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Current perspectives on *Pyrenaria*: An updated review of a lesser-known genus in Theaceae

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Abstract

The family Theaceae, commonly known as tea family, comprises approximately 600-760 accepted species distributed across tropical and subtropical regions of Asia and America. The genus *Pyrenaria* Blume, belongs to the family Theaceae, distributed throughout tropical Southeast Asia including North East India, Northern Myanmar, Indochina peninsula, and Southwestern China. The present review reveals *Pyrenaria* as a taxonomically complex, conservation-critical genus with untapped biochemical potential, where molecular systematics (Li *et al*., 2011), Indian endemism, and pharmacological significance converge. This review highlights the importance of *Pyrenaria* within the biodiversity hotspot of Northeast India and emphasizes its taxonomic, conservation and pharmacological relevance.

Keywords: biochemical potential, conservation, *Pyrenaria*, taxonomy, theaceae

Introduction

Theaceae is one of the important members of the flowering plant families, consisting of 20 genera and 600-760 accepted species with diverse ecological, economic, and horticultural significance (Luna & Ochoterena, 2004). The family commonly known as tea family has distribution across tropical and subtropical regions of Asia and America (Yan *et al.,* 2021). The regions of Southern China, Eastern Himalaya, East and Southeast Asia are recognised as the primary centre of diversity of Theaceae with the highest species richness and endemism(Cheng *et al*., 2022).

The genus *Pyrenaria* Blume belongs to the family Theaceae has distribution across tropical Southeast Asia that include North East India, Northern Myanmar, Indochina peninsula, and Southwestern China–(Li *et al*., 2011). Some representative species of *Pyrenaria* are- *Pyrenaria barringtoniifolia* (Griff) Seem.; *Pyrenaria* khasiana R. N. Paul; *Pyrenaria diospyricarpa* Kurz; *Pyrenaria cherrapunjeana* Mir (reported from India), *Pyrenaria menglaensis* G.d.Tao (reported from China), *Pyrenaria serrata* Blume (from Indonesia) etc. (Upadhaya *et al*., 2017; Pratiwi & Nurlaeni, Y. 2023). According to the IUCN red list *P. barringtoniifolia* and *P. khasiana* has been listed in Data Deficient category while, *P. cherrapunjeana* is in critically endangered category and *P. diospyricarpa* is in the category of least concern**.** *P. barringtoniifolia* is endemic to northeastern Himalayan region of India, *P. khasiana* is restricted in China and Northern India, specifically Assam and Meghalaya; *P. cherrapunjeana* is endemic to Khasi Hills in Meghalaya, India. Similarly, *P. diospyricarpa* is native to India, China and Myanmar (IUCN). In India, the genus is represented by relatively low number of species, mainly confined to the Northeast, where it occurs in tropical to subtropical broad-leaved and semi-evergreen forests (Paul & Odyuo, 2017; Roy *et al*., 2017).

Although the number of species is rather low under this genus, *Pyrenaria* has been the focus of

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attention due to its taxonomic complexity, biogeography, and conservation status, especially in India and adjacent areas (Li *et al*., 2011; Roy *et al*., 2017). Recent studies have turned to integrating classical morphology and molecular phylogeny with conservation-based field studies with more detailed insights into the *Pyrenaria* species and the relationships it has with Theaceae (Prince and Parks, 2001; Li *et al*., 2011). This is a review presents a comprehensive coverage of *Pyrenaria* including taxonomy and systematics, distribution and ecology, molecular phylogeny, conservation status, and biochemical analysis, applied research, including propagation and *ex situ* conservation.

Generic description and diagnostic traits

Historically, there have been several revisions regarding the classification of the family Theaceae because of the complexity in morphological attributes and some overlapping features of its genera. Within the family Theaceae, a wide range of genera was included by Bentham and Hooker (1862) and Takhtajan (1980), many of which were later transferred to other related families like Ternstroemiaceae and Pentaphylacaceae. Subsequent molecular phylogenetic analyses significantly revised the classification of the family. *Pyrenaria, Tutcheria, Parapyrenaria, and Sinopyrenaria* were the four separate genera which were included in the *Pyrenaria* complex. But (Li *et al*., 2011) again analysed the phylogenetic relationship of these four genera and found that they have a single coherent evolutionary relationship and therefore, the complex can be demonstrated as monophyletic. At the morphological level, a set of leaf structure, the nature of the indumentum, flower structure and morphology of the capsule has differentiated *Pyrenaria* and other related genera (*Camellia* and *Polyspora*), although the overlapping features have resulted a long history of taxonomic confusion (Prince and Parks, 2001; Li *et al*., 2011;).

Pyrenaria is characterized as a genus of trees or shrubs with simple, alternate, usually coriaceous leaves, often with conspicuous venation and dense indumentum on young parts (Li *et al*., 2011; Paul & Odyuo, 2017;). Flowers are typically axillary or terminal, solitary or in small clusters, with five sepals and five petals; the androecium is numerous-stamened, and the ovary is usually 3–5-locular with axile placentation (Paul & Odyuo, 2017). The fruit of *Pyrenaria* that contains locules and two one seeded pyrenes, which earlier considered as "pomaceous", but is now recognised as drupaceous and contain genuine seeds lacking endocarpous tissue, that dehisce loculicidally, releasing several seeds per locule (Li *et al*., 2011).

Species and infraspecific taxa of *Pyrenaria*

Globally, *Pyrenaria* comprises about 30 species with one subspecies and four varieties, distributed across tropical South-east Asia from northeastern India and northern Myanmar through south-western China and the Indo-China Peninsula to the Malaysian region and adjacent islands (Keng, 1980).The genus is particularly diverse in China with about 13 species, of which seven are endemic (Wu *et al*., 2007) and Malaysia with about eight species in Peninsular Malaysia (Keng, 1980).

Despite having a few species, the genus *Pyrenaria* shows a lot of variation in its physical characteristics across different areas. These variations are especially noticeable in features like leaf shape, flower structure and fruit type. These differences have been used to identify different species and varieties within the genus *Pyrenaria*. Keng (1980) compared the characteristics of *Pyrenaria* species and varieties reported from Malaysia to show how they vary and were related to each other. The major distinguishing morphological characters and distribution of reported *Pyrenaria* taxa, compiled from Keng (1980), are summarized in Table 1.

Table 1. Comparative morphological characteristics and distribution of species and infraspecific taxa of *Pyrenaria* (compiled and synthesized from Keng, 1980) reported from Malaysia.

Species	Variety	Habit	Leaf Characters	Flowers	Gynoecium	Fruit type	Distribution
Pyrenaria acuminata	NA	Shrubs/ small tree (5-12 m)	Narrowly elliptical, serrulate, puberulous/ sericeous beneath	3-3.5 cm, pale yellow, petals sericeous	Single, shortly branched	Depressed globose, indehiscent	Malay Peninsula, Sumatra
Pyrenaria johorensis	NA	Shrub/ tree (upto 17m)	Elliptic, glabrous above, puberulous beneath	3.5-4 cm, white, petals partly exposed	Single, unbranched	Globose, 5-lobed, dehiscent	Johore (Malay Peninsula)
Pyrenaria pahangensis	NA	Shrub/tree (3-4 m)	Large, membranaceous, false whorl	Flowers not observed	Unknown	Ovoid/ subglobose, partly dehiscent	Pahanga (Malay Peninsula)
Pyrenaria serrata	*serrata*	Small tree (upto 15 m)	Oblanceolate, serrulate, puberulous	Approximately 2cm,white,orange-yellowcentre	5, basally connate	Large, indehiscent	Sumatra, Java
	kunstleri	Shrub/tree	Elliptic, glabrous	1.5-2 cm, white	Single	Globose, indehiscent	Malay, Peninsula
	masocarpa	Shrub/ tree	Elliptic, puberulous beneath	1-1.2 cm, small	Short-branched	Small, indehiscent	Borneo
Pyrenaria tawauensis	NA	Shrub/ tree (3-10 m)	Lanceolate, verrucose beneath2	2.5-3 cm, white	5 free styles	Capsule, dehiscent	Sumatra, Borneo
Pyrenaria villosula	NA	Shrub/ Tree (3-10 m)	Elliptic, pilose beneath	1.5-2 cm, creamy white	Short branched	Succulent, indehiscent	Sumatra, Malay Peninsula
Pyrenaria viridifolia	NA	Shrub/ tree (3-10 m)	Elliptic, glabrous above	2-3 cm, light yellow	5 free styles	Immature globose	Pahang
Pyrenaria wrayi	NA	Shrub	Narrowly elliptic, hispid beneath	1.5-1.8 cm, small	Partly fused, apically branched	Depressed globose	Perek

The species and infraspecific taxa of *Pyrenaria* that have been reported in India and studied by various authors are reviewed and described below-

Bezbaruah, (1971) conducted cytological investigation on *Camellia* and some other species of Theaceae present in North East India, where the genus *Pyrenaria* is subjected to cytological studies for the first time and confirmed the presence of 2n number of chromosomes in the only reported species of the genus *P. barringtoniifolia* wildly in North East India region till that date.

Upadhaya *et al*. (2017) discovered species *Pyrenaria cherrapunjeana* which is new species to the genus *Pyrenaria* from East Khasi Hills district, Cherrapunji, Meghalaya at on altitude of 1315 m, 25°16.051'N, 91°43.302'E, in 18 April, 2015. They also taxonomically describe the plant morphology as young branchlets of the plant are light purplish-brown and sparsely hairy; the tree can reach a height of 12 meters; the leaves are simple, alternating, elliptic-oblong (7–16.5 × 3.8–5.8 cm), glabrous and dark green on top, pale with sparse hairs underneath, serrated, and have a long, acuminate apex; the axillary, solitary, ~2 cm flowers have five to six creamy-white petals, many stamens, and a five-loculed sub globose ovary. The fruits are 5-loculed, sub globose drupes (1–1.5 × 1.1–1.7 cm), densely hairy, and have stigmatic tips and a persistent calyx.

Odyuo & Roy (2017) described a new variety of *Pyrenaria khasiana* collected from Dullung Reserve forest, Lakhimpur, Assam alt. 171 m. (N27°24´36´´, E94°11´42´´), in Feb, 9, 2011 and named as *Pyrenaria khasiana* R.N. Paul var. *lakhimpurense* with morphological description almost up to 5 m tall small tree, with sparsely pubescent young branchlets; oblanceolate to spathulate leaves (22–25 × 8.5–10.5 cm), leathery, serrate, glabrous above and sparsely pubescent below; axillary solitary flowers ~4.5 cm across with 7 white petals, many basally connate stamens; a 5-loculed ovary; and free styles that produce sub globose fruits (2.5–3.5 × 2.3–3.2 cm) with 5 stigmatic protuberances, a persistent calyx, a fleshy yellowish pericarp, and 5–7 hemispheric bony seeds that bloom from February to May and fruit from June to August.

Sarma *et al*.(2017) reported a new location of *Pyrenaria khasiana* R.N. Paul var. *lakhimpurense* which was earlier found in Dullung Reserve forest of Lakhimpur district (Odyuo & Roy, 2017) in the Sonai Rupai wildlife Sanctuary of Sonitpur District. After analysing the distribution area, population size and density, they recommended the variety as critically endangered category of the IUCN mentioning the need of both ex-situ and in-situ conservation of the plant and highlighted the need and beneficial significance of study on the plant because no work on the phytochemicals constituent of the plant has been done till date.

Habitat and micro-habitat preferences

According to field observations, *Pyrenaria* species tend to prefer shaded habitats with moist soils in primary or mature secondary forests steep or in the ravines where the soil is relatively moist (Paul and Odyuo,2017; Roy *et al*.2017). *Pyrenaria cherrapunjeana*, the endemic species of the wettest Cherrapunjee Mawsynram forests, shows no regeneration despite ideal microhabitats, due to snail/insect predation of the seedlings and early fruit loss (Mir,2016; Alom *et al*.,2025). This highlights the weakness of *Pyrenaria* even in places that are climatically favourable to its existence. In Assam, populations of *P. khasiana* var. *lakhimpurense* have been recorded in reserve forests and protected areas such as Kakoi and Dullung Reserve Forests, as well as in Sonai Rupai Wildlife Sanctuary, highlighting the importance of protected-area networks for the persistence of these taxa (Roy *et al*., 2017; Sarma *et al*.,2017). Nevertheless, habitat fragmentation, changing cultivation, and infrastructure expansion are becoming major problems to the integrity of these forest patches thus impacting the populations of *Pyrenaria*.

Systematics and molecular phylogeny

Revision of the systematics of the genus *Pyrenaria* was also made significantly after the molecular phylogenetic studies. Li *et al*. (2011) examined the nuclear ribosomal ITS sequences of so-called *Pyrenaria* complex which contains *Pyrenaria*, *Tutcheria*, *Parapyrenaria* and *Sinopyrenaria.* These genera are a monophyletic group, well-supported and a sister to the *Camellia-Polyspora* clade of Theaceae, which was only evident in both the parsimony and Bayesian analyses (Li *et al*., 2011). Notably, no one of the four traditionally known genera was found to be monophyletic, instead, the species of the *Pyrenaria* complex are mixed, thus showing that morphological characteristics that defined them are homoplasious (Li *et al*., 2011). This prompted Li *et al*. (2011) to propose that the four genera be merged into *Pyrenaria* sensu lato that later sources of the group have adopted (Prince and Parks, 2001, Li *et al*., 2011).

Further research into tribe Theaceae with a variety of chloroplast and nuclear markers has led to the further establishing of the location of *Pyrenaria* in the family (Prince *et al*., 2014). These experiments prove that *Pyrenaria* is closely associated with *Camellia* and *Polyspora* though that in certain analyses; *Pyrenaria* is polyphyletic, whereas *Polyspora* is monophyletic and *Camellia* is paraphyletic (Prince *et al*., 2014). Li *et al*., (2011) conducted molecular taxonomy and phylogeny of Theaceae based on the nuclear ribosomal ITS sequence which showed intimate correlation between genera and indicated that *Polyspora* had much affinity to *Camellia* as compared to *Pyrenaria*. Altogether, these molecular results support the need of an integrative approach to taxonomy in Theaceae with the combination of

morphological, ecological, and genetic data to stabilize generic boundaries and species circumscriptions (Li *et al*., 2011; Prince *et al*., 2014).

Ex-situ conservation

In vitro propagation and micropropagation

Recent research has focused on developing propagation protocols for *Pyrenaria* species to support ex situ conservation and restoration efforts. Vijayan *et al*. (2023) analysed the protocol for in vitro propagation of *Pyrenaria khasiana* var. *lakhimpurensis* for ex situ conservation and performed multiple shoot induction, in vitro seed germination, and in vitro rooting experiments in woody plant medium and achieved results as – highest length of shoot per explant was obtained from benzyladenine, highest number of shoots per explant was obtained from the combination of benzyladenine and gibberellic acid. Among the 1, 2 and 4 nodes used for multiple shoot induction studied, highest number of shoots and highest length of shoot was obtained from 4 nodes after 4 weeks of experiment and finally after transferring the seedlings to field from the laboratory 70% survival rate was observed that demonstrate the feasibility of micropropagation. Within twelve weeks of transplantation, the in vitro raised well developed rooted plantlets were successfully acclimatized under greenhouse conditions which show uniform morphology with mother plant and exhibit normal growth. Out of these, almost 60 acclimatized plants were introduced in the office of botanical Survey of India, Shillong and Experimental Botanic Garden in Barapani, Shillong. Remaining plantlets have been distributed to various organizations across Meghalaya for reintroduction purposes, while a portion has been conserved for future restoration programs. These efforts collectively highlight the practical applicability of in vitro techniques not only for propagation but also for strengthening ex situ conservation strategies, ensuring the long-term survival and genetic preservation of this critically endangered variety (Vijayan *et al*. 2023).

Biochemical and phytochemical studies

Despite reports on a few species, biochemical investigations on *Pyrenaria* remain limited worldwide. While other members of the same family particularly *Camellia* has been extensively explored in many aspects, mainly because of the presence of several secondary metabolites with strong antioxidant activity` and its significance in medicinal and commercial field, related genera *Pyrenaria* remains less explored in any of these aspects. Table 2 summarizes published biochemical data, revealing bioactive potential of the genus across Southeast Asian taxa till date.

These findings establish *Pyrenaria* as a promising source of antifungal and antidiabetic agents. *Pyrenaria* sp.'s superior *Candida* inhibition (MIC 25 µg/mL) exceeds regional medicinal plants, suggesting novel antifungal compounds (Galappathie *et al*., 2014). *P. serrata*'s flavonoid-rich profile parallels *Camellia sinensis* but lacks terpenes/steroids, correlating with slightly lower α-amylase inhibition (Elya *et al*., 2015). High carbohydrate content may enhance *P. serrata*'s antioxidant capacity (Pratiwi & Nurlaeni, 2023).

Table 2: Investigations exploring biochemistry of *Pyrenaria* species

Species	Region	Phytochemical detected	Bioactivity	Key quantitative results	Remarks	References
Pyrenaria sp.	Island of Borneo	Not determined	Antimicrobial activity	MIC=25 µg/mL MFC=50 µg/mL (Against Candida albicans)	Highest antimicrobial activity among the 6 medicinal plants tested	(Galappathie *et al.*, 2014)
Pyrenaria serrata	Indonesia	alkaloid, flavonoid, tannin, glycoside and saponin	antidiabetic activity	percent inhibition of alpha-amylase is shown as 94.12±0.20	alpha-amylase inhibition is excellent, only 4% lower than *C. sinensis*	Elya *et al*., (2015)
	Indonesia	Carbohydrates, fat	Antioxidant activity	Carbohydrate content (85.94%)	Highest carbohydrate and strongest antioxidant activity among four fruits	Pratiwi & Nurlaeni, (2023)

Perspectives

The present review reveals *Pyrenaria* as a taxonomically complex, conservation-critical genus with untapped biochemical potential, where molecular systematics (Li *et al*., 2011), Indian endemics (Roy *et al*., 2017; Alom *et al*., 2025), and pharmacological promise (Galappathie *et al*., 2014) connect.

The genus *Pyrenaria* is an illustration of long-standing taxonomical problems of Theaceae in which the use of morphological characters has been used to indicate unclear generic delimitations in the past. Initial classification systems (Bentham and Hooker, 1862; Takhtajan, 1980) took a wider circumscription of the family, including many genera that were redefined as part of other more closely related families e.g. Ternstroemiaceae and Pentaphylacaceae. Molecular phylogenetics has been greatly applied to modify this framework, whereby the evolutionary relationships enable a more stable classification. Specifically, DNA studies involving chloroplast DNA have shown that Theaceae can be divided into different tribes with *Pyrenaria* being placed in tribe Theeae together with *Camellia* and *Polyspora* (Prince and Parks, 2001; Li *et al*., 2011).

Among the most important systematic changes, there is the revision in regards to the *Pyrenaria* complex containing historically *Tutcheria*, *Parapyrenaria*, and *Sinopyrenaria*. Molecular data provided by the nuclear ribosomal ITS sequences has shown that the taxa are a single monophyletic lineage, hence the need to recombine them to form *Pyrenaria* sensu lato (Li *et al*., 2011). The observation presents the weakness of morphology-based taxonomy since some of the diagnostic characters distinguishing the three genera are no longer homoplasious. Nevertheless, phylogenetic anomalies still persist, and some studies indicate polyphyly in *Pyrenaria* and paraphyly in genera closely related to it, e.g. *Camellia*, showing that the existing data might not completely address evolutionary patterns (Prince *et al*., 2014).

The genus *Pyrenaria* is characterized by coriaceous leaves, prominent indumentum, and multilocular ovaries producing drupaceous fruits; however, considerable morphological overlap with closely related genera often complicates species delimitation (Keng,1980; Upadhaya *et al*., 2017; Odyuo and Roy, 2017). The global comparative analysis further highlights substantial variation in key diagnostic traits, particularly in floral structure, style configuration, and fruit type, underscoring the complexity of taxonomic boundaries within the genus (Keng,1980). Among these, the configuration of the style emerges as a major diagnostic trait, with species exhibiting single, free, or partially fused styles, thereby providing important taxonomic resolution. Variation in corolla size (ranging from approximately 1 cm to 4 cm) further supports species delimitation and reflects evolutionary divergence within the genus. Additionally, fruit morphology shows clear differentiation, with both indehiscent and loculicidally dehiscent types occurring across taxa (Keng,1980). In the Indian context, recent taxonomic contributions, including the description of *P. cherrapunjeana* and *P. khasiana* var. *lakhimpurense*, have expanded the known diversity and emphasize northeastern India as an important centre of endemism (Upadhaya *et al*., 2017; Odyuo and Roy, 2017). These findings, when viewed alongside global patterns, suggest that additional undocumented diversity may still exist in underexplored forest regions, highlighting the need for further integrative taxonomic and floristic investigations.

Ecologically, shaded and humid understory conditions in primary or old-age secondary forests is a very strong preference of the species of the genus *Pyrenaria*, frequently in topographically favourable locations (slopes and ravines) (Paul and Odyuo, 2017; Roy *et al*., 2017). This kind of ecological specialization makes them more vulnerable to all disturbances of the environment. Particularly, a species decline has been noted with good climatic conditions, which is possibly due to biotic stresses, i.e., seed predation and prematurely dropping fruits (Mir, 2016; Alom *et al*., 2025). In addition, human activities such as habitat fragmentation, changing accumulation, and infrastructural development are worsening the decline of the population (Roy *et al*., 2017). This fact that *P. khasiana* var. *lakhimpurense* is closely related to the critically endangered species is an important stark reminder that both in situ and ex situ

conservation measures are urgently needed (Sarma *et al*., 2017).

Plant tissue culture methods have been improved and thus provide a possible use in conservation. The protocols of in vitro propagation such as shoot stimulation, rooting and acclimatization have been shown to yield relatively high success rates, and can be used as part of ex situ conservation and restoration programs (Vijayan *et al*., 2023). Nevertheless, there is a need of some extensive research to evaluate the genetic fidelity and long-term ecological performance of propagated individuals.

Although there is an advancement in systems and conservation, *Pyrenaria* has not been extensively studied biochemically and phytochemically. Scientific research carried out to date shows that it contains antimicrobial, antioxidant, and antidiabetic-active bioactive compounds (Galappathie *et al*., 2014; Elya *et al*., 2015; Pratiwi and Nurlaeni, 2023). *Pyrenaria* sp. showed MIC 25 0g/mL against *Candida albicans* (best of the six local medicinal plants; Galappathie *et al*., 2014). *P. serrata* had confirmed alkaloids, flavonoids, tannins, glycosides and saponins and recorded 94.12±0.20 percent α-amylase inhibition (only second to *C. sinensis* 99.11%) (Elya *et al*., 2015). Carbohydrates were highest in four species, which were tested due to their antioxidant (85.94 per cent) and have been associated with nutritional analysis (Pratiwi and Nurlaeni, 2023).

The study of *Pyrenaria* has been comparatively limited and scattered over the years and there has been a marked rise in publications in the past two decades. Preliminary studies consisted mainly of cytological studies, with an ensuing gap before the development of molecular phylogenetics studies that greatly changed the perspective regarding the genus.

The chronological trend of the studies (Table 3) demonstrates that there is a disproportional growth in research related to *Pyrenaria*. Early contributions were limited to cytological work (Bezbaruah,1971) and there was a significant change like with the advent of molecular systematics at the beginning of the 2000s (Prince and Parks,2001; Li *et al*.,2011). After 2010, the gradual rise in the study field can be explained that are mostly influenced by taxonomic discoveries and conservation evaluation, especially in North East India (Upadhaya *et al*.,2017; Odyuo and Roy,2017). Despite this progress, the thematic distribution of studies remains highly skewed.

Figure 1: Thematic distribution of research on *Pyrenaria*

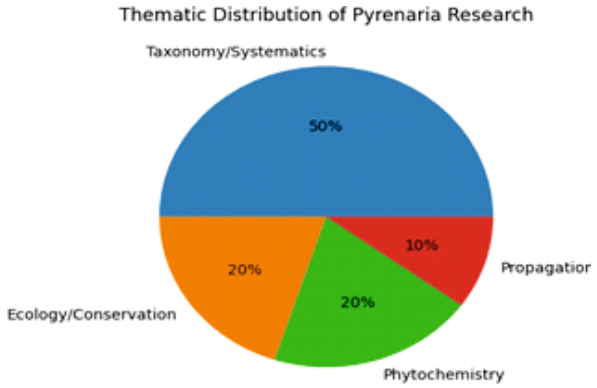

Figure 1 shows that the major percentage of research is dedicated to taxonomy and systematics studies, and research on ecology, phytochemical and propagation related aspects are relatively underexplored. Even though more recent studies have started to deal with conservation and

Research trends and knowledge gaps

Table 3: Chronological summary of major studies on the genus *Pyrenaria*

Year	papers	Topic	Key Species	References
1971	1	Cytology	*P. barringtoniifolia*	Bezbaruah (1971)
2001	1	Molecular phylogeny	*Pyrenaria* complex	Prince and Parks (2001)
2011	2	Molecular systematics	*Pyrenaria* complex	Li *et al* (2011a,b)
2014	1	Antifungal	*Pyrenaria* sp.	Galappathie *et al*. (2014)
2015	1	Antidiabetic	*P. serrata*	Elya *et al*. (2015)
2017	3	Taxonomy/ Conservation	*P. khasiana* var. *lakhimpurense*	Odyuo and Roy (2017); Sarma *et al*. (2017); Roy *et al*. (2017)
	1	New Species	*P. cherrapunjeana*	Upadhaya *et al*. (2017)
2023	1	Propagation	*P. khasiana* var. *lakhimpurense*	Vijayan *et al*. (2023)
2025	1	Ecology	*P. cherrapunjeana*	Alom *et al*. (2025)

propagation, these are still insufficient in comparison with the ecological susceptibility and possible economic significance of the genus. Besides, biochemical and phytochemical research is also very minimal especially in comparison to the closely related genera as *Camellia*, which is well researched in relation to bioactive potential. Being closely related to *Camellia,* species of the genus *Pyrenaria* may also hold possibilities to contain important phytochemicals and bioactive potential that can bring some new insight. Positive results obtained from the limited studies conducted on some species of *Pyrenaria* such as *P. serrata* in International level such as presence of phytochemicals like carbohydrates, fat and bioactive potential like antioxidant, antimicrobial and antidiabetic activity (Galappathie *et al*., 2014; Elya *et al*., 2015; Pratiwi & Nurlaeni, 2023) also suggest that the underexplored species of the genus endemically present in North East India may also possess such valuable phytochemical and therapeutic potential. Lacking of molecular characterization in any species of *Pyrenaria* found in North East India is another gap that needs proper documentation.

In contrast to several economically significant members of the family Theaceae, such as *Camellia* species used for tea, oil, and ornamental purposes, *Pyrenaria* has limited direct economic utilization. The genus primarily comprises wild forest species with ecological importance in maintaining forest structure and biodiversity. However, given its phylogenetic affinity with economically valuable taxa, *Pyrenaria* may possess untapped potential for horticultural, medicinal, or phytochemical applications. Further studies focusing on its phytochemistry and propagation could reveal prospective economic value.

Conclusion

Research on the genus *Pyrenaria* has advanced considerably in recent decades, particularly through integrative taxonomic studies, molecular phylogenetic analyses, and conservation-oriented field investigations in northeastern India and neighboring regions (Li *et al*., 2011; Paul & Odyuo, 2017; Roy *et al*., 2017). The recognition of the *Pyrenaria* complex as monophyletic and the proposal to merge several related genera under *Pyrenaria sensu lato* have clarified generic boundaries within Theaceae, while also highlighting the limitations of morphology-only approaches (Li *et al*., 2011; Prince *et al*., 2014).

Nevertheless, substantial knowledge gaps remain, especially regarding the floristics, population genetics, and biochemical properties of *Pyrenaria* species (Mir, 2016; Paul & Odyuo, 2017;). Addressing these gaps will require coordinated efforts involving field surveys, herbarium-based taxonomy, molecular genetics, and conservation biology, ideally supported by national and international funding programs focused on biodiversity and endangered species (Roy *et al*., 2017; Roy & Odyuo, 2025).

For a region as biologically rich yet threatened as northeastern India, *Pyrenaria* serves as an excellent model group for studying the interplay between taxonomy, biogeography, and conservation, with implications that extend beyond this single genus to the broader Theaceae and tropical Asian flora (Prince *et al.*, 2014; Mir, 2016). Future work should prioritize the documentation and protection of *Pyrenaria* populations, the development of robust ex situ conservation strategies, and the exploration of their potential ecological and biochemical value (Roy *et al*., 2017; Vijayan *et al*., 2023;).

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