



Taxonomy and phylogenetic position of *Fimbristylis fusiformis*, a new species of *Cyperaceae* from Thailand

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Key words

conservation status
Fimbristylis
phylogeny
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Abstract *Fimbristylis fusiformis*, an unusual new species of *Cyperaceae* from Thailand, is described and illustrated. This taxon has a single terminal spikelet per culm with a semi-distichous glume arrangement, bisexual flowers that lack perianth parts, and pistil with persistent style whose base is slightly swollen and trigonous nutlets with pubescent ribs. Phylogenetic reconstruction using ITS sequence data places this taxon in *Abildgaardieae* and sister to the rest of *Fimbristylis*. The species has a conservation status of Least Concern (LC).

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INTRODUCTION

The genus *Fimbristylis* Vahl, comprising c. 300 species, occurs mostly in the tropics and subtropics with some species occurring in warm temperate regions (Govaerts et al. 2007). The genus is morphologically diverse, with inflorescences ranging from complex umbel-like structures to a solitary spikelet. The glumes are generally spirally arranged in ellipsoid spikelets, more rarely distichously arranged, the bisexual flowers lack perianth parts and their deciduous styles have distinctly thickened base, and the nutlets often have distinct surface patterns. *Fimbristylis* is currently (e.g., Govaerts et al. 2007) treated to include the segregate genus *Abildgaardia* Vahl, the latter only differing in having a distichous glume arrangement (Goetghebeur 1998).

The genus was revised for Thailand by Simpson & Koyama (1998), who enumerated 60 species for that country. A study of undetermined material by one of us (DAS) suggested a previously undescribed species was present in eastern Thailand (Map 1). Further herbarium studies, together with associated fieldwork, confirmed that the species was new. We inferred the phylogenetic position of this new species using DNA sequence data, and describe and illustrate it here (Fig. 1–3).

MATERIALS AND METHODS

Specimens were examined from herbaria at BK, BKF, K, KKU and QBG. Fieldwork was undertaken in September 2008 and November 2011. Observations of inflorescences and fruits were made with an Olympus SZ-PT binocular microscope. Mature nutlets from the spikelet of the holotype were collected for scanning electron microscopy. Selected material was mounted on stubs with double-sided adhesive tape and coated with gold using a SC7620 mini sputter-coater (Polaron range). Micro-

graphs were generated using a JSM6460LV scanning electron microscope (JEOL Ltd.)

Using a silica gel dried sample of the new taxon, DNA was extracted using the CTAB method and the ITS marker amplified and sequenced using standard protocols and primers (Muasya et al. 2014). Contigs of forward and reverse sequences were assembled using the STADEN package (Staden 1996). Additional ITS DNA sequences, primarily taken from studies of *Abildgaardieae* (Ghamkhar et al. 2007) and *Cypereae* (Yano et al. 2012), were downloaded from GenBank. The matrix thus assembled (Table 1) included a total of 90 taxa, with representatives of subfamily *Cyperoideae*, tribes *Abildgaardieae*, *Cypereae*, *Eleocharideae*, *Fuireneae*, *Scirpeae* with *Cladium* as outgroup. The matrix was aligned using Muscle (v. 3.8.31; Edgar 2004), and further manually aligned in BioEdit (v. 7.0.9; Hall 1999). The aligned matrix was analysed using maximum parsimony in PAUP* (Swofford 2002), with heuristic searches using the random-addition-sequence method with 10 000 replicates, Tree-Bisection-Reconnection (TBR) branch-swapping with the Multrees option in effect and no maximum tree number set. Node support was evaluated using bootstrap analyses with 500 replicates, repeating the heuristic search procedure (with 10 replicates) above.

RESULTS AND DISCUSSION

Although the new species was easily identifiable as a member of subfamily *Cyperoideae* (absence of the spicoid floral structure (Simpson et al. 2003), individual flowers comprising stamens and gynoecium subtended by a glume), its generic placement within *Cyperoideae* was not immediately obvious. The combination of morphological characters, especially in the structure of the gynoecium, with the scabrous style, the apparent lack of a disjunction between the style base and nutlet, the fusiform shape of the nutlet and the fimbriate hairs at its apex and base (Fig. 1), suggested a genus other than *Fimbristylis*. Indeed, some aspects of the plant's gross morphology (e.g., a single, terminal spikelet) were superficially similar to genera such as *Trichophorum* (tribe *Scirpeae*) whereas the lack of perianth parts and possession of a persistent style with an indistinct base on the nutlet, were reminiscent of features observed in *Isolepis* (tribe *Cypereae*).

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Table 1 List of taxa sampled for the phylogenetic study.

Tribe	Taxon	Voucher	Accession number	
<i>Abildgaardieae</i>	<i>Arthrostylis aphylla</i> R.Br.	Clarke 183 (NE)	AY506757	
	<i>Bulbostylis barbata</i> (Rottb.) C.B.Clarke	Clarke 113 (NSW)	AY506764	
	<i>Bulbostylis densa</i> (Wall.) Hand.-Mazz.	Klaphake 1411 (NSW)	AY506763	
	<i>Bulbostylis funckii</i> (Steud.) C.B.Clarke	Roalson 1384 (RSA)	AF190616	
	<i>Crosslandia setifolia</i> W.Fitzg.	Clarke 246 (NSW)	AY506768	
	<i>Fimbristylis aestivalis</i> Vahl	Arai & Hirahara 18166 (OKAY)	AB250626	
	<i>Fimbristylis bisumbellata</i> (Forssk.) Bubani	Clarke 107 (NE)	AY506778	
	<i>Fimbristylis complanata</i> (Retz.) Link	Muasya 1029 (EA, K)	AY242051	
	<i>Fimbristylis composita</i> Latz	Clarke 186 (NE)	AY506756	
	<i>Fimbristylis composita</i> Latz	Clarke 213 (NE)	AY506755	
	<i>Fimbristylis composita</i> Latz	Clarke 214 (NE)	AY506754	
	<i>Fimbristylis cymosa</i> R.Br.	Wilson 10041 (NSW)	AY506798	
	<i>Fimbristylis densa</i> S.T.Blake	Clarke 119 (NE)	AY506781	
	<i>Fimbristylis dichotoma</i> (L.) Vahl	Katayama 17519 (OKAY)	AB250630	
	<i>Fimbristylis diphylloides</i> Makino	J. Jung 909179 (AJOU)	JX644883	
	<i>Fimbristylis ferruginea</i> (L.) Vahl	Hodgon 445 (NSW)	AY506797	
	<i>Fimbristylis fusiformis</i> Wangwasit & D.A.Simpson	K. Wangwasit 080927-17 (K)	KY652919	
	<i>Fimbristylis globulosa</i> (Retz.) Kunth	J. Jung 1010275 (AJOU)	JX644885	
	<i>Fimbristylis lanceolata</i> C.B.Clarke	Wilson 10113 (NSW)	AY506786	
	<i>Fimbristylis laxiglumis</i> Latz	Clarke 106 (NE)	AY506785	
	<i>Fimbristylis littoralis</i> Gaudich.	Orel 10 (NSW)	AY506790	
	<i>Fimbristylis longispica</i> Steud.	Katsuyama et al. 19910 (OKAY)	AB250636	
	<i>Fimbristylis miliacea</i> (L.) Vahl	J. Jung 909180 (AJOU)	JX644886	
	<i>Fimbristylis neilsonii</i> F.Muell.	Wilson 10051 (NSW)	AY506784	
	<i>Fimbristylis ovata</i> (Burm.f.) J.Kern.	Klaphake 1410 (NSW)	AY506758	
	<i>Fimbristylis oxystachya</i> F.Muell.	Clarke 165 (NE)	AY506762	
	<i>Fimbristylis pachyptera</i> S.T.Blake	Clarke 181 (NT)	AY506760	
	<i>Fimbristylis pauciflora</i> R.Br.	Clarke 50 (NE)	AY506783	
	<i>Fimbristylis pierotii</i> Miq.	Hoshino et al. 20053 (OKAY)	AB250639	
	<i>Fimbristylis polytrichoides</i> (Retz.) R.Br.	Clarke 91 (NE)	AY506796	
	<i>Fimbristylis rara</i> R.Br.	Clarke 105 (NE)	AY506780	
	<i>Fimbristylis schultzei</i> Boeckeler	Clarke 108 (NE)	AY506791	
	<i>Fimbristylis sericea</i> (Poir.) R.Br.	Wilson 10042 (NSW)	AY506801	
	<i>Fimbristylis sieberiana</i> Kunth	S. Jacobs 8659 (NSW)	AY506801	
	<i>Fimbristylis sieboldii</i> Miq.	J. Jung 1010277 (AJOU)	JX644884	
	<i>Fimbristylis squarrosa</i> Vahl	Arai & Hirahara 18165 (OKAY)	AB250641	
	<i>Fimbristylis stauntonii</i> Debeaux & Franch.	S.-M. Yun s.n. (AJOU)	JX644888	
	<i>Fimbristylis subbispicata</i> Nees	J. Jung 1010018 (AJOU)	JX644889	
	<i>Fimbristylis tetragona</i> R.Br.	Clarke 173 (NE)	AY506799	
	<i>Fimbristylis tristachya</i> R.Br.	Clarke 3 (NE)	AY506802	
	<i>Fimbristylis vaginata</i> (R.Br.) Domin	Bruhl 2057 (NE)	AY506759	
	<i>Fimbristylis velata</i> R.Br.	Wilson 10028 (NSW)	AY506792	
	<i>Cariceae</i>	<i>Carex esenbeckii</i> Kunth	Ikeda et al. 20814080 (TI)	AB643648
	<i>Cypereae</i>	<i>Afroscirpoides dioeca</i> (Kunth) García-Madr.	Muasya 3062 (BOL)	GU012394
		<i>Cyperus ascocapensis</i> Bauters	Muasya 1009 (EA, K)	AB685858
		<i>Cyperus brevifolius</i> (Rottb.) Hassk.	Hirahara & Yano 18135 (OKAY)	AB261669
		<i>Cyperus cyperoides</i> (L.) Kuntze	Morimoto 17532 (OKAY)	AB261665
		<i>Cyperus involucreatus</i> Rottb.	Kew Acc. 6136603 (K)	AY242052
		<i>Cyperus isolepis</i> (Nees) Bauters	Muasya 1217 (K)	AB685866
		<i>Cyperus papyrus</i> L.	Hepper 4213 (K)	AY242048
		<i>Cyperus sanguinolentus</i> Vahl	Komagine & Masyo 17655 (OKAY)	AB261671
		<i>Erioscirpus microstachyus</i> (Boeckeler) Palla	Noltie 2001562 (E)	AB643639
		<i>Erioscirpus comosus</i> (Wall.) Palla	Ikeda et al. 20814007 (TI)	AB643639
		<i>Ficinia bergiana</i> Kunth	Muasya 2337 (BOL)	AB685861
		<i>Ficinia esterhuyseniae</i> Muasya	Muasya 2312 (BOL)	GU012400
		<i>Ficinia gracilis</i> Schrad.	Faden et al. 96433 (K)	AB685862
<i>Ficinia nodosa</i> (Rottb.) Goetgh., Muasya & D.A.Simpson		Wilson 9455 (K)	GU012383	
<i>Ficinia rigida</i> Levyns		Muasya 2319 (K)	AB685863	
<i>Ficinia spiralis</i> (A.Rich.) Muasya & de Lange		HUG 2003-0699 (GENT)	GU012395	
<i>Ficinia trichodes</i> (Schrad.) Benth. & Hook.f.		Muasya 2328 (K)	AB685864	
<i>Hellmuthia membranacea</i> (Thunb.) R.W.Haines & Lye		Muasya 3081 (BOL)	GU012384	
<i>Isolepis cernua</i> (Vahl) Roem. & Schult.		Muasya 3073 (BOL)	GU012413	
<i>Isolepis crassiuscula</i> Hook.f.		Hirahara & Hoshino 19165 (OKAY)	AB261668	
<i>Isolepis hystrix</i> (Thunb.) Schrad.		Muasya 2971 (BOL)	GU012388	
<i>Isolepis levynsiana</i> Muasya & D.A.Simpson		Muasya 1151 (K)	AB685865	
<i>Isolepis marginata</i> (Thunb.) A.Dietr.		Muasya 2973 (BOL)	GU012418	
<i>Isolepis setacea</i> (L.) R.Br.		Ikeda et al. 20814046 (TI)	AB643644	
<i>Isolepis venustula</i> Kunth		Muasya 1189 (K)	GU012421	
<i>Scirpoides holoschoenus</i> (L.) Soják		HBUG 2003-1536 (GENT)	AB685867	
<i>Scirpoides thunbergii</i> (Schrad.) A.Spreng.		Muasya 1205 (K)	AB685868	
<i>Dulichieae</i>		<i>Dulichium arundinaceum</i> (L.) Britton	Waterway 2003.052 (MTMG)	DQ998949
<i>Eleocharideae</i>		<i>Eleocharis mamillata</i> (H.Lindb.) H.Lindb.	Bures et al. s.n. (BRNU)	GU977089
	<i>Eleocharis neozelandica</i> C.B.Clarke ex Kirk.	Gardner et al. AK284635 (AK)	DQ385566	
	<i>Eleocharis pusilla</i> R.Br.	Gardner et al. AK284890 (AK)	DQ385564	
	<i>Eleocharis quinqueflora</i> (Hartmann) O.Schwarz	Bures et al. s.n. (BRNU)	GU977095.1	
	<i>Eleocharis wichurae</i> Boeckeler	Hoshino et al. 17616 (OKAY)	AB180715	

Table 1 (cont.)

Tribe	Taxon	Voucher	Accession number
Fuireneae	<i>Actinoscirpus grossus</i> (L.f.) Goetgh. & D.A.Simpson	<i>Katsuyama et al. 19915</i> (OKAY)	AB261672
	<i>Schoenoplectus hotarui</i> (Ohwi) Holub	<i>Katayama 17521</i> (OKAY)	AB180720
Schoeneae	<i>Cladium chinense</i> Nees ex Hook. & Arn.	<i>H.-K. Choi 2006 s.n.</i> (AJOU)	GQ130342
Scirpeae	<i>Amphiscirpus nevadensis</i> (S.Watson) Oteng-Yeb.	<i>Helmkamp s.n.</i> (RSA)	AF190618
	<i>Eriophorum angustifolium</i> Honck.	<i>Waterway 2001.018</i> (MTMG)	DQ998950
	<i>Eriophorum gracile</i> Koch	<i>Hoshino et al. 17382</i> (OKAY)	AB261684
	<i>Eriophorum vaginatum</i> L.	<i>Starr 98007 & Scott</i> (FHO)	AY242008
	<i>Scirpus mitsukurianus</i> Makino	<i>J. Jung 808304</i> (AJOU)	GQ130354
	<i>Scirpus wichurae</i> Boeckeler	<i>J. Jung 808322</i> (AJOU)	GQ130357
	<i>Trichophorum alpinum</i> (L.) Pers.	<i>Sato 13260</i> (OKAY)	AB206270
	<i>Trichophorum dioicum</i> (Y.N.Lee & Y.C.Oh) J.Jung & H.K.Choi	<i>J. Jung 804015</i> (AJOU)	FJ797641
	<i>Trichophorum pumilum</i> (Vahl) Schinz & Thell.	<i>Ikeda et al. 20814101</i> (TI)	AB643647
<i>Trichophorum subcapitatum</i> (Thwaites & Hook.) D.A.Simpson	<i>Ikeda et al. 10042360</i> (TI)	AB679909	

The aligned matrix yielded 837 characters, of which 419 were parsimony-informative, 116 were variable but parsimony-uninformative and 302 were constant.

Parsimony analysis recovered 16 equally parsimonious trees (Fig. 4), and the ITS phylogeny is similar to results previously published using plastid (e.g., Ghamkar et al. 2007, Muasya et al. 2009) and nuclear (e.g., Yano & Hoshino 2006, Ghamkar et al. 2007) markers. These strongly supported the *Abildgaardieae* clade as having two subclades, one comprising *Bulbostylis* (including *Actinoschoenus* and *Arthrostylis*) and the other comprising *Fimbristylis*. The new taxon was sister to the rest of *Fimbristylis* in all the 16 trees generated in our study, but there was a lack of bootstrap support for the backbone topology in *Fimbristylis* in this study as well as previous studies (e.g., Ghamkhar et al. 2007) using *trnL-F* and ITS sequence data.

On present evidence, the best placement for the new species is in *Fimbristylis*. However, we were unable to assign the new taxon to any of the sections in *Fimbristylis* s.l. recognized by previous researchers (e.g., Kern 1974) and further studies are needed to elucidate the precise relationships of the new taxon.

TAXONOMIC TREATMENT

Fimbristylis fusiformis Wangwasit & D.A.Simpson, *sp. nov.*
— Fig. 1–3; Map 1

Superficially similar to *F. pauciflora* R.Br. but distinguished by the glumes 6.5–8.5 mm long (vs 2.5–3 mm long in *F. pauciflora*), nutlets fusiform, fimbriate at apex and base, with 3 longitudinal costae (vs nutlets obovate and glabrous in *F. pauciflora*). — Type: *K. Wangwasit 080927-17* (holo K; iso BK, KKU), Thailand, Ubon Ratchathani, Pha Taem National Park, 27 Sept. 2008.

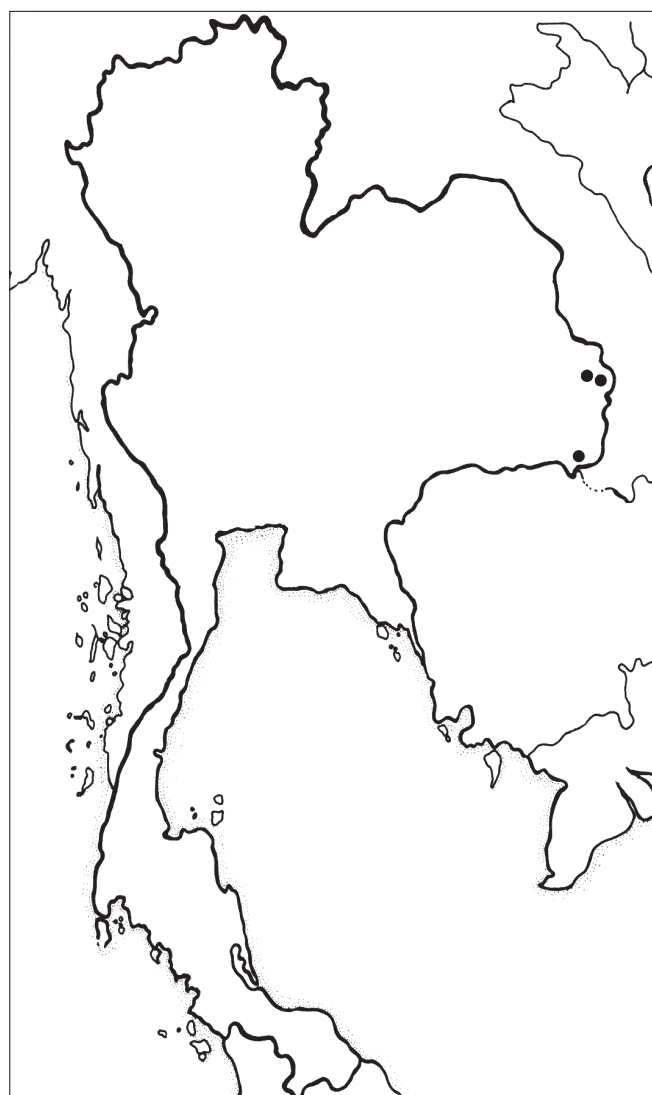
Etymology. Named after the shape of the nutlets.

Rhizomatous perennial. Culms densely tufted, 12–23 cm by 0.1–0.4 mm, trigonous, glabrous. Leaves basal; blade narrowly linear, 4–5 cm by 0.5 mm, obtuse, thickly crescentiform in cross-section, laterally flattened, glabrous; sheath 1–1.5 cm long, stramineous, sides membranous; ligule absent. Involucral bracts glume-like. Inflorescence a single terminal spikelet. Spikelet linear-cylindric, terete, 1 cm by 1.2–1.5 mm. Glumes 9 per spikelet, spirally arranged, lower glume glabrous, uppermost strigose, oblong elliptic, 6.5–8.5 by 1.5–2.3 mm, acuminate, sides membranous, stramineous, reddish brown tinged, keel obtuse, 1-nerved. Stamens 3; anthers 2–2.5 by 0.1–0.2 mm. Stigma branches 3; style persistent; style base rather indistinct, somewhat elongate, gradually widening into the nutlet, scabrous. Nutlets fusiform, trigonous, fimbriate, especially at apex and base, 2.5–3.8 by 0.5–0.85 mm, apex brown to dark brown, with minute hexagonal epidermal cells, longitudinal costae present.

Distribution — Endemic to eastern Thailand. Mostly seen in Pha Taem National Park but also observed in Phu Chong Na Yoi National Park, both in Ubon Ratchathani.

Habitat & Ecology — Open, stony places with scattered tree cover on seasonally wet, sandy soils. Altitude 227 m (Google Earth 2016).

Conservation status — Least Concern (LC; IUCN 2012). The species occurs in protected areas and is locally abundant in these localities.



Map 1 Distribution of *Fimbristylis fusiformis* Wangwasit & D.A.Simpson.

Fig. 1 *Fimbristylis fusiformis* Wangwasit & D.A.Simpson. a. Habit; b. spikelet; c. uppermost glume; d. lower glume; e. nutlet (all: K. Wangwasit 080927-17, K). — Scale bars: a = 2 cm; b = 2 mm; c–e = 1 mm. — Drawn by Khanit Wangwasit.

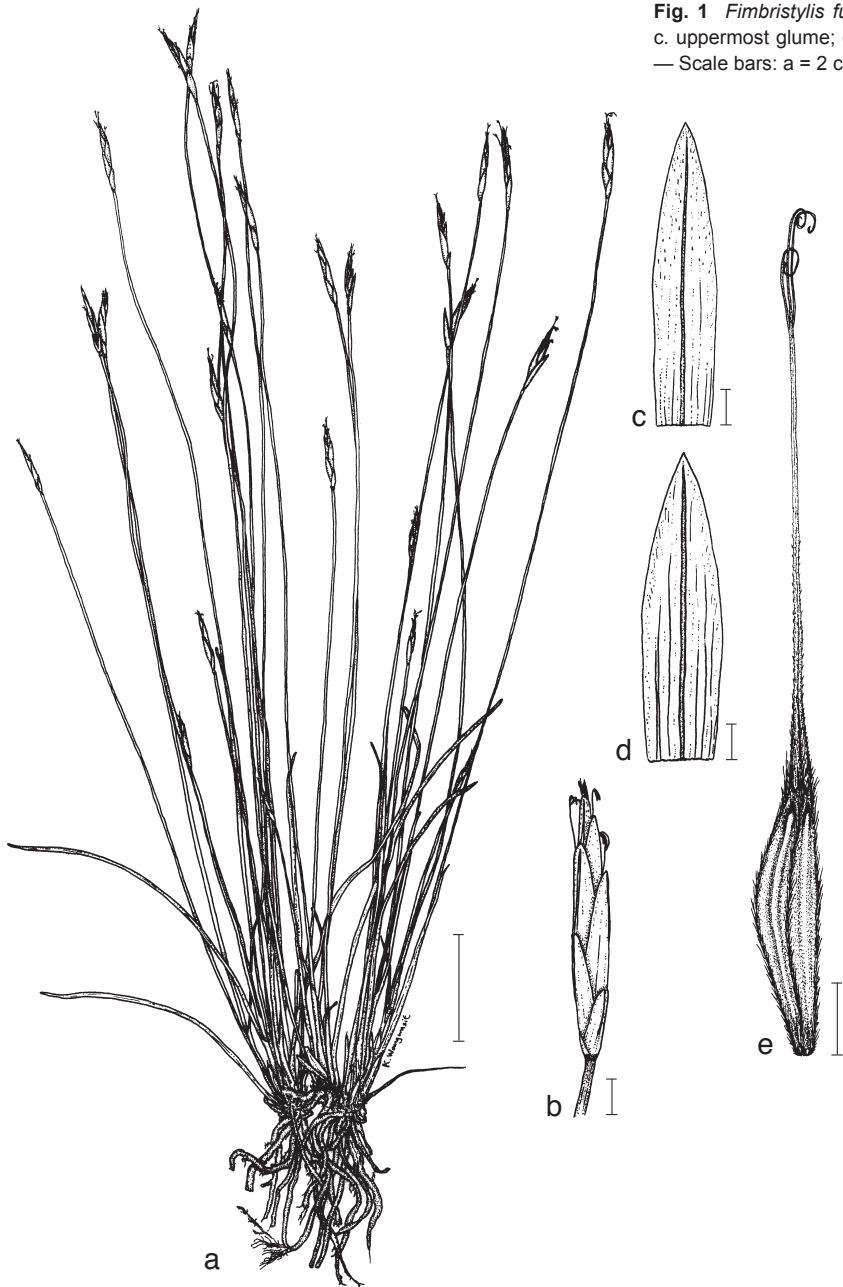


Fig. 2 *Fimbristylis fusiformis* Wangwasit & D.A.Simpson. a. Plants in habitat; b. close-up of spikelet. — Photos by D.A. Simpson.

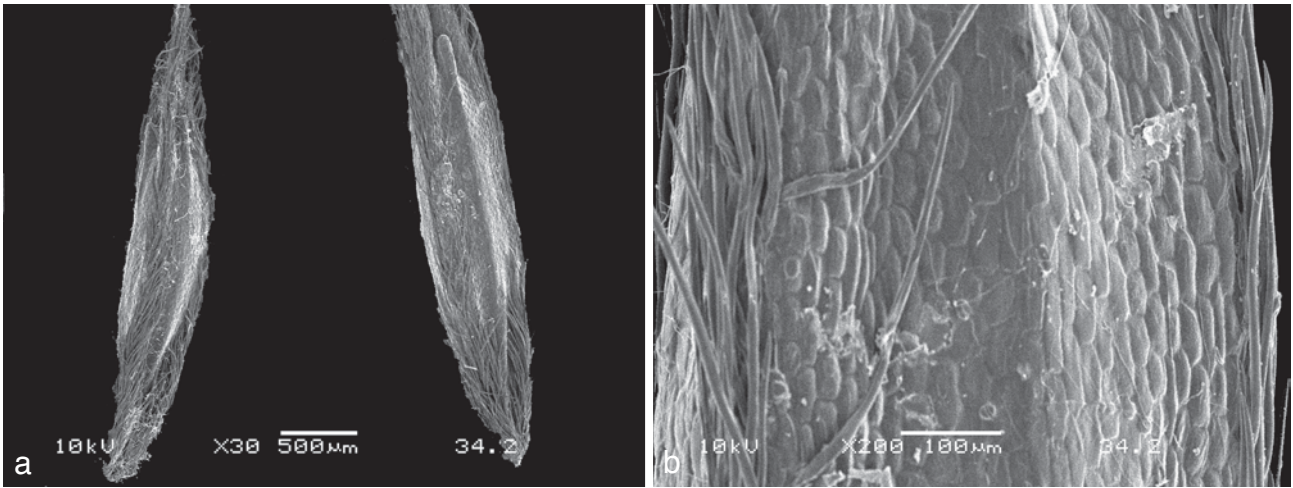


Fig. 3 SEM micrographs of the nutlet of *Fimbristylis fusiformis* Wangwasit & D.A.Simpson. a. Whole nutlet; b. nutlet surface (from K. Wangwasit 080927-17, K).

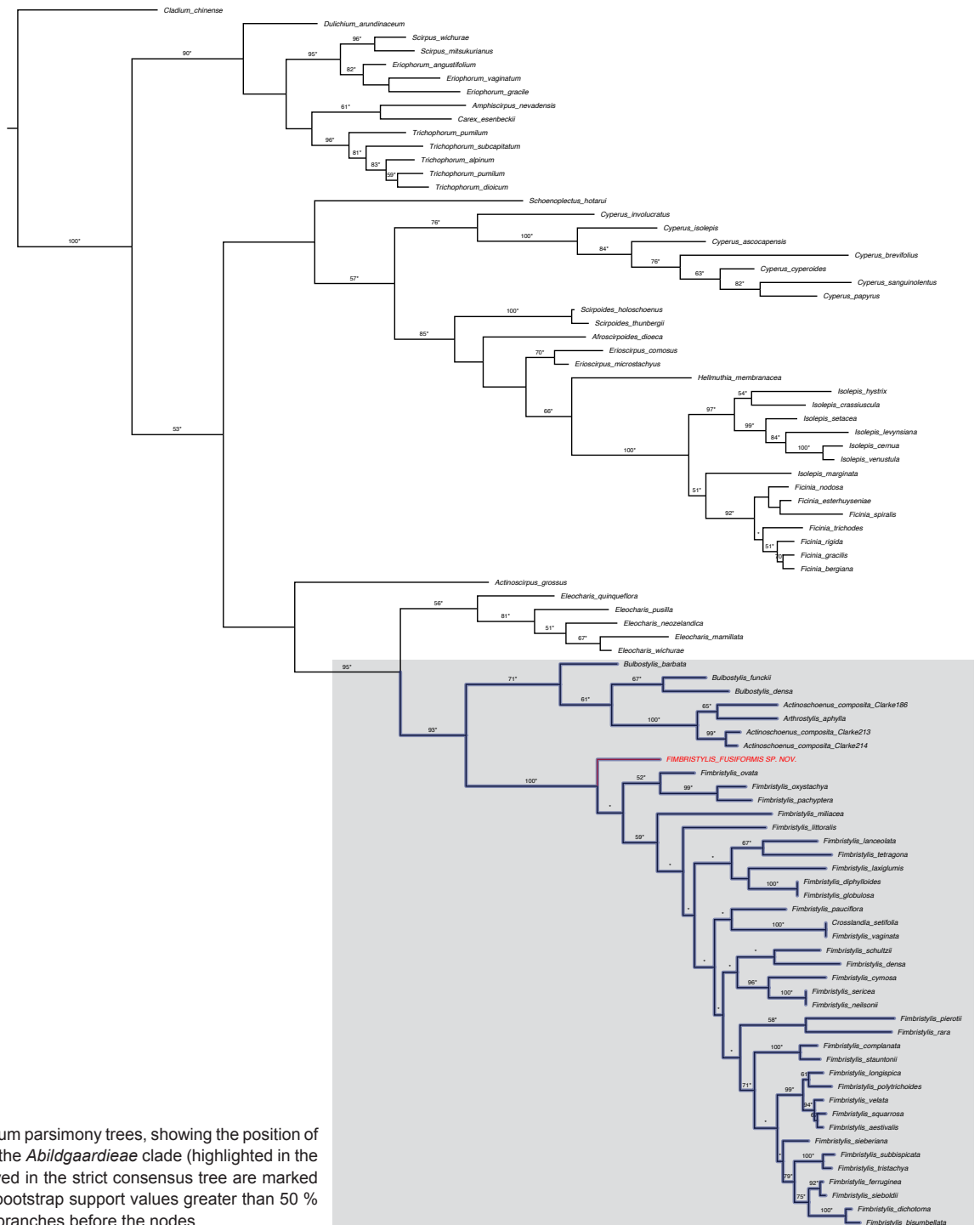


Fig. 4 One of 16 maximum parsimony trees, showing the position of *Fimbristylis fusiformis* in the *Abildgaardieae* clade (highlighted in the grey box). Nodes observed in the strict consensus tree are marked with an asterisk (*) and bootstrap support values greater than 50 % are indicated above the branches before the nodes.

Additional specimens examined. THAILAND, Ubon Ratchathani: Khong Chiam, Pha Taem National Park, Khua Nangnee Falls (N15°24'11" E105°31'02"), *Pooma, De Wilde & Duyfjes 2270* (BKF); Sribunreung District, 27 Sept. 2008, *K. Wangwasit 080927-6* (KKU).

Note — *Fimbristylis fusiformis* is superficially similar to *F. pauciflora*, in having an inflorescence with a single terminal linear-cylindric spikelet bearing a glume-like bract. We interpret these similarities to be due to morphological convergence, as the two taxa are not sister in our phylogeny.

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