamba* tribes of the Upper Siang district	*Rinko*	Root	Root extracts diluted with water (1:10) prescribed once daily for 3 days to cure fever and also to treat gastric trouble (68).
Tribes of Dibang Valley, Lower Dibang Valley and Lohit districts	*Mamiri*	Root or Rhizome	Used in fever, liver diseases, hypertension and diabetes (69).
Papum Pare district, Lower Dibang Valley district of Eastern Himalayan zone	*Mishmi teeta*	Root	Root decoction is used to treat malaria and diarrhoea (70).
Tribes of West Siang, East Siang, and Upper Siang districts	*Rinko*	Root or Rhizome	Malarial fever, backache, stomach disorder, aphrodisiac (71).
Adi people of East Siang district		Roots	Shade dried root powder is mixed with water and the mixture is boiled for few minutes and used to treat malarial patient (72). *Calotropis gigantea, Carica papaya* (seeds), *C. teeta* in composite form (paste) is given to the desired women for the prevention of pregnancy (72).
		Leaves	A mixture of leaves with *C. papaya*, *Moringa oleifera* (bark), *Solanum spirale* (roots) and bark of *Alstonia schlolaris* for abortive use (72).
Dehang Debang Biosphere Reserve - *Memba* tribe	*Ringgo, Dung tsa*	Rhizome	Dried rhizome is taken in fever, gastric, cold, cough, malaria, dysentery, headache and debility (73).
Manipuri community, local residents of Barak Valley, Assam	*Urihangam pal*	Dried leaves	Decoction of leaves is prescribed in fever (74).
Manipuri community		Leaves	Decoction is used in fever (75).
Adi, *Galo*, *Memba*, *Nyishi* and *Tagin* tribes		Whole plant (mostly leaf and rhizome)/ raw	Potent remedy for dandruff, stomachache, dysentery, diarrhea, cough and cold, gastric, malaria, fever, eye infection, loss of appetite, backache, headache, inflammation & skin allergy (10, 70, 64, 74, 76).
Nyshi tribe	-	Rhizome	Utilize to cure eye diseases and is a good appetizer, curing the digestive system. Anti-inflammatory and is useful in skin disorders (76).
Tribes of Assam and Arunachal Pradesh	*Mishmi tita*	Seeds, Roots, Rhizomes	To treat malaria (77).
		Rhizome	An oral dose of 150 g need to be given thrice a day to treat malaria (78).
Khamptis traditional healer “*Chauya*” in Arunachal Himalaya, North-east India		Roots	A macerated powder of root stirred in lukewarm water and kept for 10-20 min. The water extract is consumed orally for 3-4 days to manage diabetic condition (79).
Bomdo and Migging Village, Upper Siang District	*Tasir-gamir*	Roots	A paste of dried leaves mixed with water made from *Rori* (*Piper peepuloides* Roxb.) and roots of *Tasir-gamir* (*C. teeta* Wall) is used to relieve fever. Roots also cure malaria and stomach disorders (80).
Padam tribes	*Mishmi*	Leaves	A hair tonic made from the leaves is used to eliminate dandruff (10).
		Rhizome	When crushed and mixed with palm oil, is consumed to alleviate stomachic issues, dysentery, diarrhea and fever (10).
		Root, seeds and rhizome	Smoke and root, seeds and rhizome decoction supplemented with honey is taken thrice per day to cure malaria (70).

extract at the 300 mg/kg dose level exhibited a reduction in inflammation of 57.14%, which was less effective compared to indomethacin (25 mg/kg, p.o.). In the cotton pellet-induced granuloma test conducted on Wistar albino rats, using the same dosing schedule and standard drug, a dose-dependent decrease in granuloma formation was observed, particularly at the 300 mg/kg dose (50.14%) after 14 days of treatment, although this effect was still less than that of the standard drug (64.11%) (82).

Antimicrobial and antibacterial activity

The methanolic extract of *C. teeta* rhizomes demonstrated potent anti-microbial activity against bacterial strains such as *E. coli, S. aureus, S. typhi* and *P. aurenginosa* when tested on Muller-Hinton agar medium at concentrations of 10, 20, 40, and 60 mg, using ciprofloxacin as a standard. The MIC was reported as 10 mg for *E. coli*, 20 mg for *S. aureus*, 20 mg for *S. typhi* and 60 mg for *P. aeruginosa* (59). Additionally, berberine extracted from *C. teeta* effectively inhibits the intestinal secretory response induced by *Vibrio cholerae* and *E. coli* enterotoxins without causing any histological damage to the intestinal mucosa. Furthermore, berberine has shown inhibitory effects on various pathogens, including *Shigella dysenteriae*, *Salmonella paratyphi* and several species of *Klebsiella*, all of which are associated with numerous intestinal infections, including diarrhoea.

Anti-oxidant activity

The ethanolic extract of *C. teeta* rhizomes is rich in berberine, giving it potent antioxidant properties, as demonstrated by various *in vitro* methods, including DPPH and nitric oxide free radical scavenging assays, yielding IC50 values of 99 mg/mL and 84 mg/mL, respectively. These effects may be attributed to the presence of alkaloids, flavonoids and glycosides in the extract (59). The antioxidant capacity of *C. teeta* rhizome extracts was assessed using various solvents, including water, methanol, acetone, chloroform and n-hexane. Among these, the acetone extract showed the highest concentrations of phenolic and flavonoid content. Additionally, the free radical scavenging capacity was evaluated using the DPPH test, where the acetone extract exhibited the highest activity at 350 µg/mL, with 56.1 ± 0.006% scavenging, followed by water, chloroform and n-hexane extracts in comparison to standard ascorbic acid. The methanolic extract of *C. teeta* rhizomes demonstrated the highest inhibitory activity for ABTS and total antioxidant activity (Ferric Reducing Antioxidant Power, FRAP) at 400 µg/mL, achieving 99.93% inhibition and 113.92 ± 0.03 µM Fe(II)/g, respectively, followed by acetone, water, chloroform and n-hexane extracts. Notably, the methanolic extract surpassed the others in overall antioxidant activity, particularly when compared to the acetone extract (54).

Anti-diabetic activity

A literature search revealed that the anti-diabetic activity of the whole drug is quite limited. However, one review focused on anti-diabetic drugs describes *C. teeta* as a potent remedy for diabetes, as it stimulates maximum glucose uptake in cells (81).

Pharmacokinetic study

A total of 10 alkaloids from three *Coptis* species: *C. deltoidei, C. chinensis* and *C. teeta*, were analyzed using ultrahigh-performance liquid chromatography, electrospray ionization, and tandem mass spectrometry. This reliable and validated method revealed significant differences ($p<0.05$) in the maximum concentration (Cmax) and area under the curve ($AUC_{0-\infty}$) of the alkaloids following oral administration in beagles, indicating distinct absorption and metabolism profiles for the active constituents of the *Coptis* species (83).

Toxicological profile

The methanolic extract of *C. teeta* was found to be safe for oral administration based on a preclinical study conducted at a limit dose of 2000 mg/kg in 0.3% CMC suspension. This extract was administered to female Wistar rats following the OECD Guideline 425 (82).

Pharmacological actions of alkaloids of *C. teeta*

Detailed studies on the alkaloids found in *C. teeta,* along with their pharmacological and therapeutic actions, are provided in Table 4. These studies highlight the multifaceted therapeutic potential of *C. teeta*'s alkaloids, making them valuable for developing treatments for a variety of chronic and acute health conditions, including hypertension, diabetes, bacterial infections, depression and inflammation. Furthermore, their antioxidant properties play a crucial role in preventing oxidative stress-related disorders, thereby enhancing overall health and longevity.

Threatening status of *C. teeta*

The hidden ethnomedicinal knowledge of *C. teeta* became apparent only after British explorers examined the flora of Arunachal Pradesh. Unfortunately, in the past decade, the plant's population has declined by over 60% due to unregulated collection and forest degradation, leading to its classification as an "Endangered Species" on the IUCN Red List (A2cd ver 3.1) and its inclusion in Category II of CITES (99). *C. teeta* is among the 427 Indian medicinal plant entries listed in the Red Data Book, which notes that 28 species are considered extinct, 124 endangered, 81 rare and 34 insufficiently known. Consequently, this plant now faces a serious risk of extinction, necessitating stringent conservation efforts to safeguard its genetic biodiversity (100). Fortunately, approximately 90% of its population is still found in India, representing the majority of the global population.

According to the EXIM Policy, 29 plant species, including *C. teeta*, are prohibited from export. The Biodiversity Conservation Prioritization Project (BCPP) in India has published reports under the Endangered Species Project, categorizing the plant as Critically Endangered (CR) based on criteria A1a, 1c and 1d (101).

Several undeniable factors have contributed to the rapid decline of *C. teeta*'s population. These include the diminishing natural habitat in the Northeastern Himalayan region due to developmental activities, reduced geographic range, habitat degradation, low reproductive success, land clearing through forest fires by local communities, illegal trading, over-exploitation for medicinal and cosmetic purposes and significant population pressures. Most critically, the lack of advanced agro-technology has hindered the plant's commercial-scale cultivation, posing a severe threat to

Table 4. Summary of pharmacological actions of *C. teeta* alkaloids.

Alkaloids in *C. teeta*	Pharmacological actions
Berberine	Anti-hypertensive action by reducing endothelium-dependent contractions in spontaneously hypertensive rats by activating denosine monophosphate activated protein kinase, thereby decreasing endoplasmic reticulum stress (84).
	Delayed the onset of and attenuate the severity of hypertension, by inhibiting the renin-angiotensin system and pro-inflammatory cytokines IL6, IL17 and IL23 (85).
	Anti-diarrheal action via limiting small intestinal transit in rats (86).
	Anti-depressant and anxiolytic action by increasing corticotrophin-releasing factor and tyrosine hydroxylase expression in rats, also prevent the rise in hypothalamic corticotrophin-releasing factor and tyrosine hydroxylase expression in the locus coeruleus, and the decrease in brain-derived neurotrophic factor mRNA expression in the hippocampus (87) and significantly increase the level of norepinephrine and serotonin in the brain (88).
	Preventive role in atherosclerosis due to its cholesterol-lowering activity in clinical and preclinical trials (89).
	Potent antioxidant activities evaluated through various *in-vitro* methods by increasing cell viability, nitric oxide production, and superoxide dismutase activity of corpus cavernosum smooth muscle cells, decreasing the lactate dehydrogenase release and malondialdehyde content (90).
	Anti-trachoma action for eliminating Chlamydia trachomatis from the eye, and preventing symptom recurrence in the treatment of trachoma (58, 91).
	Significant increase the glucose uptake in 3T3-L1 adipocytes in animals and humans (92, 93), significantly reduce the HbA1c levels in diabetes (94).
	Phosphodiesterase inhibition activity (95).
	Strong antihistaminic effect (96).
Berberine and its derivatives; tetrahydroberberine and 8-oxo berberine	Iotropic, chronotropic, anti-arrhythmic and vasodilator effects, while both berberine derivatives exhibit antiarrhythmic activity (97).
Palmatine and coptisine	Antimicrobial action against *Staphylococcus aureus* significantly, along with five other microbial strains (*B. subtilis*, *B. pumilus*, *P. aeruginosa*, *C. albicans*, and *E. coli*.) (55). Antibacterial action against *S. mutans*, *S. pyogenes*, *V. cholerae*, *S. flexneri* and *S. typhi* (98).
Berberine, palmatine and columbamine	Increase the production of body's histamine and serotonin, exerting its effect in the early phase of inflammation (60).

its survival (102, 42).

Conservation strategies of *C. teeta*

India is home to a diverse range of plant habitats across various regions. In Northeast India, the tropical and subtropical zones host 24 species, including trees, herbs, shrubs and climbers, while the temperate and alpine zones are home to 15 species of similar varieties. The Indian Himalayan Region (IHR) conserves 20 species each of herbs, shrubs and trees. Additionally, 17 species of trees, herbs and shrubs have been recorded and conserved in different regions of India (69). One method of conservation is through field gene banks, which store seeds in two types of collections: a base collection at -20°C for long-term storage and an active collection at +4°C to 10°C for more frequent access. In India, three national gene banks have been established specifically for medicinal and aromatic plants. Another approach involves botanical gardens and arboreta, which serve as germplasm repositories that maintain living collections of both indigenous and exotic plants, including rare and endangered species, for purposes such as research, conservation, education and public display. India boasts approximately 140 botanical gardens, with around 30 playing a significant role in conservation. Lastly, DNA libraries represent a modern technique for storing plant genetic material in the form of DNA. This method requires the further development of strategies and procedures for the effective utilization of genetic resources. Cryopreservation, or freeze preservation, is another technique used to preserve seeds and pollen, utilizing liquid nitrogen (-165°C to -196°C) for long-term germplasm storage of orthodox plants, pollens and other plant genetic resources (100).

In-situ conservation measures are implemented in the Darjeeling Hills region, where the habitat of *C. teeta* has been designated as a protected area to ensure its continued survival. This initiative involves active cooperation from local inhabitants, the development of agro-technology and commercial-scale cultivation using improved cultivars. In addition to these measures, ex-situ conservation strategies that are familiar to local communities further aid in the preservation of the natural habitat (42).

Trading of *C. teeta* in India

M. teeta is recognized as an endangered species and is utilized by local communities in the study area of Dashing Lileng and Gobuk in the East Siang district of Arunachal Pradesh, India (68). A significant portion of the income for the local Lisu community (a Tibeto-Burman ethnic group inhabiting mountainous regions of Myanmar (Burma), southwest China, Thailand and the Indian state of Arunachal Pradesh) comes from cultivating this plant. They employ traditional agroforestry techniques that have minimal negative effects on the ecosystem (103).

Local traders pack *M. teeta* rhizomes into 15 small wicker baskets and transport them to Sadiya in Assam, where traders from various provinces come to purchase the product (104). The *Mishmis* people also engaged in a barter system with the Meyor, an ethnic Tibetan tribe, exchanging *M. teeta* for *Opium,* along with Yunnan Chinese silver. Additionally, the *Idu Mishmi* community (Chulikatiya maanu) traded Daos, Musk, Ornaments and Salt for *C. teeta* with the Assamese population. Although open selling is prohibited, the product can be obtained for around Rs. 2000/kg if a source or seller can be found (105-107).

Discussion

C. teeta, a potent ethnomedicinal plant indigenous to Arunachal Pradesh, is highly valued in both Indian and Chinese systems of medicine, particularly as a part of *Rhizoma Coptidis*. A thorough literature review of available ethnobotanical data indicates that the practice of traditional medicine is deeply rooted in tribal societies, which rely on ethnobotanical knowledge to address their primary healthcare needs. The ethnobotanical documentation gathered through various surveys and field visits highlighted the potential therapeutic benefits of *C. teeta* alongside several other ethnomedicinal plants.

The first successful attempt to compile previously unexplored data on *C. teeta* in Ayurveda and botanical floras has provided valuable insights. Ayurveda, the oldest traditional system of medicine, uses *C. teeta* as a single herb for managing multiple ailments in a few classical texts. However, despite its detailed description, *C. teeta* is notably absent from most Ayurveda formulations. The compilation of data from botanical floras may contribute significantly to its identification and authentication. Phytochemical screening, from preliminary analysis to the quantification of its chief constituent berberine, showcases nature's pharmacological richness. The diverse phytochemical composition of *C. teeta* reflects its long history in treating a variety of ailments. By bridging the gap between ethnomedicinal knowledge and scientific research, particularly on *C. teeta*, researchers can pave the way for further exploration and the discovery of novel therapeutic compounds.

Unfortunately, fully harnessing the potential of *C. teeta* is challenging due to numerous obstacles, such as illegal trading, deforestation, and cultivation difficulties stemming from its climate sensitivity and specific environmental requirements, all of which threaten its existence. However, the efforts of the Forest Department of Arunachal Pradesh and local communities have led to the implementation of comprehensive conservation strategies for *C. teeta*, promoting proper cultivation within its native geographical areas without compromising its potent phytoconstituents. This review emphasizes the importance of integrating traditional knowledge with modern scientific research to ensure the sustainable use and preservation of these invaluable natural resources for future healthcare and scientific exploration. It also highlights the gap in Ayurvedic formulations as a potential area for inclusion and study. By addressing these challenges and bridging the divide between ethnomedicinal knowledge and scientific advancement, we can enhance the development of traditional medicine systems and preserve valuable therapeutic benefits for clinical applications, thereby promoting sustainable development.

The information and data available in the scientific literature can be utilized to support biodiversity conservation and the management of endangered species in India. This can be achieved through various means, such as designing policies and legislation, planning conservation strategies, allocating resources, raising awareness and education, conducting research and fostering international collaboration, to protect India's endangered plant species and their ecosystem.

Conclusion

C. teeta, an endangered medicinal plant native to the eastern Himalayas in northeast India, is extensively documented in ancient Ayurvedic texts such as Bhavpraksha Nighantu, Saraswati Nighantu, Nighantu Adarsha and Dravyaguna Vigyan, as well as in various botanical floras. It holds significant traditional and ethnomedicinal value among the tribal communities of Northeast India, including the Mishmi, Adi, Mamba, Galo and Nyishi tribes of Arunachal Pradesh, as well as among Tibetans and the people of Myanmar. The plant is also prominent in Traditional Chinese Medicine (TCM) and has considerable economic importance due to its trade value. Classified as endangered by the IUCN Red List, *C. teeta* requires urgent measures for protection, propagation and further research to ensure its conservation and continued contributions to both the ecosystem and human health. Pharmacological studies have shown that *C. teeta* exhibits anti -diabetic, antihypertensive, antioxidant, analgesic, antimicrobial, antibacterial and anti-inflammatory properties. These effects are largely attributed to its bioactive alkaloids, including berberine (8.0-8.5% w/w), coptisine and jatrorrhizine, alongside other compounds like benzylisoquinoline alkaloids, lignans, flavonoids, terpenoids, organic acids, sterols and sterol glycosides. Correlating its ethnopharmacological uses with its phytochemical components presents a vast, untapped area for further research. This opens the door to exploring its diverse therapeutic applications and generating preclinical and clinical evidence to support its medicinal potential.

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Authors' contributions

VV conceptualized, compiled the literature and wrote the first draft with PN and MN. All authors read and approved the final manuscript.

Compliance with ethical standards

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