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Short communication

Micromorphological study of Cyperaceae flora from southwestern Nepal

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Abstract

The value of micromorphological characters as a practical guide for the taxonomic study of the members of the family Cyperaceae is indisputable. The arrangement of glumes, style structure, and nutlet characteristics of 9 genera and 46 species of the family Cyperaceae collected from the Kanchanpur District, in the southwestern Tarai region of Nepal were investigated using a stereo zoom microscope to ascertain the taxonomic utility of these characters in differentiating closely related genera and species. The studied taxa included representatives of the genera *Actinoscirpus* (Ohwi) R.W.Haines & Lye, *Bolboschoenus* (Asch.) Palla, *Bulbostylis* Kunth, *Carex* L., *Cyperus* L., *Eleocharis* R.Br., *Fimbristylis* Vahl, *Schoenoplectiella* Lye, and *Scleria* P.J.Bergius. Among the micromorphological characters, the nutlets displayed considerable diversity in shape, size, color, and surface features, making these characters valuable for delimiting taxa within the family Cyperaceae. This study highlights the significance of nutlet morphology as a powerful tool in Cyperaceae taxonomy, emphasizing its value in supporting systematic research. The diversity of nutlet characteristics among the studied taxa is illustrated with detailed photographs taken during the study.

Keywords: Cyperaceae, nut morphology, Flora, Nepal.

Introduction

Cyperaceae, commonly known as the sedge family, is the third largest monocot family after Orchidaceae and Poaceae with *c.* 95 genera and *c.* 5,600 species (Larridon *et al.* 2021; POWO 2024). The family has a cosmopolitan distribution and predominantly comprises perennial or annual herbs (Goetghebeur 1998; Dai *et al.* 2010). Species in this family are especially abundant in damp, wet, or marshy habitats.

Due to their highly reduced floral and fruit structures, and considerably uniform morphology of vegetative organs, delimitation of the members of the family Cyperaceae is often challenging (Schuyler 1971). In sedges, nutlet (achene) morphology shows considerable variation in color, size, shape, ornamentation, and epidermal sculpturing, these traits, therefore, provide useful taxonomic information for species delimitation and classification within Cyperaceae. The surface of the nutlets can be smooth or display various ornamentations, including pitted, zonate, trabeculate, verrucose, puncticulate, or tessellate patterns (Patil and Prasad 2016). With advancements in scanning electron microscopy, sedge taxonomists have naturally expanded their study to include micromorphological features of achenes to support the macromorphological data and potentially resolve systematic questions (Menapace *et al.* 2003). Classification of various Cyperaceae taxa has been effectively supported through a detailed examination of achene characteristics (Menapace 1991).

In Nepal, the family Cyperaceae is represented by 19 genera and 227 species (Bhandari *et al.* 2021; Shrestha *et al.* 2022; Ojha *et al.* 2023; Paneru *et al.* 2024), with a distribution range extending from the tropical lowlands of the Himalayan foothills (Tarai) to alpine regions (Shrestha *et al.* 2018). However, Nepal has relatively few collections of Cyperaceae members compared to other plant families. While botanical research in Nepal mostly concentrates on the mid-hills and high Himalayas, the Tarai (lowland) region is largely overlooked (Shrestha *et al.* 2018, 2022). Despite the notable diversity within the family Cyperaceae in Nepal, dedicated studies on the morphological characterization of achenes are limited. This gap underscores the need for detailed investigations into achene morphology to enhance species identification and contribute to the taxonomic understanding of this family in Nepal. This study aims to assess the diversity of Cyperaceae species in the southwestern Tarai region of Nepal and investigate distinctive achene morphological traits, arrangement of glumes, and style structure within its members collected from the study area.

Table 1. Species of the family Cyperaceae examined, and their morphological characters.

S.N.	Species	Glumes	Style	Style texture	Nut shape	Nut surface
1.	*Actinoscirpus grossus* (L.f.) Goetgh. & D.A.Simpson	Spiral	3-fid	Glabrous	Trigonous	Smooth
2.	*Bolboschoenus maritimus* (L.) Palla subsp. *affinis* (Roth) T.Koyama	Spiral	2-fid	Glabrous	Biconvex	Reticulate
3.	*Bulbostylis barbata* (Rottb.) C.B.Clarke	Spiral	3-fid	Glabrous	Trigonous	Tuberculate
4.	*Carex fedia* Nees	Spiral	3-fid	Glabrous	Trigonous	Smooth
5.	*Cyperus alulatus* J.Kern	Distichous	3-fid	Glabrous	Trigonous	Reticulate
6.	*Cyperus compactus* Retz.	Spreading radially	3-fid	Glabrous	Trigonous	Reticulate
7.	*Cyperus compressus* L.	Distichous	3-fid	Glabrous	Trigonous	Rugose
8.	*Cyperus cyperoides* (L.) Kuntze	Spiral	3-fid	Glabrous	Trigonous	Punctate
9.	*Cyperus difformis* L.	Clustered	3-fid	Glabrous	Trigonous	Punctate
10.	*Cyperus distans* L.f.	Distichous	3-fid	Glabrous	Trigonous	Punctate
11.	*Cyperus dubius* Rottb.	Clustered	2-fid	Glabrous	Trigonous	Rugose
12.	*Cyperus exaltatus* Retz.	Distichous	3-fid	Glabrous	Trigonous	Reticulate
13.	*Cyperus flavidus* Retz.	Distichous	2-fid	Glabrous	Biconvex	Punctate
14.	*Cyperus haspan* L.	Distichous	3-fid	Glabrous	Trigonous	Rugose
15.	*Cyperus iria* L.	Distichous	3-fid	Glabrous	Trigonous	Reticulate
16.	*Cyperus mindorensis* (Steud.) Huygh	Clustered	3-fid	Glabrous	Biconvex	Reticulate
17.	*Cyperus niveus* Retz.	Distichous	3-fid	Glabrous	Trigonous	Rugose
18.	*Cyperus nutans* Vahl	Distichous	3-fid	Glabrous	Trigonous	Rugose
19.	*Cyperus paniceus* (Rottb.) Boeck.	Spiral	3-fid	Glabrous	Trigonous	Punctate
20.	*Cyperus pilosus* Vahl	Distichous	3-fid	Glabrous	Trigonous	Punctate
21.	*Cyperus platystylis* R.Br.	Distichous	3-fid	Glabrous	Trigonous	Reticulate
22.	*Cyperus pumilus* L.	Distichous	2-fid	Glabrous	Biconvex	Punctate
23.	*Cyperus rotundus* L.	Distichous	3-fid	Glabrous	Trigonous	Reticulate
24.	*Cyperus tenuispica* Steud.	Distichous	3-fid	Glabrous	Trigonous	Rugose
25.	*Cyperus unioloides* R.Br.	Distichous	2-fid	Glabrous	Biconvex	Punctate
26.	*Eleocharis acutangula* (Roxb.) Schult.	Spiral	3-fid	Glabrous	Biconvex	Pitted
27.	*Eleocharis atropurpurea* (Retz.) J.Presl & C.Presl	Spiral	2-fid	Glabrous	Biconvex	Smooth
28.	*Fimbristylis aestivalis* (Retz.) Vahl	Spiral	2-fid	Ciliate	Biconvex	Reticulate
29.	*Fimbristylis bisumbellata* (Forssk.) Bubani	Spiral	2-fid	Ciliate	Biconvex	Smooth
30.	*Fimbristylis dichotoma* (L.) Vahl	Spiral	2-fid	Ciliate	Biconvex	Trabeculate
31.	*Fimbristylis falcata* (Vahl) Kunth	Spiral	3-fid	Ciliate	Trigonous	Tuberculate
32.	*Fimbristylis littoralis* Gaudich.	Spiral	2-fid	Ciliate	Trigonous	Reticulate
33.	*Fimbristylis naikii* Wad.Khan & Lakshmin.	Spiral	2-fid	Ciliate	Biconvex	Reticulate with Verruculose
34.	*Fimbristylis ovata* (Burm.) Kern.	Spiral	3-fid	Ciliate	Trigonous	Irregularly rugose
35.	*Fimbristylis quinquangularis* (Vahl) Kunth	Spiral	3-fid	Ciliate	Trigonous	Reticulate with Verruculose
36.	*Fimbristylis schoenoides* (Retzius) Vahl	Spiral	2-fid	Ciliate	Biconvex	Reticulate
37.	*Fimbristylis stolonifera* C. B. Clarke	Spiral	2-fid	Ciliate	Biconvex	Reticulate
38.	*Fimbristylis tomentosa* Vahl	Spiral	2-fid	Ciliate	Biconvex	Pitted
39.	*Schoenoplectiella articulata* (L.) Palla	Spiral	2-fid	Glabrous	Trigonous	Smooth
40.	*Schoenoplectiella juncoides* (Roxb.) Lye	Spiral	2-fid	Glabrous	Biconvex	Transverse wavy lines
41.	*Schoenoplectiella lateriflora* (J.F.Gmel) Lye	Spiral	3-fid	Glabrous	Trigonous	Transverse wavy lines
42.	*Schoenoplectiella praelongata* (Poir.) Lye	Spiral	3-fid	Glabrous	Trigonous	Transverse wavy lines
43.	*Schoenoplectiella mucronata* (L.) J.Jung & H.K.Choi	Spiral	3-fid	Glabrous	Trigonous	Smooth
44.	*Scleria biflora* Roxb.	Spiral	3-fid	Glabrous	Globose	Pitted
45.	*Scleria levis* Retz.	Spiral	3-fid	Glabrous	Ovoid	Hairy
46.	*Scleria psilorrhiza* C.B.Clarke	Spiral	3-fid	Glabrous	Ovoid	Smooth

Materials and methods

During fieldwork in Kanchanpur District (latitude: 28.50° – 29.05° N; longitude: 80.52° – 80.90° E; elevation: 160 to 1528 m above sea level), southwest Nepal, plant specimens, in the fruiting stage, of the family Cyperaceae were collected. Species identification was thoroughly verified by consulting relevant literature (Wadoodkhan and Lakshminarasimhan 2008; Dai *et al*. 2010; Dey and Prashanna 2015; Wadoodkhan 2015) and comparing them with the type and general specimens housed at CAL, KATH, and TUCH, and with specimen photographs available on online databases (assessed via https://gbif.org). The nutlets were examined under a stereo zoom microscope, and images were captured using a Samsung Galaxy A52 camera. In addition, the arrangement of glumes, and style structure were also studied with the help of a stereo zoom microscope. Field specimens were preserved as herbarium samples following standard methods (e.g., Forman and Bridson 1989) and are housed at KATH for future reference.

Results and discussion

We examined nutlets from 9 different genera, encompassing 46 species, providing valuable insights into their morphological diversity and characteristics (Table 1; Plates 1 and 2). Nutlet shape, size, and texture were important taxonomic characteristics to identify and differentiate the taxa within the family Cyperaceae. These characteristics have also been used to classify species within Cyperaceae by Patil and Prasad (2016), Clarke (1894), Malla *et al*. (1986), Noltie (1994), Kukkonen (2001), Dai *et al*. (2010), and Waddodkhan (2015).

Our study revealed variability in nutlet shapes, which varied from biconvex, trigonous, and ovoid to globose, highlighting the remarkable structural diversity present within the members of the family Cyperaceae. Most of the studied species of *Actinoscirpus*, *Bulbostylis*, *Carex*, *Cyperus*, and *Schoenoplectiella* showed trigonous nutlets. However, the nutlets were biconvex in *Cyperus flavidus*, *C. mindorensis*, *C. pumilus*, *C. unioloides,* and *Schoenoplectiella juncoides*. Similarly, species of *Bolboschoenus*, *Eleocharis,* and *Fimbristylis* typically showed biconvex nutlets, though some species such as *Fimbristylis falcata*, *F. littoralis*, *F. ovata,* and *F. quinquangularis* were characterized by trigonous nutlets. The nutlets of *Scleria levis* and *S. psilorrhiza* were ovoid, whereas those of *S. biflora* were globose. This variation in nutlet shape underscores the complexity and adaptability of these species, reflecting their evolutionary responses to different ecological niches.

In addition to shape, the surface characteristics of the nutlets exhibited considerable variation in recorded species of Cyperaceae, with textures varying widely across species. The surfaces were observed to be smooth in some species (e.g., *Actinoscirpus grossus*, *Carex fedia*, *Eleocharis atropurpurea*, *Fimbristylis bisumbellata*, *Schoenoplectiella articulata*, *S. mucronata,* and *Scleria psilorrhiza*), while others displayed intricate patterns, such as reticulate structures (*Bolboschoenus maritimus* subsp. *affinis*, *Cyperus alulatus*, *C. compactus*, *C. exaltatus*, *C. iria*, *C. mindorensis*, *C. platystylis*, *C. rotundus*, *Fimbristylis aestivalis*, *F. littoralis*, *F. schoenoides*, and *F. stolonifera*), reticulate combined with verruculose features (*Fimbristylis naikii* and *F. quinquangularis*), or surfaces marked by tuberculate formations (*Bulbostylis barbata*, *Fimbristylis dichotoma*, and *F. falcata*). Furthermore, certain nutlets were characterized by rugose, punctate, or pitted textures, while others showed trabeculate patterns or distinctive transverse wavy lines (Table 1; Plates 1 and 2). The nutlets were rugose in *Cyperus compressus*, *C. dubius*, *C. haspan*, *C. niveus*, *C. nutans*, *C. tenuispica*, and *Fimbristylis ovata*. The nutlets were punctate in *Cyperus cyperoides*, *C. difformis*, *C. distans*, *C. flavidus*, *C. paniceus*, *C. pilosus*, *C. pumilus*, and *C. unioloides*. The surface was pitted in *Eleocharis acutangula*, *Fimbristylis tomentosa,* and *Scleria biflora*. The nutlets were trabeculate in *Fimbristylis dichotoma*. Nutlets in all species of *Schoenoplectiella* had transverse wavy lines except smooth in *S. articulata* and *S. mucronata*.

The arrangement of glumes in most of the species of *Cyperus* studied was distichous except spiral in *C. cyperoides* and *C. paniceus*, and radially spreading in *C. compactus*. The glumes were spiral in all species of *Actinoscirpus*, *Bolboschoenus*, *Bulbostylis*, *Carex*, *Eleocharis*, *Fimbristylis*, *Schoenoplectiella,* and *Scleria* except distichous in *Fimbristylis ovata*. The arrangement of glumes has been used in other studies to identify and delimit the taxa within Cyperaceae (Wadoodkhan 2015; Dai *et al*. 2010).

Members within the family Cyperaceae possessed a 3-fid style with some exceptions. The 3-fid style was found in most of the members of *Actinoscirpus*, *Bulbostylis*, *Carex*, *Cyperus*, *Scleria*, *Eleocharis,* and *Schoenoplectiella* except, *Cyperus dubius*, *C. flavidus*, *C. pumilus*, *C. unioloides*, *Eleocharis atropurpurea*, *Schoenoplectiella articulata* and *S. juncoides* which showed 2-fid style. Similarly, species of *Fimbristylis* had 2-fid style except 3-fid in *F. falcata*, *F. littoralis*, *F. ovata* and *F. quinquangularis*. The style was glabrous in all species of *Actinoscirpus*, *Bolboschoenus*, *Bulbostylis*, *Cyperus*, *Eleocharis*, *Schoenoplectiella,* and *Scleria* while the style of all species of *Fimbristylis* was ciliate. In previous studies, variations in style within the family Cyperaceae have been used as important characters to delimit taxa (Clarke 1894; Wadoodkhan 2015; Noltie 1994; Kukkonen 2001; Dai *et al*. 2010).

Conclusions

This study represents a step toward understanding the diversity and taxonomic significance of glumes, style, and nutlets in the family Cyperaceae in Nepal. These traits display a remarkable diversity, which makes them an excellent resource for taxonomic studies. Particularly, the nutlet characters, ranging from variations in shape to intricate surface textures, provide critical insights that aid in delimiting the species within the family. This study highlights the significance of nutlet morphology as a powerful tool in Cyperaceae taxonomy, emphasizing its value in supporting systematic research. The findings confirmed the Cyperaceae family's heterogeneity in southwestern Nepal.

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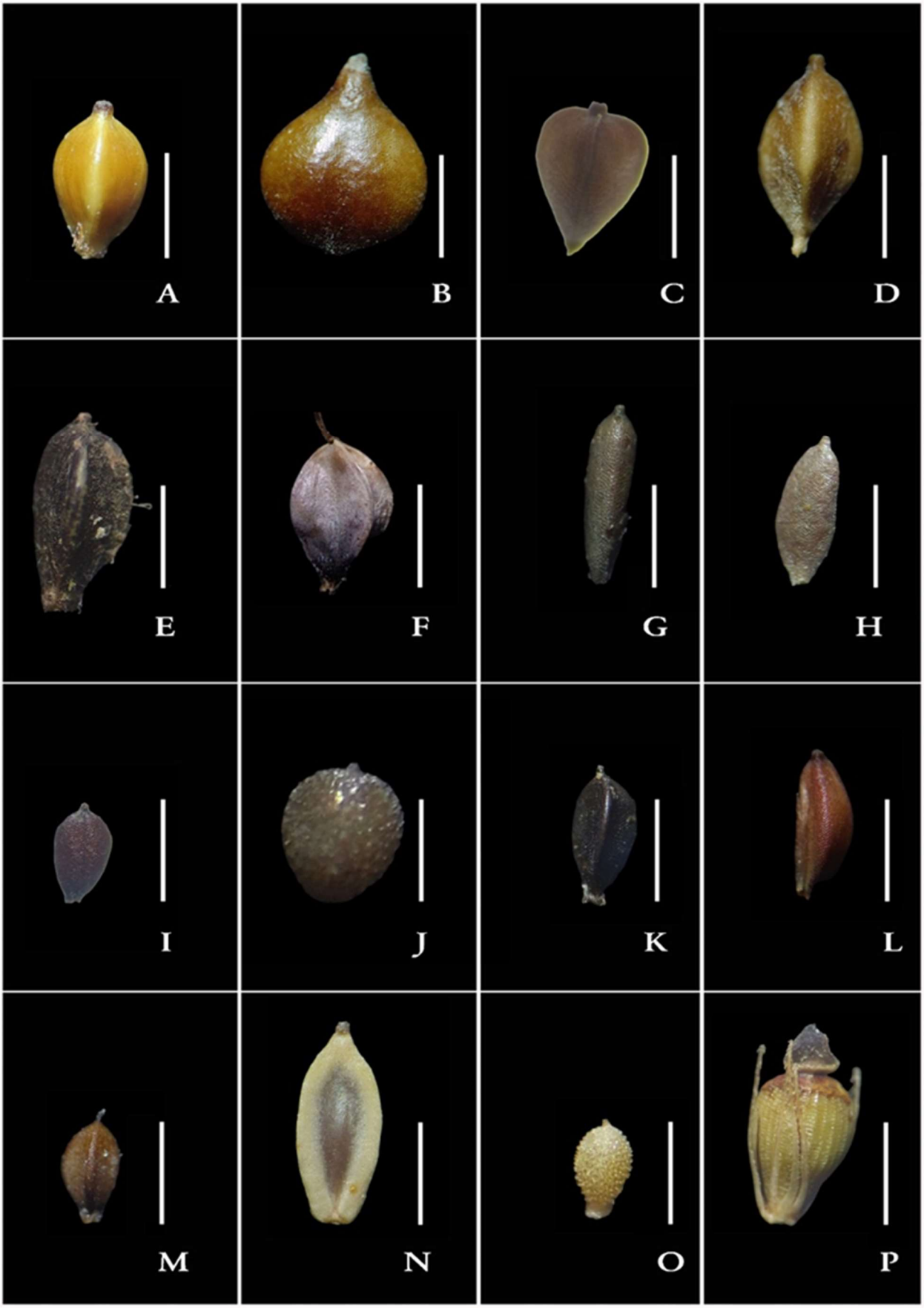

Plate 1. Variation in nutlet morphology in Cyperaceae: A, *Actinoscirpus grossus*; B, *Bolboschoenus maritimus* subsp. *affinis*; C, *Bulbostylis barbata*; D, *Carex fedia*; E, *Cyperus alulatus*; F, *Cyperus compressus*; G, *Cyperus distans*; H, *Cyperus dubius*; I, *Cyperus flavidus*; J, *Cyperus haspan*; K, *Cyperus iria*; L, *Cyperus paniceus*; M, *Cyperus pilosus*; N, *Cyperus platystylis*; O, *Cyperus tenuispica*; and P, *Eleocharis acutangula* [scale bars = 1 mm (A-H, K-N, and P) and 0.5 mm (I, J, and O)].

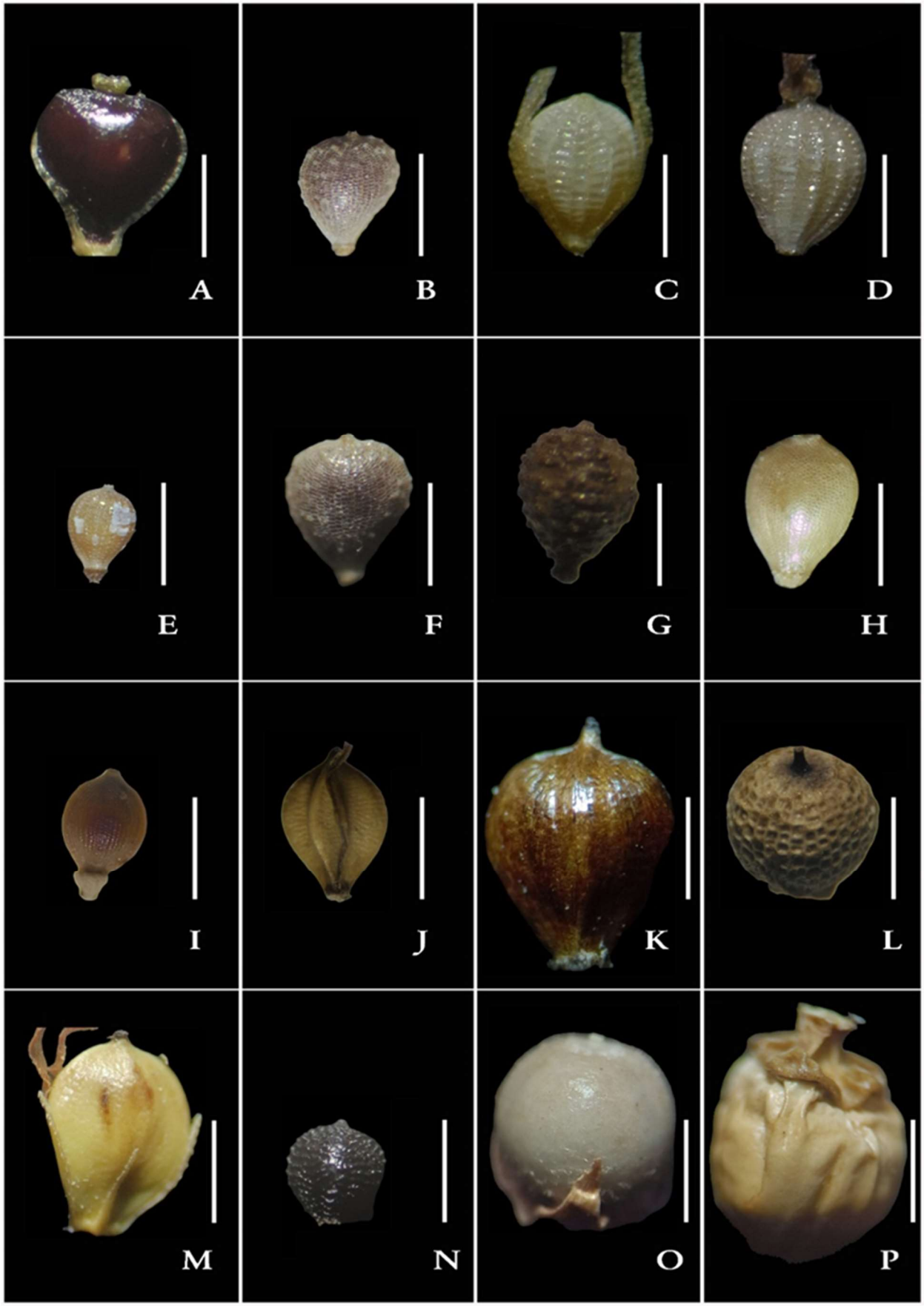

Plate 2. Variation in nutlet morphology in Cyperaceae: A, *Eleocharis atropurpurea*; B & F, *Fimbristylis naikii*; C, *Fimbristylis bisumbellata*; D & E, *Fimbristylis dichotoma*; G, *Fimbristylis quinquangularis*; H, *Fimbristylis schoenoides*; I, *Fimbristylis tomentosa*; J, *Schoenoplectiella praelongata*; K, *Schoenoplectiella mucronata*; L, *Scleria biflora*; M, *Schoenoplectiella juncoides*; N, *Schoenoplectiella lateriflora*; O, *Scleria levis*; and P, *Scleria psilorrhiza* [scale bars = 1 mm (B, D-F, I-M, O, and P) and 0.5 mm (A, C, G, and N)].

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