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A New Species of *Isodon* (Lamiaceae, Nepetoideae) from Yunnan Province, Southwest China

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Abstract—*Isodon wui* (Lamiaceae), from Mt. Jiaozi in Yunnan province, is newly described and illustrated. The new species is morphologically most similar to *I. irroratus* but is smaller and has narrowly ovate (vs. ovate) leaves and leaf surfaces with unicellular, eglandular (vs. clavate, glandular) trichomes. The new species differs from *I. irroratus* in geographical distribution by occurring in central Yunnan instead of northwestern Yunnan and Sichuan. Features of the new species pertaining to leaf surface anatomy, pollen morphology, and geographical distribution are described, and a key to all 42 species of *Isodon* in Yunnan province is provided.

Keywords—*Isodon wui*, subtribe Isodoninae, taxonomy, Tribe Ocimeae, trichome morphology.

Isodon (Schrad. ex Benth.) Spach (Lamiaceae: Nepetoideae: Ocimeae) is a morphologically diverse and species-rich genus of herbs and shrubs (Li and Hedge 1994; Paton et al. 2004). The genus is characterized by a combination of morphological characters: bracteolate cymes, 4/1-bilabiate corolla limbs (four lobes on the upper lip and one lobe on the lower), equally or subequally 5-toothed or 3/2-bilabiate calyces, and free filaments inserted at the base of the corolla tube (Li 1988). Generally, plants of the genus have an affinity for xeric habitats in thickets, disturbed roadsides, hot-dry ravines, and montane forests.

Species delimitation in *Isodon* has been problematic because of relatively high levels of morphological variation, incomplete lineage sorting of ancestral polymorphisms, or hybridization (Maki et al. 2010; Harris and Klooster 2011). As currently circumscribed, the genus comprises roughly 100 species that occur in two disjunct areas: tropical Africa (two species), and subtropical to temperate East Asia (Codd 1968, 1984; Li 1988; Mabberley 2008). In China, 77 species and 10 varieties have been reported, of which 63 species and six varieties are endemic and geographically restricted and southwest China is considered to be the diversity center of the genus (Zhong et al. 2010).

Li (1988) divided the genus into four sections: sect. *Isodon*, sect. *Pyramidium* (Benth.) H. W. Li, sect. *Amethystoides* (Benth.) H. W. Li, and sect. *Melissoides* (Benth.) H. W. Li. Section *Isodon* contains around two-thirds of the species and was further subdivided into ten series. However, molecular phylogenetic studies (Maki et al. 2010; Zhong et al. 2010) neither reflect previous taxonomic treatments at the section and series levels (Wu and Li 1977; Li 1988) nor support the monophyly of *Isodon*. Rather, the genus can only be considered monophyletic when the monotypic genus *Skapanthus* C. Y. Wu & H. W. Li is included in *Isodon* (Zhong et al. 2010).

In July 2008, during a joint expedition for the project “Research on the Plants of Mt. Jiaozi” carried out by the Kunming Forestry Bureau and Kunming Institute of Botany, an unusual isolated population of *Isodon* was discovered, and four specimens were collected by the authors. We attempted to key these plants in *Flora Yunnanica* (Wu et al. 1977) as well as Li’s (1988) monograph and the updated treatment of Lamiaceae in *Flora of China* (Li and Hedge 1994), but were unsuccessful. Thorough morphological examination revealed that this population differed substantially from other species of *Isodon*. In this paper, we describe and illustrate the new

species (Fig. 1) and compare it morphologically to its most similar congener (Table 1).

MATERIALS AND METHODS

To verify morphological differences between the probable new species and other potentially closely related *Isodon* species, herbarium materials (including types) from CDBI, E, IBK, IBSC, K, KUN, L, and PE were examined (abbreviations following Holmgren et al. 1990; see electronic supplement). After careful comparison of specimens, we deemed *I. irroratus* (Forrest ex Diels) Kudo to be the species that is morphologically most similar to the putative new species. This recognition guided our selection of additional morphological characters to further investigate, which pertain to plant habit, leaf morphology, trichome morphology, inflorescence structure, calyx morphology, and pollen structure.

The description of the potential new species, as well as the comparison with *I. irroratus* (Table 1), was carried out through the observation and analyses of herbarium specimens and our own field collections. Measurements were made using a micrometer under a microscope. Methods for examining trichome micromorphology follow Xiang et al. (2010). Materials for pollen morphology were prepared according to Abu-Asab and Cantino (1989). For each species, pollen grains were removed from five buds. Pollen samples were affixed to specimen tabs with double-sided tape and then sputter-coated with gold-palladium. Observations were conducted using either a KYKY-10000B (Science Instrument Company, Beijing, China) scanning electron microscope (SEM) with 15 KV voltage (Kunming Institute of Botany, Yunnan, China) or a JEM-1011 (JEOL Ltd., Tokyo, Japan) transmission electron microscope (TEM) with 30 KV voltage (Kunming Medical University, Yunnan, China). Pollen terminology follows Harley et al. (1992) and Punt et al. (2007).

RESULTS AND TAXONOMIC TREATMENT

Isodon wui C. L. Xiang et E. D. Liu, sp. nov.—TYPE: CHINA. Yunnan: Dongchuan County, Jiulong Village, Mt. Jiaozi, alt. 2,730 m, 26°21′24.0″N, 102°55′08.7″E, on the edge of mixed forest, 26 Jul 2008, C. L. Xiang & E. D. Liu HP9958 (holotype: KUN!).

Species affinis *I. irroratus* (Forrest ex Diels) Kudo, sed habito parvo, 15–20 cm alto, lamina anguste ovata, margine sparsim serrata a medio ad apicem, apice acuminata, utrinque piloso unicelluloso; cymis plerumque 1–3 flore, floribus sparsis, pedunculis 0.5–0.8 cm longis differt.

Perennial shrubs, 15–20 cm tall. Rhizomes woody, 3–5 mm diam., twisted. Stems 2–3 mm diam, terete, erect, sparsely finely puberulent, trichomes gray, bark peeling longitudinally. Leaves opposite; lamina 1–2 cm × 0.5–1 cm, thick papery, narrowly ovate, base broadly cuneate, margin sparsely serrate above the middle, apex acute; adaxial surface green, sparsely covered

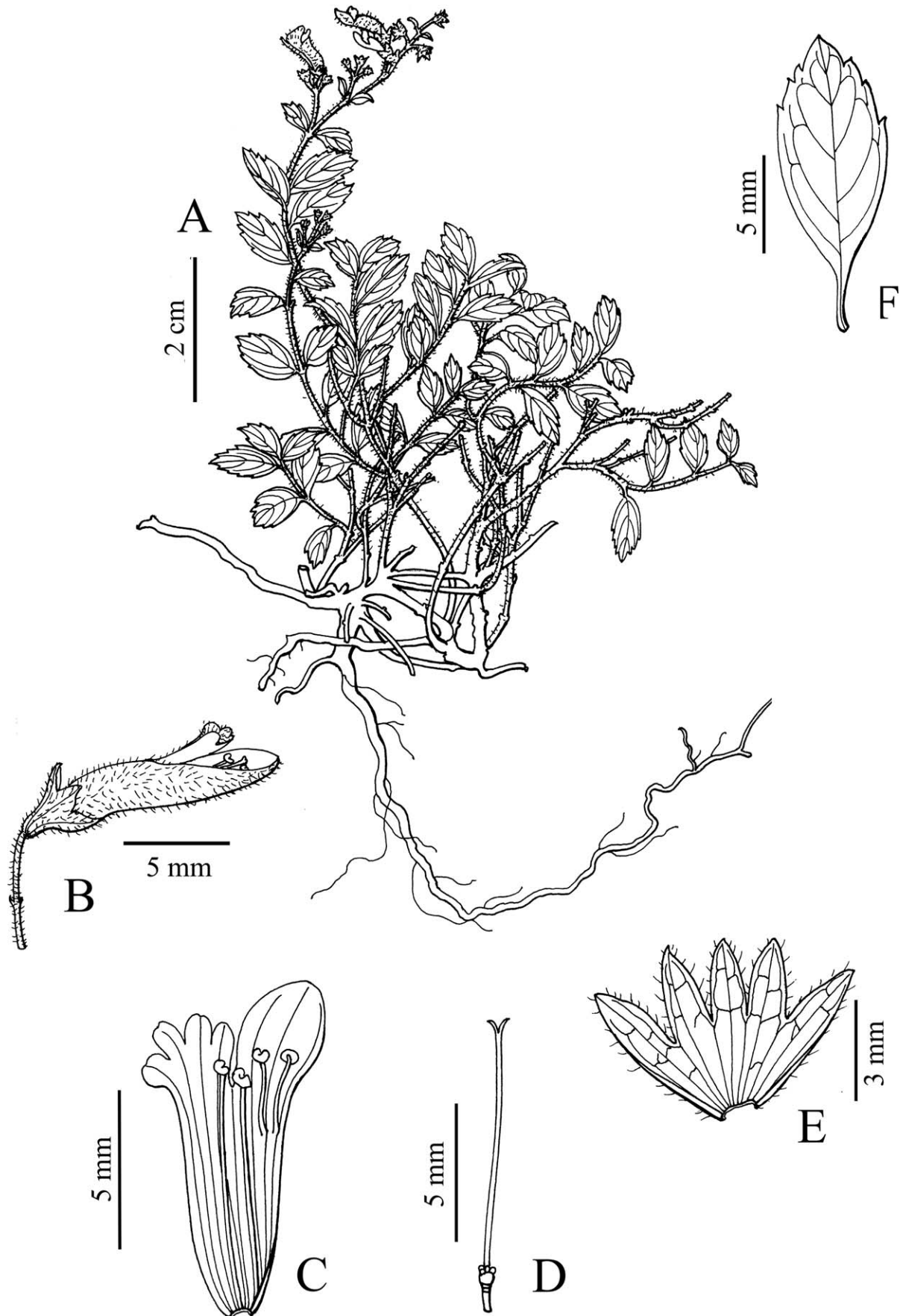


FIG. 1. Diagnostic morphological features of *Isodon wui* C. L. Xiang & E. D. Liu (C. L. Xiang and E. D. Liu HP9958). A. Habit. B. Flower in lateral view. C. Opened flower. D. Pistil. E. Calyx. F. Leaf blade.

TABLE 1. Morphological differences between *Isodon wui* and *I. irroratus*.

Character	<i>I. wui</i>	<i>I. irroratus</i>
Stem length	15–20 cm	30–100 cm
Leaf length	2 cm	3 cm
Leaf width	1 cm	2.5 cm
Leaf blade condition	Margin sparsely serrate above the middle	Margin densely crenate except for entire base
Leaf shape	Narrowly ovate	Ovate
Unicellular trichomes	Abundant	Absent
Clavate glandular trichomes	Absent	Abundant
Number of flowers per cyme	Generally 1-flowered	3–7 flowers
Cymes	Sparsely arranged	Densely arranged
Peduncle length	0.5–0.8 cm	1–1.5 cm
Pollen size	44 × 29 μm	35 × 20 μm
Polar / equatorial axis diameter	1.52	1.75

with capitate glandular trichomes and simple unbranched eglandular hairs, abaxial surface densely covered with capitate glandular trichomes, occasionally mixed with eglandular hairs; lateral veins generally 4 pairs. Petioles 0.1–0.25 cm long, with appressed, eglandular hairs 0.2–0.4 mm long. Inflorescences of axillary monochasial cymes, discrete, cymules generally 1-flowered, solitary; floral bracts ovate to lanceolate, shorter than cymes; bracts similar to stem leaves, but decreasing in size in distal portions of inflorescence; bracteoles minute, narrowly lanceolate, ca. 1 mm. Pedicels 0.5–1 cm long, minutely hairy, with eglandular hairs 0.2–0.3 mm long. Calyces 3–5 mm × 3–5 mm, nearly regular; tube broadly campanulate, conspicuously 10-veined, 0.9–1.2 cm long, the exterior covered with appressed, eglandular hairs and scattered yellow glands; lobes triangular, ca. 1/2 as long as tube, subequal, 1–2 mm × 1–1.8 mm, purplish, minutely pubescent with appressed, eglandular hairs and capitate glandular hairs on both sides. Corolla purple, ca. 1.5 cm × 0.5 cm, densely pubescent outside; tube to 1.1 cm long; 2-lipped, upper lip 4-cleft, recurved, ca. 2.5 mm long; lower lip entire, concave, navicular, ca. 4 mm long. Stamens 4, included within corolla; filaments free, 2.5–3.5 mm long; anther bithecos, apex confluent. Style included, stigma equally 2-cleft. Fruit not seen. Figure 1.

Trichome Morphology—Figure 2 shows the morphology of trichomes on leaves of the new species and *I. irroratus*. Two basic types of trichomes were recognized: glandular and eglandular. Glandular trichomes are subdivided into capitate and clavate trichomes while eglandular trichomes are simple. *Isodon wui* has two kinds of trichomes, capitate glandular trichomes and simple eglandular trichomes, both of which are situated mainly on veins. In *I. irroratus*, clavate glandular trichomes and capitate glandular trichomes were observed, but no eglandular trichomes. Those of the clavate type are densely distributed across the entire epidermis.

Pollen Morphology—Figure 3 shows the pollen size and shape of the two species. Pollen grains of *I. wui* (Figs. 3a, b, e), like nearly all members of subfamily Nepetoideae, are hexacolpate (Cantino and Sanders 1986). Polar axis (*P*) = 44 μm (42–46 μm), equatorial axis (*E*) = 29 μm (27–31 μm). Pollen shape, *P/E*: 1.52, subprolate-prolate. Sexine ornamentation is inconspicuous suprareticulate and has many perforations. The TEM ultrastructure of the pollen wall indicates columellae are much longer than both the tectum and the

foot layer, and seemingly unbranched (data not shown). The foot layer is discontinuous and comprises about one-fifth of the total wall thickness. The intine is one-third to one-half of the total exine thickness. In *I. irroratus* (Figs. 3c, d, f), pollen grains are also hexacolpate, polar axis (*P*) = 35 μm (33–37 μm), equatorial axis (*E*) = 20 μm (17–22 μm). Pollen shape, *P/E*: 1.75, prolate. Sexine ornamentation is suprareticulate.

Distribution, Habitat, and Phenology—Based on present collections, *Isodon wui* is a rare species that is endemic to Mt. Jiaozi. It occurs only in limited areas in one locality: Jiulong Village, Mt. Jiaozi, Dongchuan County, Yunnan, China, on dry slopes under or on the edge of mixed forests. The first author undertook a botanical expedition to Yunnan, Guizhou, Sichuan, Gansu and Tibet Provinces in 2009 and 2010, but no additional populations of this species were found. Additional collections in the future may help to clarify its full distribution. Flowering occurs between July and August.

Etymology—We named this species *Isodon wui* in honor of Professor Cheng-Yi Wu, a prominent botanist from Kunming Institute of Botany, Chinese Academy of Sciences, to honor his significant work on the flora and vegetation of China for over 70 yr. He is also an expert on the Lamiaceae of China. Working together with Professor Hsi-Wen Li, he has made great contributions to the knowledge of this family since the 1960s. In the past 40 yr, Wu and Li have published approximately 90 new combinations and described more than 230 new taxa of Lamiaceae from China. Most of their type specimens are deposited at KUN and PE, important herbaria for studying Chinese Lamiaceae. In 2007, Professor Cheng-Yi Wu was awarded the State Preeminent Science and Technology Award of China for his outstanding achievement in the fields of systematic botany and phytogeography, as well as plant diversity, conservation, and sustainable use of plant resources.

Conservation Status—*Isodon wui* is restricted to Mt. Jiaozi and is, based on our observations, uncommon in the area. Further exploration may result in the discovery of additional localities for the new taxon. Because the only known population occupies an area of less than 50 km², *I. wui* should be classified as CE – critically endangered category following the IUCN guidelines (IUCN 2008), at least until other populations are found.

DISCUSSION

Following the classification of Li (1988), the new species described here should be placed in sect. *Isodon* ser. *Longitubi* (C. Y. Wu & H. W. Li) H. W. Li. *Isodon longitubus* (Miq.) Kudo is the type species of ser. *Longitubi*. Species in this series have large and stout flowers that are approximately 1.2–2 cm long, corolla tubes twice as long as the limb, campanulate calyces, and calyx lobes subequal or slightly bilabiate (Wu and Li 1977; Li 1988). However, because the monophyly of all series in sect. *Isodon* was unresolved (Maki et al. 2010; Zhong et al. 2010), here we can only conclude that *I. wui* is morphologically most similar to *I. irroratus*, due to their shared similarities in general floral and calyx morphology.

The two species differ in at least 12 characters pertaining to plant stature, leaf size and shape, inflorescence, indumentum, and pollen (Table 1). These two species also have different geographical distributions. *Isodon irroratus* is known from five localities in dry, warm valleys in northwestern Yunnan and southwestern Sichuan. In contrast, *I. wui* is endemic to central Yunnan and is only known from Mt. Jiaozi.

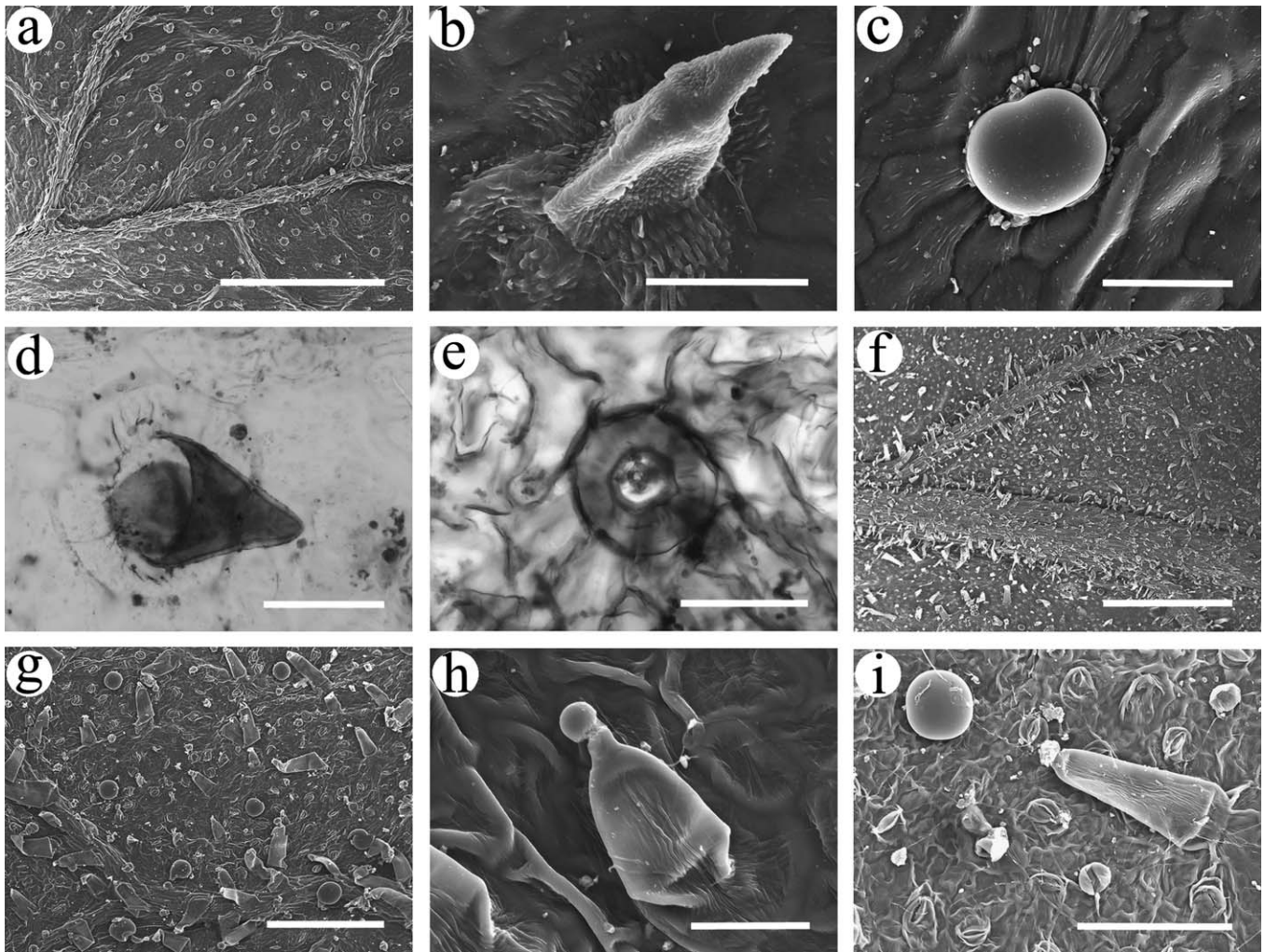


FIG. 2. Micrographs of trichomes. a. trichomes on adaxial surface. b. Unicellular trichomes (SEM). c. Capitulate glandular trichomes (SEM). d. Unicellular trichomes (LM). e. Capitulate glandular trichomes (LM). f, g. Trichomes on adaxial surface (SEM). h. Clavate glandular trichomes (SEM). i. Trichomes on abaxial surface. a-e: *Isodon wui*. f-i: *Isodon irroratus*. Scale bars = 1 mm (a, f), 50 μm (b-e), 300 μm (g), 30 μm (h), 100 μm (i).

KEY TO THE SPECIES OF THE GENUS *ISODON* FROM YUNNAN PROVINCE

1. Leaves in whorls of 3–4 *I. ternifolius*
1. Leaves always opposite 2
 2. Fruiting calyx with 5 equal teeth, erect 3
 3. Stems and inflorescences densely purplish- or brownish-tomentose *I. enaderianus*
 3. Stems and inflorescences with indumentum not as above 4
 4. Leaves long-petiolate; flowering calyx gray-lanate *I. ericalyx*
 4. Leaves sessile or short-petiolate; calyx pilose 5
 5. Leaves ovate, petiole 1–6 mm long *I. phyllostachys*
 5. Leaves broadly ovate, sessile *I. pantadenius*
 2. Fruiting calyx with 5 subequal teeth or 2-lipped, recurved 6
 6. Corolla 1.2–2.0 cm 7
 7. Calyx campanulate, not tinged purplish *I. bulleyanus*
 7. Calyx broadly campanulate, purplish or dark purple-red 8
 8. Stems quadrangular; panicles strongly spreading *I. forrestii*
 8. Stems terete; panicles slightly spreading 9
 9. Plants 30–100 cm; leaves ovate; cymes densely arranged, 3–7 flowered *I. irroratus*
 9. Plants 15–20 cm; leaves narrowly ovate; cymes sparsely arranged, 1-flowered *I. wui*
 6. Corolla less than 1.2 cm 10
 10. Fruiting calyx with 5 equal or subequal teeth or inconspicuously 2-lipped 11
 11. Corolla tube spreading or straight; fruiting calyx teeth less than 5 mm 12
 12. Corolla mostly yellow or yellowish *I. flavoides*
 12. Corolla white, rose, or blue 13
 13. Leaves narrowly lanceolate to elliptic-lanceolate, base narrowly cuneate, margin remotely serrate above middle *I. walkeri*
 13. Leaves ovate to ovate-lanceolate, base rounded to cuneate-attenuate, margin crenate or serrate except at base 14

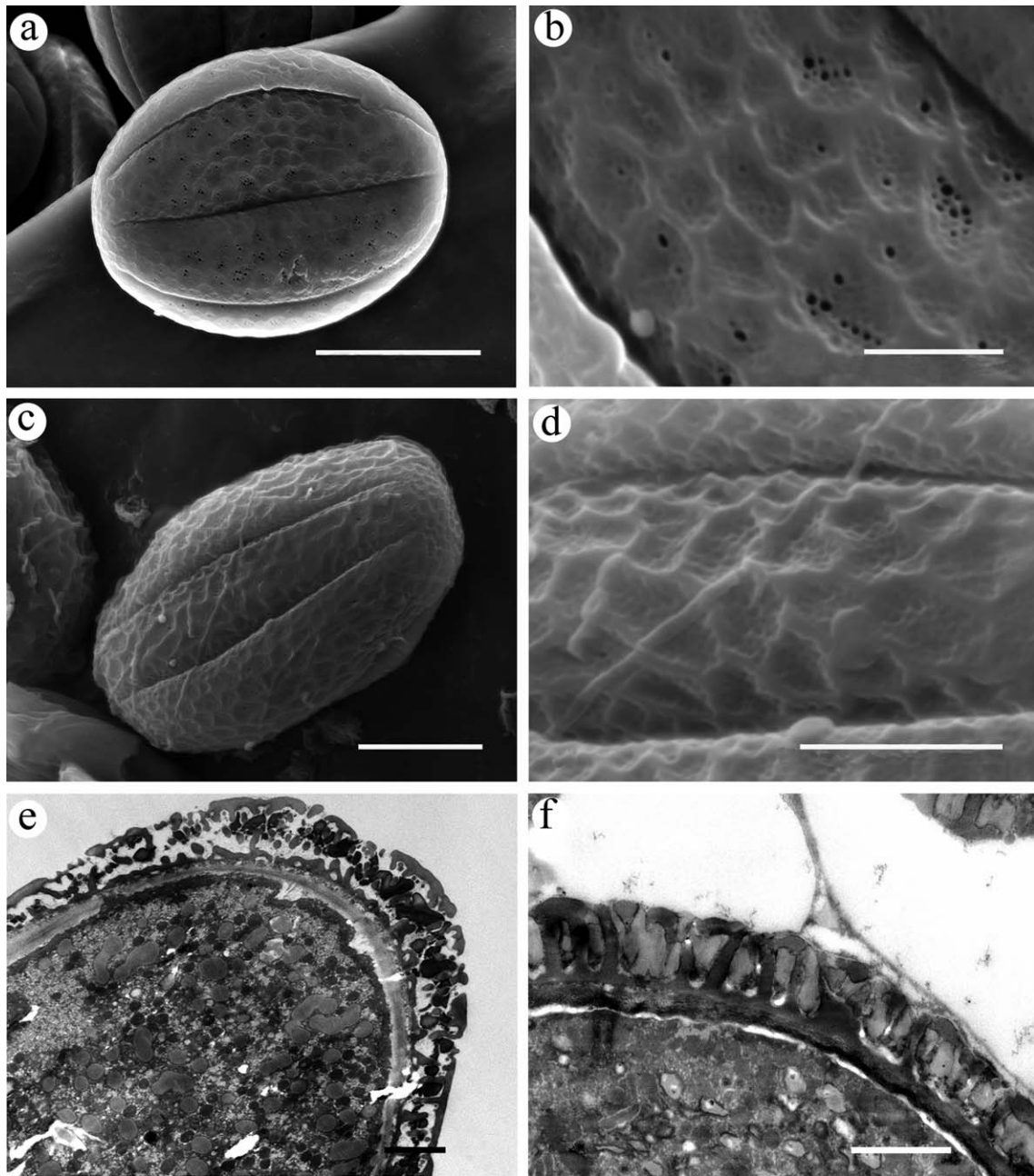


FIG. 3. Scanning electron micrographs and transmission electron micrographs of pollen grains. a, c. Whole pollen (SEM); b, d. SEM micrographs of exine surface; e, f. TEM micrographs of pollen wall. a, b, e. *Isodon wui*. c, d, f. *Isodon irroratus*. Scale bars = 20 μm (a), 5 μm (b, d), 10 μm (c), 2 μm (e, f).

- 14. Inflorescences gray-tomentulose *I. calcicolus*
- 14. Inflorescences with hairs never gray 15
- 15. Inflorescences papillate-velutinous; leaves scaly hirsute, especially on midrib and veins of abaxial surface *I. yuennanensis*
- 15. Inflorescences not papillate-velutinous; leaves villous or hirtellous, especially on midrib and veins of abaxial surface 16
- 16. Calyx densely villous *I. hispidus*
- 16. Calyx sparsely villous basally *I. lophanthoides*
- 11. Corolla tube declinate; fruiting calyx teeth generally longer than 5 mm 17
- 17. Calyx teeth extending to middle of calyx or more 18
- 18. Cymes in interrupted spikelike panicles *I. interruptus*
- 18. Cymes in continuous narrow spikes 19
- 19. Leaves subcircular to ovate-oblong, 1.2–1.8 \times 0.6–1.8 cm, strongly netted *I. scoparius*
- 19. Leaves larger, inconspicuously netted 20
- 20. Panicles terminal, 1.5–13 cm, cymes 3–5 flowered *I. setschwanensis*
- 20. Panicles terminal or axillary, 20–30 cm, cymes 3–15 flowered *I. angustifolius*

17. Calyx with small teeth never extending to middle of calyx 21
21. Branchlets, leaves, and calyces sparsely hairy; leaves usually not corrugate 22
22. Stem leaves less than 2 cm *I. glutinosus*
22. Stem leaves more than 2 cm *I. pleiophyllus*
21. Branchlets, leaves, and calyces variously dense hairy; leaves mostly corrugate 23
23. Branchlets, leaves, and calyces densely stellate-tomentose or stellate-lanate 24
24. Calyx teeth ca. 1/3 as long as calyx tube 25
25. Leaves without a brown gland on lower surface of each tooth apex *I. rugosus*
25. Leaves with a brown gland on lower surface of each tooth apex 26
26. Panicles 8–20 cm *I. leucophyllus*
26. Panicles 3–5 cm *I. adenolomus*
24. Calyx teeth ca. as long as calyx tube 27
27. Leaves 3–8 cm *I. grandifolius*
27. Leaves less than 2.5 cm *I. oresbius*
23. Branchlets, leaves, and calyces with different hairs than above 28
28. Leaves conspicuously discolored 29
29. Calyx teeth narrowly triangular *I. wikstromioides*
29. Calyx teeth broadly triangular *I. tenuifolius*
28. Leaves not discolored 30
30. Cymes sessile or short pedunculate; branchlets, inflorescences, and calyces densely hirtellous *I. hirtellus*
30. Cymes conspicuously pedunculate; branchlets, inflorescences and calyces not hirtellous 31
31. Leaves ovate-lanceolate *I. loxothyrsus*
31. Leaves ovate-oblong, rhomboid to ovate-triangular 32
32. Leaves ovate-oblong, base rounded *I. xerophilus*
32. Leaves rhombic to ovate-triangular, base broadly cuneate to truncate *I. rugosiformis*
10. Fruiting calyx conspicuously 2-lipped 33
33. Cymes few flowered, axillary, in terminal racemose panicles 34
34. Cymes in axils of mid and upper cauline leaves, which are not reduced upwards *I. melissoides*
34. Cymes in axils of floral leaves, which are gradually reduced toward branched apex *I. adenanthus*
33. Cymes loosely many flowered, often conspicuously pedunculate 35
35. Calyx lips extending to middle of calyx 36
36. Cymes in narrow panicles 37
37. Stamens slightly exerted *I. phyllopodus*
37. Stamens included *I. coetsa*
36. Cymes in spreading panicles 38
38. Corolla yellow *I. sculponeatus*
38. Corolla bluish purple *I. megathyrsus*
35. Calyx lips extending below middle of calyx 39
39. Cymes in narrow panicles *I. exisoides*
39. Cymes in spreading panicles 40
40. Leaf blade base not cordate *I. weisiensis*
40. Leaf blade base shallow cordate 41
41. Corolla blue *I. flabelliformis*
41. Corolla whitish, pale yellow or yellow, tinged reddish purple *I. scrophularioides*

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