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COMMUNICATION

Stypopodium Kütz. - a new generic record for India from the Bay of Bengal

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Abstract: The study highlights the first-ever documentation of the genus *Stypopodium* along the Indian coastline, specifically in Andhra Pradesh. Previously reported in various Indian Ocean regions but not in India, this discovery fills a significant gap in understanding its distribution. The species *Stypopodium zonale* is thoroughly examined, including its physical characteristics, microscopic features, habitats, distribution, and taxonomic notes, complemented by accompanying photo plates. Additionally, the proposal of a lectotype for heterotypic synonyms, namely *Fucus zonalis*, *Zonaria lobata*, and *Zonaria fuliginosa* is presented.

Keywords: Andhra Pradesh, Dictyotaceae, generic report, phaeoplast, *Stypopodium zonale,* taxonomic conflicts, typification.

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Author contributions: YASK—contribution towards the field survey, collection, preservation, identification of the specimens and consultation of herbaria; development of research concept and manuscript preparation. MP—contribution towards the field survey; supervision of research, identification of the specimen, supervision of research, and finalization of the manuscript. SV—assisted with the survey and collection of the specimens.

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INTRODUCTION

Dictyotales is a unique group characterized by their exclusive morphological characters such as erect or prostrate, flattened, dichotomously branched, or flabby thallus with numerous phaeoplasts, without pyrenoids and exhibit isomorphic diplohaplophase life cycle. Presently, this order embraces a single family Dictyotaceae with 349 taxa belonging to 27 genera (Guiry & Guiry 2022). *Dictyopteris, Dictyota*, *Lobophora*, *Stoechospermum, Stypopodium,* and *Zonaria* of this family are referred to be the dominant components of the phytobenthos. In view of the generic composition of the family Dictyotaceae, *Lobophora*, *Padina*, *Stoechospermum*, *Stypopodium* and *Zonaria* are the analogous genera that possess strong morphological similarity (De Clerck et al. 2006).

The genus *Stypopodium* is a pervasive group of algae spread over tropical and temperate regions. This genus is characterized by strongly lacerated or clefted flabellate thallus, bands of hyaline filaments (pheophytic hairs), cells on the margins of the thallus; parenchymal structure with abundant phaeoplasts in cortical cells with several epidermal cells; sporangia with four spores and lack of paraphyses on sporangia sori (Misra 1996; Abbas & Shameel 2014). This genus was established by Kützing (1843) with 3 species viz., *Stypopodium fuliginosum*, *S. flavum* and *S. atomaria*. The species constitution of this genus had many controversies regarding their identity with other similar genera (Mayhoub & Billard 1991). The distinctness of this genus was initially not accepted by Borgesen (1914), Howe (1918), Taylor (1985), Allender and Kraft (1983), and this genus was placed under the genera *Padina* and *Zonaria*. Later, the exclusive characters of this genus were examined and taxonomically validated by Weber-van (1913), Papenfuss (1940, 1977); Nizamuddin & Aisha (1991).

A sum of 19 infraspecific binomials was proposed and 8 taxa were accepted taxonomically (Guiry & Guiry 2022). The occurrence of this genus in the Indian Ocean was reported from Kenya, Madagascar, Pakistan, Singapore, South Africa, Sri Lanka, and Tanzania, except for the coastline of India (Abbas & Shameel 2014). The existence of this genus was not reported from the shoreline of India. But, Misra (1996) has included *Stypopodium zonale* in his Phaeophyceae in India without referring to any specimen. Later, Silva et al. (1996); Oza & Zaidi (2001); Krishnamurthy & Ezhili (2013) included this species in the algae flora of India based on Misra's report. Thorough literature indicates that earlier workers specified this genus without proper details on the type, occurrence, taxonomic treatments, specimen examinations, etc.

Stypopodium zonale was collected for the first time from the coastline of India, during the field explorations of the Appughar coastline, Andhra Pradesh (Image 1). The collected samples exhibit unique characteristics resembling known genera such as *Padina, Lobophora, Stoechospermum, Stypopodium*, and *Zonaria* within the family Dictyotaceae. Preservation followed standard methodologies of Wet Preservation (Liquid preservation) and Dry Preservation (Herbarium), as outlined by Srinivasan (1969). To ensure accurate species identification, both external and internal morphology of specimens were examined using optical microscopes (Nikon Eclipse 50i; Carl Zeiss. Axio Lab. A1) equipped with a computer-attached DSLR camera. Selected herborized specimens underwent Scanning Electron Microscope (SEM) analysis following standard protocols of Carl Zeiss (Model No: Evo 18). Reference sources consulted include contributions by Agardh (1824), Martius (1828), Kützing (1843), Howe (1918), Mayhoub & Billard (1991), Lamouroux (1805, 1809), Papenfuss (1940, 1977), Nizamuddin and Aisha (1996). Additionally, herbarium specimens housed at CAL, BSIS, Kolkata; MH, Coimbatore; and NFMAH, Mandapam, Ramanathapuram were consulted, along with specimen images from Digital Herbaria of Paris Museum (P); British Museum (BM); Kew (K); Muséum National d'Histoire Naturelle (MNHN); The National Herbarium of Victoria (MEL); and New York Botanical Garden (NY). Further systematic details on *Stypopodium zonale* are enumerated as follows:

Taxonomic Treatment: *Stypopodium zonale* (J.V.Lamour.) Papenf.,

Bot. Not.205. 1940. *Zonaria zonalis* (J.V.Lamour.) Howe, Fl. Bermuda. 507. *Fucus zonalis* J.V.Lamour., Diss. Fucus., 38. 1805.

Type: Haiti, Saint Domingue (in Sancti-Dominici insulæ oris habitat), *Lamouroux* (1805: pl. 25, fig.1!) *Lectotype is* designated here.

Stypopodium lobatum (C.Agardh) Kütz. Tab. Phyc. 25. 1859.

Zonaria lobata C.Agardh, Syst. Alg. 265.1824.

Type: Mari Atlantico, Teneriffam, s.d., *s.col.*, *48220,* (NY [02136680, digital image!]); Residual syntype: Mari Atlantico, Teneriffam, s.d., *s.col.*, *48222* (n.v.) *Lectotype is* designated here.

Stypopodium fuliginosum (C.Martius) Kütz. Phycol. General.341. 1843.

Zonaria fuliginosa C.Martius, Icon. Pl. Crypt.16. 1828.

Type: Brazil, In litore Brasiliae, Cabo Frio s.d.,

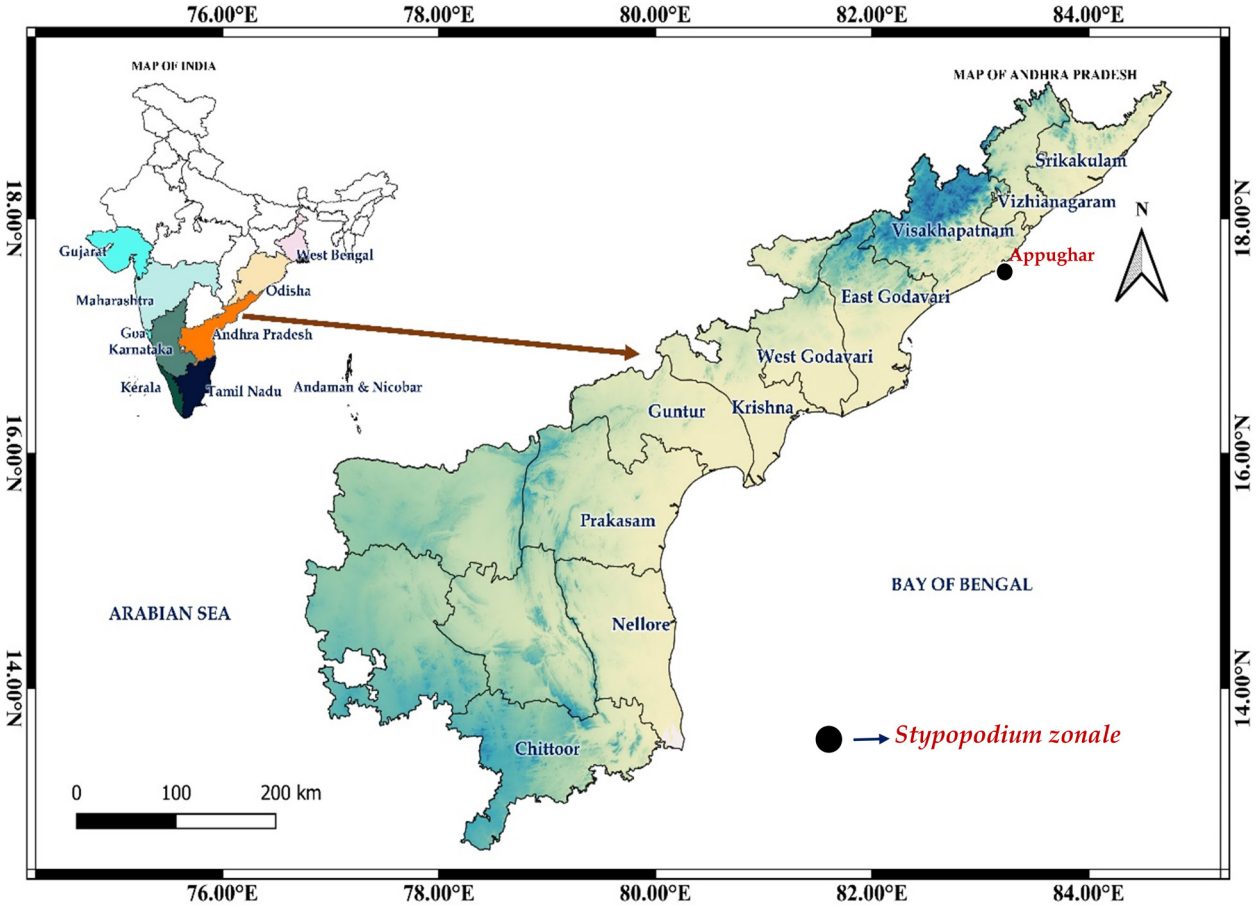

Image 1. Coastline of Andhra Pradesh with the collection locality of *Stypopodium zonale*

C.F.P.Martius, s.n. (MEL [MEL537302, digital image!]); Residual syntype: Brasilia, s.d., *s.cl.* s.n. (MEL [MEL537303, digital image!] *Lectotype is* designated here

Habit: Thalli erect or prostrate, tawny to dark brown, fine to membranous or slightly coriaceous, flabellate with broad blades. Solitary or clustered patches forming groups of 3–10 individual blades, 4–11 cm in height, 8–5 cm in broad, lacerated or clefted with cuneate bases. Thallus differentiated into rhizoidal-shaped holdfast, compressed or flattened stipe (sometimes reduced), and flabellate blades (Image 2. a–d); The thallus is transversely zoned with concentric rows of hairs on both surfaces in regular intervals of 2.5–16 mm (Image 2. f & g). Holdfast rhizoidal or disc-shaped, firmly attached on the substratum, 5–8 mm in diameter. Stipe flatted or reduced, erect, 10–18 mm long. Blades flabellate, broadly obtuse at apex, attenuate at base, 3–9 x 3.5–4.3 cm, entire to undulate at the margin (Image 2. e). Generative assemblies are scattered throughout the dorsal surface of the thalli (Image 2. k).

Microscopic observation: The surface view of the cells variously sized, slightly squarish or rectangular, elongated in vertical rows, dark brown, 15–28 x 5–12 µm (Image 2. l). Hair bands present on both surfaces, hairs filamentous, uniseriate, 2–4 celled, subcylindrical to cylindrical, 14–17 x 80–120 µm (Image 2. j & m). The upper apical zone consists of 3–6 layers of cells, outer and inner peripheral cells squarish, thin-walled with dense phaeoplasts (Image 2. o), 6–13 x 8–14 µm; cortical cells 2–3 layers, thick-walled, quite larger, elongated with intercellular spaces arranged in regular tiers, 18–37 x 18–26 µm (Image 2. n). The middle portion contains 2–7 layers, cells in a peripheral region are small, thin-walled cubical to quadrate or squarish, 12–19 µm x 13–21 µm; the cortical region consists of 2–4 layers, cells large, thick-walled with intercellular spaces (Image 2. i). The basal zone consists of 4–9 layers; cells in upper and lower peripheral regions, small, thin-walled, squarish, 13–23 x 12–26 µm; the cortical cells thick-walled, slightly elongated, intercellular spaces, 31–35 x 25–29 µm (Image 2. h & o). Numerous groups of dark brown sporangia were observed on both surfaces of the thallus, sessile, lightly rounded or oval, 40–54 µm in

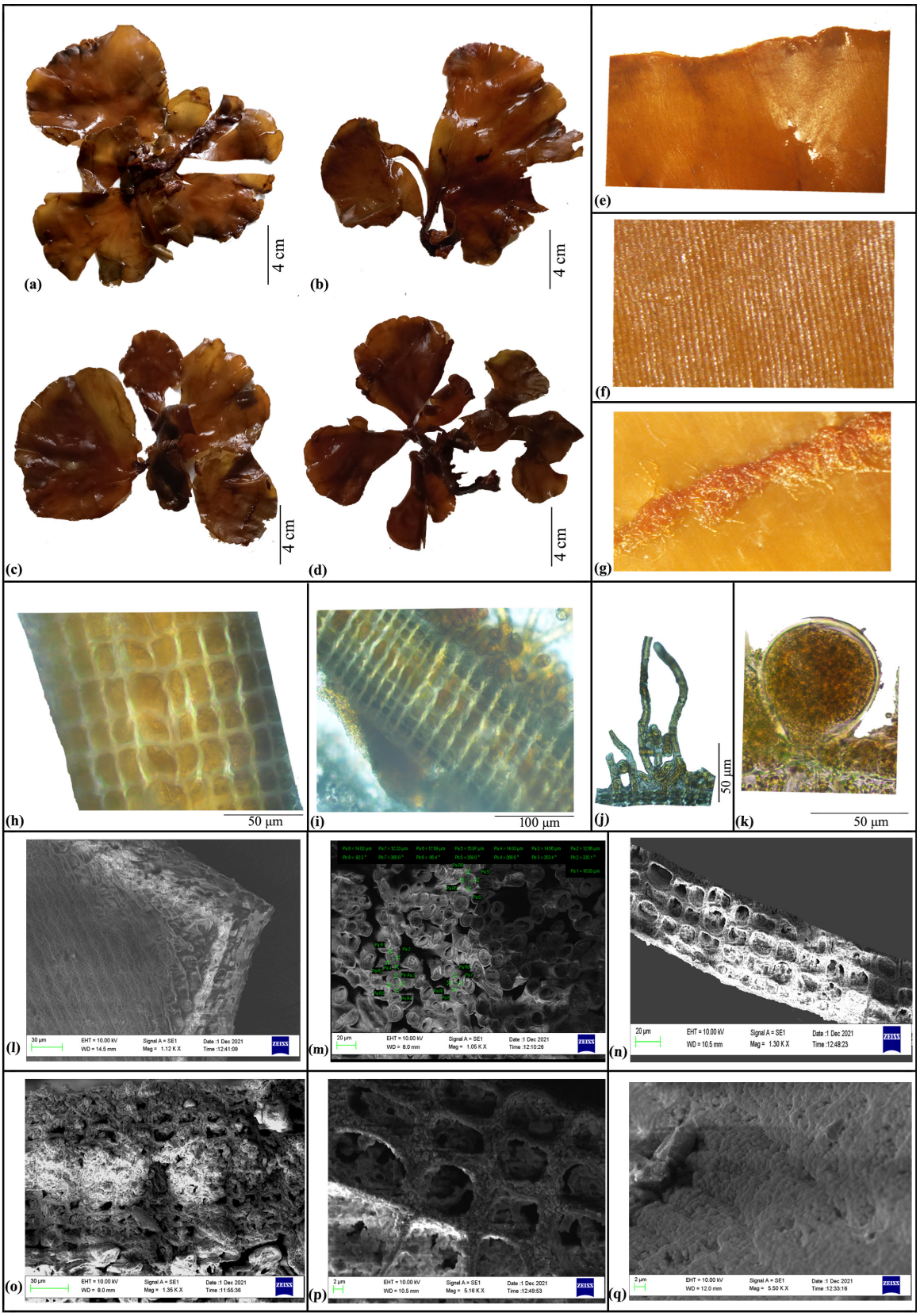

Image 2. a–d—Morphological variations on thallus of *S. zonale*; e, Entire to Undulate margin | f & g—Surface view of the thallus with phaeophytic hairs | h & i—C.S. of basal and middle portion *S. zonale* | j & k—Phaeophytic hairs and immature sporangium | l—Surface view of thallus | m & n—Cross section of phaeophytic hairs and middle portion | o & p—Abundance of phenoplasts and cubic to squarish shaped cortical cells | q—Granular to globular texture of thallus on surface view under SEM.

diameter; each sporangia has four spores.

Habitat: Moderately growing at intertidal and shallow water zones of Appughar on the rocky substrate at depths of 0.8–1 m during pre-monsoon seasons. This species has a communal association with *Amphiroa fragilissima* (L.) J.V.Lamour., and *Jania rubens* (L.) J.V.Lamour.

Distribution: Africa, Caribbean Islands, China, Ghana, Indonesia, Islands of Australia & and New Zealand, Islands of the Atlantic Ocean, Japan, Pacific Islands, Pakistan, Philippines, Sri Lanka, Spain, South America, Western Atlantic, and India (Andhra Pradesh).

Specimen Examined: INDIA: Andhra Pradesh, Visakhapatnam, Appughar, 17°44'26.8»N 83°20'42.1»E, 23 March 2017, *Palanisamy M & Aron Santhosh Kumar Y 137233* (MH).

Note: The epithets *Fucus zonalis* J.V.Lamour., *Dictyota zonata* Lamour., *Zonaria zonalis* (J.V.Lamour.) Howe (1918), *Zonaria lobata* C.Agardh, *Stypopodium lobatum* (C.Agardh) Kütz., *Zonaria fuliginosa* C.Martius and *Stypopodium fuliginosum* (C.Martius) Kütz. are currently regarded as a synonym of *Stypopodium zonale* (J.V.Lamour.) Papenfuss (1977) due to the morphological orientation. In the protologue of *Fucus zonalis*, it is stated that the specimen was collected from the coastline of Saint Domingue and did not specify the type details of this species (Lamouroux, 1805). Later, this transferred as *Dityota zonata* and mentioned the collection locality from Antillis by Lamoroux (1809) which was the heterotypic locality of *F. zonalis*. The collections of the *D. zonata* from Caen (CN) herbarium were examined by Mayhoub and Billard (1991) and they denoted *D. zonata* as the type specimen of the epithet *F. zonalis.* But their proposal was ambiguous since both the specimens were collected from different localities as per the protologues of Lamouroux. Hence, the illustration (1805: pl. 25, fig.1!) mentioned in the protologue of *F. zonalis* is designated here as lectotype based on articles, 9.3 of the International Code of Nomenclature for algae, fungi, and plants (Turland et al. 2018).

Syntypes of *Zonaria lobata* (Nos. 48220 and 48222) from Teneriffam of Mari Atlantico were deposited in LD (Herbarium Agardh). Now, the photograph of *Z. lobata* (Nos. 48220) is maintained in NY (02136680, digital image!) detailed with habitat (Teneriffam). On the other hand, the specimen Nos. 4822.20 was not spotted or traceable in any of the herbaria anywhere. Therefore, No. 48220 (02136680, digital image!) could be the type specimen of *Z. lobata* as per the protologue furnished by Agardh (1824). Likewise, *Zonaria fuliginosa* was proposed by Martius (1828) typified from the coastline of Brazil (In litore Brasiliae); later, it was placed under the genus *Stypopodium* and synonymised to *S. fuliginosum* by Kützing (1843). The type of the species epithet *Z. fuliginosa* was indistinct. The collection deposited in MEL contains two specimens (MEL537302 & MEL537303, digital image!) collected from Brazil. The specimen MEL537302 was annotated with the proper details of *Z. fuliginosa* with collector's name (Martius), Habitat (In litore Brasiliae), and without collection number pencilled by Sonder. But the specimen MEL537303 was not specified in detail except on habitat. Therefore, specimen MEL537302 could be the type specimen of *Z. fuliginosa* as per the prologue proposed by Martius (1828). Hence, the lectotype of *Z. fuliginosa* and *Z. lobata* is designated here based on articles, 9.1, 9.2, and 9.3 of the International Code of Nomenclature for algae, fungi, and plants (Turland et al. 2018).

Significance: The lipophilic extract of this species produces an atomaric acid with anti-Leishmania amazonensis activities (Soares et al. 2016). Also, the compound Stypoldione inhibits microtubule polymerization and sperm motility (Pal et al. 2014).

DISCUSSION

The species *Stypopodium zonale* of Dictyotaceae (Dictyotales) under the class Phaeophyceae has morphological affinities among the other species of this same genus and with other genera of this same family (Shameel 2012). The distribution of this species has been documented worldwide, covering the Indian Ocean from Pakistan to South Africa (Abbas & Shameel 2014). However, the occurrence of *S. zonale* from the Indian Ocean has a lacuna on the species' identity and needs to be inspected in view of Verlaque & Boudouresque (1991) and Silva et al (1996). In this present study, the gross morphological characters (Image 2. a–q), such as the surface view of the cells (squarish or rectangular), hair bands (filamentous and uniseriate), cortical cells (2–3 layers), with intercellular space (18–37 x 18–26 µm), cells in middle portion (cubical to quadrate or squarish) and sporangia (sessile with 4 spores) were observed to limelight the presence of this species from India.

The thallus of the species is erect or prostrate thalli with strong laceration and transversely zoned by bands of pheophytic hairs on both sides of the thallus. Also, concentric rows were found on both thallus surfaces in regular intervals. Blades flabellate, broadly obtuse at the apex, attenuate at the base with undulate. The layers of cells in the thallus show great variation in their position;

the upper apical zone with 3–6 layers of cells (squarish), the middle portion with 2–7 layers (cubical to quadrate or squarish), the basal zone with 4–9 layers (squarish) with intercellular spaces. Also, it contains groups of dark brown rounded or oval-shaped sessile sporangia (four spores) on both thallus surfaces. The observation from this study shows minor variations from the specimens of Nizamuddin & Perveen (1986) and Nizamuddin & Aisha (1996) from Pakistan. However, the morphological characteristics found in the specimens from India agree with those previously carried out in Atlantic localities (Taylor 1960; Verlaque & Boudouresque 1991; Dawes & Mathieson 2008) and Pakistan specimens (Abbas & Shameel 2014). Also, the observation of the present study is confined to the protologue of the type species (Lamouroux 1805).

CONCLUSION

In India, the occurrence of *Stypopodium zonale* was not validated with the collection of this specimen. Its occurrence on the Indian coastline has been considered for a long time due to the report of Misra (1996). But in the present study, the ascertaining features of this species were clarified and discussed in detail by obtaining the gross morphology and anatomy of the species. The present study deals with the taxonomically significant features to resolve the uncertainty regarding the identity of S. *zonale* distributed in India. The outcomes of the present attempt furnished the type details, habit, habitat, and specimens examined and significant notes on the erroneous reference cited by various authors. Also, the lectotypification of 3 binomials (*Zonaria zonalis, Z. lobate,* and *Z. fuliginosa*) was designated here in favor of articles 9.3 of the International Code of Nomenclature for algae, fungi, and plants (Turland et al. 2018). For many species of the genus *Stypopodium* no data are available on recent morphological studies towards the difficulties on the distinctive characteristics of each species. Hence, it is necessary to attempt morphological and molecular phases to establish the boundaries between species. Additionally, our present study highlights the morphological and microscopic features that provide more precise credentials and clarification to the taxonomic conflicts of *Stypopodium zonale* from India.

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