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Research Paper

A COMPREHENSIVE REVIEW OF TURMERIC'S WILD COUSIN: *Curcuma pseudomontana* J. GRAHAM

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Abstract

Curcuma pseudomontana J. Graham, is a herbaceous perennial from the Zingiberaceae family. It is native to peninsular India and thrives in diverse habitats, including wet grasslands and rock crevices. This review discusses its taxonomical, anatomical, ethnobotanical, phytochemical, pharmacological, and ecological importance. Traditional uses include treating various ailments, while phytochemical analysis reveals a rich array of bioactive constituents. Pharmacological activities encompass antibacterial, antioxidant, and anticancer properties. This review serves as a comprehensive resource for future research and emphasizes the need for conservation strategies to safeguard this species from further decline.

Key words: Hill Turmeric, Zingiberaceae, Native, Vulnerable, Ethnobotany, Taxonomy.

INTRODUCTION

Native to peninsular India, *Curcuma pseudomontana* J. Graham is a herbaceous perennial belonging to the family Zingiberaceae. It thrives in various habitats, including wet grasslands, riparian zones, and moderately high altitudes, particularly within rock crevices and soil-rich areas [1,2]. This species is widely distributed in both peninsular and extra-peninsular India, specifically in the states of Maharashtra, Karnataka, Kerala, Andhra Pradesh and Telangana, with reports of its occurrence in the forested Naikongchhari area of the Bandarban district in Bangladesh [3–6]

The generic name "*Curcuma*" is derived from the Arabic word "*karkum*" signifying yellow colour, in reference to the rhizome's distinctive yellow hue [7]. Taxonomically, *C.pseudomontana* was previously reduced to *C.montana* by Baker

(1890)[8] and Schumann (1904) [9], with further designation of *C.pseudomontana* J. Graham as *'nomen rejiciendum'* in the Index Kewensis (i:672, 1895) [10]. However, observations by Graham (1839)[11] and Santapau (1945)[10] distinctively establish the tubers of *C.pseudomontana* as oblong or globose and borne at the ends of fibrous roots, rather than palmate and sessile, thus differentiating it from *C.montana*.

This plant is known by various names across India, such as *Tavaksheera* in Ayurveda, *Kachura* in Hindi, *Raan halada* in Marathi, and *Kattu manjal* in Tamil [12]. It has been traditionally utilised for treating a variety of ailments, including sprains, snake bites, skin ailments, blood impurities, diabetes, jaundice, leprosy, diarrhoea, heart conditions, cuts, wounds, among others. Furthermore, it holds cultural and aesthetic significance and is cultivated as a prospective ornamental species in certain Indian states. It is also referred to as *"Gauri's phool"* (Flower of Gauri) in Maharashtra due to its use during the Ganesh Puja to venerate the goddess, Gauri [7,13].

Phytochemical analysis of *C.pseudomontana* has revealed a diverse array of bioactive constituents in different extracts, including amino acids, alkaloids, carbohydrates, flavonoids, glycosides, phenols, phytosterols, proteins, saponins, steroids, tannins, terpenoids, Vitamin E and Vitamin C [14,15]. Additionally, various parts of the plant exhibit pharmacological activities such as antibacterial and antifungal activity, antioxidant activity, anticancer activity, anti-inflammatory activity, anti-tubercular activity and antifertility activity.

Unfortunately, the population of *C.pseudomontana* has significantly declined, particularly in the Western Ghats, primarily due to habitat loss and overharvesting. Other threats include mining, hydroelectric development, forest clearing, agriculture, fires, agrochemical use, introduction of exotic species and commercial exploitation, which have led to a reduction in the regional forests by 7% of their original extent. Furthermore, the plant faces threats of overharvesting for medicine, loss of habitat as observed in the Jhabua district of Madhya Pradesh [7,16–19].

In light of these concerns, this comprehensive review aims to underscore the importance of *C.pseudomontana* by highlighting its ethnobotanical, phytochemical, pharmacological, and ecological significance. Furthermore, it aims to identify existing research on the plant and highlight gaps in the current understanding, serving as a guide for future research and a call to action for the development of conservation strategies to prevent the species from becoming endangered.

Table 1- Classification of *C.pseudomontana*

Bentham and Hooker	APG IV
Class - Monocotyledonae Series - Epigyne Order - Scitaminae Tribe- Zingibereae Genus- *Curcuma* Species- *Curcuma pseudomontana*	Kingdom - Plantae Clade - Tracheophytes Clade - Angiosperms Clade - Monocots Clade - Commelinids Order - Zingiberales Family - Zingiberaceae

Synonyms:

Curcuma grahamiana Voigt [Illegitimate]

Curcuma ranadei Prain

Common Names:

Table 2- Common names of *C.pseudomontana*

Language	Name
English	Hill Turmeric
Hindi	*Kachura*
Marathi	*Raanhalada, Shindalavana/Shindalavani*
Tamil	*Kattu manjal*
Malayalam	*Kattu manjal*
Ayurveda	*Tavaksheera*
Telugu	*Adavi pasupu*

IUCN Status: VU (Vulnerable)

Distribution:

Indian Distribution [3–6,20–23]

- Maharashtra: Ahmednagar, Mumbai, Kolhapur, Pune, Raigad, Satara, Sindhudurg, Khandala, Matheran, Kasara, Thane, Nasik, Aurangabad, Akola, Amravati, Bhandara, Yavatmal, Nagpur, Chandrapur, Dapoli, Ratnagiri

- Rajasthan: Banswara
- Andhra Pradesh: Nellore, Visakhapatnam
- Kerala: Idukki, Palakkad, Kottayam, Wayanad, Malappuram, Kannur, Thiruvananthapuram, Kozhikode, Kuttiady, Anaimalai Hills, Silent Valley, Attappadi
- Karnataka: Kodagu, Dharwad, Devikoppa, Mysuru, Gopalaswami hills
- Telangana: Karimnagar
- Central India: Satpuda, Achanakmar Amarkantak Biosphere Reserve
- Madhya Pradesh: Jhabua

Bangladesh: Bandarban district

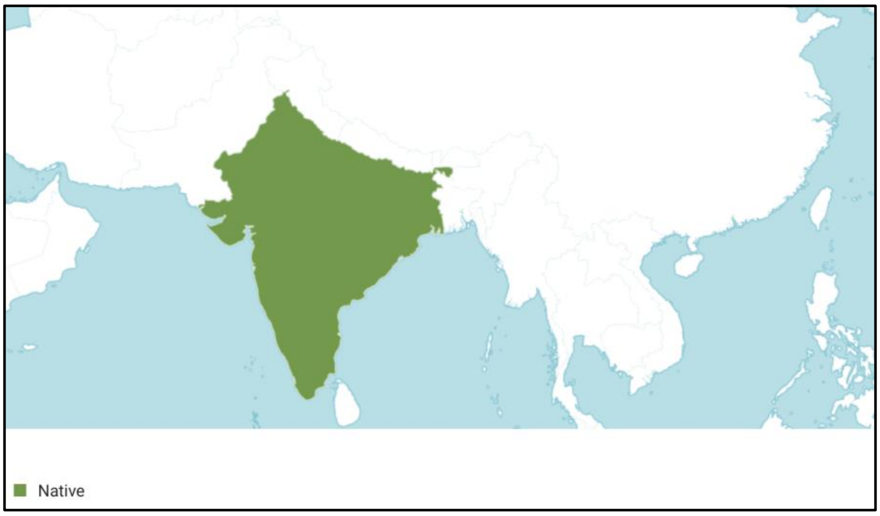

Figure 1- Distribution map of *Curcuma pseudomontana* J. Graham [24]

Taxonomy:

The genus *Curcuma*, which belongs to the family Zingiberaceae, has a long and complex history of taxonomic revisions. Bentham and Hooker in their work "Genera Plantarum" (1883) [25], recognized four tribes under the order Scitamineae, namely *Zingibereae*, *Marantaeae*, *Cannae* and *Musaeae*. Subsequently, these tribes were elevated to the rank of families by other authors. Due to the presence of spiral phyllotaxy and absence of essential oils in some members of the family Zingiberaceae, Schumann in his contribution to Das Pflanzenreich (in Engler, 1900, 1902, 1904) [9] further divided the family into two subfamilies: Zingiberoideae and Costoideae. The subfamily Zingiberoideae included the genera *Zingiber, Curcuma, Globba* and others, while the subfamily Costoideae comprised the genera *Costus, Tapeinochilos* and others. Later, Hutchinson (1959) [26] renamed the order Scitamineae as Zingiberales and split the family Zingiberaceae into four tribes: Costeae, Hedychieae, Globbeae and Zingibereae. Subsequent authors like Cronquist, Dahlgren, Nakai, Takhtajan and Tomlinson [27–31] identified the subfamily Costoideae as a distinct family, Costaceae, and reorganised the subfamily Zingiberoideae into four tribes: *Hedychieae, Alpinieae, Zingibereae* and *Globbeae*. The genus *Curcuma* was assigned to the tribe *Hedychieae* along with *Hedychium, Kaempferia* and others. However, based on molecular data (ITS and matK), Kress et al. (2002)[32] proposed a new system that divided the family Zingiberaceae into four subfamilies and six tribes. According to this system, the genus *Curcuma* was placed in the tribe *Zingibereae* of the subfamily Zingiberoideae, together with *Zingiber, Kaempferia, Hedychium* and others.

The infrageneric classification of *Curcuma* is challenging and complex, as the genus exhibits a wide range of morphological variation. Many authors have attempted to classify the genus based on various morphological characters, such as the position of the spike, the presence or absence of spurs, the tuber characteristics and others. Roxburgh (1820) [33] was the first to divide the genus into two unnamed sections based on the position of the spike (central or lateral). This scheme was followed by Horaninov (1862) [34], who named the sections as *Exantha* (lateral spikes), *Mesantha* (terminal spikes) and *Amphiantha* (lateral and terminal spikes). Baker (1890) [8] replaced the section *Amphiantha* with *Hitcheniopsis*. However, these characters were found to be unreliable, as the position of the spike varied with the flowering season [33] and the colour of the coma was variable in some species especially *Curcuma pseudomontana* [10,35]. Therefore, Schumann (1904) [9] introduced the subgeneric concept and divided the genus into two subgenera based on the presence or absence of spurs: *Eucurcuma* Schum. (spurs present) and *Hitcheniopsis* Baker (spurs absent). He included the sections Exantha and Mesantha in the subgenus *Eucurcuma*. Valeton (1918) [36] was not happy with the classification laid down by the previous authors and considered the subgenus *Hitcheniopsis* to be heterogeneous. Hence, he abandoned the subgenus *Hitcheniopsis*, and introduced a new subgenus- *Paracurcuma.*

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Table 3 - Classification of the family Zingiberaceae modified from Kress et al., 2002 [32]

Family - Zingiberaceae						
Subfamily	Siphonochiloideae W. J. Kress	Tamijioideae W. J. Kress	Alpinioideae Link		Zingiberoideae Haask.	
Tribe	Siphonochileae W. J. Kress	Tamijieae W. J. Kress	Alpinieae A. Rich.	Riedelieae W. J. Kress	Zingibereae Meisn.	Globbeae Meisn.
Seasonality	Dormancy period	Evergreen	Evergreen	Evergreen	Dormancy period	Dormancy period
Rhizomes	Fleshy	Fibrous	Fibrous	Fibrous	Fleshy	Fleshy
Plane of distichy of leaves	Perpendicular to rhizome	Perpendicular to rhizome	Perpendicular to rhizome	Perpendicular to rhizome	Parallel to rhizome	Parallel to rhizome
Extrafloral nectaries	Absent	Absent	Present on leaf blades	Absent	Absent	Absent
Lateral staminodes	Petaloid, fused to labellum	Petaloid, fused to labellum	Small or absent, never petaloid	Small or absent, never petaloid	Petaloid, free from or fused to labellum	Petaloid, free from labellum and sometimes connate to filament
Labellum	Not connate to filament	Not connate to filament	Not connate to filament	Not connate to filament	Not connate to filament	connate to filament in slender tube
Filament	Short	Short	Medium	Medium, sometimes arching	Short to long	Short to long, sometimes arching
Anther crest	Petaloid	Petaloid	Petaloid or absent	Petaloid or absent	Petaloid or absent, d, or well-developed and wrapped around style	Spurred or absent
Ovary	3-locular (sometimes incompletely so)	1-locular	1- or 3-locular	3-locular	3-locular (sometimes incompletely so)	1-locular
Placentation	Axial	Parietal	Axial or parietal	Axial or free central	Axial, basal, or free columnar	Parietal

Capsule	Fleshy	Unknown	Silique-like, opening by longitudinal slits	Indehiscent or fleshy	Fleshy and dehiscent	Globbose and dehiscent
Genera	*Siphonochilus*	*Tamijia*	*Aframomum* *Alpinia* *Amomum* *Aulotandra* *Cyphostigma* *Elettaria* *Elettariopsis* *Etlingera* *Geocharis* *Geostachys* *Hornstedtia* *Leptosolena* *Paramomum* *Plagiostachys* *Renealmia* *Vanoverberghia*	*Burbidgea* *Pleuranthodium* *Riedelia* *Siamanthus*	*Boesenbergia* *Camptandra* *Cautleya* *Cornukaempferia* *Curcuma* *Curcumorpha* *Distichochlamys* *Haniffia* *Haplochorema* *Hedychium* *Hitchenia* *Kaempferia* *Laosanthus* *Nanochilus* *Paracautleya* *Parakaempferia* *Pommereschea* *Pyrgophyllum* *Rhynchanthus* *Roscoea* *Scaphochlamys* *Smithatris* *Stadiochilus* *Stahlianthus* *Zingiber*	*Gagnepainia* *Globba* *Hemiorchis* *Mantisia*
Incertae Sedis			*Siliquamomum*		*Caulokaempferia*	

Velayudhan et. al., [37,38] also recognized two subgenera, *Curcuma* and *Paracurcuma*, based on the presence or absence of anther spurs. They subdivided the subgenus *Curcuma* into three sections based on tuber characteristics: *Tuberosa* (sessile tubers), *Nontuberosa* (sessile tubers absent) and *Stolonifera* (stoloniferous tubers). *C.pseudomontana* was placed in: Subg. *Eucurcuma* > Sect. *Nontuberosa* > Subsect. *Nontuberomesantha*.

Leong-Škorničková et al., [39] revised the infrageneric classification of *Curcuma*. They identified 3 subgenera namely- *C.* subg. *Curcuma*, *C.* subg. *Ecomatae* and *C.* subg. *Hitcheniopsis,* wherein, *C.pseudomontana* was placed in *C. subg. Curcuma*

In addition to the morphological classification, molecular identification of *C. pseudomontana* and other *Curcuma* species has also been carried out by various researchers [40–43].

Jagtap [40] performed DNA fingerprinting of *C.pseudomontana* using the rbcL primer. The PCR product of 530bp is available at NCBI (Accession No.KJ949626). He also constructed a maximum likelihood phylogenetic tree for the genus *Curcuma* using the data generated for *C.pseudomontana* and the available data at NCBI for other species.

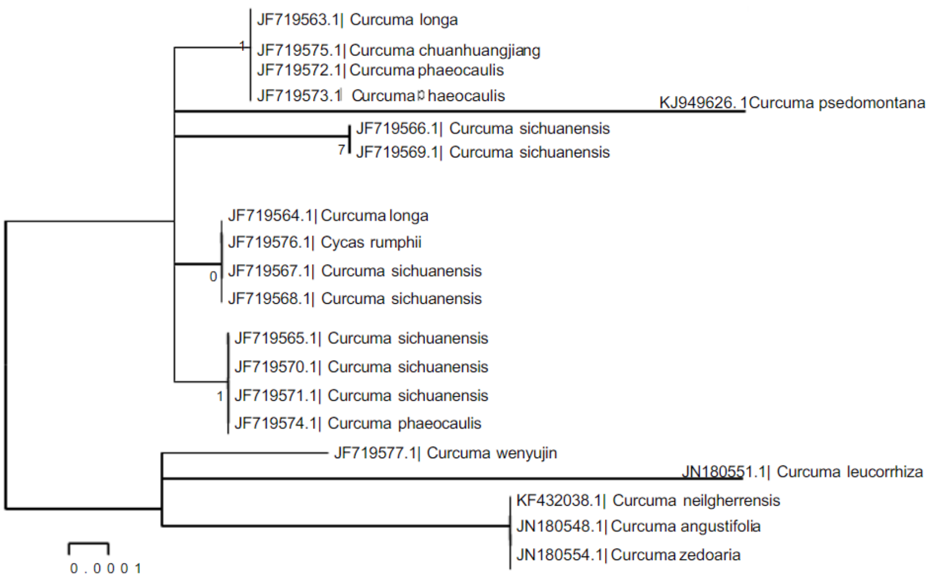

Figure 2- Maximum likelihood phylogenetic tree for the genus *Curcuma* [40]

Mangesh Dagawal & Bhogaonkar [41,44] developed genetic fingerprints of *C.inodora* (12 varieties), *C.pseudomontana* and *C.longa* using RAPD and ISSR markers. Syamkumar & Sasikumar [45] developed genetic fingerprints of 15 *Curcuma* species:

C.amada Roxb., *C.aromatica* Salisb., *C.aromatica* Salisb., *C.aeruginosa* Roxb., *C.caesia* Roxb, *C.comosa* Roxb., *C.decipiens* Dalz., *C.ecalcarata* Sivarajan & Indu, *C.haritha* Mangalay & Sabu, *C.longa* L., *C.montana* Wall., *C.malabarica* Vela et al., *C.pseudomontana* Grah., *C.raktakanta* Mangalay & Sabu, *C.sylvatica* Val., *C.zedoaria* Rosc. using 8 ISSR and 39 RAPD markers. These molecular studies provide valuable insights into the genetic diversity and phylogenetic relationships of *Curcuma* species.

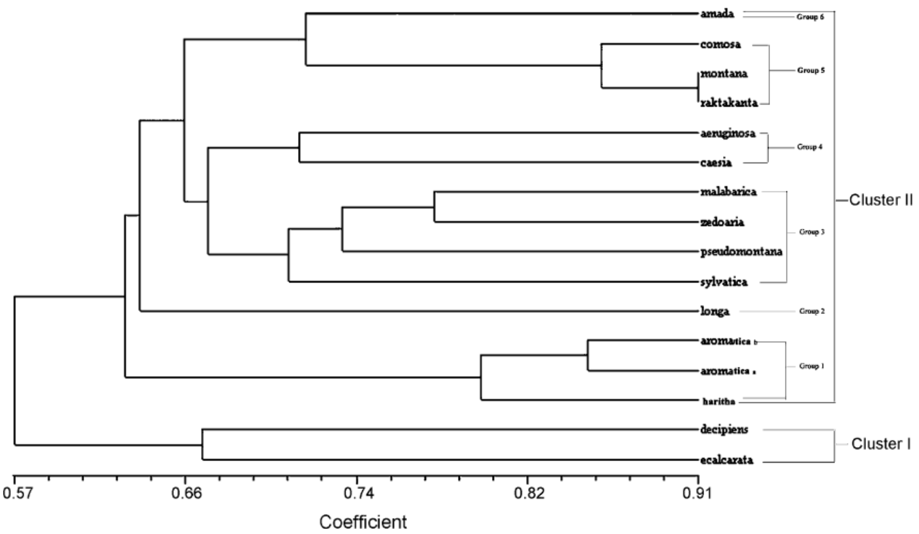

Figure 3- Dendrogram of 15 *Curcuma* species from India [45]

METHODS AND MATERIALS

A comprehensive study was conducted to learn more about the morphological traits of *C.pseudomontana* in the Western Ghats. All pertinent scientific material published up until the end 2023 was located using electronic search (ScienceDirect, PubMed, ScienceDirect, and Google Scholar). The study involved a great deal of time and effort, and to fill in any gaps in the observed data, close examination consulting earlier studies was done. Taxonomic databases and published floras were utilised to authenticate the identity and to further investigate their classification.

RESULTS

Morphological Description:

The plant's morphological characteristics are detailed in various studies [3,5,10,35,46,47].

Habit: An erect herb.

Roots: Fibrous. Rootstock is small, bearing tiny almond-like or subglobose tubers at the ends of the fibres. However, it does not have sessile tubers. Rhizomes are conical to cylindrical. Both the tubers and rhizomes are white internally when young and yellowish to orangish when mature.

Leaves: The leaves are simple, uniformly green, and can reach a length of 30 to 60 cm or more, including the petiole. Lamina 10-15 cm broad, lanceolate oblong, with an acute to acuminate apex. The margin is entire, tapering to the base, and the petioles are 20-35 cm long. Petiole is stout and cannelled above. Petiole forms a sheath.

Inflorescence: The inflorescence is racemose, with oblong spikes. The peduncles are 8-10 cm long and are embraced by leaf-sheaths. It arises either with or before the leaves. The spike is lateral at the beginning of the flowering season and central towards the end.

Flowers: Bright yellow flowers, usually 2 or 3 in each bract, with flowering bracts 3-4. The bracts are obovate-lanceolate, green with an acute pink tip. The bracts of the coma are oblong-lanceolate, with only the lowest having purple edges, while the upper ones are more or less uniformly mauve-purple.

Calyx: Membranous, 3-lobed, pale creamy yellow to white, apex round to subacute, occasionally splitting longitudinally.

Corolla: Pale cream when young, turning yellow when mature, corolla lobe 3 cm in height, petals subequal, dorsal petal larger than others, ovate in shape, apex acute to mucronate, lateral petals ovate with obtuse apex and hyaline margin.

Androecium: The androecium consists of one perfect stamen with a short filament. The anthers are not crested, being contiguous and spurred at the base. Lateral staminodes are 2 in number, oblong and petaloid, and the lip is orbicular with a deflexed tip.

Gynoecium: The gynoecium features a trilocular, inferior ovary with many ovules on axile placentation. Ovary is densely hirsute on the outside. The style is filiform, and the stigma is 2-lipped. 2 nectaries present near the style base.

Fruit: The fruit is dehiscent, globose, and a 3-valved capsule. The seeds are ovoid or oblong, usually arillate.

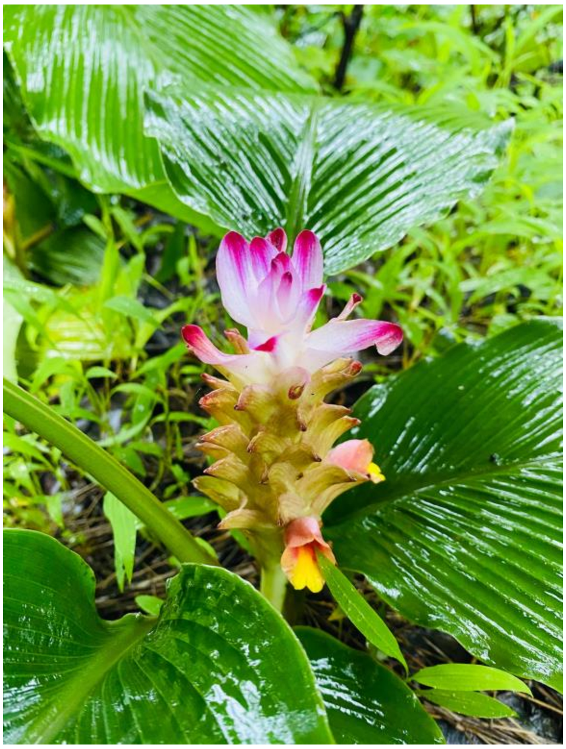

Figure 4- Habit of *C.pseudomontana*

Anatomical Description:

Petiole anatomy of 12 *Curcuma* species was comparatively studied by Anu S & Mathew Dan [48]

Outline of TS- Open U shape

Epidermis- Uniseriate, circular epidermal cells, Cells somewhat similar in size, Trichomes absent

Ground tissue- The cortex contains hypodermis composed of Oval to hexagonal Parenchymatous cells and small abaxial vascular bundles. 1-3 layered chlorenchyma between the hypodermis and main vascular bundles forms an undulate pattern, delineating the air canal walls. The remaining ground tissue is made up of parenchyma with thin walls and two inner arcs of vascular bundles that vary in size. The pith is composed of parenchymatous cells, relatively larger than subepidermal cells.

Vascular bundles- The vascular bundles of the petiole are arranged into 3-4 major arcs (I to IV). The main bundle arc (I) is located close to the abaxial surface and has uniformly sized bundles in the centre that get smaller as they approach the margin. Two air channels, internally crossed by trabeculae or diaphragm, surround each major vascular bundle. Smaller bundles are arranged alternating with arc I bundles to form bundle arc II. Arc III is adaxial to bundle arc I and has moderate-sized bundles. Furthermore, a separate arc (bundle arc IV with 1-4 vascular bundles) may be formed by tiny vascular bundles close to the adaxial surface. Bundle arc IV's terminal progressively merges with bundle III.

Vascular bundles are conjoint, collateral and closed. bundle arc I possess a fibrous or sclerenchymatous bundle sheath that is incomplete. Xylem is towards pith and phloem is towards the epidermis.

Xylem- There are 1-2 sizable metaxylem elements in the xylem, and 1-3 protoxylem elements are positioned adaxially to them. Reduced vascular tissues and contracted protoxylem are characteristics of vascular bundles in accessory arcs. The xylem and phloem are separated by a layer of angular xylem parenchyma.

Phloem- Phloem consists of sieve tubes, companion cells, and parenchyma.

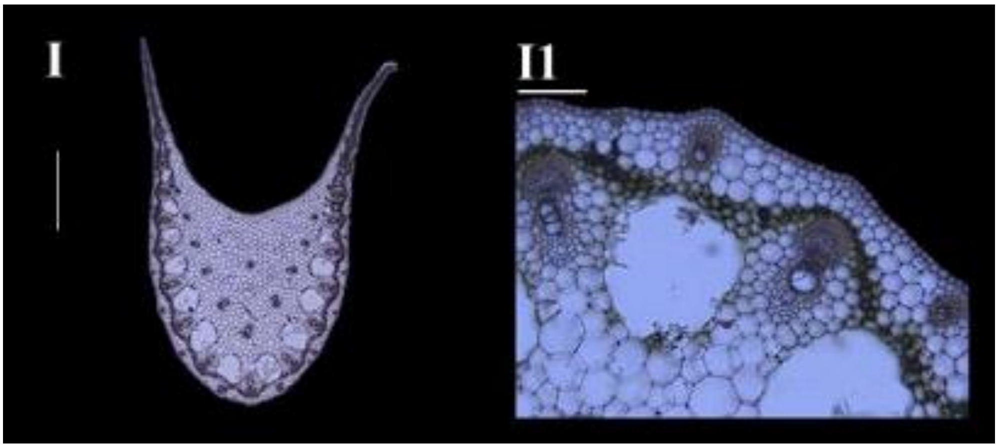

Figure 5- Petiole outline and TS of petiole of *C.pseudomontana* [48]

Cytogenetic studies:

Curcuma pseudomontana has a somatic chromosome number of 2n = 42. This is the most common chromosome number in the genus *Curcuma*, and it corresponds to a hexaploid level with a basic chromosome number of x = 7. (2n=6x=42). The 2C nuclear DNA content is 2.29 pg. The intraspecific variation in genome size is low- 2.4 % [49]

Ethnobotany:

Curcuma pseudomontana is a herb with many ethnobotanical uses. It has been used for centuries to treat a variety of ailments such as sprains, snake bites, skin ailments, blood impurities, diabetes, jaundice, leprosy, diarrhoea, heart conditions, cuts, wounds and more. For example, rhizomes boiled in oil are used to treat sprains and snake bites, while dried rhizomes are used to treat skin ailments and blood impurities [50,51].

Graham in 1839 reported that when there is a shortage of grains, the tubers are boiled and eaten by the natives [11].

The Bagata tribe utilises the plant to cure diabetes, while the Savara, Bagata, and Valmiki tribes in Andhra Pradesh use tuber extracts to treat jaundice [12]. Additionally, leprosy, diarrhoea, and heart conditions are treated with underground parts of *C.pseudomontana*, particularly the rhizome. [52]

According to Patil & Patil and Reddy et al. [53,54], the Jatapu, Kaya, and Yannadi tribesmen use hot tuber mash to cure body swelling, while the Khand tribals applies the mash to cuts and wounds and applies it to the head for cooling purposes.

According to Jagtap et al. and Devarkar [55,56], the Korku tribe in Maharashtra's Amravati area uses fresh tubers as a blood cleanser and dried rhizome's smoke to hypnotise people.

The Jatapu and Savara tribes of Andhra Pradesh boil tubers to increase a woman's milk production [57]. While the tribals from sacred groves of East Godavari district add salt to boiled and mashed tubers and administer it orally to nursing mothers once a day for 7 days to increase lactation [58]. Other tribes from Eastern Ghats of Northern Andhra Pradesh use the rhizomes to treat diabetes, jaundice and use it as a galactagogue [59].

The Purandhar tribal community in Maharashtra uses tuber extracts to purify their blood. [60].

Rhizomes are used by the Irula tribal people of Sigur Plateau (Nilgiri Biosphere Reserve) to treat cuts and wounds [61].

The rhizomes are used by the Kattunayakan tribe in the Malappuram district of Kerala to treat cardiac diseases [20]. The rhizomes are also used by tribal members from the Gundla Brahmeswaram Wildlife Sanctuary, Andhra Pradesh to treat weakness, leprosy and muscle discomfort [62].

The Chenchu, Erukala, and Lambada communities of the Achampet Forest division in Nallamala Hills, Telangana, utilise rhizome paste to treat skin issues and cough [63].

The Koyas from Warangal North Forest Division, Northern Telangana use the tubers for their antiseptic properties [64].

Reddy et al., reported that the tubers of *C.pseudomontana* are used to treat veterinary diseases like Anthrax. [65]

Inhabitants of Dodamarg taluka in Sindhudurg district of Maharashtra use the rhizome for ulcers and antiseptic properties [66].

The tribes Yerukalas and Lambadis from Pocharam Wildlife Sanctuary, Telangana use the leaves as meal plates and the tubers against wounds and jaundice [67].

It's also a source of powdered arrowroot and is employed in regional and indigenous medicines. The plant is known as "Gauri's phool" (Flower of Gauri) in Maharashtra because it is used during the Ganesh Puja to venerate the goddess, Gauri [7].

Rhizome juice of *C.pseudomontana* is an effective treatment for rheumatism, and in Northeast India, it is infused with ginger to facilitate a smooth delivery. Rhizome powder is beneficial for intestinal worms, leucoderma, scabies, smallpox, and other ailments [68].

In the Bangladeshi region of Ramu-Naikongchhari, rhizomes are used to treat stomach aches, diarrhoea, and indigestion in human beings. It is used as feed and to treat infections in animals [6].

Communities in the Vallapuzha Panchayath of Palakkad district, Kerala use the plant against leprosy and dysentery [69]

In certain Indian states, *C.pseudomontana* is also cultivated as a prospective ornamental species [13].

Phytochemistry:

The phytochemical analysis of *Curcuma pseudomontana* conducted by various researchers has revealed a diverse array of bioactive constituents in different extracts, shedding light on the plant's potential medicinal and nutritional properties.

Kaliwal & Hiremath and Shriram & Bhuktar [14,15] identified a wide range of bioactive constituents in the plant, including amino acids, alkaloids, carbohydrates, flavonoids, glycosides, phenols, phytosterols, proteins, saponins, steroids, tannins, terpenoids, Vitamin E, and Vitamin C.

- Elemental Composition:

  The rhizomes of *C.pseudomontana*, as analysed through ICP-spectroscopy by Jagtap [1], exhibited the presence of elements such as Fe, Mn, Zn, Cu, and Se, with Fe showing the highest concentration and Cu the lowest. Additionally, Kanase & Singh [70] reported the presence of N, P, K, Na, S, Ca, Mg, Cu, Zn, Fe, and Mn in the rhizomes.

- Physicochemical Evaluation:

  Kanase & Singh [70] further characterised the rhizomes of *C.pseudomontana* through physicochemical evaluation, indicating total ash value (13.98%), water-soluble ash value (4.25%), acid-insoluble ash value (1.40%), Chloroform extractives (2%), Alcohol-soluble extractives (13.68%), Water-soluble extractives (18.95%), moisture content (4%) and pH (3.8). Fluorescence analysis was also conducted.

- Essential Oil Analysis:

  Muniyappan & Perumal [71] conducted GC-MS analysis of the essential oil extracted from *C.pseudomontana* rhizomes, identifying 104 components, including Benzene (1,5 dimethyl-4-hexenyl)-4-methyl-, β-Elemenone, Germacrone, Pseudocumenol, Benzofuran, Gamma-Curcumene, Xanthorrhizol, and 7-methanoazulene.

- GC-MS Analysis of Methanolic Extracts:

  Santhoshkumar & Yusuf (2019) [72] detected compounds 1-heptatriacotanol, β-caryophyllene epoxide, kauren-18-ol, acetate, and (4.beta.)-retinal using GC-MS analysis of methanolic extracts of *C.pseudomontana* rhizomes.

- Isolation of Bioactive Peptide:

  Banu & Kumar [73] isolated and characterised a 2.97 KDa cationic peptide, caP4, from *C.pseudomontana*, exhibiting broad-spectrum antibacterial activity and stability against proteolytic degradation. They also studied its activity at ambient temperature and pH and its biofilm inhibition activity. Its secondary structure has been elucidated and mode of action against *E.coli* studied [74].

- TLC and HPTLC Analysis:

  Jagtap [75] conducted HPTLC analysis of the rhizome, revealing the presence of flavonoids like Rutin, Quercetin, Epigenin, Hesperidin, Diosmin, Kaempferol, Catechin, Astrangnlin, Luteolin, and Isoquercitrin. Phenolic acids like Chlorogenic acid, Caffeic acid, Coumaric acid, and Vanillic acid were also identified. Saponins were found to be in abundance.

  Dagawal & Bhogaonkar [76,77], fingerprinted the flavonoid and phenolics profile using HPTLC. The flavonoid fingerprint showed 6 bands whose rf values ranged from 0.31 to 0.92, while the phenolics fingerprint showed presence of 9 bands with rf values ranging from 0.21 to 0.88.

  Dagawal & Bhogaonkar [78] also fingerprinted the TLC profiles of sesquiterpenoids of *C.pseudomontana* from Amravati district.

- Nutritional Analysis:

  Jadhao & Bhuktar [79] reported the leaf protein and fibre content of *C.pseudomontana* to be 2.0% and 12.30% respectively.

Pharmacology:

Antibacterial and antifungal activity:

Synthesised curcumin-capped nanoparticles (CUR-AuNPs) were evaluated for their antibacterial effectiveness against *Pseudomonas aeruginosa, Staphylococcus aureus, Bacillus subtilis*, and *Escherichia coli*, demonstrating notable antibacterial activity surpassing that of the control Streptomycin [80].

Rhizome extracts exhibited significant antimicrobial efficacy against a range of microorganisms, including Staphylococcus aureus, *Bacillus subtilis*, *S.scuir, E.coli, Klebsiella pneumonia, Pseudomonas aeruginosa, Shigella flexneri* (NCIM-5265), *Salmonella typhi* (NCIM-2501), *Aspergillus niger* (MTCC 281), *Aspergillus flavus* (MTCC 2456), *Aspergillus fumigatus* (MTCC 870), *Aspergillus terreus*, and *Candida albicans* (MTCC 3018) [1,14,15].

The leaf and root extracts exhibited activity against *E.coli* (NCIM-2931), *Pseudomonas aeruginosa* (NCIM-5029), *Shigella flexneri* (NCIM-5265), *Salmonella typhi* (NCIM-2501), and *Staphylococcus aureus* (NCIM-5021) [15].

Antioxidant activity:

The antioxidant properties of CUR-AuNPs were investigated [80]. The DPPH method was employed to assess the antioxidant activity of *Curcuma pseudomontana* rhizome extracts. The methanol extract exhibited a scavenging activity of 87.42%, while the aqueous extract showed 72.49% activity. Additionally, the chloroform extract demonstrated 41.92% activity, and the acetone extract exhibited 30.8% activity [1]

In the in-vitro antioxidant study of the oil extracted from mature rhizomes of *C. pseudomontana*, the essential oil displayed significant inhibition efficiency against free radicals. The inhibition efficiency was found to be nearly equal to that of the standard Ascorbic acid (96.2%) at a concentration of 25 µl/mg [71].

Anticancer activity:

Bisht et al., [81] conducted research on the potential anticancer and cytotoxic/antiproliferative properties of *Curcuma pseudomontana*'s tubers and rhizomes. They investigated the effects of plant extracts on BHK-21 cell lines, examining their cytopathic, antiproliferative, and cytotoxic activities. The IC50 value, representing the concentration at which 50% inhibition occurs, ranged from 2 to 20mg.

Anti-inflammatory activity:

The anti-inflammatory effects of CUR-AuNPs were examined in vitro through the HRBC method [80]. In the in vitro analysis of the oil sample using the HRBC method, it exhibited a maximum inhibition efficiency of 95.3%, slightly shy of the standard Diclofenac sodium's inhibition rate of 97.2% [71].

Anti-tubercular activity:

At 100 and 50 mg/ml, several rhizome extracts demonstrated notable effectiveness against *Mycobacterium tuberculosis* H37RV. The outcomes were compared to the standard values of streptomycin, ciprofloxacine, and pyrazinamide [14].

Anti-fertility activity:

Curcuma longa was used to compare the spermatogenic, anti-implantation, and abortifacient properties of the methanolic extract of *Curcuma pseudomontana.* The activities of C.longa extracts were found to be more significant in comparison with the activities of *C.pseudomontana* extracts [82].

Ecology

C.pseudomontana is typically found in shaded, moist environments along stream banks, exhibiting a preference for elevations ranging from 800 to 2500m [38,46]. Rahangdale and Rahangdale [2] observed *C.pseudomontana* thriving in the microhabitats of rock crevices and soil-rich areas within the Northern Western Ghats. Additionally, Nair [83] highlighted that the cardamom thrips, *Sciothrips cardamomi* Ramk. (order Thysanoptera and family Thripidae) a significant insect pest of cardamom (*Elettaria cardamomum* Maton.), finds a breeding ground on *C.pseudomontana* as well.

DISCUSSION

This review provides a comprehensive overview of the current state of knowledge on the phytochemistry and pharmacology of *Curcuma pseudomontana* J. Graham, highlighting its potential as a rich source of novel natural products for drug development. The plant is known to produce a variety of secondary metabolites, especially sesquiterpenoids, flavonoids, and phenolics, which have exhibited diverse biological activities. Various extracts and fractions of the plant have also shown some very promising activities against cancer and tuberculosis, a major public health problem in India and worldwide. However, the specific compounds responsible for these activities and their mechanisms of action remain largely unknown, necessitating further research to identify and characterise them using advanced analytical and molecular techniques. Despite its substantial ethnobotanical and pharmacological significance, the declining population of *C.pseudomontana* in the Western Ghats is a cause for concern. Urgent conservation measures are imperative to safeguard this invaluable resource, while concurrently conducting comprehensive studies to underscore its significance. The review also emphasises the need for validating and substantiating the ethnobotanical uses of *C.pseudomontana*, which could provide insights into its potential medicinal properties and applications. By conducting rigorous scientific studies to corroborate the traditional knowledge and practices, the plant could be utilised more effectively and sustainably for the benefit of human health and well-being.

Declaration

This paper features Anushka Agarwal and Harshwardhan Gupta as co-first authors. The contributions of the co-first authors were deemed equivalent, and therefore they are listed in alphabetical order.

Conflict of interest

We hereby declare that there is no potential for conflict of interest among the authors and that the work complied with all applicable ethical guidelines.

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