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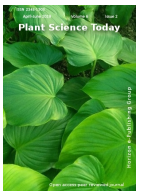

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Review Article

Review on the genus *Tectaria* Cav. from India

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Abstract

The fern genus *Tectaria* Cav. (Tectariaceae) is one of the largest, morphologically diverse and more complex genera having difficulties in identifying the species and their groups. Since its description, a number of new genera had been separated from it or merged within it created considerable ambiguity. Thus, the main aim of the present review is to provide comprehensive information of the taxonomy, cytology, anatomy, palynology and molecular research carried out so far on the genus *Tectaria.* Present work is not merely compilation but includes personal observations and is presented here after critical evaluation.

Keywords: Fern; diversity; cytology; taxonomy; Tectariaceae

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Introduction

As an important group of ferns, different species of *Tectaria* are known to occupy a variety of ecological niches across different habitats in numerous forest ecosystems of the country. The diversity, conservation status and state of knowledge of *Tectaria* (Tectariaceae) are not uniform worldwide. The genus *Tectaria* Cav., is popularly known as "halberd fern", was described by Cavanilles (1). The genus is mostly distributed in tropical regions and maximum species are terrestrial in rain forests (2). The word *Tectaria* was derived from Latin words "*tectum*" means "*a covering*" and the "*adjectival suffic-aria*", referring to the "*indusium*" (118). Generally, *Tectaria* species are small to large sized herbs, having erect, suberect or creeping rhizome, monomorphic or dimorphic, unipennate, bipinnate-tetrapinnate fronds, growing along the roadsides, edges of hills and hillocks, along the water channels from low to high altitude or in different forests types (semi-arid to evergreen forests) (48). Due to its remarkable diverse morphology, there is no unanimous opinion on the number of species in this genus. According to Tryon and Tryon (3) and Kramer (4) there are nearly 150 species, while Holttum (5) and Ding *et al.* (2) considered about 230 species throughout the globe. However, according to PPG-I (6) there are ca. 200 species are accepted internationally.

Thus, the present review intends to compile various studies on this fern from worldwide and critically evaluates the issues related to the taxonomy, anatomy, cytology, palynology and molecular research on this genus.

Taxonomic history

The treatment of tectaroid ferns has un-orthodoxically undergone several changes in their names time to time. It was popularly known as

Aspidium Sw., whereas few species were treated under the *Dryopteris* Adans., *Nephrodium* Marthe ex Michx., *Pleocnemia* C. Presl., and *Polystichum* Roth. The genus *Tectaria* was described by Cavanilles (1). Soon after discovery of *Tectaria*, describe a new genera *Aspidium* by Swartz (7) for the same and this name was widely accepted by several pteridologists. Later on, many new genera, *viz*., *Arcypteris* Underw., *Pleocnemia* C. Presl, and *Sagenia* C. Presl, were described and accepted by many pteridologists (8-10). Beddome (11-12) reported different tectaroid ferns, *viz*., *Aspidium* and *Plecomenia*, although these generic delimitations were widely adopted at that time by pteridologists; it was ultimately recognized as illegitimate names. However, the concept of *Tectaria* was progressively accepted by pteridologists in the 20th century.

The first major work on tectaroid ferns in the 20th century was Christensen's "*Index Filicum*" (13). Further, he realised that the species listed under the genus *Dryopteris* were an unnatural mixture which indeed needs further study. First time he pointed out the presence of ctenitoid type of hairs in the species aggregate under the genus *Dryopteris*. He distinguished *Ctenitis* from *Dryopteris*, pointing out the relationship of the former to *Tectaria* and also has anastomosing veins in thelypteroid ferns. At the same time, Copland (14) studied the Philippine species and recognized seven groups, *viz*., the *Arcypteris* group, the *Cicutariae* group, the *Crenatae* group, the *Decurrentes* group, the *Pleocnemia* group, the *Trifoliatae-Polymorphae* group, and the *Vastae* group. Subsequently, Christensen (15) made an effort to differentiate natural assemblies within that mixture by exploring the species of tropical America. Later on, he published a monograph "*Index Filicum*" (16), subgenera, though he observed them as very diverse and specified that some should eventually have generic rank. Blater and d'Almeida (17) studied the ferns of Bombay presidency and reported 06 species of *Aspidium*. Ching (18) for the treatment of *Tectaria* from China and Sikkim-Himalaya, divided the genus into three sections, *viz*., *T. sect. Arcypteris* (Underw.) C. Chr., *T. sect. Pleocnemia* (C. Presl) Diels, and *T. sect. Eutectaria* Ching (=*T. sect. Tectaria*). Christensen (19) published the classification of extant ferns retained a major family Polypodiaceae with two subfamilies, one is Dryopteridoideae which includes the genus *Dryopteris* and second is Thelypteridaceae which includes the genus *Tectaria* with other related genera. Later on, Ching (20) divided Christensen's Polypodiaceae into several families, amongst these Aspidiaceae is one which is similar to Christensen's subfamily Dryopteridoideae. This family Aspidiaceae is divided into tribes, Aspidieae (includes *Tectaria* and its allies) and Dryopterideae (includes *Dryopteris* and related genera). Ching (20) also accepted the genera, *viz*., *Arcypteris* Underw., *Pleocnemia* C. Presl, and *Sagenia* C. Presl. Holttum (21) raised these tribe to subfamily rank but placed under the family Dennstaedtiaceae. For separating these subfamilies, different characters, *viz*., *costae, smaller rachises grooved, and groove with raised edges* for the Dryopteridoideae and *costae raised, not grooved, presence of hairs* for the Aspidieae were used. He accepted many new genera, *viz*., *Amphiblestra* C.Presl, *Arcypteris* Underw., *Ctenitis* (C. Chr.) C. Chr., *Cyclopeltis* J. Sm., *Dictyoxiphium* Hook., *Hemigramma* Christ, *Heterogonium* C.Presl, *Lastreopsis* Ching, *Pleocnemia* C. Presl, *Pleuroderris* Maxon, *Pteridrys* C. Chr. & Ching, *Quercifilix* Copel., *Stenosemia* C. Presl and *Tectaria* Cav., in his classification system. At the same time Copland (22) recognized a large family Aspidiaceae, including the genera, *viz*., *Thelypteris* and its allies, *Athyrium*, *Diplazium* and *Lomariopsis*. Subsequently, Holttum (23) *Arcypteris* Underw., is maintained as different from *Tectaria* and is very closely related to *Pleocnemia* rather than *Tectaria*. Pichi Sermolli (24) had proposed to conserve the family Aspidiaceae but it failed because the family name Aspidiaceae is illegitimate since it is based on an illegitimate generic name *Aspidium*. Nayar (25) didn't follow the Ching's classification and placed tectarioid and *Dryopteris* group of ferns in separate subfamilies of Dryopteridaceae. Mathew (26) studied diversity of pteridophytes of Darjeeling district and reported *Tectaria cicutaria* and *T. polymorpha* from Darjeeling. Sledge (27) studied the tectarioid ferns of Ceylon and reported five genera (*Hypodematium*, *Ctenitis*, *Lastreopsis*, *Tectaria* and *Pteridrys*) and sixteen species with the rejection of the genus *Quercifilix*. In disparity, a number of unlike genera had been isolated from *Tectaria*, *viz*., *Aenigmopteris* Holttum, *Amphiblestra*, *Aspidium*, *Camptodium*, *Cardiochlaena* Fée, *Chlamydogramme* Holttum, *Cionidium* T. Moore, *Ctenitopsis* Ching ex Tardieu & C. Chr., *Dictyoxiphium*, *Dictyopteris* J.V. Lamour., *Dryomensis* Fée, Fadyenia, *Hemigramma, Heterogonium*, *Luerssenia* Kuhn ex Luerssen, *Microbrochis* C. Presl, *Phlebiogonium* Fée, *Pleocnemia*, *Pleuroderris*, *Podopeltis* Fée, *Psomiocarpa* C. Presl, *Pseudotectaria* Tardieu-Blot, *Quercifilix*, Sagenia, *Stenosemia*, and *Trichiocarpa* (Hook.) J. Sm., by various pteridologists (28). In addition, some species of *Ctenitis* and *Dryopteris* Adans., are often treated as members of *Tectaria* which has on occasion led to unstable delimitations of those genera (3,29). Holttum (30) studied the genus *Tectaria* from Mascarene Islands. On the basis of venation patterns, he divided the genus *Tectaria* of Mascarene Islands into three groups *i.e. Group I* includes the species (*T. picta* and *T. puberula*) having elaborate network of veins, with free veinlets, often branched, which run in all direction in the areoles of the network including the areole of the main veins of the pinnae. *Group II* includes the species (*T. gemmifera*) had no free veinlets in the areoles of the costae and costules, few outwardly directed

unbranched veinlets however present in other areoles and *Group III* includes the species (*T. fuscipes*) having free veins with or without areoles along the costa. Dixit (31) published a censes on Indian Pteridophytes and considered ten genera, *viz*., *Acrorumohra, Ctenitis, Ctenitopsis, Cyrtomium, Didymochlacna, Lastreopsis, Pleocnemia, Pteridrys, Quercifilix, Tectaria* etc., in the family Aspidiaceae. Holttum (32) had carried out survey on tectaroid ferns of Asia, Malesia and Western Pasific and proposed seventeen new species of the genus *Ctenitis*, one new generic name and made four new combinations of this genus. Also, discussed difference between *Ctenitis* and *Tectaria*. The genus *Ctenitis* has free veins, differing from the Holttum's third group of *Tectaria* in the position of origin of the basal basiscopic vein in each pinna-lobe. Ctenitis also differs from *Tectaria* in the presence of scales on all the axes of the frond and in the thin, clathrate structure of the smaller scales. In *Tectaria* the scales are usually confined to the stipe and are never clathrate. Panigrahi (33) had proposed a new family Tectariaceae (rejecting the family Aspidiaceae) and it was accepted by subsequent researchers. It includes 17 genera and 527-538 species including *Tectaria* and some other closely related genera. Pande (34) studied the ferns of Kumaon Hills and recorded two species of *Tectaria, viz*., *T. coadunata* and *T. dubia*. Holttum (35) described some new taxa in *Tectaria* group from Malesia and new combinations of *Tectaria* were also made. Khullar (36) documented the members of *Tectaria*, *Dryopsis* and *Ctenitis* of Tectariaceae found in the West Himalayas. A broad-leaf variant of fern rheophyte, *Tectaria lobbi* is reported from Borneo (37). They concluded that broad-leaved forms are developed from the narrow-leafleted one, which took place during the course of evolution of Rheophytes from dryland species, although the direction of changes was opposite in the two cases. Manickam and Irudayaraj (38), Irudayaraj & Bir (39) and Rajagopal & Bhat (40) reported different species of *Tectaria*, *viz*., *T. coadunata, T. paradoxa, T. polymorpha* and T. *wightii* from Western Ghats. During the floristic survey of pteridophytes from Tawau Hills, Sabah, Bidin & Jaman (41) reported three species of tectaroid ferns, *viz*., *Pleocnemia conjugata, Tectaria angulata* and *T. singaporeana*. At the same time Jaman, *et al*. (42) surveyed the pteridophytes of Bario, Keiabit Highlands and reported *Ctenitis aciculate, Pleocnemia hemiteliiformis* and five species of *Tectaria*. Chandra (43) in his "*Ferns of India*" listed six genera of tectaroid ferns, *viz*., *Tectaria* (22), *Pleocnemia* (1), *Pteridrys* (2), *Lastreopsis* (1), *Dryopsis* (6) and *Ctenitis* (3) under the subfamily Tectarioideae. Rojas (44) studied the tectaroid ferns from Nicaragua, Costa Rica, Panama, Colombia and Peru and described many new species, *viz*., *Ctenitis sotoana* A. Rojas, *Megalastrum ctenitoides* A. Rojas, *Tectaria darienensis* A. Rojas, *T. faberiana* A. Rojas, *T. longipinnata* A. Rojas, *T. murilloana* A. Rojas, *T. pascoensis* A. Rojas and *T. subdimorpha* A. Rojas along with a new combination of *Megalastrum karstenianum* (Klotzsch) A. Rojas. *Tectaria polymorpha* is reported from Hainan Island, China (45). They merged the variety *T. polymorpha* var. *subcuneata* under *T. polymorpha* and also discussed the morphological variation of *T. subtriphylla* and differences between *T. simonsii* and *T. media.* Smith (46) described two new species of *Tectaria, viz*., *T. atropurpuria* and *T microsora* from the Rio Cenepa Area, Amazonas and Peru. Fraser-Jenkins (47) published a "*Taxonomic Revision of Indian Subcontinental Pteridophytes*" and listed 01 species of *Ctenitis,* 06 species of *Dryopsis*, 01 species of *Heterogonium,* 01 species of *Lastreopsis*, 01 species of *Pleocnemia,* 03 species of *Pteridrys* and 22 species of *Tectaria*. Patil *et al*. (48) studied the *Tectaria* from Northern Western Ghats and reported 04 species from which *T. fuscipes* was added as new distributional record for Western Ghats of India. Antony *et al*. (49) reported an African element, *Tectaria puberula* as a new distributional record for India. Recently, Dong (50) is corrected the misapplication of the name *Tectaria subsageniacea* (Tectariaceae) in China. Similarly, A new species of *Tectaria*, *Tectaria moranii* (Tectariaceae), from Costa Rica is described (51). Also, Fraser-Jenkins *et al*. (52) published a book on Indian pteridophytes "*An Annotated checklist of Indian Pteridophytes Part – 2*" and retained 24 species of *Tectaria*. After reviewing the literature, it was observed that genus *Tectaria* having more complexity hence many new genera separated from the genus world-wide while some of them were merged. However, in India since last 2-3 decades very much confusions were created on the occurrence of species as well as in identification of earlier pteridologists. Hence there is an urgent need to study the taxonomy of the genus *Tectaria* from which helps to solve the taxonomic complex in India.

Taxonomy

Tectaria is terrestrial, medium to large size herb, growing along the cut edges of hills and hillocks or edges of river, having erect (*T. ingens* and *T. paradoxa*), suberect (*T. chattagrammica, T. fuscipes* and *T. trimenii*) short creeping (*T. polymorpha* and *T. simonsii*) or long creeping rhizome (*T. coadunata, T. impressa, T. wightii* and *T. herpetocaulos*) (Fig. 1 a-d); *fronds* either monomorphic (*T. coadunata*), dimorphic (*T. fuscipes, T. heterocarpa, T. polymorpha, T. wightii* and *T. zeilanica*) or subdimorphic (*T. paradoxa*); lamina decurrens (*T. decurrens* and *T. vasta*), simple pinnate with or without lower pinnae lobe (*T. heterocarpa, T. polymorpha, T. wightii* and *T. pseudosiifolia*), bipinnate-tripinnate (*T. chattagrammica, T. coadunata, T. fuscipes,*

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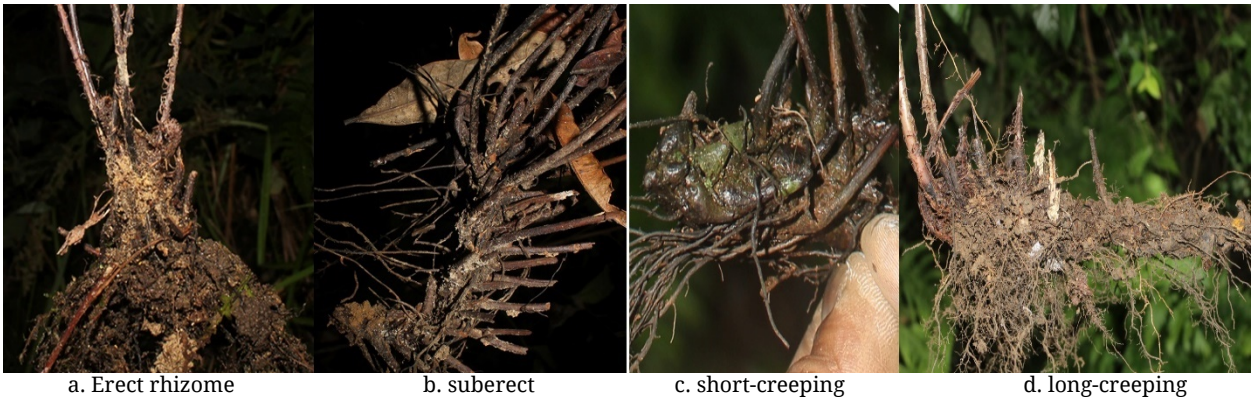
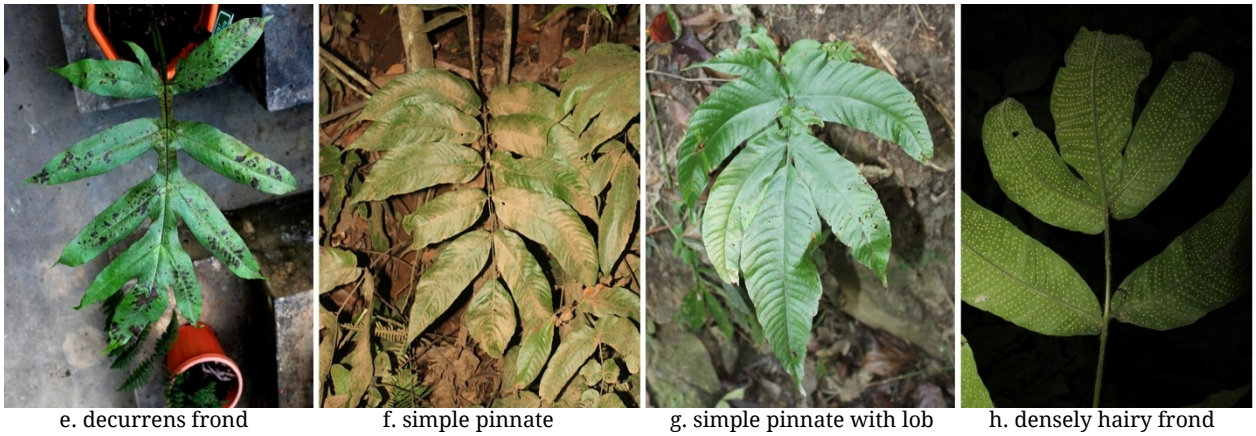
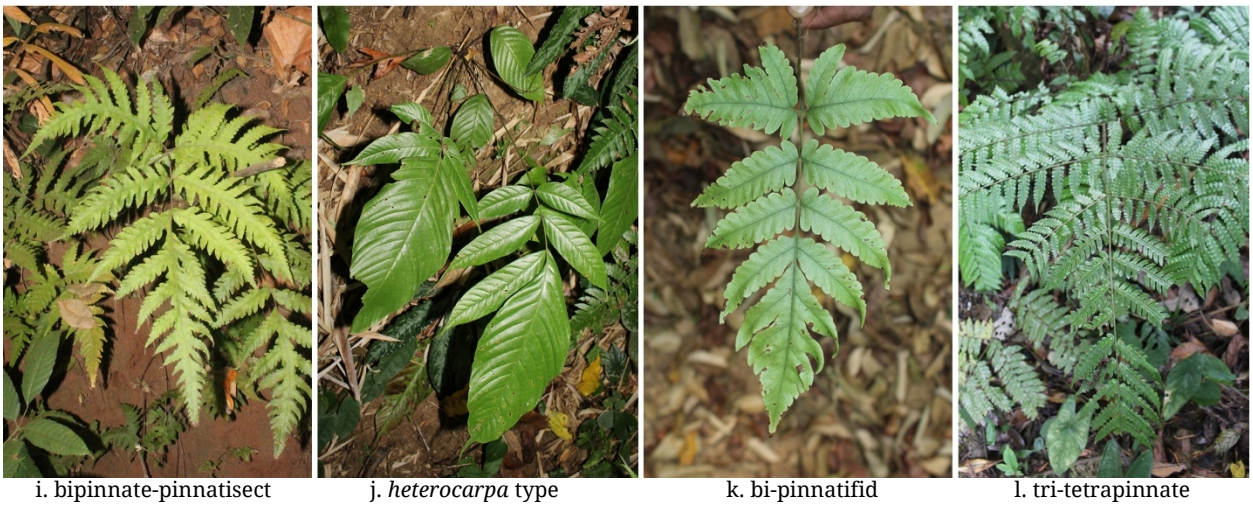


a. Erect rhizome b. suberect c. short-creeping d. long-creeping

Fig. 1 (a–d): Different type of rhizome in the genus *Tectaria*

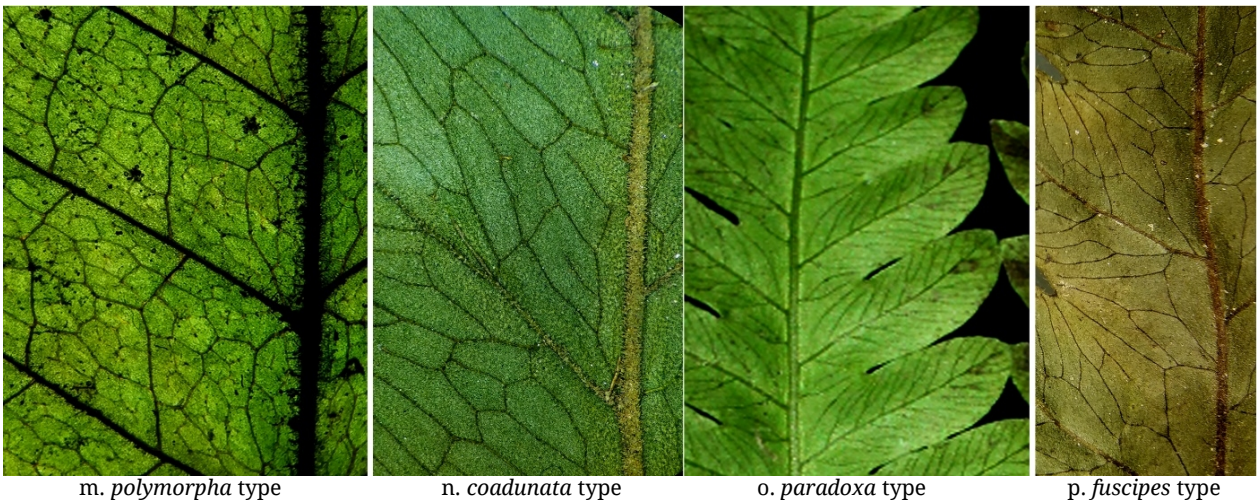


e. decurrens frond f. simple pinnate g. simple pinnate with lob h. densely hairy frond



i. bipinnate-pinnatisect j. *heterocarpa* type k. bi-pinnatifid l. tri-tetrapinnate

Fig. 1 (e–l): Different type of types of pinnae in the genus *Tectaria*



m. *polymorpha* type n. *coadunata* type o. *paradoxa* type p. *fuscipes* type

Fig. 1 (m–p): Different type of types of venation pattern in the genus *Tectaria*

T. gemmifera, T. impressa, T. paradoxa and *T. puberula*) or > tripinnate (*T. ingens*) (Fig. 1 e-l); lamina densely hairy on both side (*T. coadunata, T. puberula and T. multicaudata*), lamina hairy on lower side only (*T. pseudosiifolia*), lamina sparsely scaly both side (*T. fuscipes* and *T. impressa*), lamina glabrous (*T. griffithii, T. heterocarpa, T. wightii* and *T. vasta*); *veins* visible on lower side, they are *polymorpha type i.e.* anastomosing with branched included veinlets (*T. polymorpha, T. heterocarpa, T. pseudosiifolia* and *T. wightii*); *coadunata type i.e.* anastomosing without branched veinlets (*T. coadunata, T. chattagrammica, T. gemmifera, T. griffithii, T. multicaudata* and *T. puberula*) *paradoxa types veins i.e.* free veins (*T. paradoxa* and *T. ingens*) and *fuscipes type i.e.* free but areole along the costa and costule (*T. fuscipes* and *T. trimenii*) (Fig. 1 m-p); *sori* many, indusiate (*T. coadunata, T. fuscipes, T. ingens, T. paradoxa,*), exinduciate (*T. wightii*); *indusia* either persistent (*T. paradoxa*) or shaded (*T. polymorpha*); *spores* monolete or trilete. The treatment of tectaroid ferns has un-orthodoxically undergone several changes in their names time to time.

In India, about 35 species were reported by earlier workers (31,38,53,48) of which 24 species were accepted by Fraser-Jenkins *et al.* (52) (Table 1). On the basis of type of fronds, venation pattern, all the collected *Tectaria* species were categorised into 3-groups, *viz.*, Group I - polymorpha complex, Group II - coadunata complex, and Group III - paradoxa complex (Table 2).

The Group I - *polymorpha complex* includes the species which are having subdimorphic-dimorphic, simple pinnate, lobed or unlobed fronds, veins anastomosing forming areoles with branched veinlets. The species, *viz.*, *Tectaria decurrens, T. fauriei, T. herpetocaulos, T. heterocarpa, T. kehdingiana, T. melanocaulos T. polymorpha, T. pseudosiifolia, T. simonsii, T. wightii* and *T. vasta* are included in the Group I. The *coadunata complex* includes the species which are having monomorpic-subdimorphic or dimorphic, adnate, bipinnate to tetrapinnate fronds, vein anastomosing with included veinlets. The species, *viz.*, *Tectaria chattagrammica, T. coadunata, T. gemmifera, T. griffithii, T. impressa, T. multicaudata T. puberula, T. subconfluens* and *T. zeilanica*. are included in the Group II. The *paradoxa complex* includes the species which are having subdimorphic-dimorphic, bipinnate to bipinnatified fronds, veins free, with or without areoles at along the costa or costule and without included veinlets. The species, *viz., Tectaria fuscipes, Tectaria ingens, T. paradoxa* and *T. trimenii* are included in the Group III.

Diversity and distribution in India

On the basis of climate and ecology, India is divided into 10 biogeographic regions, *viz.*, Trans Himalaya (cold), Himalaya's (cold-moderate), North-East (cold-moderate), Gangatic plain (moderate-warm), Desert (hot), Semi-Arid (moderate-hot), Deccan Peninsula (moderate-warm), Western Ghats (cold-moderate), Indian Coasts (humid-warm), Andaman and Nicobar Islands (humid-warm). A sum total of 24 species were reported from India by Fraser-Jenkins *et al*. (2018). All these species were distributed in different bio-geographic regions of India (Table 1). They are either growing along the river, stream, water fall, or along the roadside, hilly slopes and cut edges. All the species were collected in between 200 – 1800 m. The majority of species (14 species) were found in Eastern Himalaya's (*Tectaria chattagrammica, T. coadunata, T. decurrens, T. fauriei, T. fuscipes, T. griffithii, T. heterocarpa, T. ingens, T. multicaudata, T. polymorpha, T. pseudosiifolia, T. simonsii, T. subconfluens* and *T. vasta*) followed by North-East region nestle 13 species (*T. chattagrammica, T. coadunata, T. decurrens, T. fauriei, T. fuscipes, T. griffithii, T. heterocarpa, T. impressa, T. ingens, T. polymorpha, T. simonsii*, *T. subconfluens* and *T. vasta*), Western Ghats having 09 species (*T. coadunata, T. fuscipes, T. gemmifera, T. paradoxa, T. polymorpha, T. puberula, T. trimenii, T. wightii,* and *T. zeilanica*) and Gangetic plains having 09 species (*Tectaria chattagrammica, T. coadunata*, *T. decurrens*, *T. fauriei*, *T. fuscipes*, *T. heterocarpa, T. impressa, T. polymorpha* and *T. simonsii*) whereas 1-5 species were collected from other biogeographic zones. However, none of the species were collected or reported from Desert. The most common species are *Tectaria coadunata, T. fuscipes* and *T. polymorpha* whereas other species are restricted to 1-3 biogeographic zones (Fig. 2). The species, *viz.*, *T. paradoxa, T. wightii* and *T. trimenii* are endemic to the Western Ghats and Sri Lanka. However, the species, *viz.*, *T. chattagrammica, T. fauriei, T. griffithii, T. heterocarpa, T. ingens, T. pseudosiifolia, T. simonsii, T. subconfluens* and *T. vasta* are restricted to either Eastern Himalaya's or North-East India, whereas the species, *viz.*, *T. paradoxa T. puberula, T. wightii* and *T. zeilanica* are restricted to Western Ghats and the species, *viz.*, *T. herpetocaulos, T. kehdingiana* and *T. melanocaulos* are restricted to Andaman and Nicobar Islands.

Anatomical studies

Though, anatomical studies on vascular cryptogams are carried out time to time by different pteridologists, anatomy of this group is relatively unexplored. The most primitive type of stele *i.e.* protostele is reported in Filicineae, and subsequently solenostelic and dictyostelic vascular systems gradually evolved from this primitive type of stele in rhizome (55). Rhizome, stipe and rachis of all tectarioid ferns possess dictyostelic vascular systems whereas in roots stele shows presence of protostele. Copeland (22) investigated anatomy

Table 1: *Tectaria* species with account on their identity, diversity and distribution studies from India

Species	Identity in India	Distribution	Reported by
Tectaria brachiata (Zoll. & Moritzi) C.V.Morton	Error for *T. impressa*	-	Fraser-Jenkins, (47)
T. chattagrammica (C.B.Clarke) Ching	Identity confirmed	Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram and Tripura	Fraser-Jenkins *et al*., (52)
T. cicutaria (L.) Copel.	Error for *T. coadunata*	-	Fraser-Jenkins (47)
T. coadunata (Wall. ex Hook. & Grev.) C. Chr.	Identity confirmed	Throughout India	Manickam and Irudayaraj (38); Singh & Panigrahi 53; Patil *et al*. (48); Fraser-Jenkins *et al*. (47)
T. decurrens (C.Presl) Copel.	Identity confirmed	Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Tamil Nadu and Tripura	Singh & Panigrahi (53); Fraser-Jenkins *et al*. (47)
T. dubia (C.B.Clarke & Baker) Ching	Syn. of *T. griffithii*	-	Fraser-Jenkins (47)
T. fauriei Tagawa	Identity confirmed	Arunachal Pradesh, Assam State, Meghalaya	Fraser-Jenkins *et al*. (52)
T. fuscipes (Wall. ex Bedd.) C.Chr	Identity confirmed	Arunachal Pradesh, Assam, Karnataka, Manipur, Mizoram, Meghalaya, Nagaland, Sikkim, Tripura and West Bengal	Singh & Panigrahi (53); Patil *et al*. (48); Fraser-Jenkins *et al*. (52)
T. gemmifera (Fee) Alston	Identity confirmed	Kerala, Tamil Nadu	Fraser-Jenkins *et al*. (52)
T. gigantea (Blume) Copel.	Syn. of *Heterogonium giganteum*	North-East India	Fraser-Jenkins (47)
T. griffithii (Baker) C. Chr.	Identity confirmed	Arunachal Pradesh, Assam, Meghalaya	Singh & Panigrahi (53); Fraser-Jenkins *et al*. (52)
T. herpetocaulos Holttum	Identity confirmed	Andaman & Nicobar Islands,	Fraser-Jenkins *et al*. (52)
T. heterocarpa (Baker) Ching,	Identity confirmed	Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, West Bengal	Singh & Panigrahi (53); Fraser-Jenkins *et al*. (52)
T. impressa (Fee) Holtum	Identity confirmed	Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, West Bengal	Fraser-Jenkins *et al*. (52)
T. ingens (Desv.) C.Chr.	Identity confirmed	Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland	Fraser-Jenkins *et al*. (52)
T. khonsaensis Sarn.Singh & Panigrahi	Syn. of *T. polymorpha*	North-East India	Fraser-Jenkins *et al*. (52)
T. kehdingiana (Kuhn) M.G. Price	Identity confirmed	Andaman & Nicobar Island	Fraser-Jenkins *et al*. (52)
T. macrocarpa (Bedd.) B.K.Nayar & Geev.	Syn. of *T. wightii*	-	Fraser-Jenkins *et al*. (52)
T. macrodonta C. Chr.	Syn. of *T. coadunata*	-	Fraser-Jenkins *et al*. (52)
T. mehrae Panigrahi & Sarn.Singh	Syn. of *T. multicaudata*	-	Fraser-Jenkins *et al*. (52)
T. melanocaulos (Blume) Copel.	Identity confirmed	Andaman & Nicobar Island	Fraser-Jenkins *et al*. (52)
T. multicaudata (C.B. Clarke) Ching	Identity confirmed	Arunachal Pradesh, Assam, Meghalaya, Sikkim	Fraser-Jenkins *et al*. (52)
T. pandurifola (C.Chr.) C.Chr.	Error for *T. heterocarpa*	North-East India	Fraser-Jenkins *et al*. (52)
T. paradoxa Sledge	Identity confirmed	Andhra Pradesh, Karnataka, Kerala, Tamil Nadu	Patil *et al*. (48); Fraser-Jenkins *et al*. (52)
T. polymorpha (Wall, ex Hook.) Copel.	Identity confirmed	Throughout India	Singh and Panigrahi (53); Patil *et al*. (48); Fraser-Jenkins *et al*. (52)
T. pseudosiifolia Fraser-Jenkins & Wangdi	Identity confirmed	Arunachal Pradesh	Fraser-Jenkins *et al*. (52)
T. puberula C.Chr.	Identity confirmed	Kerala	Antony *et al*. (49); Fraser-Jenkins *et al*. (52)
T. simonsii (Baker) Ching	Identity confirmed	Assam, Meghalaya, Nagaland, and Sikkim	Kholia (54); Fraser-Jenkins *et al*. (52)
T. subconfluens Ching	Identity confirmed	Arunachal Pradesh, Assam, Meghalaya	Singh and Panigrahi (53); Fraser-Jenkins *et al*. (52)
* *T. subtriphylla* (Hook. & Arn.) Copel.	Identity confirmed	Tamil Nadu	Fraser-Jenkins *et al*. (52)
T. trimenii C. Chr.	Identity confirmed	Kerala, Tamil Nadu	Fraser-Jenkins *et al*. (52)
T. variolosa (Wall. ex Hook.) C. Chr.	Syn. of *T. impressa*	-	Fraser-Jenkins *et al*. (52)
T. vasta (Blume) Copel.	Identity confirmed	Andaman & Nicobar Islands (Nicobars), Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura	Singh and Panigrahi (53); Fraser-Jenkins *et al*. (52)
T. wightii (C. B. Clarke) Ching	Identified taxon	Karnataka, Kerala and Tamil Nadu	Manickam and Irudayaraj (38); Patil *et al*. (48); Fraser-Jenkins *et al*. (52)
T. zeilanica (Houttuyn) Sledge	Identified taxon	Kerala and Tamil Nadu	Fraser-Jenkins *et al*. (52)

of the young sporophytes of several species of family Aspidiaceae. Subsequently, Holttum (23) studied anatomy of *Pleocnemia* and observed that vascular strands in stipe are abundant than that of *Tectaria*. *Pleocnemia* shows a single ring of small accessory strands along with additional large strands on the adaxial side. Rao and Khare (56) studied the anatomy of *Tectaria amplifolia* and observed the external ring or sclerotic ring of endodermis, which is an important character of tectarioid ferns. White (57) investigated the ontogenetic changes in stellar patters in young sporophytes of seven species of *Tectaria* and documented significance variations in the pattern of stele, which may help to resolve taxonomic problems in the Aspidiaceae.

Chandra and Kaur (58) elucidated vascular organization in the rhizome of ten species of *Tectaria* and noticed reduction in number of vascular strands and sclerenchyma cells in some species of *Tectaria*. According to them reduction of vascular strands in stele is an advanced character whereas presence of sclerenchyma strand is a primitive feature. Studies on venation pattern of many tectarioid ferns was carried by Salgado (59) and concluded that free vein pattern is probably representing a primitive feature from which much complex ones are evolved. According to him, complex included veinlets is the next step in the evolution of venation. The order and regularity in the arrangement of veins in *Pteridrys syrmatica* is more advance pattern. On the basis of anatomy of *T grandifolia*, Salgado and Valera (60) also determined that radially symmetrical dictyostele, orderly arrangement of venation, linear soral arrangements, monolete spores and perisporate condition of spores may be considered as advanced character. Mittal and Bir (61) studied anatomy of *Ctenitis apiciflora* and *C. nidus* from the members of the same family and observed large number of sclerotic nests in the ground tissue of both rhizome and petiole. Jadhav (62) investigated anatomy of some pteridophyte species which includes *T. coadunata*. Ding *et al*. (63) in studied phylogeny and character evolution of the fern genus *Tectaria* in the Old-World species and analysed the venation pattern. They proposed 4 types of venation pattern in *Tectaria, viz.*, fully free (or occasionally connected), partly free (forming costal and costular areoles, with few additional areoles without included veinlets), partly anastomosing (forming costal and costular areoles, with many additional areoles, but areoles lack of included veinlets) and fully anastomosing with free veinlets in nearly all areoles. In the genus *Tectaria* type of stele is dictyostele (observed in the rhizome, stipe and rachis) and protostele (observed in roots). As far as anatomical studies are concerned, only few species are investigated world-wide. However, in India, anatomy of a single species *i.e. T. coadunata* is studied while similar information on rest of the 23 species is lacking (Table 3). Therefore, there is an urgent need to study the anatomy of *Tectaria* species from India.

Cytological studies

Chromosome numbers is one of the important diagnostic features of cyto-taxonomy and is extensively used for species identity including delimitation of the taxa but chromosome data for all the species are not available. In pteridology, cytological studies are not thoroughly conducted because of poorly established methodology and existence of polyploidy. However, the studies are upsurge after the publication by Manton (64) "*Problems of Cytology and evolution in the Pteridophytes*". The cytological studied from Indian subcontinents possess both diploid apogamous and triploid apogamous. The diploid apogamous is well distributed in Himalaya's (65–68). The basic chromosome number of genus *Lastreopsis* is n=40 (69), which is similar to the genus *Ctenitis*. The cytological studies were carried out on variations in the number of chromosomes on the basis of different taxonomic groups, regions with different climate, geology, other environmental and historical factors (70-71). Evolution in many ferns involves changes in ploidy level and reproductive system. Ploidy and reproductive system are also involved in the biogeography of ferns (72,73,74). Cytology of family Aspidiaceae from South India was carried out by Bhavnandan (75) and reported chromosome number of *Tectaria* is 2n=40, 2n=80 and 2n=200. Khare (76) published a note on the chromosome number of the fern flora of Amarkantak Hills, Central India. Cytology of different *Tectaria* species was carried out (3) and stated that mostly *Tectaria* having diploids with n=40 or tetraploids with n=80. Khare and Kaur (77) reported a new cytotypes of *Pteris vittata* from Lucknow (Uttar Pradesh, India). Irudayaraj & Manickam (78) studied the cytology of some pteridophytes of Western Ghats and reported basic chromosome number n=41 for *T. paradoxa* and *T. wightii*. Cytotaxonomic study of ferns from Yunnan (China) was studied (79) and reported the chromosome number of *T. fuscipes* (n=80). Karyomorphological studies on three Indian species of *Tectaria, viz., Tectaria fuscipes, T. macrodonta* and *T. polymorpha* have studied (80) and reported that all the three species are diploids and the basic chromosome number is n=40. Irudayaraj *et al*. (81) studied the intraspecific variation in South India ferns and rediscovery of the rare diploid cytotype of *Christella parasitica* (Thelypteridaceae: Pteridophyte). Bir and Varma (82) published a chromosome atlas of the Indian pteridophytes (included many *Tecteria* species). According to them cytological data played a significant role in the identity and phylogenetic affinities of several species and genera of ferns (82). Zhao and Dang (83) described a new hybrid of *Tectaria* (Tectariaceae) from Southern China.

Table 2: Groups of *Tectaria* based on morphological characters

***Polymorpha* complex**	*Tectaria decurrens, T. fauriei, T. herpetocaulos, T. heterocarpa, T. kehdingiana, T. melanocaulos T. polymorpha, T. pseudosiifolia, T. simonsii, T. wightii* and *T. vasta*.
***Coadunata* complex**	*Tectaria chattagrammica, T. coadunata, T. gemmifera, T. griffithii, T. impressa, T. multicaudata T. puberula, T. subconfluens* and *T. zeilanica*.
***Paradoxa* complex**	*Tectaria fuscipes, T. ingens, T. paradoxa* and *T. trimenii*.

Table 3: *Tectaria* species with account on anatomy, cytology and palynology from India

Species	Anatomical Studies	Chromosome Data	Palynology
T. chattagrammica (C.B.Clarke) Ching	Not yet studied	Not yet studied	Not yet studied
T. coadunata (Wall. ex Hook. & Grev.) C. Chr.	Studied (11)	*n*= 40 & 41 (82)	Studied (87)
T. decurrens (C.Presl) Copel.	Not yet studied	*n*=40 II	Not yet studied
T. fauriei Tagawa	Not yet studied	*n*= 40 III	Not yet studied
T. fuscipes (Wall. ex Bedd.) C.Chr	Not yet studied	*n*= 40; *2n*=80 (88)	Studied (87)
T. gemmifera (Fee) Alston	Not yet studied	*n* = 41 (86)	Studied (89)
T. griffithii (Baker) C. Chr.	Not yet studied	*n*= 40 (90)	Not yet studied
T. herpetocaulos Holttum	Not yet studied	Not yet studied	Not yet studied
T. heterocarpa (Baker) Ching,	Not yet studied	Not yet studied	Not yet studied
T. impressa (Fee) Holtum	Not yet studied	*n*= 78 (90)	Studied (87)
T. ingens (Desv.) C.Chr.	Not yet studied	Not yet studied	Not yet studied
T. kehdingiana (Kuhn) M.G. Price	Not yet studied	Not yet studied	Not yet studied
T. melanocaulos (Blume) Copel.	Not yet studied	Not yet studied	Not yet studied
T. multicaudata (C.B. Clarke) Ching	Not yet studied	Not yet studied	Not yet studied
T. paradoxa Sledge	Not yet studied	*n*= 40 & 80 (78)	Not yet Studied
T. polymorpha (Wall, ex Hook.) Copel.	Not yet studied	*n*= 40, 41 & 80 *2n*=80 (88)	Studied (87)
T. pseudosiifolia Fraser-Jenkins & Wangdi	Not yet studied	Not yet studied	Not yet studied
T. puberula C.Chr.	Not yet studied	Not yet studied	Not yet studied
T. simonsii (Baker) Ching	Not yet studied	*n*=78 (90)	Not yet studied
T. subconfluens Ching	Not yet studied	Not yet studied	Not yet studied
T. trimenii C. Chr.	Not yet studied	Not yet studied	Not yet studied
T. vasta (Blume) Copel.	Not yet studied	n=78 (90)	Not yet studied
T. wightii (C. B. Clarke) Ching	Not yet studied	*n* = 41 (78,88,86)	Studied (89)
T. zeilanica (Houttuyn) Sledge	Not yet studied	Not yet studied	Not yet studied

Vijaykant and Sathish (85-86) studied cytology of some pteridophytes from Kolli Hills. Recently, Vijaykant *et al*. (86) studied the cytology of ferns (including *T. gemmifera* and *T. wightii*) from Kolli Hills, Eastern Ghats, Tamil Nadu, India.

Amongst the 24 species of *Tectaria*, cytology of 12 species (half of reported species) were studied (Table 3). There are many species yet to be studied the cytology. The basic chromosome number of genus *Tectaria* is 40 & 41.

Palynological studies

Palynological studies are taxonomical markers in presuming phylogenetic relationship amongst species. Spores are the essential genetic material for sexual reproduction of vascular cryptogams. In vascular cryptogams, two types of spore are recognized, *viz*., monolete and trilete. Monolete spores are bilaterally symmetrical (mostly ellipsoidal) with a linear aperture whereas trilete spores are radially symmetrical with a triradiate aperture. The monumental work on spores and pollen morphology was carried out by Erdtman's (91-93). After this publication in palynological studies on different groups of vascular plants increased significantly. Spore morphology of ferns was carried out by Brown (94). Nayar and Devi (87) investigated the spore morphology of twelve species of *Tectaria* and a single species of *Ctenitis*. According to them, all spores of Tectariod ferns are monolete, bilateral and perisporate. Rao & Khare (64) studies the spores of *Tectaria amplifolia*. An importance of spore study in fern taxonomy

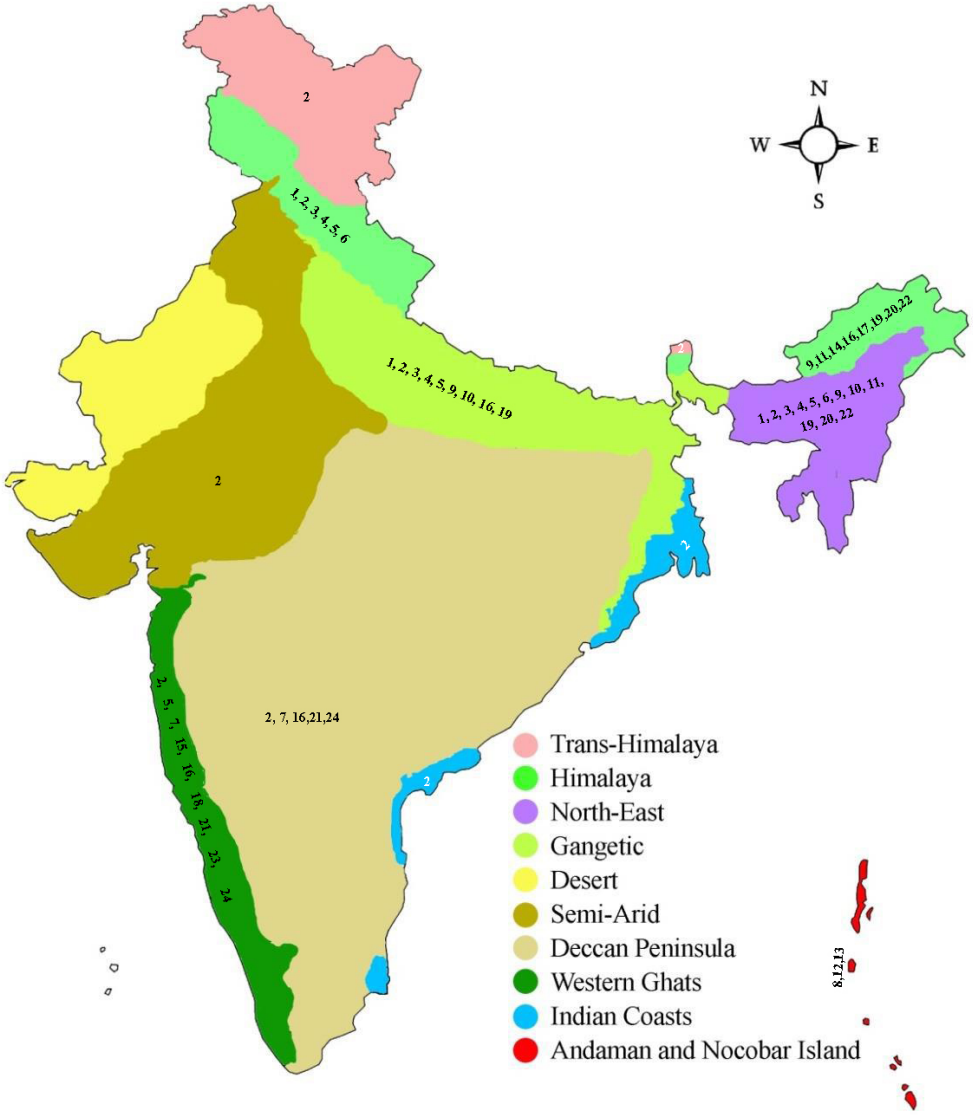


Fig. 2: 1. *Tectaria chattagrammica,* 2. *T. coadunata,* 3. *T. decurrens*, 4. *T. fauriei*, 5. *T. fuscipes,* 6. *T. griffithii*, 7. *T. gemmifera,* 8. *T. herpetocaulos*, 9. *T. heterocarpa,* 10. *T. impressa,* 11. *T. ingens*, 12. *T. kehdingiana,* 13. *T. melanocaulos*, 14. *T. multicaudata,* 15. *T. paradoxa,* 16. *T. polymorpha,* 17. *T. pseudosiifolia,* 18. *T. puberula,* 19. *T. simonsii,* 20. *T. subconfluens,* 21. *T. trimenii,* 22. *T. vasta,* 23. *T. wightii,* 24. *T. zeilanica*

has been stressed by a number of authors and to name Bir (95), Verma (96) Nayar and Devi (87). Devi (97) gave an account of the pteridophytic spores with respect to morphological, aerobiological, environmental and biochemical aspects. The spore of tectaroid ferns through SEM was studied by Holttum (98,99) and concluded that external form of *Tectaria* spore closely resemble with *Ctenitis* and *Heterogonium*. The comparative spore morphology of *T. coudanata* and *T. periya* was studied by Nayar & Geevarghese (100). Moy (102) studied the spore-morphology of five species *Tectaria* and *Ctenitis* through SEM (Scanning Electronic Microscopy) and TEM (Transmission electron microscopy). According to him (102) *Tectaria* and *Oleandra* spores are having a close resemblance with each other. Sharma & Sharma (103) also studied the spores of Indian species *i.e. Tectaria coadunata*. Holttum & Lin (104) studied the spores of *Pseudotectaria decaryana* using SEM and showed that the later species is different from those of *Tectaria* while it closely looks similar with *Ctenitis* and *Dryopsis*. Tryon and Lugardon (105) studied spores of tectaroid ferns, *viz.*, *Tectaria, Ctenitis, Dryopsis, Pteridrys* and *Pleocnemia* using SEM and TEM and provided a detailed idea about the spore ornamentation. Palynology data is very useful for taxonomic purposes at all levels of fern families and below it (106). Chen (107) studied the spore morphology of dryopteridae ferns and observed that the echinulated ornamentation of spores found in *Tectaria* and *Dryopsis* were quite different from each other. This result supported that Dryopteridoid ferns are different from Tectarioid ferns. However, *Lastreopsis* have similar spore ornamentation with genera in Dryoterideae. The characters of the spores suggest that they possess an important phylogenic value at the species level particularly in ornamentation and structure of the perispores (108). Palynology of eleven species of the genus *Tectaria* Cav. (Tectariaceae-Polypodiaceae) has been carried out (109). According to them, all species are having ellipsoidal, monolete spores and their size ranges in between 25-53µm. The biggest spore was observed in *T. transiens*. Vijayakanth *et al.* (89)

studied the palynomorphic studies on the pteridophytes (including the species *Tectaria wightii*) of Kolli Hills, Eastern Ghats, Tamil Nadu. The spores of all *Tectaria* species are having different surface patterns, *viz.*, reticulate, granulose, verrucate, psilate, rugulate, cristate, echinate, tuberculate with different shapes such as tetrahedral, globose, ellipsoidal and spherical.

Amongst the 24 species of *Tectaria*, spore morphology (SEM) of 06 species were studied (Table 3). There are many species yet to be studied the spore morphology.

Molecular studies

Recent molecular studies assimilating *Tectaria* have significantly enhanced our knowledge of its limitation and phylogeny. Plastid data have supported the inclusion of *Cionidium, Ctenitopsis, Dictyoxiphium, Fadyenia, Hemigramma, Heterogonium, Podopeltis, Psomiocarpa, Quercifilix,* and *Stenosemia* in *Tectaria* (107,110-114). Ding *et al.* (63) have studied the relations within the *Tectaria* with emphasizes on the Old-World species. They used plastid data of 76 accessions of ca. 53 species from China and Philippine (Old World) and 04 accessions representing ca. 04 species from the New World. Subsequently, Zhang *et al.* (115) analysed both the plastid and nuclear data of 23 accessions representing only 17 species of *Tectaria* and drawn a phylogeny of Tectariaceae. A Classification of the fern genus *Tectaria* (Tectariaceae: Polypodiales) based on molecular and morphological evidence is proposed by Zhang and Zhang (116). As far as India is concerned no reports are available on molecular aspects of Indian species.

Barcode of Life Data Systems (BOLD) is a web-based workbench and database supporting the acquisition, storage, analysis, and publication of DNA barcode records. It also has a provision to provide field photographs, herbarium specimen photographs and nucleotide sequence of the plant submitted for comparison of closely related or unidentified plant taxa. DNA barcoding is a method to achieve accurate and rapid species identification by using short and standard DNA regions (117). Hence, there is an urgent need to analyze Indian *Tectaria* species at molecular level and produce the barcode for each species.

Conclusion

The review of literature signifies that no much attention is paid on anatomy, cytology, palynology and molecular systematics of *Tectaria* from the different regions of the World including Indian species of *Tectaria.* Therefore, there is an urgent need to understand the diversity, taxonomy, anatomy, cytology, palynology and molecular studies on this genus from India as well as the world.

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Competing Interests

The authors have no conflict of interests.

Authors' contribution

SMP and RNK collected the specimens from the field and wrote the initial draft of the manuscript, KSR corrected the MS and made grammatical corrections. All the authors approved the final manuscript.

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