

## Discription of *Arisaema* (Araceae) found in Bhutan and new additions to the Flora of Bhutan

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### Abstract

The seven sections of the genus *Arisaema* found in Bhutan are described based on the morphological evidences of 16 species of *Arisaema* known from the Bhutan Himalaya: sect. *Anomala* Gusman & L. Gusman, sect. *Arisaema*, sect. *Dochafa* (Schott) H. Hara, sect. *Nepenthoidea* (Engler) H. Hara, sect. *Sinarisaema* Nakai and sect. *Tenuipistillata* Engler, sect. *Tortuosa* (Engl.) Nakai. of the seven recognised sections, sect. *Arisaema* is the most diverse section with eight species recorded from Bhutan. In this paper *Arisaema petiolulatum* Hook.f. and *Arisaema anatinum* Brugg. are documented as new records for Bhutan.

**Keywords.** Araceae, *Arisaema*, distribution, habitat, new records, sections, taxonomy

### Introduction

The genus *Arisaema* Mart., commonly known as Cobra Lilies in Asia is one of the most diverse genera in the family Araceae. Of the 692 recorded species, about 240 are accepted species (Govaerts *et al.*, 2021). They are either deciduous or evergreen perennial herbs with a single spathaceous inflorescence emerging from the underground stem, mostly distributed in the subtropical and temperate regions of Asia (Murata, 2011; Ohi-Toma, 2016). Classification of *Arisaema* species was initiated by Schott (1860) where he grouped into four un-

published major groups. Subsequently, several authors work on the taxonomy of the genus *Arisaema* (Engler, 1920; Nakai, 1950; Hara, 1971; Murata, 1984; Gusman and Gusman, 2002; 2006). Murata (2011) and Murata *et al.* (2013) published a revised sectional classification based on an unpublished molecular phylogenetic analysis and recognized 14 sections, including the section *Odorata* J. Murata. Most recently, Ohi-Toma *et al.* (2016) recognized 15 sections in the genus based on the morphological characters and phylogenetic relationships and recognised one additional section to the 14 sections recognized by Murata (2011) and Murata *et al.* (2013). The section *Fimbriata*, an unranked *Fimbriata* (Engler, 1920) which was synonymized under the section *Attenuata* by Murata (2011) has been reinstated as a monotypic section in having bisexual spadix and a long spadix

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appendage that extends from the spathe (Ohi-Toma *et al.*, 2016).

Noltie (1994) in the Flora of Bhutan recorded 14 *Arisaema* species but did not attempt to assign the species of *Arisaema* recorded from Bhutan into sections and provide a description of sections found in Bhutan.

The occurrence of *Arisaema anatinum* Brugg. and *Arisaema petiolulatum* Hook.f. have not been documented in the country so far and it is hereby reported as new records for Bhutan. Distribution and habitat provided for taxa in each section are based on Noltie, 1994 and the field experiences of the authors.

## Materials and Methods

For morphological-based section assignment and description, we followed Gusman and Gusman (2006), Li *et al.* (2010) and Murata *et al.* (2013) using the morphological terminologies and descriptions (Noltie, 1994; Li *et al.* 2010). Specimens of *Arisaema petiolulatum* Hook.f. and *Arisaema anatinum* Brugg. were collected from the cool broadleaved forests of Samdrup Jongkhar and Trongsa districts during the NWFP survey, annual bird festival, and mammal survey in 2019 and 2020. Photographs of



**Figure 1.** *Arisaema petiolulatum* Hook.f. **A.** Flowering plant in habitat; **B.** Rhizome; **C.** Leaf (Adaxial surface view); **D.** Inflorescence (lateral view); **E.** Female spadix.

the plants were taken using Nikon D3400 and GPS eTrex 30x was used for recording elevation and geo-coordinates. The identity of the species was confirmed by reviewing the taxonomic literature (Hook.f., 1893; Noltie, 1994; Gusman and Gusman, 2006; Li *et al.*, 2010; Brugg., 2018) and specimens in the herbaria (THIM, NY, P, MICH, NL, K, and MNHN). Protologues and images of type specimens were referred from JSTOR Global Plants website (<http://plants.jstor.org>). Collected specimens are deposited at National Herbarium (THIM), National Biodiversity Centre, Thimphu, Bhutan.

## Results and Discussion

The seven sections of genus *Arisaema* known from Bhutan Himalaya are described based on morphology and the 16 species, including the two new additions, are assigned to their relevant sections: sect. *Anomala* Gusman & L. Gusman, sect. *Arisaema*, sect. *Dochafa* (Schott) H. Hara, sect. *Nepenthoidea* (Engler) H. Hara, sect. *Sinarisaema* Nakai and sect. *Tenuipistillata* Engler, sect. *Tortuosa* (Engl.) Nakai. Of the seven recorded sections, sect. *Arisaema* is the most diverse section with eight species in Bhutan. The species in each section occupy different habitats in the broadleaved forests, conifer forests, and rhododendron forests at an elevation ranging from 150–4300 m.

## Notes on the Sections of the Bhutanese *Arisaema*

*Arisaema* sect. *Anomala* Gusman & L. Gusman, *Aroideana* 26: 40 (2003).

Li *et al.* in Zhu *et al.*, *Fl. China*, 23: 44. 2010; Murata *et al.* *J. Jap. Bot.* 88: 44. 2013; Murata *et al.*, *Act. Phytotax. Geobot.* 65 (3): 164. 2014. —Type: *Arisaema anomalum* Hemsl.

Plants evergreen, underground stem rhizomatous, cylindric, roots present all over the rhizomes. Leaves and inflorescence emerge from the rhizome separately with their cataphylls. Phyllotaxy spirodistichous, leaf trifoliolate.

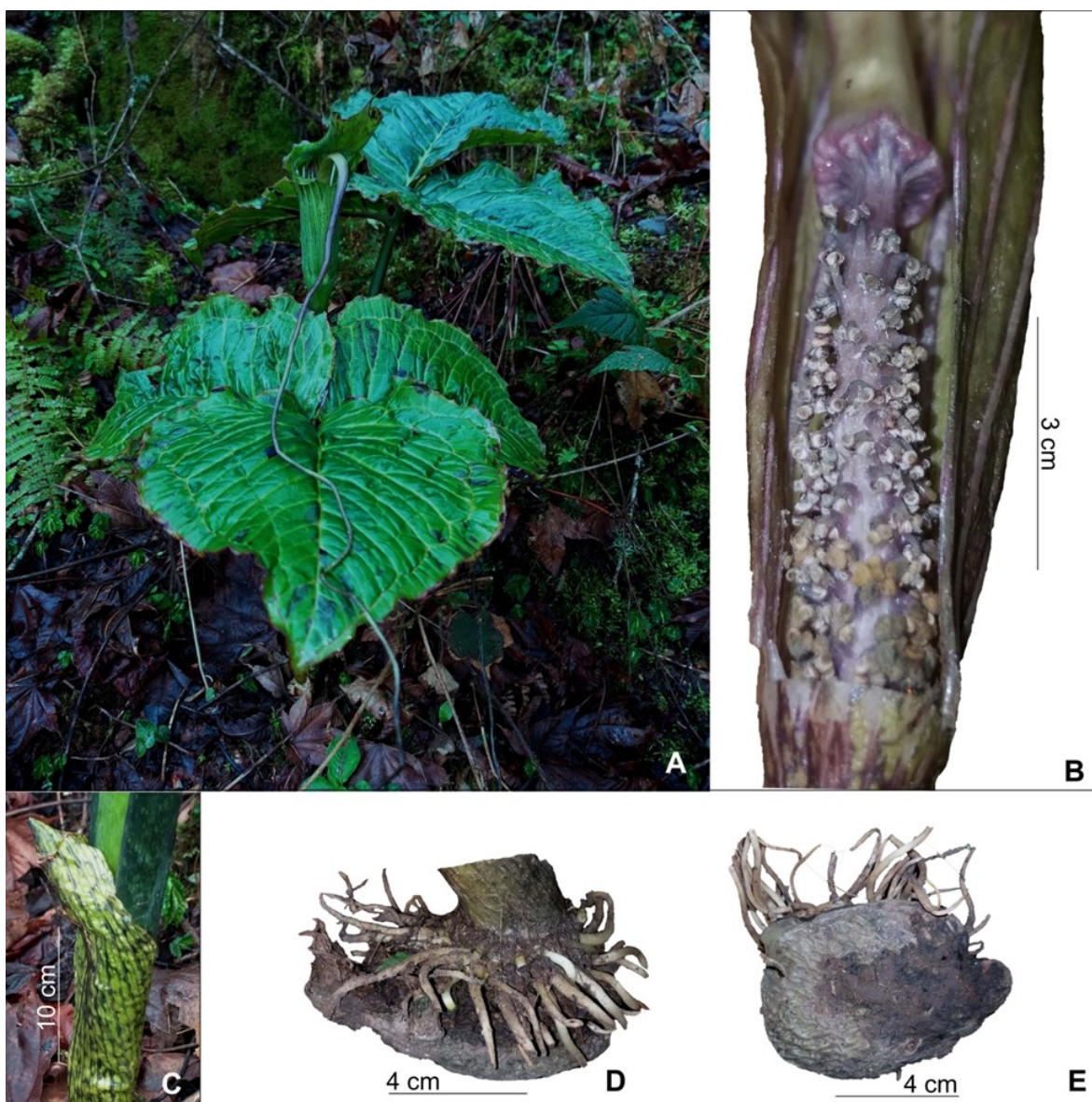
Spadix appendix slightly to long-exserted from the tube, and neuter present above the female fertile zone. *Arisaema petiolulatum* Hook.f. is the only species documented in this section from Bhutan and is reported as a new record to Bhutan in this paper.

*Arisaema petiolulatum* Hook.f., *Fl. Brit. India* 6:498. 1893; Chatterjee, *Bull. Bot. Surv. India* 8:130. 1955; A.S. Rao & D.M.Verma, *Bull. Bot. Surv. India* 19: 13. 1976 (1979); Pradhan, *Himal. Cobra Lilies* 65. 2002; Gusman & L. Gusman, *Arisaema*. Ed.2. 93. 2006.

*Arisaema listeri* Prain ex Burkill, *Rec. Bot. Surv. India* x. 397 (1925); *Arisaema inkiangense* H.Li, *Acta Phytotax. Sin.* 15(2): 106 (1977); *Arisaema inkiangense* var. *maculatum* H. Li, *Acta Phytotax. Sin.* 15(2): 106 (1977). — Lectotype: India, Arunachal Pradesh, Abor Hills, south slopes of Bapu, 700 m, 07.03.1912, I.H. Burkill 36912 (CAL0000026228!).

Evergreen perennials, 35–80 cm tall. Subterranean stems rhizomatous, 4–8.5 × 2–3 cm, purple inside in cross-section. Roots numerous, white. Pseudostems inconspicuous. Cataphylls 3, enveloping peduncle, pinkish-brown, 6–25 cm long. Leaf single, trifoliolate; petioles 20–60 cm long, 0.6–2 cm wide, pale to dark green, glabrous; leaflets-3, petiolulate, apex acuminate, base cuneate, margins entire, adaxially green, abaxially pale green, variegated with white patches; central leaflet elliptic, 12.5–22 × 6–8 cm, petiolule 2–3.5 cm long; lateral leaflets asymmetric, subequal or slightly larger than a central leaflet, ovate-lanceolate to elliptic-lanceolate, 13–23 × 4–6.5 cm, petiolule 1.5–2.5 cm long, shorter than petiolule of the central leaflet. Inflorescence associated with the old leaves from the previous season; peduncles slender, 25–32 × 0.5–0.8 cm, pale greenish-white, glabrous; spathe tube cylindrical, green, whitish at the base, 5–6 cm long, 1–1.5 cm wide at base, slightly funnel-shaped at the mouth, mouth margins auriculate, auricles 0.6–0.8 cm wide, slightly revolute; spathe limb ovate-lanceolate, horizontal or drooping, 7–8 ×





**Figure 2.** *Arisaema anatinum* Brugg. **A.** Flowering plant in habitat; **B.** Male spadix; **C.** Cataphyll; **D** -**E.** Tuber (lateral and underside view).

2.8–3.5 cm, apex acuminate, margins entire, green, glaucous, veins raised above. Bisexual spadix, 5.5–7 cm long; fertile zone 1–2 × 0.6–0.8 cm; pistils compactly arranged; ovoid, green, 1.5–2 mm; style absent; stigma papillose, stellate, pale white; male fertile zone c. 1.5 cm long, male flowers few, laxly arranged, stipitate, stipe c. 2 mm, 1–4-androus; appendix up to 5 cm long, slightly exerted from the tube, cylindrical at base and tapering to the upper part, truncate at apex, pale green, glabrous, neuter present. Male spadix c. 6 cm long; fertile zone c. 2 cm long, c. 0.3 cm across; male flowers

laxly arranged, sessile, 3–5-androus; appendix c. 3.8 cm long, slightly curved at the apex; neuters absent. Infructescence cylindric, 5–6 cm long, 2.8–3 cm wide; berries ovoid, compactly arranged, c. 1.2 cm long, 0.5–1 cm diam., green when young, turns yellow then to red on maturity.

*Phenology:* Flowering and fruiting in September – March.

*Ecology and Habitat:* As an undergrowth in evergreen forests from 700 to 2100 m eleva-

tions.

*Distribution:* China, India, Myanmar and new to Bhutan (Zhemgang and Samdrup Jongkhar).

*Specimens examined:* Bhutan, Samdrup Jongkhar, Khoyar, 1882 m, 27°00'28" N, 91°34'38"E, 25.5.2019, D. Tshering 16 (THIM15869). India, Meghalaya, East Khasi Hills, Mawryngkneng, 10.11.1951, 1219 m, Koelz WN 29014 (MICH!); *Ibid*, W.N. Koelz 29014 (NL!); Manipur, Karong, 1067 m, 27.10.1950, W.N. Koelz 26761 (MICH!); Manipur, Forest in ascent to Seripharai, 2682 m, 16.01.1882, G. Watt 5917 (K!).

*Notes:* *Arisaema petiolulatum* was a doubtful record from Bhutan and detailed descriptions were not provided in the Flora of Bhutan. A note on its record was made by Manudev *et al.* (2018) was available on its distribution but it was without any details. Here we reported this species as a new record to Bhutan with detailed description based on herbarium specimen which was collected from Samdrup Jongkhar after through examinations of the species in the field.

#### **Arisaema sect. Arisaema**

Li *et al.*, in Zhu *et al.*, Fl. China, 23: 52. 2010; Murata *et al.*, J. Jap. Bot. 88: 44. 2013; Murata *et al.*, Act. Phytotax. Geobot. 65 (3): 165. 2014. —Type: *A. speciosum* (Wall.) Mart. ex Schott.

Plant deciduous, underground stem tuberous, roots around the base of the central shoot only. Leaf 1–2, trifoliolate, central leaflet sessile or petiolulate. Spathe tube sometimes lamellate inside, limb often widened and/or galeate. Spadix appendix attenuate, appendix prominently long and then exerted from the tube and stipitate, distally filiform or tail like; neuters absent, staminate flowers dehiscing by a single horse-shoe-shaped slit. Fruiting peduncle erect.

*Distribution and habitat.* Eight taxa are recognized in this section which is distributed in Chukka, Sarpang, Haa, Thimphu, Punakha,

Gasa, Wangdue, Trongsa, Bumthang, Mongar, and Samdrup Jongkhar districts: The taxa are *Arisaema anatinum* Brugg., *Arisaema dilatatum* Buchet., *Arisaema elephas* Buchet., *Arisaema galeatum* N.E.Br., *Arisaema griffithii* Schott, *Arisaema propinquum* Schott, *Arisaema speciosum* (Wall.) Mart. and *Arisaema utile* Hook.f. ex Engl. These species grow among rocks and margins of subtropical to Rhododendron forests, in the open Blue pine forest and open grasslands at 2000–4300 m elevations.

*Arisaema anatinum* Brugg., Blumea 63:147–149. 2018.

Type:— M. Bhaumik 2502 (holo CAL), India, Arunachal Pradesh State, Lower Dibang District, Mayodia, 2690 m a.s.l., 21 Apr. 1999; P. Bruggeman PBR749 (para L, male and female in spirit, prepared from cult.). Figure 2.

*Notes:* The plant was first discovered and described in 2018 based on the type specimens collected from Dibang district under Arunachal Pradesh in India. Brugg. (2018) has mentioned the distribution of *Arisaema anatinum* in Trashigang, Bhutan based on the information shared by Johan Nilson, Gothenburg Botanic Garden but there was no proof or specimens to substantiate its occurrence in Bhutan. Here we reported this as a new record to Bhutan based on the herbarium specimens collected from central Bhutan in 2019. To confirm the identity, morphological characteristics of the specimens were cross-checked with the protologue and are found to perfectly matching with the description. Detailed descriptions are substantiated by Brugg. 2018. However, the plant reported from central Bhutan has Spadix appendix 7–10 mm across at the base and extend up to 50 cm long. The addition of this character gives complete descriptions of the newly described species.

*Phenology.* Flowering in April–May, and fruiting in September–October.

*Habitat and Ecology:* In Bhutan, we authenticate the distribution of the species in Trongsa and Zhemgang districts. The distribution in Trashigang (Brugg., 2018) is neglected in this paper due to the lack of evidence to support the claim. An extended distribution range in other districts of the country can not be neglected especially in the areas with the same geological and climatic conditions which favour the growth and survival of this species. This taxon prefers shaded areas in the cool broadleaved and conifer forests, and at the edges of bamboo thickets in moist and humus-rich soil at 2300–3300 m elevations.

*Specimens examined:* Bhutan, Trongsa, Nelagang, 3000 m, 27°18'5.38"N, 90°39'48.80"E 03.8.2019, P. Gyeltshen, 44 (THIM17724).

**Arisaema** sect. **Dochafa** (Schott) H. Hara, Bull. Univ. Mus. Univ. Tokyo 2: 344. 1971.

Li *et al.*, in Zhu *et al.*, Fl. China, 23: 63. 2010; Murata *et al.*, J. Jap. Bot. 88: 42. 2013; Murata *et al.*, Act. Phytotax. Geobot. 65 (3): 165. 2014. —Type: *Arisaema flavum* (Forssk.) Schott.

Plant deciduous, underground stem tuberous or rhizomatous and rooting around the central shoot only. Phyllotaxy quincuncial, leaf pedate. Spathe small, limb incurved, ovate. Spadix bisexual, appendix sessile, shorter than the fertile zone, neuters absent. Male flowers are subsessile and densely arranged. Infructescence nodding. Fruiting peduncle erect or nodding.

*Distribution and Habitat:* Only one taxon is found in the section. Regionally, it is distributed in Chukha, Haa, Thimphu, Punakha, Mongar, and Lhuntse districts. It grows in open fields and meadows at 2100–2800 m elevations.

**Arisaema** sect. **Nepenthoidea** (Engler) H. Hara, Bull. Univ. Mus. Univ. Tokyo 2: 325. 1971. Li *et al.*, in Zhu *et al.*, Fl. China, 23: 56. 2010; Gusman & L. Gusman ex J. Murata, *Arisaema* in Japan: 63. 2011; Murata *et al.*, J. Jap. Bot.

88: 44. 2013; Murata *et al.*, Act. Phytotax. Geobot. 65 (3): 174. 2014. —Type: *Arisaema nepenthoides* (Wall.) Schott.

Plant deciduous, underground stem tuberous or rhizomatous and rooting around the central shoot only. Phyllotaxy quincuncial. Leaves palmate, leaflets 5(-7). Spadix base stipitate, spadix appendix erect, terete, slightly exserted from the tube, neuters absent, female flowers bottle-shaped. Fruiting peduncle erect.

*Distribution and Habitat:* This section is represented by a single taxon: *Arisaema nepenthoides* Mart. which is distributed in Chukka, Sarpang, Haa, Thimphu, Punakha, Wangdue, Tongsa, Bumthang, and Samdrup Jongkhar districts. It grows on the edges and banks of the broadleaved forests up to Alpine forest, and sometimes beside streams at 1800–3440 m elevations.

**Arisaema** sect. **Sinarisaema** Nakai, J. Jap. Bot. 25: 6. 1950; Gusman & L. Gusman, Gen. *Arisaema*, ed. 2. 349. 2006; Hara, Fl. E. Himal. 347. 1971; Li *et al.*, in Zhu *et al.*, Fl. China, 23: 65. 2010; Murata *et al.*, J. Jap. Bot. 88: 44. 2013. —Type: *Arisaema formosanum* (Hayata) Hayata.

Plant deciduous, underground stem tuberous and rhizomatous and roots around the shoot. Phyllotaxy spirodistichous, radial leaves at least 7 leaflets, more or less same length, eophyll simple. Spathe limb apex caudate to acuminate, and spadix appendix clavate, exserted from the tube, rugose, or knobbed at the apex.

*Distribution and Habitat:* So far, only three species: *Arisaema consanguineum* Schott, *Arisaema concinnum* Schott, and *Arisaema echinatum* Schott. are recorded from this section. It is distributed in Chukka, Sarpang, Ha, Gasa, Thimphu, Paro, Punakha, Trongsa, Bumthang, Tashigang and Tashiyangtse districts. The species in this section prefers an open or disturbed forest, meadows, under-

scrubs, riverbanks, and edges of oak and blue pine forests at 300—3400 m elevations.

**Arisaema** sect. **Tenuipistillata** Engler, Pflanz. 73(IV. 23F): 151, 195. 1920.

H. Hara, Univ. Mus. Univ. Tokyo. Bull. 2: 346 (1971); Li *et al.* in Zhu *et al.*, Fl. China, 23: 65. 2010; Murata *et al.*, J. Jap. Bot. 88: 42. 2013; Murata *et al.*, Act. Phytotax. Geobot. 65 (3): 165. 2014. —Type: *Arisaema jacquemontii* Blume.

Plant deciduous, underground stem tuberous and rhizomatous and roots around the shoot. Phyllotaxy quincuncial, leaf palmate, leaflets 5 (-7), bilateral, rachis absent. Spadix stipitate; appendix longer than the fertile zone, slightly to long exserted from the tube, neuters absent. Female flowers fusiform. Fruiting peduncle erect.

*Distribution and Habitat:* Only one species: *Arisaema jacquemontii* Blume, is recorded for this section and is distributed in Haa, Gasa, Thimphu, Trongsa, Bumthang, Mongar, and Lhuntse districts. Species in this section grow in open grassy places of conifer and Rhododen-

dron forests, forest edges, and clearings at 2250—4300 m elevations.

**Arisaema** sect. **Tortuosa** (Engl.) Nakai, Bot. Mag. (Tokyo) 43: 524 (1929).

H. Hara, Bull. Univ. Mus. Univ. Tokyo 2: 344. 1971; Li *et al.* in Zhu *et al.*, Fl. China, 23: 65. 2010; Murata *et al.*, J. Jap. Bot. 88: 44. 2013; Murata *et al.*, Act. Phytotax. Geobot. 65 (3): 165. 2014. —Type: *Arisaema tortuosum* (Wall.) Schott.

Plant deciduous, underground stem tuberous and rhizomatous, roots around the shoot. Leaf pedate. Spadix appendix elongated, and gradually attenuated, and exceeding spathe, neuters absent or present.

*Distribution and Habitat:* Only one species: *Arisaema tortuosum* Steud. ex Engl. is documented from this section in Bhutan. Regionally, it is distributed in Chukha, Sarpang, Samdrup Jongkhar, Thimphu, Punakha, Trongsa, Tashigang, and Gasa districts. Species in this section grow at the edges and disturbed areas in broadleaved forests at 150—3050 m elevations.

## Key to the Sections of Bhutanese *Arisaema* species

- 1a. Plant evergreen, underground stem rhizomatous, leaf trifoliate ..... *A.* sect. *Anomala*
- 1b. Plant deciduous, underground stem tuberous or rarely rhizomatous, leaf radial or bilateral symmetry ..... 2
- 2a. Leaf radial symmetry ..... *A.* sect. *Sinarisaema*
- 2b. Leaf bilateral symmetry, trifoliolate or pedate, spadix stipitate, sessile, attenuate ..... 3
- 3a. Spadix appendix stipitate, trifoliolate or palmate ..... 4
- 4a. Leaf blade trifoliolate, ovary bottle-shaped ..... *A.* sect. *Nepenthoidea*
- 4b. Leaf blade palmate, ovary fusiform ..... *A.* sect. *Tenuipistillata*
- 3b. Spadix appendix sessile or attenuate ..... 5
- 5a. Spadix appendix sessile, leaf pedate ..... *A.* sect. *Dochafa*
- 5b. Spadix attenuate, leaf trifoliolate or pedate ..... 6
- 6a. Leaf trifoliolate ..... *A.* sect. *Arisaema*
- 6b. Leaf pedate ..... *A.* sect. *Tortuosa*

## Conclusion

Seven sections of *Arisaema* are documented from Bhutan with 16 species including the two new records. Of the seven recorded sections, the *Arisaema* sect. *Arisaema* is the most diverse section in the country with eight species recorded till date. *Arisaema petiolulatum*

Hook.f. and *Arisaema anatinum* Brugg are documented as the new records for Bhutan. We recommend further explorations of the genus in the country, based on both morphology and molecular data to better understand the sectional delimitation and evolutionary relationship of the species within the genus.

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