



A Comprehensive Review on Ethnobotany, Phytochemistry and Pharmacological Activities of the Genus *Haplanthodes*

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ABSTRACT :

The genus *Haplanthodes* Kuntze (Acanthaceae) is a small endemic Indian genus comprising four recognized species, namely *Haplanthodes neilgherryensis*, *H. plumosa*, *H. tentaculata* and *H. verticillata*, together with one variety. This review compiles the available information on the taxonomy, morphology, vernacular names, habitat, ethnobotany, phytochemistry and pharmacological activities of the genus. Cladode form, capsule indumentum, calyx structure, seed surface and anatomical features are described as the main characters for species identification and authentication. Traditional uses are best documented for *H. tentaculata*, which is used for wound healing, stamina improvement, diabetes, kidney disorders and fever. Phytochemical studies have reported phenylpropanoids, sesquiterpenoids, phytosterols, flavonoids and fatty acid derivatives, with allyltetramethoxybenzene and stigmasterol reported from *H. verticillata* and a new flavanone glycoside isolated from *H. neilgherryensis*. The reported pharmacological activities include antioxidant and in vitro anticancer effects of *H. verticillata*, analgesic and antipyretic effects of *H. tentaculata* and increased glucose uptake by the flavanone glycoside. No phytochemical or pharmacological investigation has been reported for *H. plumosa*, and toxicity data are not available for the genus. Research gaps and future directions, including bioactivity-guided isolation, in vivo validation and safety evaluation, are discussed.

Keywords: *Haplanthodes*, Acanthaceae, Ethnobotany, Phytochemistry, Pharmacological Activities, Medicinal Plants

1. Introduction

Haplanthodes Kuntze is a member of the family Acanthaceae and is an endemic genus of the Indian subcontinent that is mainly found in peninsular India. It belongs to the order Lamiales and also closely related with members of the tribe, especially *Andrographis* and *Haplanthus*. The genus is notable for its unique set of morphological features that include specialized cladodes associated with inflorescences, sub actinomorphic flowers, included stamens, and pouched stamens along with characteristic pollen morphology. It is of interest with respect to the restricted geographical distribution while presenting distinctive morphological and reproductive characters [2, 21].

Taxonomical studies established four species of *Haplanthodes*, namely *Haplanthodes neilgherryensis* (Wight) R.B.Majumdar, *H. plumosa* (T.Anderson) Panigrahi & G.C.Das, *H. tentaculata* (L.) R.B.Majumdar and *H. verticillata* (Roxb.) R.B.Majumdar. Recent studies have established a number of diagnostic characters that can be employed to distinguish the closely related species of the genus. Seed micromorphology, pollen characters, and vegetative and reproductive features played an important role. In particular, the seeds are distinctive with two grooves while possessing hygroscopic hairs. The pollen grains are generally trizonocolporate with reticulate exine ornamentation [2]. Molecular phylogenetic investigations supported the distinctiveness of the genus and its relation with allied genera *Andrographis* and *Haplanthus* [21].

Members of *Haplanthodes* are mainly herbaceous plants associated with tropical and subtropical habitats of India including regions of the Western Ghats. Their occurrence and habitat preferences contribute to ecological and botanical importance. Leaves, inflorescences, flowers, cladodes and fruits of different species usually show characteristic variations that are helpful in species identification and pharmacognostic characterization. The restricted occurrence of the genus highlights further the importance to ensure proper taxonomic authentication and conservation of species [2, 13].

Among the species of the genus, *Haplanthodes verticillata* has received increased scientific attention due to traditional importance and reported biological activities. Being a spiny, branched herb associated with the Western Ghats, it possesses distinctive foliage, inflorescences and bluish to violet flowers. Preliminary phytochemical investigations of *Haplanthodes* species have reported the occurrence of several classes of secondary metabolites including flavonoids, phenolic compounds, alkaloids, terpenoids and other bioactive constituents. In particular, investigations of flavonoid constituents across different species of *Haplanthodes* indicate the potential of the genus as a source of structurally diverse plant metabolites [10].

The increasing interest in *Haplanthodes* is also associated with reports of antioxidant, antimicrobial and other pharmacological properties, even if the available literature is comparatively limited with respect to extensively investigated medicinal genera of Acanthaceae. Thus, the systematic evaluation of the ethnobotanical information, pharmacognostic characteristics, phytochemical constituents and pharmacological activities of *Haplanthodes* is important for understanding its medicinal potential. A comprehensive review of the genus may highlight the existing research gaps providing a scientific basis for investigations involving isolation, characterization and bioactivity-guided evaluation of its bioactive compounds.

2. Taxonomy and Species Diversity of I

Haplanthodes Kuntze is a small endemic genus of flowering plants belonging to the family Acanthaceae and order Lamiales. The genus is restricted to the Indian subcontinent, with its species occurring predominantly in peninsular India. *Haplanthodes* was historically associated with the closely related genera *Haplanthus* and *Andrographis*, and several species have undergone changes in generic placement and nomenclature. Modern taxonomic studies based on morphology, pollen characters, seed micromorphology and molecular evidence have helped to clarify the systematic position and species boundaries of the genus. The recent comprehensive revision of *Haplanthodes* recognized four species, namely *Haplanthodes neilgherryensis* (Wight) R.B.Majumdar, *Haplanthodes plumosa* (T.Anderson) Panigrahi & G.C.Das, *Haplanthodes tentaculata* (L.) R.B.Majumdar and *Haplanthodes verticillata* (Roxb.) R.B.Majumdar. In addition, *H. neilgherryensis* var. *toranganensis* was recognized as a distinct variety [2]. The four species are currently also listed by the World Flora Online under *Haplanthodes* Kuntze [23].

The genus possesses several morphological characters that distinguish it from allied members of Acanthaceae. One of its most characteristic features is the occurrence of specialized, reduced branchlets known as cladodes, which are associated with the inflorescence. The morphology of these cladodes varies considerably among species and provides an important diagnostic character for species identification. Other significant generic characters include sub actinomorphic flowers, included stamens, characteristic anther morphology and distinctive pollen grains. Seed morphology is particularly important in the taxonomy of the genus. *Haplanthodes* produces seeds with two distinct grooves and hygroscopic hairs, a combination of characters that helps distinguish the genus from the related genera *Andrographis* and *Haplanthus*. Based on scanning electron microscopy, two major seed-surface sculpturing patterns, namely reticulate and micropapillate types, have also been recognized [2].

2.1 *Haplanthodes neilgherryensis* (Wight) R.B.Majumdar

Haplanthodes neilgherryensis is one of the four recognized species of the genus and is primarily associated with the montane regions of southern peninsular India, particularly the Nilgiri and adjoining Western Ghats regions. The species is characterized by relatively delicate, thin and filiform cladodes. Its morphological characters distinguish it from *H. verticillata*, which possesses conspicuously stiff and spinose cladodes. *H. neilgherryensis* also shows distinctive floral and vegetative characteristics that support its recognition as a separate species. A distinct variety, *H. neilgherryensis* var. *toranganensis*, has been recognized in the recent taxonomic revision, adding further morphological diversity within this species complex [2, 13].

2.2 *Haplanthodes plumosa* (T.Anderson) Panigrahi & G.C.Das

Haplanthodes plumosa is distinguished primarily by its characteristic plumose or feathery appearance, produced by the dense hairs associated with the cladodes and inflorescence. The species was historically treated under different taxonomic combinations, including *Haplanthus plumosus* and *Haplanthodes tentaculata* var. *plumosa*, before being recognized at species level. The plumose nature of the reproductive region represents one of its most conspicuous diagnostic features. Its taxonomic history illustrates the difficulty in delimiting closely related taxa within the genus and the importance of combining vegetative, reproductive and micromorphological characters for accurate identification [2, 23].

2.3 *Haplanthodes tentaculata* (L.) R.B.Majumdar

Haplanthodes tentaculata is another recognized species of the genus and has a relatively broad taxonomic history. The species was originally described under the name *Ruellia tentaculata*, and its nomenclatural history has been discussed in detail in the modern revision of the genus. It generally possesses relatively short cladodes, usually less than approximately 1.5 cm long, which are comparatively soft and non-bristly. The cladodes are an important feature for distinguishing *H. tentaculata* from *H. verticillata*. The capsule is pubescent, whereas *H. verticillata* has a glabrous capsule. These characters, together with floral and calyx morphology, are useful for species identification [2, 4].

2.4 *Haplanthodes verticillata* (Roxb.) R.B.Majumdar

Haplanthodes verticillata is one of the best-characterized species of the genus and is commonly associated with rocky slopes and habitats of the Western Ghats. The species is characterized by relatively long, stiff and bristly or spinose cladodes, generally exceeding 1.5 cm in length. These cladodes may be sharply pointed and represent a particularly useful field character for distinguishing *H. verticillata* from the other species. The capsule is characteristically glabrous, providing an additional diagnostic feature. The species has attracted considerable pharmacological and phytochemical interest and is therefore particularly relevant to medicinal-plant research [4, 10, 20].

2.5 Diagnostic characters of the genus

The combination of macromorphological and micromorphological features provides an effective basis for identifying *Haplanthodes* species. Among these, cladode morphology, calyx structure, capsule indumentum, seed-surface ornamentation and pollen morphology are particularly informative. A simplified identification framework recognizes *H. verticillata* by its longer, bristly cladodes and glabrous capsule. The remaining species generally possess shorter and non-bristly cladodes with pubescent capsules, after which calyx morphology can be used to distinguish *H. plumosa* from *H. tentaculata* [2].

Recent comparative anatomical work has further demonstrated that internal anatomical characters can complement external morphology in species identification. Differences in the shape of the leaf midrib, vascular-bundle arrangement and cladode anatomy have been reported among *H. verticillata*, *H. tentaculata*, *H. plumosa*, *H. neilgherryensis* and its variety *toranganensis*. Such anatomical characteristics may be particularly useful in pharmacognostic authentication when reproductive structures are unavailable [11].

Thus, *Haplanthodes* represents a morphologically distinctive and taxonomically important endemic genus of Acanthaceae comprising four recognized species and one recognized variety. The combination of distinctive cladodes, floral characters, seed morphology, pollen features and anatomical characteristics provides a reliable basis for species delimitation. These taxonomic features are also highly relevant to pharmacognosy because correct species identification and authentication are essential prerequisites for subsequent phytochemical and pharmacological investigations.

3. Vernacular Names and Species-wise Description of Haplanthodes

Table 1: Classification of the genus *Haplanthodes*

Rank	Classification
Kingdom	Plantae
Clade	Angiosperms
Order	Lamiales
Family	Acanthaceae
Genus	<i>Haplanthodes</i> Kuntze

The genus *Haplanthodes* Kuntze belongs to the family Acanthaceae and represents a small endemic group of Indian flowering plants. The genus currently comprises four recognized species, namely *Haplanthodes neilgherryensis* (Wight) R.B.Majumdar, *Haplanthodes plumosa* (T.Anderson) Panigrahi & G.C.Das, *Haplanthodes tentaculata* (L.) R.B.Majumdar and *Haplanthodes verticillata* (Roxb.) R.B.Majumdar. In addition, *H. neilgherryensis* var. *toranganensis* P.V.Deshmukh & Lekhak is recognized as an infraspecific taxon. The species are endemic to India and occur mainly in peninsular India, with distribution extending across different regions of the Western Ghats and adjoining areas [2, 23].

3.1 *Haplanthodes neilgherryensis* (Wight) R.B.Majumdar

Haplanthodes neilgherryensis is commonly referred to as **Nilgiri haplanthodes** in English. Documented regional names include **Nila Jakara** in Marathi and Gujarati and **Kambalipoo Kurinji** (கம்பளிப்பூ குறிஞ்சி) in Tamil. The species name *neilgherryensis* refers to the Nilgiri Hills, reflecting its historical association with this region. The species has a complex nomenclatural history and was formerly treated under *Haplanthus* and, subsequently, as a variety of *H. tentaculata*. The current taxonomic treatment recognizes it as a separate species [2, 3].

Morphologically, *H. neilgherryensis* is distinguished by its **thin, soft and filiform cladodes**. The terminal spike of cladodes and flowers is relatively densely arranged, with short internodes. The species differs from *H. verticillata* by lacking the latter's stiff, sharply bristly cladodes. The taxonomic distinction of *H. neilgherryensis* is supported by a combination of morphological, seed and pollen characters. A distinct variety, *H. neilgherryensis* var. *toranganensis*, has also been recognized based on differences including longer cladodes, lax internodes, a longer corolla, more extensively hairy ovary and more densely hygroscopically hairy seeds [2, 21].



Fig no:1 habitat and inflorescence of A. *H. verticillata*, B. *H. neilgherryensis*, C. *H. neilgherryensis toranganensis*, D. *H. tentaculata*, E. *H. plumosa* [Deshmukh PV.et.al 2021 page no 201–222]

3.2 *Haplanthodes plumosa* (T.Anderson) Panigrahi & G.C.Das

Haplanthodes plumosa is an endemic Indian species with its currently documented native range particularly associated with Maharashtra. No well established vernacular name for *H. plumosa* could be confirmed from the major botanical databases consulted; therefore, a regional vernacular name should not be assigned without a reliable floristic or ethnobotanical source [6, 23].

The specific epithet *plumosa* refers to its characteristic plume-like or feathery appearance. The most conspicuous diagnostic feature is the presence of

dense, soft hairs on the cladodes particularly towards their lower portion, giving the inflorescence a plumose appearance. The cladodes are relatively short and non-prickly compared with those of *H. verticillata*. *H. plumosa* has an important nomenclatural history, previously being treated in combination with *H. tentaculata* and under *Haplanthus plumosus*. The species has since been recognized as a distinct species, and the modern revision formally maintains it as one of the four accepted species of *Haplanthodes* [2, 23].

3.3 *Haplanthodes tentaculata* (L.) R.B.Majumdar

Haplanthodes tentaculata is commonly known as tentacled *haplanthodes*. Documented regional names include Vhadlem Kalem Kiraytem in Konkani and Fikat Nila Jakara in Marathi. A Gujarati name, Nil Jakara, has also been recorded in recent vernacular-name compilations, although vernacular-name usage should be interpreted cautiously given that some historical names overlap with taxa that were formerly treated differently taxonomically [3, 5].

The species is an erect herb and is characterized by relatively short, soft and hairy cladodes generally up to about 1.5 cm long. The cladodes are non-prickly and have an inconspicuously bifid apex. The flowers range from whitish to violet shades, with darker markings in the throat. Compared with *H. verticillata*, the cladodes are shorter, softer and non-spinose, while the capsule is pubescent. The species has a particularly complex nomenclatural history, its basionym is *Ruellia tentaculata* L., and has also been treated under *Haplanthus tentaculatus* and *Bremekampia tentaculata*. The present accepted name is *Haplanthodes tentaculata* (L.) R.B.Majumdar [2, 17].

3.4 *Haplanthodes verticillata* (Roxb.) R.B.Majumdar

Haplanthodes verticillata is commonly known as spiny bottle brush. Several regional names have been documented, including Kastula and Kala Kiriya in Hindi, Jakara in Marathi, Kalu Kariya in Gujarati, Kalem Kiraytem in Konkani and Ottu Mudi Kurinji in Tamil [3, 5].

The species is characterized by its distinctive stiff, spinose and verticillately arranged cladodes, which are generally longer than those of the other species, may exceed 1.5 cm in length, and are sharply pointed, can be conspicuously bristly, representing one of the most useful field characters for identification. The capsule is glabrous, contrasting with the pubescent capsule of *H. tentaculata*. The combination of long, bristly cladodes and a glabrous capsule, provides a useful diagnostic distinction from the other species of the genus [2, 18].

The species has also undergone several nomenclatural changes, it was originally described as *Justicia verticillata* Roxb. and has since appeared under names including *Eranthemum verticillatum*, *Haplanthus verticillaris* and *Bremekampia verticillata*. The currently accepted name is *Haplanthodes verticillata* (Roxb.) R.B.Majumdar [2, 18].

3.5 Comparative significance of vernacular and morphological characters

The vernacular names of *Haplanthodes* species frequently reflect their geographical origin, flower colour, general appearance or distinctive morphology. For example, the name Nilgiri *Haplanthodes* associated with *H. neilgherryensis* reflects its historical association with the Nilgiri region, whereas the English name spiny bottle brush for *H. verticillata* reflects its conspicuous spiny and brush-like appearance. Similarly, the name tentacled *Haplanthodes* is descriptive of the tentacle-like cladodes of *H. tentaculata*. Such vernacular names are useful ethnobotanical information; however, their use should be accompanied by botanical authentication given that the same vernacular name may occasionally be applied to more than one taxon [3, 5].

From a taxonomic and pharmacognostic perspective, cladode morphology provides one of the most useful characters for distinguishing the four species. *H. verticillata* possesses stiff, spinose cladodes; *H. tentaculata* has soft and non-spinose cladodes; *H. plumosa* is characterized by densely hairy, plume-like cladodes; while *H. neilgherryensis* and its variety *toranganensis* possess thin, soft and filiform cladodes. These external characters are supported by anatomical differences and can therefore be useful for authentication of crude plant material when flowers or fruits are absent [2, 11].

Because vernacular names may vary geographically and may change with taxonomic interpretation, the accepted botanical name should be used as the primary identifier in scientific literature. Vernacular names should preferably be reported together with their language, geographical source and appropriate botanical reference.

4. Morphological Characteristics of *Haplanthodes* Species

Members of the genus *Haplanthodes* are herbaceous plants belonging to the family Acanthaceae, and are characterized by a distinctive combination of vegetative and reproductive features. The genus is particularly recognized by its specialized cladodes associated with the inflorescences. Although the species are morphologically similar, differences in cladode structure, indumentum, calyx, capsule and other floral characters provide useful diagnostic features for species identification. Recent comparative studies have further demonstrated that both external morphology and internal anatomy are valuable for distinguishing the closely related taxa of *Haplanthodes* [2, 11].

The most conspicuous morphological character of the genus is the cladode which varies considerably amongst species. *Haplanthodes verticillata* possesses stiff, spinose and verticillately arranged cladodes, whereas *H. tentaculata* has comparatively smooth and non-spinose cladodes. In *H. plumosa* the lower portion of the cladodes is densely hairy, producing a characteristic plume-like appearance, in *H. neilgherryensis* and *H. neilgherryensis* var. *toranganensis* the cladodes are thin, soft and filiform, these differences are particularly useful for species identification when flowers and fruits are absent [2, 11].

The species also differ in reproductive characters including calyx morphology, corolla characteristics including capsule indumentum and seed surface. *H. verticillata* can be distinguished by its long, bristly cladodes and glabrous capsule, whereas *H. tentaculata* has shorter, smooth cladodes and a pubescent capsule. Seed morphology provides additional taxonomic information given that *Haplanthodes* seeds possess two grooves and hygroscopic hairs, while

seed-surface sculpturing shows species-level variation [2]. Pollen grains of the genus are generally oblate or prolate-spheroidal, distinctly triangular and trizonocolporate with reticulate exine ornamentation [2].

Table 2: Comparative morphological characteristics of *Haplanthodes* species

Morphological character	<i>H. neilgherryensis</i>	<i>H. neilgherryensis</i> var. <i>toranganensis</i>	<i>H. plumosa</i>	<i>H. tentaculata</i>	<i>H. verticillata</i>
Habit	Herbaceous, erect	Herbaceous, erect	Herbaceous, erect	Herbaceous, erect	Herbaceous, erect
Stem	Slender, branched	Slender, branched	Branched	Branched	Branched
Cladodes	Thin, soft and filiform	Thin, soft and filiform	Short, densely hairy, plume-like	Short, smooth and non-spinose	Stiff, spinose and verticillate
Cladode indumentum	Comparatively sparse/soft	More densely hairy	Dense hairs on lower portion	Smooth or sparsely hairy	Bristly/spinose
Cladode appearance	Filiform	Filiform	Plumose/feathery	Tentacle-like, non-spinose	Spiny/bristle-like
Cladode length	Relatively short to moderate	Longer than typical <i>H. neilgherryensis</i>	Short	Generally ≤ 1.5 cm	Generally > 1.5 cm
Leaves	Simple, opposite, sessile/subsessile	Similar to species	Simple, opposite	Simple, opposite	Simple, opposite
Leaf surface	Pubescent to sparsely hairy	Hairy	Hairy	Hairy	Usually hairy
Inflorescence	Spike-like, associated with cladodes	Similar, relatively lax	Dense, plumose appearance	Spike-like	Dense, brush-like
Calyx	Five-lobed	Five-lobed	Characteristically plumose	Five-lobed	Five-lobed
Corolla	Bilabiate/tubular, violet-blue to bluish	Similar	Bluish/violet	Whitish to violet	Violet-blue
Stamens	Two, included	Two, included	Two, included	Two, included	Two, included
Anthers	Characteristic of genus	Similar	Similar	Similar	Similar
Ovary	Superior, hairy	More extensively hairy	Superior	Superior	Superior
Fruit/capsule	Pubescent	Pubescent	Pubescent	Pubescent	Glabrous
Seeds	Two-grooved, hygroscopic hairs	Two-grooved, densely hygroscopic hairs	Two-grooved	Two-grooved	Two-grooved
Seed surface	Reticulate/micropapillate type	Reticulate/micropapillate type	Reticulate/micropapillate type	Reticulate/micropapillate type	Reticulate/micropapillate type
Key diagnostic feature	Thin, soft, filiform cladodes	Longer cladodes, lax internodes and distinctive reproductive characters	Plumose, densely hairy cladodes	Short, smooth, non-spinose cladodes + pubescent capsule	Long, stiff, spinose cladodes + glabrous capsule

4.1 Species-wise Morphological Description

4.1.1 *Haplanthodes neilgherryensis* (Wight) R.B.Majumdar

This species is an erect herb with slender branched stems and thin, soft, filiform cladodes associated with the inflorescences. The vegetative and reproductive characters distinguish it from the more conspicuously spinose *H. verticillata*. The flowers are borne in spike-like inflorescences and possess the characteristic floral organization of the genus. The seeds have the characteristic two grooves and hygroscopic hairs [2, 11].

4.1.2 *Haplanthodes neilgherryensis* var. *toranganensis*

This variety resembles *H. neilgherryensis* in its general habit and thin, soft, filiform cladodes but differs in several quantitative and reproductive characters. It is characterized by comparatively longer cladodes, lax internodes, a longer corolla, a more extensively hairy ovary and more densely hygroscopically hairy seeds. These characters were considered significant for recognizing it as a distinct variety [2].

4.1.3 *Haplanthodes plumosa* (T.Anderson) Panigrahi & G.C.Das

The species is an erect herb with branched stems and short cladodes. The most characteristic feature is the **dense hair covering on the lower part of the cladodes**, which produces a conspicuous plume-like or feathery appearance and is reflected in the specific epithet *plumosa*. The reproductive structures are associated with these specialized cladodes, giving the inflorescence a distinctive appearance. The species can be separated from *H. tentaculata* and *H. verticillata* primarily by the nature and indumentum of its cladodes [2, 11].

4.1.4 *Haplanthodes tentaculata* (L.) R.B.Majumdar

H. tentaculata is an erect, branched herb characterized by relatively short, smooth and non-spinose cladodes. The cladodes are generally up to approximately 1.5 cm long and differ markedly from the stiff, bristly cladodes of *H. verticillata*. The flowers occur in spike-like arrangements and may vary from whitish to violet. The capsule is **pubescent**, which is an important diagnostic feature separating this species from *H. verticillata* [2, 11].

4.1.5 *Haplanthodes verticillata* (Roxb.) R.B.Majumdar

H. verticillata is an erect, branched herb characterized by conspicuous **stiff, spinose and verticillately arranged cladodes**. The cladodes are generally longer than those of *H. tentaculata* and may exceed 1.5 cm in length. The flowers are typically violet-blue and occur in dense, brush-like inflorescences. The **glabrous capsule**, together with long, stiff and bristly cladodes, represents one of the most useful diagnostic combinations for identifying the species. These morphological characteristics also account for its common description as the “spiny bottlebrush” [2, 11].

4.2 Important Diagnostic Characters

Among the morphological features examined in *Haplanthodes*, **cladode morphology is the most conspicuous character for preliminary species identification**. The recent comparative study confirmed that *H. verticillata* has stiff, spinose and verticillate cladodes; *H. tentaculata* has smooth and non-spinose cladodes; *H. plumosa* has densely hairy lower cladodes producing a plume-like appearance; and *H. neilgherryensis* together with its variety *toranganensis* possesses thin, soft and filiform cladodes [11]. Capsule indumentum provides another useful character, particularly for separating *H. tentaculata* with its pubescent capsule from *H. verticillata* with its glabrous capsule [2].

In addition to external morphology, anatomical characteristics of the leaf and cladode can support species identification. Comparative anatomical investigations have reported differences in leaf midrib outline and vascular-bundle organization among the five recognized taxa. Such characters are particularly valuable in pharmacognostic authentication because vegetative material may be encountered without flowers or fruits [11].

Overall, the combination of **habit, cladode morphology, indumentum, floral characters, capsule surface, seed morphology and anatomical features** provides a useful morphological framework for identification and authentication of *Haplanthodes* species. These characters are particularly important for pharmacognostic studies because accurate botanical identification is an essential prerequisite for the phytochemical and pharmacological evaluation of medicinal plant material.

5. Habitat and Ethnobotany of *Haplanthodes*

5.1 Habitat and ethnobotanical importance of *Haplanthodes*

The genus *Haplanthodes* is an endemic Indian genus of Acanthaceae, with its species occurring mainly in peninsular India. The species occupy different ecological habitats, ranging from seasonally dry tropical habitats and dry slopes to wet tropical regions and forest-associated habitats. *Haplanthodes neilgherryensis* is predominantly distributed in western India and is associated with seasonally dry tropical vegetation, whereas *H. verticillata* occurs in western and central India and is also associated with seasonally dry tropical habitats. *H. tentaculata* has a wider distribution extending from Gujarat to Kerala and occurs primarily in wet tropical environments. *H. plumosa* has a comparatively restricted known distribution in Maharashtra and is associated with wet tropical habitats [2, 3, 5, 6, 11, 16, 17, 18, 21, 23].

The species are generally found in open slopes, grasslands, forest margins, rocky areas and forest undergrowth. *H. verticillata* has been recorded on dry slopes among grasses, while *H. tentaculata* occurs in forest-associated habitats and tropical regions. Such ecological differences may contribute to the morphological variation observed within the genus [1, 18].

Ethnobotanical information on *Haplanthodes* is comparatively limited and is unevenly distributed among the species. Among the recognized taxa, *H. tentaculata* has the most clearly documented traditional medicinal importance. Traditional uses reported for this species include **wound healing, improvement of stamina, management of diabetes, kidney-related disorders and fever**. Recent ethnopharmacological research has specifically described these traditional claims and investigated the analgesic and antipyretic potential of the leaves [14].

The root of *H. tentaculata* has also been recorded in medicinal-plant databases in association with the traditional treatment of **wounds and injuries** [4]. In addition, recent phytochemical research has highlighted the traditional use of the plant for healing and stamina enhancement and has investigated its chemical constituents, including moslosooflavone, squalene, D-allose and phytol [22].

Haplanthodes verticillata, commonly known as spiny bottle brush, is another species with documented medicinal significance. However, compared with *H. tentaculata*, species-specific ethnobotanical information is relatively less systematically documented. Available floristic and medicinal-plant resources establish its occurrence and traditional recognition in several regions of India, but individual therapeutic claims should be supported by specific ethnobotanical references rather than generalized across the genus [7, 18].

For *H. neilgherryensis* and *H. plumosa*, reliable species-specific ethnobotanical information is comparatively scarce in the literature. Therefore, these species should primarily be discussed in terms of their geographical distribution and habitat unless additional ethnobotanical studies are identified. This limited documentation represents an important research gap and indicates the need for systematic ethnobotanical investigations of the less-studied members of the genus.

Table 3: Habitat, distribution and ethnobotanical information

Species	Major distribution/habitat	Habitat characteristics	Documented ethnobotanical/medicinal information
<i>H. neilgherryensis</i>	Western India; associated with peninsular India	Mainly seasonally dry tropical habitats; Western Ghats/Nilgiri-associated regions	Species-specific medicinal information is limited; should not be assigned traditional uses without a specific source

Species	Major distribution/habitat	Habitat characteristics	Documented ethnobotanical/medicinal information
<i>H. neilgherryensis</i> var. <i>toranganensis</i>	Restricted taxon within the distribution of <i>H. neilgherryensis</i>	Localized habitat; associated with peninsular Indian vegetation	Very limited ethnobotanical documentation
<i>H. plumosa</i>	Mainly Maharashtra	Wet tropical habitat; associated with its restricted regional distribution	No well-established species-specific traditional medicinal use was identified in the sources reviewed
<i>H. tentaculata</i>	Gujarat to Kerala	Primarily wet tropical habitats; forest-associated areas	Wound healing, stamina improvement, diabetes, kidney-related disorders and fever; root reported for wounds/injuries
<i>H. verticillata</i>	Western and Central India; also reported from several peninsular Indian states	Seasonally dry tropical habitats; dry slopes among grasses, forest margins/undergrowth	Traditional medicinal significance is reported, but species-specific ethnobotanical documentation is comparatively limited

5.2 Habitat and ethnobotanical significance

Haplanthodes species are endemic to India and are mainly distributed in peninsular India, where they occur in diverse habitats ranging from seasonally dry tropical regions and dry grassy slopes to wet tropical forests and forest margins. *H. neilgherryensis* and *H. verticillata* are primarily associated with seasonally dry habitats, whereas *H. tentaculata* and *H. plumosa* are predominantly associated with wet tropical regions [2, 3, 5, 6, 11, 16, 17, 18, 21, 23].

Ethnobotanical documentation of the genus is relatively limited and varies among species. *H. tentaculata* has the most clearly documented traditional medicinal importance and has been traditionally used for wound healing, improving stamina, diabetes, kidney-related disorders and fever. Its root has also been reported for the management of wounds and injuries [8, 14]. *H. verticillata* is also recognized as a medicinal plant, although species-specific ethnobotanical evidence is less systematically documented. In contrast, reliable traditional-use information for *H. neilgherryensis*, its variety *toranganensis*, and *H. plumosa* remains limited. This uneven distribution of ethnobotanical evidence highlights the need for further field-based studies to document the traditional knowledge and medicinal potential of the less-investigated taxa.

6. Phytochemistry

6.1 *H. verticillata*

Successive Soxhlet extraction of the whole plant with hexane, chloroform, ethyl acetate, ethanol and water gave yields of 1.7%, 0.8%, 1.9%, 2.7% and 3.4% respectively. Preliminary screening showed flavonoids and carbohydrates in the ethyl acetate, ethanol and aqueous extracts, glycosides only in the ethyl acetate extract, steroids in the hexane, ethyl acetate and ethanol extracts, triterpenoids in all extracts except chloroform, and alkaloids only in the chloroform extract [9].

Gas chromatography-mass spectrometry (GC-MS) analysis of the ethyl acetate extract identified 85 compounds. The major constituents were allyltetramethoxybenzene (23.2%), linoleyl acetate (5.89%), kessane (4.12%), eudesma-4(14),11-diene (3.06%), neophytadiene (2.84%), muurola-4,10(14)-dien-1 β -ol (2.8%) and myristicin (2.31%); others included caryophyllene, bergapten, elemicin, β -bisabolol, linolenic acid and squalene. Column chromatography yielded a white crystalline compound identified as stigmasterol by GC-MS and direct-insertion mass spectrometry (MS) [9]. A curated database additionally lists the phenolic acids vanillic acid and 4-hydroxybenzoic acid and the flavone C-glycosides vitexin and isovitexin from the leaf [15].

6.2 *H. tentaculata*

Physicochemical parameters (moisture, ash and extractive values) and preliminary phytochemical tests of the aerial parts have been reported for methanol, acetone and n-hexane extracts. GC-MS of the macerated methanol extract identified moslosooflavone, squalene, D-allose and phytol as prominent constituents [22]. The compound haplanthin is listed for the species in the Indian Medicinal Plants, Phytochemistry And Therapeutics (IMPPAT) database [15].

6.3 *H. neilgherryensis*

Chemical investigation of this Western Ghats endemic led to the isolation of a new flavanone glycoside, 5-hydroxy-7-methoxy-8-O- β -D-glucopyranosyl-2S-flavanone, together with three known flavonoids: 7-O-methyl dihydrowogonin, 7-O-methyl wogonin and andrographidine C. Structures were established by one-dimensional (1D) and two-dimensional (2D) nuclear magnetic resonance (NMR) spectroscopy and high-resolution mass spectrometry (HRMS) [19].

6.4 *H. plumosa*

No phytochemical investigation has been reported.

The phytoconstituents reported from the genus are summarised in Table 4.

Table 4: Phytoconstituents reported from *Haplanthodes* species

Species	Class	Compounds	Method / source
<i>H. verticillata</i>	Phenylpropanoids	Allyltetramethoxybenzene, myristicin, elemicin	GC-MS, ethyl acetate extract
<i>H. verticillata</i>	Sesqui- and diterpenoids	Kessane, eudesma-4(14),11-diene, caryophyllene, β -bisabolol, neophytadiene	GC-MS
<i>H. verticillata</i>	Phytosterols / triterpenes	Stigmasterol (isolated), squalene	Column chromatography, MS
<i>H. verticillata</i>	Fatty acid derivatives	Linoleyl acetate, linolenic acid	GC-MS
<i>H. verticillata</i>	Flavonoids and phenolic acids	Vitexin, isovitexin, vanillic acid, 4-hydroxybenzoic acid	Database record (leaf)
<i>H. tentaculata</i>	Flavonoid / terpenoids / sugar	Moslosooflavone, squalene, phytol, D-allose	GC-MS, methanol extract
<i>H. tentaculata</i>	–	Haplanthin	Database record
<i>H. neilgherryensis</i>	Flavanone glycoside	5-Hydroxy-7-methoxy-8-O- β -D-glucopyranosyl-2S-flavanone	NMR, HRMS
<i>H. neilgherryensis</i>	Flavonoids	7-O-Methyl dihydrowogonin, 7-O-methyl wogonin, andrographidine C	NMR, MS

7. Pharmacological Activities

7.1 Antioxidant activity

The 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical-scavenging activity of *H. verticillata* extracts was compared with ascorbic acid (half-maximal inhibitory concentration, IC_{50} , 65.53 μ g/mL). The ethyl acetate extract was the most active (IC_{50} 63.53 μ g/mL), followed by the aqueous (67.92 μ g/mL), ethanol (85.66 μ g/mL), chloroform (93.05 μ g/mL) and hexane (97.47 μ g/mL) extracts [9]. The activity of the polar and semi-polar extracts is consistent with the presence of flavonoids and other phenolics.

7.2 Anticancer activity

The ethyl acetate extract of *H. verticillata* reduced the viability of A549 human lung cancer cells in a dose-dependent manner in the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay, with viability falling to 17.73% at the highest concentration tested and a reported IC_{50} of 40.51 μ M; cisplatin was used as the positive control [9]. Because the IC_{50} of a crude extract is expressed in molar units in this report, the value should be interpreted cautiously until it is confirmed in a mass-based unit.

7.3 Analgesic and antipyretic activity

The aqueous leaf extract of *H. tentaculata* was evaluated using network pharmacology, in silico methods and in vivo models. In mice, it reduced acetic acid-induced writhing and was tested in the Eddy's hot plate model; in rats, it was tested against Brewer's yeast-induced pyrexia. The authors concluded that the extract has analgesic and antipyretic effects acting through central and peripheral pathways, which supports the traditional use of the plant for pain and fever [14].

7.4 Antidiabetic potential

The new flavanone glycoside from *H. neilgherryensis* increased glucose uptake in L6 rat skeletal muscle cells with a half-maximal effective concentration (EC_{50}) of 5.8 μ M, compared with 2.7 μ M for the reference drug rosiglitazone [19]. This is the only direct evidence of antidiabetic potential in the genus and relates to an isolated compound rather than a crude extract.

Table 5: Pharmacological activities reported for *Haplanthodes* species

Species	Activity	Extract / compound	Model	Key result
<i>H. verticillata</i>	Antioxidant	Ethyl acetate extract	DPPH assay	IC_{50} 63.53 μ g/mL (ascorbic acid 65.53)
<i>H. verticillata</i>	Anticancer	Ethyl acetate extract	MTT, A549 cells	Dose-dependent cytotoxicity; IC_{50} 40.51 μ M
<i>H. tentaculata</i>	Analgesic, antipyretic	Aqueous leaf extract	Mouse writhing and hot plate; rat yeast-induced pyrexia	Activity reported via central and peripheral pathways
<i>H. neilgherryensis</i>	Glucose uptake	Flavanone glycoside	L6 myotubes	EC_{50} 5.8 μ M (rosiglitazone 2.7)
<i>H. plumosa</i>	–	–	–	No data

8. Discussion and Research Gaps

The available literature shows that *Haplanthodes* is chemically and pharmacologically under-explored. Several points emerge from this review.

1. **Uneven coverage.** Most data concern *H. verticillata* and *H. tentaculata*. *H. plumosa* has not been studied phytochemically or pharmacologically, and

H. neilgherryensis has been studied only for its chemistry and one activity.

2. **Traditional claims versus evidence.** Analgesic and antipyretic activity of *H. tentaculata* partly validates its traditional use, but wound healing, diabetes and kidney claims remain untested. The use of *H. verticillata* root for asthma [12] has not been examined pharmacologically.

3. **Preliminary methodology.** Much of the phytochemical work relies on GC-MS profiling of extracts, which identifies volatile and low-polarity compounds but does not establish which constituents are responsible for activity. Flavonoid C-glycosides and phenolic acids listed in databases need confirmation in primary studies.

4. **Limited biological models.** Evidence is mostly in vitro (DPPH, a single cancer cell line). Antimicrobial, anti-inflammatory, hepatoprotective and antidiabetic studies on crude extracts are lacking, and no toxicity data exist.

5. **Plant part and standardisation.** Different studies use roots, leaves, aerial parts or the whole plant with different solvents, and pharmacognostic standardisation is limited.

Future work should include bioactivity-guided isolation, quantification of marker compounds such as vitexin, isovitexin and stigmasterol, in vivo validation, acute and sub-chronic toxicity, mechanism-of-action studies and conservation-aware cultivation of these endemic species.

9. Conclusion

The genus *Haplanthodes* comprises four endemic Indian species with a modest but promising body of evidence. *H. verticillata* shows antioxidant and in vitro anticancer activity, *H. tentaculata* shows analgesic and antipyretic effects, and *H. neilgherryensis* yields a flavanone glycoside that stimulates glucose uptake. Systematic phytochemical and pharmacological investigation, particularly of *H. plumosa* and *H. neilgherryensis*, together with in vivo and toxicity studies, is needed to determine the therapeutic value of this genus.

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Declarations

Conflict of interest: The authors declare that they have no known financial, commercial, or personal conflicts of interest that could have influenced the work reported in this review article. All authors confirm that the research was conducted independently and that no external organization or individual had any role that could bias the content or conclusions of this manuscript

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