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Front Cover: Terminalia santisukiana Patthar. & Poopath

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# **Obituary: Prof. Dr Thawatchai Santisuk (1944–2020)**



Prof. Dr Thawatchai Santisuk, one of Thailand's most widely respected plant taxonomists, passed away on 3 July 2020 at the age of 76, after a long illness. He was born in Songkhla on 20 March 1944. He graduated with a Bachelor's degree from the Faculty of Forestry at Kasetsart University in 1967, followed by a Master's degree in Plant taxonomy from the University of Edinburgh in 1970 and a PhD in Plant taxonomy from the University of Copenhagen in 1976.

Prof. Thawatchai was a superb botanist and ecologist, as well as a brilliant teacher, actively involved in many aspects of botanical science in Thailand. He spent his whole career with the Forest Herbarium, Royal Forest Department (BKF), which later became the Department of National Parks, Wildlife and Plant Conservation, based in Bangkok. His most important and lasting contribution was as Editor-in-Chief of the Flora of Thailand and Thai Forest Bulletin (Botany). He was deeply committed to the Flora project, with a lasting legacy of bringing the production of the Flora to international standards. He was a very able ambassador for the Flora, representing Thai botany at many international meetings. He actively engaged with the members of the Flora editorial board and was very welcoming to the many Thai and foreign botanists who visited BKF (often over a delicious lunch in a local restaurant).

Prof. Thawatchai was equally at home working on ecological projects. In particular, he published an outstanding article on vegetation types in Thailand (in Thai), which remains the most important ecological treatise on Thai forest types. He travelled to herbaria around the world, not only to study the Thai collections of many plant families but to bring new advances in botanical research and education back to BKF and other Thai botanical institutes. He was also awarded a Professorship at Kasetsart University.

In later years, Prof. Thawatchai was a fellow of the Academy of Science, The Royal Society of Thailand. He accompanied HRH Princess Maha Chakri Sirindhorn on a number of local and overseas visits and continued to undertake extensive botanical surveys throughout the country. He edited many manuscripts for various publications, with critical comments that would point out modern ways of classification. His vast knowledge of the Thai flora was passed on to a younger generation of botanists at BKF. Kasetsart and other universities where he taught the botany components of courses in advanced Taxonomy, Palynology and Pharmaceutical Botany. He was also a member of many committees for Master's and Doctoral degrees, a reflection of his excellent supervision skills.

Prof. Thawatchai was honoured by having several taxa named after him. The genus *Santisukia* Brummitt (Bignoniaceae) was named for him to acknowledge his contribution to Bignoniaceae - one of the first families that he contributed to the Flora of Thailand. Four species have also been named after him: *Croton santisukii* Airy Shaw (Euphorbiaceae), *Glochidion santisukii* Airy Shaw (Euphorbiaceae), *Glochidion santisukii* Airy Shaw (Euphorbiaceae), *Impatiens santisukii* T.Shimizu (Balsaminaceae) and *Terminalia santisukiana* Patthar. & Poopath (Combretaceae). Dick Brummitt, Kenneth Airy Shaw and Tatemi Shimizu were all good friends of Prof. Thawatchai, while Nannapat Pattharahirantricin and Manop Poopath were two of his students who later became colleagues in the Forest Herbarium.

Prof. Thawatchai is survived by his wife Paiparn, his son Chakorn and his twin grandchildren. His kind, gentle and polite personality will be very much missed but he will forever remain in our memories.

Kongkanda Chayamarit & David A. Simpson On behalf of the Flora of Thailand Editorial Board members

## Two new species of Pittosporum (Pittosporaceae) for the Flora of Thailand

TIMOTHY M.A. UTTERIDGE<sup>1</sup>

#### ABSTRACT

Two new species of *Pittosporum* (Pittosporaceae) are reported for Thailand. *Pittosporum lacrymasepalum* from Trat Province and *P. maxwellii* from Doi Inthanon, Chiang Mai Province are described and illustrated.

KEYWORDS: Apiales, conservation assessment, Doi Inthanon, taxonomy, Trat.

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#### **INTRODUCTION**

Pittosporum Banks ex Gaertn. is the largest genus in the Pittosporaceae with approximately 200 species, distributed from the Pacific, New Zealand through Malesia and extending into Africa and Madagascar (Gowda, 1951; Haas, 1977; Chandler et al., 2007). The genus was revised for Flora Malesiana (Bakker & van Steenis, 1957; for additions see Bakker, 1958, 1962; van Steenis, 1972, 1978; Utteridge, 2000; Hicks & Utteridge, 2002; Cayzer & Chandler, 2018), but has yet to be treated for the Flora of Thailand. Several Thai species were included in Gowda's (1951) revision of the genus in the 'Sino-Indian Region' where 53 species were recognised. However, some of the names and species limits used in Gowda (1951) were rather broad with disjunct distributions, and several taxa have been refined in recent treatments as more specimens and field observations became available; see, for example taxonomic changes in the Flora of China by Zhang et al. (2003, and discussed below).

In Thailand, the genus is found throughout the country in nearly all habitat types ranging from *Pittosporum ridleyi* L.W.Cayzer & G.Chandler in Southern Thailand to the new species described here found on Doi Inthanon, Thailand's highest peak. During preliminary studies of the material for the forthcoming Flora account, the following specimens did not match any existing species in Thailand or the surrounding regions and are described here as

new; descriptions and a key to all species in Thailand will be presented in the final Flora of Thailand treatment currently in preparation. Both of the new species described here are superficially similar to P. balansae A.DC. because of the leaf size and shape as well as the few-flowered terminal inflorescences with 2-valved fruits. Gowda (1951) placed a group of species with similar morphology into a 'Balansaecomplex' based on fruit and seed characters. The new species described here differ in several diagnostic characters including indumentum, sepal and petal size and shape and fruit and seed characters. The sepals are especially different - in P. balansae they are comparatively long with regard to the petals, lanceolate and ca 6 mm long ( $\pm$  half petal length) becoming reflexed on maturity, whereas both of the new species described here have close-fitting, nonreflexing ovate sepals less than 2 mm long (<<sup>1</sup>/<sub>4</sub> petal length).

Within the genus, the majority of species of *Pittosporum* are now known to be localised endemics (Gowda, 1951; Haas, 1977; Gemmill *et al.*, 2002; Cayzer & Chandler, 2018; Carter *et al.*, 2018), with few wide-ranging species within or between regions. For example, in the Pacific region, most species are endemic to an island, mountain top or a particular substrate (Haas, 1977). The description of the species here allows unique combinations of character variation and distribution patterns to be revealed that can be tested as hypotheses of relationships, rather

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than being lost within a morphologically heterogenous and widespread species. Indeed, genetically distinct and range-restricted populations requiring recognition as new species have been shown to occur throughout Indo-China as a result of the intensive plot work of the Center of Asian Conservation Ecology at Kyushu University (e.g., Souladeth *et al.*, 2019; Tagane *et al.*, 2019; Zhang *et al.*, 2020).

Members of the genus are functionally dioecious and will show sexual dimorphism between staminate and pistillate plants; however, it has been shown that both sexes have inconsistencies and staminate plants can have viable ovules (Cayzer, pers. comm.). In New Guinea, P. nubigenum Ridl. was studied by Utteridge (2000) and showed no significant differences between sexes in calyx and pedicel length, but the number of flowers per inflorescence, and petal and filament sizes were greater in staminate plants; some collections of staminate plants had fruit, and the species was concluded to be dioecious with low levels of inconstancy in the sexes (paradioecy, see Sakai & Weller, 1999). Unfortunately, due to the limited number of collections available for study of the two new species described here, only staminate plants in flower have been found, and more collections are needed to allow full descriptions of the different sexes.

#### TAXONOMY

#### Pittosporum lacrymasepalum Utteridge, sp. nov.

Differs from other *Pittosporum* species in Thailand and surrounding countries in the combination of the ferrugineous hairs on the young vegetative parts, terminal, few-flowered inflorescences, sepals 1–1.4 mm long (less than <sup>1</sup>/<sub>5</sub> petal length) with an acute apex, the ovary sparsely hairy at the base, and the 2-valved capsules with only 4 or 5 relatively small seeds each 4–5 mm long. Type: Thailand. Krat [=Trat], Kao Kuap [12°23'N 102°47'E], 1,700 m, 26 Dec. 1929 (fl.), *Kerr 17781* (holotype **BK** [digital image!]; isotypes **K!**, **L** [digital image!]). Fig. 1.

Shrubs to 2 m tall. Young parts, especially bud scales, ferrugineous hairy, very soon glabrous. *Leaves* clustered at branchlet apex; petiole 0.5-1.5 cm long, ferrugineous hairy on the adaxial surface when young, soon glabrous; lamina elliptic to oblanceolate,  $5-11.5 \times 1.5-3.5$  cm, chartaceous, glabrous ad- and abaxially, drying dark olive-green

adaxially, pale olive-brown abaxially; secondary veins 5-9-paired, secondary and lower order venation distinct abaxially, indistinct to distinct adaxially; base cuneate, margins entire, flat and smooth after drying, apex acute to attenuate or very slightly acuminate. Inflorescences terminal, laxly cymose, with <5 flowers (staminate plants), or flowers solitary (pistillate plants, only seen in fruit), glabrous; peduncle up to 3 mm long; bracts ovate, apex acute, up to 0.5 mm long, margins entire. Staminate flowers: pedicel 2.5-4.5 mm long; sepals free, ovate, apex acute, 1-1.4 mm long, glabrous; petals free, 5.5-6.5 mm long; stamens slightly shorter than petals, filaments ca 4 mm long, anthers 1.4–1.6 mm long; ovary long ovoid, sparsely hairy at the base, placentas at base of ovary, ovules 4-6(-9) per placenta. Pistillate flowers not seen. Fruits dehiscent, 2-valved capsules, wider than long, globose to oblongoid and somewhat laterally compressed, valves  $0.9-1.1 \times 0.8-1.4$  cm; pericarp thinly woody, with numerous horizontal striations internally. Seeds 4-5, subreniform, 4-5 mm along the longest axis, not cohering.

Thailand.— SOUTH-EASTERN: Trat [Kao Kuap [12°23'N 102°47'E], 1,700 m, 26 Dec. 1929 (fl.), *Kerr 17781* (**BK** [digital image BK208009], **K**, **L** [digital image, L1886256]); ibid., 22 May 1930 (fr.), *Put 2951* (**BK** [digital image, BK202974], **K**, **L** [digital image, L1886313]); ibid., 25 May 1930 (fr.), *Put 3023* (**BK**-2 sheets [digital images, BK202972, BK202973], **K**)].

Distribution.— Endemic to Thailand (so far known only from Kao Kuap).

Ecology.— "Common in light evergreen forest" fide *Kerr 17781*; Trat, like peninsular Thailand, has rains throughout the year; this species was collected at 1,700 m alt. which would be a lower montane evergreen forest type.

Etymology.— Named after the tear-shaped sepals (*lachryma* or *lacryma*, Latin, a tear, see Jackson 1905: 142).

Provisional conservation assessment.— DD (Data Deficient). The species is only known from three collections from the same locality from 1929 and 1930. The area lies along the border with Cambodia and appears to be forested on satellite imagery (Google Earth data from 2020); further field observations on the species and the quality of habitat are needed.



Figure 1. *Pittosporum lacrymasepalum* Utteridge. A. habit; B. leaf outline; C. leaf venation and margin detail; D. flower; E. individual sepal; F. flower with petals removed showing stamens, ovary and style; G. fruit and pedicels; H. dehisced fruit; J. seeds. A–F. *Kerr 17781* (**K**); G–J. *Put 2951* (**K**). All drawn by Hazel Wilks.

Notes.— This species differs from its close relatives in its distribution and its unique combination of characters: the low shrub habit to 2 m height, ferrugineous hairs on the young vegetative parts, relatively small, elliptic to oblanceolate leaves with distinct petioles, few-flowered terminal inflorescences, the relatively short, ovate sepals with an acute apex, the ovary sparsely hairy at the base only, and the 2-valved capsules with only 4 or 5 relatively small seeds.

Whilst there is no contemporary phylogenetic taxonomic framework of Pittosporum, or recent revision of the group in Indo-China and Thailand, Gowda's (1951) revision of the genus in the region can be used as an identification tool. This species would key to the informal 'Bivalvae' group of Gowda (1951) on account of the 2-valved capsule, even though the number of fruit valves is not always consistent with species. Gowda's (1951) complexes within the 'Bivalvae' are less clear-cut to key out, and relying on overlapping fruit and seed characters without the dimensions and size range clearly defined in his key, the species would be best placed within the 'Balansae-complex' based on the fruit and seed size, but also keys out somewhat to the 'Floribundumcomplex' in having short sepals and small capsules (but that group often has relatively large, terminal, many-flowered panicles).

Although superficially similar to *P. balansae* on account of the elliptic leaves and the terminal inflorescence with few flowers, *P. lacrymasepalum*, as well as the other new species described herein, *P. maxwellii* Utteridge **sp. nov.**, is quite different in the floral structure, especially in the key diagnostic characters of sepal size and shape. *Pittosporum balansae*, as represented by the populations in Thailand, has lanceolate sepals, 5–6 mm long (about half petal length), whereas the two new species here have very short ovate sepals not longer than 2 mm long (less than <sup>1</sup>/<sub>5</sub> petal length).

In Thailand, the only other species likely to be confused with this new species is the other species described here, *P. maxwellii* Utteridge **sp. nov.**, on account of the habit and the short sepals less than 2 mm long. However, *P. lacrymasepalum* differs in the shorter petioles, the indumentum of the floral parts (*P. lacrymasepalum*: pedicels, sepals and corolla entirely glabrous; *P. maxwellii*: pedicels and sepals hairy, petal margins ciliate) and the smaller fruit (*P. lachrymasepalum* fruit valves  $0.9-1.1 \times 0.8-1.4$  cm; *P. maxwellii* fruit valves  $1.6-2 \times 1.5-1.8$  cm). Finally, both taxa are range restricted endemics with *P. lacrymasepalum* in the southern-eastern Trat Province bordering Cambodia, whilst *P. maxwellii* is endemic to Doi Inthanon in Chiang Mai Province in the north of the country.

*Put 3023* is noted (in Thai) to be a small tree on the BK specimen, and was determined as *P. ferrugineum* W.T.Aiton at Kew. Specimen labels of collections made by Put Phraisurind, a Thai assistant of Kerr, usually have his name stamped in the centre of the label and not next to the printed 'Collector' field, thus leaving it seemingly blank – unfortunately, some mischievous person has put 'A. Hitler' in the blank Collector field on *Put 2951*, no doubt after the specimen was received at Kew.

Tagane et al. (2019: 137) report the newly described Cambodian species, Dichapetalum cambodianum Tagane & Nagam., as a new record to Thailand from a Put collection from Kao Kuap, and Dendropanax siamensis Craib (Araliaceae) was described from Kao Kuap (Esser & Jebb, 2019). Although the latter species is now synonymized with D. maingayi King now, this is still the only Thai record for this taxon (Esser & Jebb, 2019), and this disjunct distribution between Malacca and Kao Kuap suggests a link between the two regions; the only species of Malaysian Pittosporum similar to P. lacrymasepalum is P. reticosum Ridl. (which just extends into southern Thailand at Yala), on account of the similar sized leaves, but that species has relatively long sepals compared to the petal length and long, fine pedicels up to 2 cm long. Clearly, the area of Kao Kuap would merit further study, such as the compilation of a critical checklist from the literature and, especially, more fieldwork; however, there have been no recent visits to this area because of the many landmines throughout this border area (Pooma, pers. comm.).

#### Pittosporum maxwellii Utteridge, sp. nov.

Similar to *Pittosporum balansae* in the shrubby habit, relatively small leaves, the terminal inflorescences and the 2-valved fruit capsules, but differs in having more numerous secondary veins with 7–9-pairs (*P. balansae*: 6–7 pairs), only 2–5 flowers per inflorescence (*P. balansae*: 3–9 flowers), the triangular to ovate sepals less than <sup>1</sup>/<sub>3</sub> petal length (*P. balansae*: lanceolate, > half petal length) and the 8–11 mm long petals (*P. balansae* ca 8 mm long). Type: Thailand. Chiang Mai Province, Doi Inthanon National Forest, east side, north of km 38, Huai Hoi area, 1,700 m, 30 Jan. 1993 (fl.), Maxwell 93-115 (holotype **BKF!**, isotypes **CMUB** [digital image!], **L** [digital image!]). Fig. 2.

Shrubs or treelets 1.5–3 m tall. Young parts, especially bud scales, densely ferrugineous hairy, soon sparsely hairy then glabrescent. Leaves clustered at branchlet apex, pseudowhorled; petiole 0.5-0.9 cm long, sparsely hairy abaxially; lamina narrowly elliptic to narrowly oblanceolate,  $(5-)8-13 \times 1.4-3.1$ cm (sometimes with a reduced leaf up to 2.3 cm long at the base of the pseudowhorl), chartaceous, ferrugineously hairy on the abaxial surface only when young, soon glabrous ad- and abaxially when mature, drying olive-green adaxially, pale olive-brown abaxially; secondary veins 7-9-paired, secondary and lower order venation distinct abaxially, indistinct to distinct adaxially; base cuneate, margins entire, flat and smooth after drying, apex acute to attenuate. Inflorescences terminal, umbellate with 2-5 flowers or aggregated single flowers, hairy; subsessile or with a short peduncle up to 5 mm long; bracts narrowly ovate to lanceolate, apex acute, up to 0.5 mm long, margins ciliate. Staminate flowers: pedicel 6.8-10.3 mm long, hairy; sepals free, triangular to ovate, apex acute-rounded, tiny, 1.25–2 mm long (< 1/5 petal length), sparsely hairy, margins ciliate; petals free but adhering for 3/4 of their length in mature flowers, 8-11 mm long (at maturity), margins very shortly ciliate; stamens slightly shorter than petals, filaments ca 6 mm long, anthers ca 2 mm long; ovary long ovoid, sparsely hairy, ovules 3-5 per placenta. Pistillate flowers not seen. Fruits globose, dehiscing by 2 valves, valves  $1.6-2 \times 1.5-1.8$  cm; pericarp leathery, eventually thinly woody. Seeds 3-5, subreniform, 6-7 mm along the longest axis.

Thailand.— NORTHERN: Chiang Mai [Doi Inthanon National Forest, Siri Phum Waterfall, 1,100 m, 26 Feb. 1979 (fl.), *Koyama et al. T-15563* (**BKF**-2 sheets); Doi Inthanon, east side, north of km 38, Huai Hoi area, 1,700 m, 30 Jan. 1993 (fl.), *Maxwell* 93-115 (**BKF**, **CMUB** [digital image, CMUB 01256], L [digital image, L4176908]); Doi Inthanon, 1,900 m, 22 Jan. 1969 (fl.), *Nooteboom et al.* 822 (**BKF**, L [digital image, L1657130]); Doi Inthanon, 1,500 m, 22 Mar. 1967 (fl.), *Smitinand et al. 10268* (**BKF**); Doi Inthanon, 2,000 m, 23 Mar. 1967 (fl.), *Smitinand et al. 10298* (**BKF**); Doi Inthanon, Kanzaki plot, transect line 2, 1,688 m, 7 Nov. 2011 (st.), *Tagane et al. T348* (**BKF**); Doi Inthanon, 15 Apr. 1970 (fr.) *Weraweat 85* (**BKF**)].

Distribution.— Endemic to Doi Inthanon.

Ecology and phenology.— Collected from evergreen forest and tropical lower montane forest, 1,100–2,000 m alt. Flowering & fruiting: January–April.

Etymology.— This species is named in honour of James F. Maxwell (1945–2015), botanist and prolific collector with an unparalleled knowledge of the flora of Thailand, as well as a champion for fieldwork and plant taxonomy: "no aspect of computer or molecular technology can be used as a substitute for dedicated field work, diligent herbarium research, and competent production of keys, descriptions, and other observations" (from Maxwell's Preface to the 'Vascular Flora of Ko Hong Hill, Songkla Province, Thailand' quoted in Webb *et al.*, 2016).

Provisional conservation assessment.— The Extent of Occurrence is 965 km<sup>2</sup> and the Area of Occupancy 20 km<sup>2</sup> (AOO based on user defined cell width of 2 km), both metrics fulfilling the geographic range criterion of the Endangered category of the IUCN Red List (IUCN 2012). However, the subcriteria are not fulfilled, for example, the exact locations of the collections are problematic to determine and Doi Inthanon is a National Park with protected status. The species is provisionally evaluated as Near Threatened (NT) here requiring more data to confirm the exact status of the species.

Notes.— *Pittosporum maxwellii* is unique in having the following combination of characters: shortly petiolate, narrowly elliptic to narrowly oblanceolate leaves, few-flowered terminal inflorescences, flowers with tiny sepals and petals adhering for <sup>3</sup>/<sub>4</sub> of their length in mature flowers, and the 2-valved fruits with 3–5 seeds. The shortly ciliate petal margins allow the petals to adhere for <sup>3</sup>/<sub>4</sub> of their length, i.e. the hairs act somewhat like 'velcro'. From field notes, the corolla is recorded as being yellow (*Koyama et al. T-15563*), yellow-green (*Maxwell 93-115; Nooteboom et al. 822*) or greenish (*Smitinand et al. 10268*).



Figure 2. *Pittosporum maxwellii* Utteridge. A. habit; B. leaf venation and margin detail; C. flower; D. flower opened to show stamens and ovary; E. sepal lobes; F. dehisced fruit; G. seed. A–E from *Maxwell 93-115* (**BKF** & **L**); F & G from *Weraweat 85* (**BKF**). All drawn by Mahsarahka Rungkrajang.

Like P. lacrymasepalum, this new species differs from P. balansae in several characters including the number of flowers (P. maxwellii: 2-5 flowers per inflorescence; *P. balansae*: 3–9 flowers), and the sepal size and shape (P. maxwellii: triangular to ovate, 1.25-2 mm long; P. balansae: lanceolate, 5-6 mm long); in addition, the petals of P. maxwellii are slightly longer than P. balansae which are usually ca 8 mm long. The species is also similar to P. baileyanum Gowda in the few seeds (less than 8), the narrow leaves (ca 4 times as long as broad) and the pedicellate flowers. However, Pittosporum baileyanum was described by Gowda based on Pittosporum balansae A.DC. var. angustifolium Gagnep., and Zhang et al. (2003) recognised Gagnepain's variety rather than Gowda's species and placed Pittosporum baileyanum within a broader Pittosporum balansae. Pittosporum balansae var. angustifolium is distributed in China (Guangdong, Guangxi, Hainan) and Vietnam (northern and central areas including Quang Ninh and Thừa Thiên-Huế Provinces).

On Doi Inthanon, the only other recorded species of *Pittosporum* is *P. napaulense* (DC.) Rehder & E.H.Wilson, collected from the mid-altitudes at ca 1,200 m (though usually recorded between 700 and 1,000 m), and so does overlap with the habitat range although *P. maxwellii* is usually found at higher altitudes above 1,600 m. *Pittosporum napaulense* is unlikely to be confused with *P. maxwellii* being a tree to 20 m and with inflorescences with several to many flowers with a distinct central axis and larger oblanceolate to obovate-lanceolate or elliptic leaves,  $6-19 \times 3.5-8$  cm.

Specimens of *P. maxwellii* were determined as *P.* aff. *tetraspermum* Wight. & Arn. by Maxwell, but this species is now known to be restricted to southern India and Sri Lanka, and has 2 placentas each with only 2 basal ovules as the name suggests.

Specimens of *P. maxwellii* have been determined as *Schoepfia* Schreb. (Olacaceae) on several occasions, as well as Thymelaeaceae. This species was not recorded or mentioned in Gardner *et al.* (2000).

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# *Psammosilene tunicoides* (Caryophyllaceae) a new generic and species record for Thailand

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#### ABSTRACT

*Psammosilene tunicoides*, a new generic and species record for Thailand, is reported. The new record was discovered on a degraded calcareous substrate mountain in the western part of Thailand near the Thai-Myanmar border. The species was previously reported to be endemic to SW China. This occurrence in Thailand greatly extends the distribution of the species. A lectotype is designated here.

KEYWORDS: degraded calcareous substrate mountain, Doi Hua Mot, insufficiently known genus, lectotypification, medicinal plant, monotypic genus, taxonomy, Umphang District.

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#### **INTRODUCTION**

Psammosilene W.C.Wu & C.Y.Wu (Caryophyllaceae), first described in 1945 (Wu & Wu, 1945), is a monotypic genus distributed in temperate montane regions in south-west China (Bittrich, 1993). Bittrich (1993) suggested the genus has a close relationship with Dianthus L., Kohlrauschia Kunth, Petrorhagia (Ser.) Link and Velezia L. in the subfamily Caryophylloideae according to seed morphology, but also stated that the genus is insufficiently known and needs further study. An account of the family Caryophyllaceae in Thailand was revised by Phuphathanaphong (1992) with eight genera recognised but did not record Psammosilene in the account. The genus is characterised by the long conical subfleshy root, several prostrate stems, subsessile leaves, glandular and tubular-campanulate and 15-veined calyx tube, spathulate petals, and the two styles (Wu & Wu, 1945; Bittrich, 1993; Lu et al., 2001). There are two genera in Thailand that have sepals connate, Silene L. and Vaccaria Wolf, but these genera otherwise have quite different morphologies compared to Psammosilene.

Psammosilene tunicoides W.C.Wu & C.Y.Wu has been widely used as a medicinal plant in China to check bleeding, relieve pain and promote blood circulation, and has also been used as an important ingredient in some well-known Chinese traditional medicine formulations (Lian et al., 2011). Long-term uncontrolled exploitation has caused a reduction in geographic range and population size of P. tunicoides and now the species is at great risk of extinction: the species was listed in the China Plant Red Data Book as rare and endangered (Fu, 1992; Qu et al., 2010) and over-exploitation has led to the destruction of many wild P. tunicoides populations (Zhang et al., 2018). The discovery in Thailand means that the species is not as narrowly distributed as once thought which could be good news for its long-term survival.

This new record was discovered during a plant collecting trip to Doi Hua Mot, a unique 'Bald-Headed' degraded calcareous substrate mountain in Umphang District, Tak Province, western part of Thailand. Several new species have been reported from this botanically unique area which is mostly covered

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with short grasses and herbs (Craib, 1926; Imlay, 1939; Barnett, 1961; Pedersen *et al.*, 2003; Suddee & Paton, 2009; Esser & Jebb, 2010; Kidyoo & Watthana, 2012; Triboun & Middleton, 2012; de Wilde & Duyfjes, 2013; Gale *et al.*, 2014; Soh *et al.*, 2014; Suddee *et al.*, 2014; Paton *et al.*, 2016; Mattapha *et al.*, 2017, 2018; Chantanaorrapint & Suddee, 2018; Pornpongrungrueng *et al.*, 2019; Nansai *et al.*, 2020); see Table 1.

#### MATERIALS AND METHODS

The description and illustrations of this new generic and species record are based on both fresh materials and herbarium specimens collected from Doi Hua Mot. The new record was compared to images of herbarium specimens available online. The provisional conservation assessment was made following the IUCN Standard and Petitions Committee (2019).

#### DESCRIPTION

Psammosilene tunicoides W.C.Wu & C.Y.Wu in L.P.King *et al.*, Icon. Pl. Medic. Libro Tien-Nan-Pen-Tsao Lanmaoano. 1: t. 1. 1945; Lu *et al.*, Fl. China 6: 108. 2001.—*Silene cryptantha* Diels, Notes Roy. Bot. Gard. Edinburgh 5: 180. 1912, nom. illeg. non Viviani (1824). Type: China, NW Yunnan, eastern flank of the Lichiang range, July 1906, *Forrest 2783* (lectotype **E** [E00301701, online image seen], designated here; isolectotype **P** [P04985835, online image seen]). Fig. 1 & 2.

Perennial herb. *Roots* brownish-yellow, long conical, 7–15 cm long, subfleshy. *Stems* several, prostrate, purplish-green, 10–30 cm long, branched or not, pubescent. *Leaves* subsessile, ovate to ovate-lanceolate,  $0.6-2.5 \times 0.5-1$  cm, apex acute, base broadly cuneate to rounded, margin entire, glabrous above, thinly pubescent otherwise glabrous below, lateral veins obscure. *Inflorescence* a terminal thyrse,

Table 1. New species reported from Doi Hua Mot, Umphang District, Tak Province.

Species	Family	Publication Year
Impatiens patula Craib	Balsaminaceae	1926
Strobilanthes graminea J.B.Imlay	Acanthaceae	1939
Dichiloboea glandulifera Barnett [= Paraboea glandulifera (Barnett) C.Puglisi]	Gesneriaceae	1961
Sirindhornia mirabilis H.A.Pedersen & Suksathan	Orchidaceae	2003
Teucrium scabrum Suddee & A.J.Paton	Lamiaceae	2009
Schefflera poomae Esser & Jebb	Araliaceae	2010
Hoya lithophytica Kidyoo	Apocynaceae	2012
Paraboea siamensis Triboun	Gesneriaceae	2012
Paraboea takensis Triboun	Gesneriaceae	2012
Lagerstroemia huamotensis W.J. de Wilde & Duyfjes	Lythraceae	2013
Nervilia umphangensis Suddee, Rueangr. & S.W.Gale	Orchidaceae	2014
Buxus sirindhorniana W.K.Soh, von Sternb., Hodk. & J.Parn.	Buxaceae	2014
Porpax thaithongiae Suddee, Promm. & Watthana	Orchidaceae	2014
Scutellaria tenasserimensis A.J.Paton	Lamiaceae	2016
Flemingia sirindhorniae Mattapha, Chantar. & Suddee	Fabaceae	2017
Sophora huamotensis Mattapha, Suddee & Rueangr.	Fabaceae	2018
Thismia thaithongiana Chantanaorr. & Suddee	Burmanniaceae	2018
Phyllanthus huamotensis Pornp., Chantar. & J.Parn.	Phyllanthaceae	2019
Viola umphangensis S.Nansai, Srisanga & Suwanph.	Violaceae	2020



Figure 1. *Psammosilene tunicoides* W.C.Wu & C.Y.Wu: A. Habit; B. Calyx outer surface; C. Calyx inner surface; D. Petal; E. Stamen; F. Ovary and styles. Drawn by Orathai Kerdkaew.



Figure 2. *Psammosilene tunicoides* W.C.Wu & C.Y.Wu: A. Habit; B. Root; C.–D. Inflorescence; E.–F. Flower. A.–B. by W. Kiewbang; C., F. by T. Phutthai; D.–E. by N. Tetsana.

densely glandular pubescent; bracts ovate, thin, 1-2 mm long, glabrous inside, glandular pubescent outside. Flowers 3-5 mm in diam. Pedicels very short or flowers sessile. Calyx green, tubular-campanulate, 4-6 mm, glabrous inside, densely glandular pubescent outside, 15-veined, 5-toothed; calyx teeth triangularovate, margin membranous, apex obtuse or acute. Petals 5, free, purplish-pink with 3 longitudinal purple lines, narrowly spathulate, 6-8 mm long, glabrous on both surfaces, apex retuse, margin entire, base with long yellow attenuate claw. Stamens 5, attached opposite calyx teeth, exserted beyond calyx, 7-9 mm long; filaments glabrous; anthers pinkishpurple. Ovary sessile, narrowly obovoid, ca 7 mm long, 1-locular with 2 ovules; styles 2, ca 3 mm long, separated from base. Capsule clavate, ca 7 mm long, membranous, indehiscent, enclosed by persistent calvx. Seeds not seen.

Thailand.— NORTHERN: Tak [Umphang District, Doi Hua Mot, along dirt road to Mae Lamung Khi village, 15°49'47.2"N, 98°53'39.4"E, at 864 m elev., 25 Aug. 2019, fl. & fr., *Suddee et al.* 5509 (**BKF!**)].

Distribution.— China.

Ecology.— Open grassland on a degraded calcareous substrate mountain with *Strobilanthes graminea* J.B.Imlay dominant, 800–900 m alt. Flowering & fruiting: recorded in August.

Vernacular.— Kamlang chang phlai (กำลังช้าง พลาย).

Provisional Conservation Assessment.— This species is known only from one location in Umphang District with an estimated Area of Occupancy (AOO) of around 0.5 km<sup>2</sup>. Only one small population of around 10 individuals was seen. The species occurs in an area that local villagers use for cattle grazing. Increased cattle numbers and forest fires in the dry season might increase disturbance in the area and this could affect the survival chances of this species. It is assessed here as nationally Critically Endangered, CR B2ab(iii); D in Thailand, following IUCN Standard and Petitions Committee (2019).

Note.— *Silene cryptantha* Diels is a later homonym of *Silene cryptantha* Viv. and, therefore, illegitimate. When describing their genus and moving this species into it, Wu & Wu (1945) realised this and gave the species a replacement name, *Psammosilene tunicoides*, which is nevertheless typified by the type of *Silene cryptantha* Diels. The sheet at **E** with complete specimen, label, and with annotation by C.Y.Wu is chosen as a lectotype.

This species is easily recognised in the field by the several prostrate stems and the subsessile ovate to ovate-lanceolate leaves. The Thai plants were compared to the available online specimen images from China (GBIF, PE). The plants from Thailand are smaller than the plants from China and the petals of the Thai plants are all retuse at the apex, whereas this character varies from obtuse to retuse in China. The other morphological characters are similar.

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#### New records of the genus Psychotria (Rubiaceae) from Thailand

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#### ABSTRACT

Four species of *Psychotria* are newly recorded from Thailand: *P. bonii*, *P. griffithii*, *P. langbianensis* and *P. pachyphylla*. Descriptions and list of synonyms are provided and a lectotype for *P. bonii* is designated.

KEYWORDS: lectotypification, Psychotrieae, revision, taxonomy, Gentianales. Accepted for publication: 28 May 2020. Published online: 15 July 2020

#### **INTRODUCTION**

The genus *Psychotria* L. is characterized by its sheathing and caducous interpetiolar stipules, conspicuous colleters at lower part of adaxial surface of stipules, short and straight corolla tube, valvate petals in bud, drupaceous fruits with two pyrenes, hemispherical in cross-section seeds, a flattened to furrowed ventral seed surface and a ribbed to rounded dorsal seed surface, presence of an ethanol soluble pigment in the seed coat and ruminate endosperm (Robbrecht, 1989; Nepokroeff et al., 1999; Sohmer & Davis, 2007). The genus is one of the most diverse genera of Rubiaceae and consists of approximately 2,000 species (Davis et al., 2001) distributed throughout the tropics. In Thailand, 38 species were recorded by Craib (1934) and 12 species listed by Pooma & Suddee (2014). Recently, during extensive field and herbarium surveys for the taxonomic revision of Psychotria in Thailand, we found four species that are new records for Thailand. Moreover, lectotypification of one name is required. All cited specimens have been seen by the first author.

#### TAXONOMIC TREATMENT

**1. Psychotria bonii** Pit. in Lecomte, Fl. Indo-Chine 3: 347. 1924. Type: Vietnam, Tonkin, Khien Khe, Dong Ham mount, 14 May 1883, *Bon 2137*  (lectotype **P** [P00601775!] designated here; isolectotype **P** [P00604047!]). Fig. 1.

Erect shrubs, 0.3–0.8 m tall; branches glabrous, longitudinal ridges absent. Stipules interpetiolar, caducous, ovate, 0.5-0.8 by 0.5-0.9 cm, bilobed, lobes lanceolate, apex acute, margin serrate with scabrousciliate, outer surface glabrous, inner surface with dense colleters interspaced with hairs at base. Leaves narrowly ovate, elliptic or elliptic-ovate, (2.5-)5.5-18.3 by 2.5-6.3 cm, apex attenuate, acuminate or acute, base cuneate, margin undulate, chartaceous, glabrous on both surfaces or rarely puberulous on lower surface; domatia absent; midrib depressed above and distinctly prominent below; lateral veins (9-)10-13 pairs, brochidodromous with collector vein along leaf length; petioles (0.8–)1.2–2.2 cm long, glabrous. Inflorescences terminal or pseudo-axillary, a lax panicle-like thyrse, trichotomous; peduncle 3-5 cm long, glabrous or sparsely puberulous at node; primary inflorescence branches 2, opposite, sparsely pubescent; flowers in inflorescence unit (2-)3, lax. Bracts persistent, cup-like, 0.7-1.1 by 1–1.5 mm, apex truncate, margin villous-ciliate, upper surface puberulous at base, lower surface sparsely puberulous. Leaf-like bracts absent or rarely present, elliptic-oblong, 1.4–2.1 by 0.5–0.8 mm, apex acuminate, glabrous on both surfaces. Flowers sessile or sub-sessile; floral bud apex rounded

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without corolla protrusion; pedicels absent or 0.2-0.5 mm long, glabrous; floral bracts persistent, scale-like, 0.3–0.5 by 0.3–0.4 mm. Calyx tubular, tube 0.4-0.5 mm long, glabrous on both sides; lobes 4, triangular, 0.3–0.5 by 0.6–0.8 mm, apex acute, margin entire with scabrous-ciliate near apex, glabrous on both sides. Corolla white, short salverform, tube 2.2-5.3 mm long, glabrous outside, villous at throat inside; lobes 4, elliptic to elliptic-ovate, 0.9-1 by 1-1.1 mm, apex acute, reflex, margin entire. Stamens 4; filaments 0.3–0.4 mm long, glabrous; anthers basifixed, elliptic-oblong, 0.8-0.9 by 0.3-0.4 mm, apex acute, glabrous, anther basal protrusion absent. Ovary inferior, 2-locular, glabrous; style 1.1-1.2 mm long, glabrous; stigma 2-lobed, lobes rounded, puberulent. Infructescences elongated, 1-2.5 mm long, glabrous. Fruits drupaceous, ellipsoid, slightly bilobed at apex, glabrous, calyx persistent; pyrenes 2, hemiellipsoid, 5.4-7 by 4-5.1 mm, dorsal surface convex, longitudinal ridges and grooves absent, ventral surface concave, longitudinal ridges absent, longitudinal groove 1. Seeds hemiellipsoid, 5.4-7 by 4-5.1 mm, dorsal surface convex without longitudinal ridges, ventral surface concave without longitudinal ridges; endosperm ruminate.

Thailand.— NORTH-EASTERN: Phetchabun [Nam Nao NP, Huai Ya Khuea, 10 Aug. 2015, *Srisuk* 958 (**KKU**); ibid., 24 July 2016, *Srisuk 1001* (**KKU**); ibid., 11 Mar. 2017, *Srisuk 1018* (**KKU**)]; Loei [Phu Luang WS, from Ban Na Luang to northern ridge, alt. ca 1,000 m, 3 Dec. 1965, *Tagawa et al. T-1053* (**AAU**, **E**, **K** (2 sheets)); Phu Luang WS, trail to Khok Huai Tae, Ban Na Noi, alt. 900–1,100 m, 19 Dec. 2001, *Chamchumroon V.C.1216* (**BKF**)]; Bueng Kan [Phu Wua WS, natural trail from headquarter, alt. 200 m, 27 Aug. 2001, *Pooma et al. 2793* (**BKF**, **L**); Phu Wua WS, Hui Phai Waterfalls, 21 Oct. 2015, *Srisuk 972* (**KKU**)].

Distribution.- Vietnam.

Ecology.— Shaded areas or along streams in hill evergreen forest.

Phenology.— Flowering March–June, fruiting May–September.

Vernacular.— Kha nang song phu (คนางสองพู).

Notes.— This species was previously only known from montane evergreen forest in Tonkin (Bavi and Dong-ham mountains), northern Vietnam. However, after collecting in the same type of habitat in the North-Eastern Thailand, some specimens were found with flowers and fruits and identified with the key to species of *Psychotria* in Indochina (Pitard, 1924) as well as compared with specimens in P and it is clearly the same species because of its ellipsoid fruit and seeds surfaces without ridges. Thus, the distribution of this species is extended to the North-Eastern Thailand.

Morphologically, *P. bonii* is similar to *P. lanceolaria* Ridl. because of its glabrous stems and lower surface of leaves and presence of brochidodromous with collector vein along leaf length, but *P. bonii* is distinguished by its shorter calyx lobes and corolla tube, 0.3–0.5 mm and 2.2–5.3 mm long, respectively (1–1.2 mm and 3.7–3.9 mm long in *P. lanceolaria*), triangular calyx lobes (lanceolate in *P. lanceolaria*) and ellipsoid, slightly bilobed fruits (ovoid to ellipsoid and entire in *P. lanceolaria*).



Figure 1. Psychotria bonii Pit.: A. inflorescence; B. immature fruits. Photos by T. Srisuk.

Psychotria bonii was described by Pitard (1924) but only localities and collectors were referred in the protologue as "Tonkin: Mt. Bavi (Balansa); Khienkhé, au mt Dong-ham (Bon)". Several specimens related to the protologue collected from Tonkin by Balansa (Mt Bavi: Balansa 2730 [P00604049, P00604052]) and Bon ('Kien-khé, au mt Dongham': Bon 2137 [P00601775, P00604047], Bon 2380 [P00604054, P00604055], Bon 2521 [P00604050, P00604051], Bon 2943 [P00604048, P05024992]) were found in P. These specimens were collected between 1883 and 1888, well before P. bonii was described by Pitard (1924), and these specimens could be considered as the original material for this name in conformity with ICN Art. 9.4(a) (Turland et al., 2018). The specimen Bon 2137 with barcode no. P00601775 is the most complete and well preserved, therefore, selected here as lectotype of the name. Thus, the other duplicate, barcode no. P00604047, is an isolectotype in conformity with ICN Art. 8.1, Art. 9.3 and Rec. 9A.1. (Turland et al., 2018).

2. Psychotria griffithii Hook.f., Fl. Brit. India 3: 171. 1880; Ridl., Fl. Malay Penins. 2: 137. 1923.— *Uragoga malaccensis* Kuntze, Revis. Gen. Pl. 2: 956. 1891.— Type: Malaysia, Malacca, *Griffith s.n.* [Kew distrib. no. 3044] (lectotype **K** [K000777141!] designated by Turner (2019)).

Erect shrubs, 0.5–1 m tall; branches glabrous, longitudinal ridges present. Stipules interpetiolar, caducous, ovate-lanceolate, 5.8-1.2 by 5-6.9 mm, apex acuminate, margin entire, outer surface glabrous, inner surface with dense colleters interspaced with hairs at base. Leaves elliptic, elliptic-obovate or elliptic-oblong, (7.5-)10.3-23.2 by 6.5-7.8 cm, apex acuminate, base cuneate, margin entire, recurved, coriaceous, upper surface glabrous, turning pale greenish-brown when dried, lower surface glabrous, turning bright greyish-brown, greenish-brown or reddish-brown when dried; domatia foveolate; midrib conspicuously grooved above when dried and distinctly prominent below; lateral veins 8-13 pairs, eucamptodromous without collector vein; petioles 1.5-2.7 cm long, glabrous. Inflorescences terminal, a lax panicle-like or verticillate-like thyrse, trichotomous or rarely pentatomous; peduncle 3-13.4 cm long, sparsely to densely tomentose; primary inflorescence branches 2-3, sub-opposite, opposite or verticillatelike, tomentose; flowers in inflorescence unit 1(-3), lax. Bracts caducous, ovate to lobed-lanceolate, 1.8-3.7 by 2-3.1 mm, apex acute to acuminate, margin dentate or dentate with pilose-ciliate, upper surface densely pilose, lower surface glabrous. Leaflike bracts absent. Flowers sub-sessile to pedicellate; floral bud apex rounded with corolla protrusion; pedicels 0.9-1.2 mm, sparsely tomentose; floral bracts persistent, scale-like, 0.7-1.1 by 0.9-1.5 mm. Calyx tubular, tube 0.6-1.2 mm long, glabrous on both sides; lobes 4-5, triangular, 0.2-0.5 by 0.5-1.2 mm, apex acute to acuminate, margin entire, glabrous on both sides. Corolla white, short salverform, tube 1.5–1.7 mm long, glabrous outside, villous at throat inside; lobes 4, ovate or elliptic-ovate, 1.4-1.5 by 1-1.3 mm, apex acute, reflex, margin entire, glabrous on both sides. Stamens 4-5; filaments 0.8-1 mm long, glabrous; anthers dorsifixed, elliptic-oblong, 1.3-1.4 by 0.5-0.7 mm, apex acute, glabrous, anther basal protrusion absent. Ovary inferior, 2-locular, glabrous; style 2-2.3 mm long, glabrous; stigma 2-lobed, lobes linear, puberulous. Infructescences elongated, 1.2-2 mm long, glabrous to sparsely puberulous. Fruits drupaceous, ellipsoid-globoid to sub-globoid, entire, glabrous, calyx persistent; pyrene 2, hemiellipsoid to hemispheroid, 5.1-7 by 4.2-6.7 mm, dorsal surface convex, longitudinal ridges 2-4 or rarely obscure, ventral surface concave, longitudinal ridge 1; longitudinal grooves 2. Seeds hemiellipsoid, hemiovoid or hemispheroid, 4.5-5.5 by 3.8-4.3 mm, dorsal surface convex, longitudinal ridge 1, ventral surface concave, longitudinal ridge 1, longitudinal grooves 2; endosperm ruminate.

Thailand.— PENINSULAR: Ranong [Khlong Nakha WS, alt. 50–100 m, 24 Apr. 1974, *Larsen & Larsen 33325* (AAU, L)].

Distribution.- Malaysia, Singapore, Indonesia.

Ecology.— Shaded areas in hill evergreen forest.

Phenology.— Flowering March–June, fruiting May–September.

Vernacular.— Phut khao (พุดเขา).

Notes.— This species was previously recorded from lowland dipterocarp and hill evergreen forests in Malaysia, Singapore and Indonesia (Hooker, 1880; Ridley, 1923). However, after investigation of herbarium specimens in several herbaria (**AAU**, **K**, **L**), the specimen *Larsen & Larsen 33325*, collected from Ranong Province, Peninsular Thailand was found in **AAU** and **L**, and compared with specimens in **K**, as well as relevant literature (Hooker, 1880; Ridley, 1923). It was found to be the same species because of its thick coriaceous leaves, presence of foveolate domatia and verticillate-like inflorescences, lax inflorescence unit and tomentose peduncles and pedicels; it is also found in the same habitat, in hill evergreen forest. Therefore, this species is newly recorded for Thailand.

*Psychotria griffithii* is morphologically somewhat similar to *P. connata* Wall. because of its thick coriaceous leaves, presence of foveolate domatia and verticillate-like inflorescences. However, *P. griffithii* is distinguished by its longer petioles, 1.5–2.7 cm long (0.6–1.2 cm long in *P. connata*), lax inflorescence unit (dense in *P. connata*), tomentose peduncles and pedicels (glabrous in *P. connata*), as well as shorter corolla tube, 1.5–1.7 mm long (2.4–2.6 mm long in *P. connata*).

**3. Psychotria langbianensis** Wernham, J. Nat. Hist. Soc. Siam 4: 137. 1921; Hô, Câyco Viêtnam 3(1): 243: 1993. Type: Vietnam, South Annam, Langbian province, Dalat, alt. 1,524 m, Apr. & May 1918, *Kloss s.n.* (holotype **BM** [BM000945374!]).

Erect shrubs, 1-1.5 m tall; branches densely pilose, longitudinal ridges absent. Stipules interpetiolar, caducous, ovate, 0.6-1.3 by 0.3-1 cm, bilobed, lobes lanceolate, apex acuminate, margin piloseciliate, outer surface densely pilose, inner surface pilose near apex and with dense colleters interspaced with hairs at base. Leaves elliptic or elliptic-ovate, (5.7–)7.7–15.7 by (1.2–)2.8–5.3 cm, apex acuminate, base cuneate or attenuate, margin pilose-ciliate, recurved, chartaceous, upper surface mostly glabrous and sparsely pilose at margin and base, turning pale greyish-brown to blackish-brown when dried, lower surface densely pilose, especially at midrib and veins; domatia absent; midrib depressed above and distinctly prominent below; lateral veins 9-12 pairs; brochidodromous with collector vein near apex and eucamptodromous vein near base; petioles 0.5-2.2 cm long, densely pilose. Inflorescences terminal, a lax panicle-like thyrse, trichotomous; peduncle up to 1.5 cm long, densely pilose; primary inflorescence branches 2, opposite, densely pilose; flowers in inflorescence unit 2-3, lax. Bracts caducous, lanceolate, 2-3.2 by 1-2.1 mm, apex acuminate, margin lobed with pilose-ciliate, upper surface pilose, lower surface densely pilose. Leaf-like bracts absent. Flowers sub-sessile to pedicellate; floral bud apex rounded without corolla protrusion; pedicels 0.5-2.5 mm long, densely pilose; floral bracts caducous, lanceolate to lanceolate-oblong, 1.5-2 by 1-1.5 mm, apex acuminate, margin pilose-ciliate, upper surface glabrous and sparsely pilose at base, lower surface pilose. Calyx tubular, tube 0.9-1.1 mm long, densely pilose outside, glabrous inside; lobes 5, lanceolate, 0.8-1.5 by 0.7-1.2 mm, apex acuminate, margin pilose-ciliate, densely pilose outside, glabrous inside. Corolla white, short salverform, tube 2.9-3 mm long, sparsely to densely pilose outside, densely villous at throat inside; lobes 5, ovate-lanceolate, 2-2.5 by 1.3-1.5 mm, apex acute, reflex, margin entire, upper surface glabrous, lower surface sparsely scabrous. Stamens 5; filaments 1.2-1.5 mm long, scabrous; anthers sub-dorsifixed, elliptic-oblong, 1.4–1.5 by 0.6–0.7 mm, apex rounded, scabrous, anther basal protrusion absent. Ovary inferior, 2-locular, glabrous; style 4.2-4.6 mm long, tomentose; stigma 2-lobed, lobes rounded, puberulous. Infructescences sessile to sub-sessile, 0.5-2.5 mm long, densely pilose. Fruits drupaceous, ellipsoid to ellipsoid-ovoid, entire, sparsely pilose, calyx persistent; pyrenes 2, hemiellipsoid to hemiovoid, 4.4-6.7 by 3.1-5 mm, dorsal surface convex, longitudinal ridges 4-5, longitudinal grooves 3-4, ventral surface flatten to sub-concave, longitudinal ridge 1, longitudinal grooves 2. Seeds hemiovoid to hemiellipsoid, 4.9-5.2 by 2.8-3.2 mm, dorsal surface convex, longitudinal ridges 3, longitudinal grooves 4, ventral surface flatten to sub-concave, longitudinal ridge 1, longitudinal grooves 2; endosperm ruminate.

Thailand.— PENINSULAR: Yala [Bang Lang NP, alt. 150–350 m, 17 July 1993, *Puff & Sridith* 930717-1/4 (AAU, PSU)].

Distribution.— Vietnam.

Ecology.— Shaded or open areas in hill evergreen forest.

Phenology.— Flowering April–May, fruiting May–August.

Vernacular.— Kram hin khao (กรามหินเขา).

Notes.— *Psychotria langbianensis* was previously only recorded from Vietnam (South

in **AAU** and **PSU** and compared with specimens in **AAU** and **BM** as well as relevant literature (Wernham in Baker *et al.*, 1921). It was found that it is the same species because of its glabrous on upper leaf surface with sparsely pilose at margin and base and sparsely to densely pilose on the outer surface of corolla tube. Thus, the distribution of this species is extended to Peninsular Thailand in hill evergreen forest — the same type of habitat as previously recorded in Vietnam.

Morphologically, *Psychotria langbianensis* resembles *P. cambodiana* Pierre ex Pit. because of its hairy stems and leaves, bilobed stipules and lack panicle-like thyrse, but *P. langbianensis* is distinguished by its upper leaf surface that is glabrous with sparsely pilose at margin and base (pilose all over the upper leaf surface in *P. cambodiana*), longer corolla tube, 2.9–3 mm long (2–2.3 mm long in *P. cambodiana*), sparsely to densely pilose on the outer surface of corolla tube (glabrous in *P. cambodiana*).

Wernham (in Baker et al., 1921) described P. langbianensis without designation of type of the name but based on specimens collected by Kloss from south Annam. He noted locality of original materials in protologue that "Dalat, 5,000 ft., white. shrub.". After extensive investigation of herbarium specimens from various herbaria. Only a single specimen that matched the protologue was found in BM, the place where Wernham was working and Kloss collections were deposited. This specimen no. Kloss s.n. [BM000945374] with labeled "Dalat, 5,000 ft., Langbian Province, South Annam., White. Shrub., April & May 1918, C. Boden Kloss" is accepted here as holotype in conformity with Art 9.1 (Note 1) and Rec. 9A.1 (Turland et al., 2018), even though holotype was not directly designated by author in the protologue.

Additional specimens examined.— VIETNAM: Central Vietnam [Annam, Langbian, April–May 1918, *Kloss s.n.* (**BM**); Lam Dong, Lang Bian Mountain, 14 July 1984, *Tirvengadum & Tam 1575* (**AAU**); Lam Dong, Lac Duong, municipalite Da Chay, vicinities Klong Lanh village, 31 km to NE from Dalat city, alt. 1,850–1,950 m, 15 Mar. 1997, *Averyanov et al. VH 2664* (**AAU**); ibid., 15 Mar. 1997, Averyanov et al. VH 2670 (AAU); Lam Dong, Lac Duong, municipalite Da Chay, 35 km to NE from Dalat city, alt. 1,500 m, 26 Mar. 1997, Averyanov et al. VH 3227 (AAU); Lam Dong, Bao Loc, camp de Bola, 16 July 1984, Tirvengadum & Tam 1623 (AAU)].

**4. Psychotria pachyphylla** (King & Gamble) Ridl., Fl. Malay Penins. 2: 129. 1923.— *P. sarmentosa* Blume var. *pachyphylla* King & Gamble, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 74(2): 6. 1906. Type: Malaysia, Penang, July 1890, *Curtis 2215* (lectotype **K** [K000777164!] designated by Turner & Kumar (2018)).

Climber; branches glabrous, longitudinal ridges absent. Stipules interpetiolar, caducous, ovate, 3.5-5.1 by 4.2-5.5 mm, apex acuminate, margin entire, outer surface glabrous, inner surface pilose near apex and with dense colleters interspaced with hairs at base. Leaves elliptic to elliptic-ovate, 7.5-12.9 by 4.3–6.9 cm, apex acute or acuminate, base cuneate, margin entire, recurved, coriaceous, upper surface glabrous, turning greyish-brown or blackish-brown when dried, lower surface glabrous, turning bright grayish-brown or reddish-brown when dried; domatia absent; midrib depressed above and distinctly prominent below or grooved above when dried and prominent below; lateral veins 8-9 pairs; brochidodromous with collector vein near apex and eucamptodromous vein near base; petioles 1-1.7 cm long, glabrous. Inflorescences terminal, a lax paniclelike thyrse, trichotomous; peduncle up to 3.9 mm long, glabrous; primary inflorescence branches 2, opposite, glabrous or sparsely puberulous; flowers in inflorescence unit (1–)2–3, lax. Bracts caducous, lanceolate to ovate-lanceolate, 2–2.5 by 0.5–1.2 mm, apex attenuate, acute to acuminate, margin puberulousciliate, upper surface glabrous, lower surface sparsely puberulous, Leaf-like bracts absent. Flowers sub-sessile to pedicellate; floral bud apex rounded without corolla protrusions; floral bracts persistent, lanceolate, 0.4-0.6 by 0.5-0.7 mm, apex acute to acuminate, margin entire or lobed with puberulous-ciliate, upper surface glabrous, lower surface sparsely puberulous; pedicels 0.7-1.2 mm long, sparsely puberulous, elongate when fruiting. Calyx tubular, tube 0.4–0.5 mm long, glabrous to sparsely puberulous outside, glabrous inside; lobes 5-6, triangular, 0.4-0.6 by 0.5-0.7 mm, apex acute,

margin puberulous-ciliate, outer surface sparsely puberulous, inner surface glabrous. Corolla short salverform, tube 2.4-2.6 mm long, sparsely puberulous outside, villous at throat inside; lobes 5-6, lanceolate to ovate-lanceolate, 1.5-1.7 by 1-1.3 mm, apex acute, reflex, margin puberulous-ciliate, upper surface papillose, lower surface sparsely puberulous. Stamens erect, 5-6; filaments 0.7-1 mm long, glabrous; anthers dorsifixed, oblong, 0.9-1 by 0.2-0.3 mm, glabrous to sparsely puberulous at apex, apex rounded, anther basal protrusion 0.1-0.2 mm long. Ovary inferior, 2-locular, sparsely puberulous; style 3.5-4 mm long, densely puberulous; stigma 2-lobed, lobes obovate-oblong, sparsely puberulous. Infructescences elongated, 1.4-4.8 mm long, sparsely to densely puberulous. Fruits drupaceous, ellipsoid, entire, glabrous, calyx persistent; pyrene 2, hemiellipsoid to hemispheroid, 3.1-4.8 by 3.1-4.2 mm, dorsal surface convex, longitudinal ridges 4, longitudinal grooves 5, ventral surface flatten, longitudinal grooves 2, shallowly. Seeds hemiellipsoid to hemispheroid, 2.8-3 by 2.5-3.1 mm, dorsal surface convex, longitudinal ridges 4, longitudinal grooves 5, ventral surface flatten, longitudinal grooves 2, endosperm ruminate.

Thailand.—PENINSULAR: Narathiwat [Unknown place, 19 Apr. 1972, *Sangkachand et al. 1094* (E, K, L, P); Waeng, Nikhom Waeng, alt. 300–500 m, 4 Mar. 1974, *Larsen & Larsen 32922* (AAU, K (2 sheets), L, P (2 sheets))].

Distribution.— Nicobar Islands, Malaysia, Singapore, Indonesia.

Ecology.— Shaded or open areas in swamp forest or riparian evergreen forest.

Phenology.— Flowering March–June, fruiting May–September.

Vernacular.— Duk kai yan (ดูกไก่ย่าน).

Notes.—*Psychotria pachyphylla* was previously known from Nicobar Islands, Malaysia, Singapore and Indonesia (Ridley, 1923; Turner & Kumar, 2018), but after investigation of herbarium specimens in several herbaria (**AAU**, **E**, **K**, **L**, **P**), it was found that some specimens collected from Narathiwat Province, Peninsular Thailand are the same species because of the climbing habit, coriaceous and elliptic to elliptic ovate leaves and depressed or grooved midribs on the upper leaf surface when dried; in addition, this species was found in shaded or open area in swamp forest or riparian evergreen forest. Thus, the distribution of this species is now extended to Peninsular Thailand.

Morphologically, *P. pachyphylla* resembles *P. serpens* L. because of its climber habit, coriaceous and elliptic to elliptic ovate leaves, lax panicle-like thyrse and whitish fruit when ripening. However, *P. pachyphylla* is distinguished from *P. serpens* by its depressed or grooved midribs at upper leaf surface when dried (raised in *P. serpens*), sessile to sub-sessile peduncle with up to 3.9 mm long (1.5–6.8 cm long in *P. serpens*), sparsely puberulous at lower surface of bracts (glabrous in *P. serpens*) and anther basal protrusion present with 0.1–0.2 mm long (absent in *P. serpens*).

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# *Begonia colliculata* (Begoniaceae), a new species from Nam Kading National Protected Area, Bolikhamxai Province, Laos

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#### ABSTRACT

Begonia colliculata is described and illustrated with photographs from Nam Kading National Protected Area, in the Bolikhamxai Province of Laos.

KEYWORDS: *Begonia*, Biodiversity, Laos, new taxon, taxonomy. Accepted for publication: 15 July 2020. Published online: 24 July 2020

#### **INTRODUCTION**

Twenty-seven native Begonia L. taxa are recorded from Laos (Hughes, 2008; de Wilde et al., 2011; Averyanov & Nguyen, 2012; Souvannakhoummane et al., 2016, 2018; Yang et al., 2018; Hughes et al., 2018; Averyanov et al., 2019; Ding et al., 2020; Lanorsavanh et al., 2020). The Nam Kading National Protected Area, located in the centre of Laos, has a diverse vascular flora yet remains undersurveyed. Floristic research was carried out in this area between 2017–2019, allowing the discovery and description of several new species (Souladeth et al., 2017, 2019; Tagane et al., 2018; Yang et al., 2018; Souvannakhoummane et al., 2019) as well records of various new taxa for the flora of Laos (Tagane et al., 2017). In a field survey in deciduous forest of this Protected Area, a population of Begonia characterized by beautiful red flowers, cane-like stems and variegated leaves with a dark red undersurface was observed. Based on living collections and herbarium investigations, material collected from this population was found to represent a new species of Begonia sect. Platycentrum A.DC., and

is described and illustrated below; ecological information, conservation status and affinities are also provided.

#### TAXONOMIC TREATMENT

**Begonia colliculata** Souvann. & Lanors., **sp. nov.**, (Section *Platycentrum*). Figs. 1 & 2.

Begonia colliculata is similar to Begonia hekouensis S.H.Huang, but differs in having verrucous peduncles (vs densely villous), bracts with a strigose margin (vs ciliate), sparsely strigose tepals (vs villous), a sparsely strigose and colliculate ovary with a broadly falcate-elongate dorsal wing (vs densely purplish brown villous and not colliculate, dorsal wing ligulate). It is also similar to *B. crocea* C.-I Peng but differs in having a cane-like stem (vs stemless), leave blade ovate-lanceolate (vs broadly ovate), inflorescences arising from axils on the stem (vs arising directly from the horizontal rhizome) and anthers elliptic-oblong, apex rounded (vs fusiformobovate, apex acuminate) (Table 1). Type: Laos. Bolikhamxai Province, Pak Kading District, Nam

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Kading National Protected Area, 18°34'17.9"N, 104°03'26.6"E, 297 m elevation, 22 Oct. 2019, *Lanorsavanh & Xayalath SL 1999* (holotype **HNL!**; isotypes **E**, **FOF!**, **KKU**, **QBG**, Biology Herbarium of National University of Laos).

Monoecious rhizomatous herb. 30-45 cm tall. *Rhizomes* elongate, stout,  $8-12 \times 1.2-2$  cm, gravish with many fibrous roots. Stems cane-like, 25-35 cm long, 3-5 mm thick, dark brown-green, succulent, pilose. Leaves 3-5 per stem, alternate, lamina succulent when fresh, membranous when dry, asymmetric, ovate-lanceolate,  $15-27 \times 8-12$  cm, base oblique cordate, apex acuminate, margin biserrate; adaxial surface waxy, dark green, slightly vertucous and sparely scabrid; abaxial surface reddish, scabrid and densely pilose on veins; venation palmate, veins 7-9, prominent beneath. Petioles 5-22 cm long, dark brown-green, fleshy, pilose. Stipules triangular,  $12-22 \times 3-6$  mm, margin entire, apex acuminate, outer surface pilose, reddish-green. Inflorescences compound cymes, arising from axils of the leafy stem, branched 2-4 times, bisexual, 10-15 cm long, staminate flowers distal and pistillate flowers basal, protandrous. Peduncles 5-10 cm long, green-reddish to dark brown, terete, verrucose. Bracts lanceolate,  $10-20 \times 5-8$  mm, apex acute, margin strigose, pilose on outer surface, glabrous on inner surface, pale green. Staminate flowers: pedicels 10–15 mm long, straight, recurved near apex, reddish, strigose; tepals 4, reddish, outer pair elliptic-orbiculate,  $14-15 \times$ 10-12 mm, apex obtuse-rounded, strigose on outer surface, inner pair elliptic-oblong,  $8-10 \times 3.5-5$  mm, apex rounded to obtuse, glabrous; stamens ca 119, bright yellow, filaments free, cluster, 1.2-2.2 mm long, anthers elliptic-oblong, 1.8-2 mm long, dehiscing by longitudinal slits near the apex, apex rounded. Pistillate flowers: pedicels 10-15 mm long, dark red to green, sparsely villous, scabrid on surface; tepals 5, red, outer pair unequal, elliptic,  $14-15 \times 10-11$ mm, apex rounded, sparsely strigose and scabrid on outer surface, inner 3 smaller, narrowly elliptic, 9-13  $\times$  5–8 mm, apex rounded, glabrous to scabrid on outer surface; ovary green, red-brown toward on wings, few sparsely strigose, colliculate on surface (event distinctive on wings), with 3 unequal wings; dorsal wing broadly falcate-elongate or elongatetriangular, lateral wing triangular, apex acute; 2-locular, placentation axillary, two branches per locule; styles 2, connate at the middle into common stalk, dark yellow, stigma spiral and minutely papillose. Fruits green, globose,  $20-25 \times 50-55$  mm (including wigs), strigose, colliculate on surface. Seeds numerous, ellipsoid, ca  $0.4 \times 0.25$  mm, reticulate, brownish-yellow.

Table 1: Comparison of characters among Begonia colliculata, B. crocea and B. hekouensis

Characters	Begonia colliculata	<i>B.</i> $crocea^1$	B. hekouensis <sup>2</sup>
Stems	25–35 cm long, pilose	stemless	ca 30 long, brown appressed hairy
Leaves	ovate-lanceolate, $15-27 \times 8-12$ cm	broadly ovate, ca $30.5 \times 24$ cm	ovate, ca $16.5-22 \times 13-15$ cm
Inflorescences	cymes arising from axils in leafy stem, peduncle verrucous	cymes arising from rhizomes, peduncle glabrous	cymes arising from axils in leafy stem, peduncle densely villous
Bracts	margin strigose	margin entire	margin villous
Staminate flowers	tepals outer pair elliptic- orbiculate, strigose, inner pair elliptic-oblong, stamens ca 119, anther apex rounded	tepals outer pair ovate, glabrous, inner pair elliptic or narrowly obovate, stamens ca 100 or more, anther apex acuminates	tepals outer pair broadly ovate, villous, inner pair elliptic, stamens numerous, anther apex rounded
Pistillate flowers	tepals unequal, elliptic, narrowly elliptic, sparsely strigose	tepals subequal, obovate, glabrous	tepals unequal, largest broadly ovate, villous
Ovary	Strigose, colliculate, dorsal wing broadly falcate-elongate	glabrous, dorsal wing narrowly oblong	densely purplish brown villous, dorsal wing ligulate

<sup>1</sup>Peng et al., 2006; <sup>2</sup>Huang & Shui, 1994



Figure 1. *Begonia colliculata* Souvann. & Lanors.: A habit; B. stipule; C. pistillate flowers, front view; D. pistillate flowers, lateral view; E. styles and stigma; F. cross section of fruit; G. staminate flowers, front view; H. staminate flowers, back view; I. stamens; Drawn by K. Souvannakhoummane from *SL1999* (HNL).

Distribution and habitat.—To date, known only from the type locality in Nam Kading National Protected Area, Bolikhamxai province, Laos (Map 1). Plants are found in evergreen montane forest on rocks near stream and growing on humus-rich cliffs and rocks in sandy soil slopes with *Elatostema* sp. (Urticaceae), Asteraceae and Poaceae.

Phenology.—Flowering recorded in October, estimated between September to October and fruiting October to December.

Entomology.— The specific epithet "colliculata" refers to the colliculate surface of the ovary and fruit.

Vernacular.— Som koung deang (Red begonia).

Preliminary conservation assessment.— Vulnerable VU D2. This species is known only from a single locality in Nam Kading National Protected Area with an occurrence of around 1,690 km<sup>2</sup>. The overall population size is estimated to the number of less than 50 mature individuals. It is assessed here as Vulnerable, VU criterion D2, following IUCN criteria (2019).



Figure 2. *Begonia colliculata* Souvann. & Lanors.: A habit; B. staminate inflorescence; C. pistillate inflorescence; D. fruit, lateral view; E. pistillate flower, front view; F. pistillate flower, lateral view; G. staminate flowers, back view; H. staminate flowers, front view; scale bar: 1 cm; photo by S. Lanorsavanh from *SL1999* (**HNL**).



Map 1: Type locality (red circle) in Nam Kading National Protected Area (green area).

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#### Heterostemma brownii (Apocynaceae), a new record for Laos and Thailand

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#### ABSTRACT

Heterostemma brownii is reported as a new record for the floras of Laos and Thailand. A lectotype is also designated for the name Heterostemma brownii. A description based on Thai and Lao collections, photographs and notes are provided.

KEYWORDS: Asclepiadoideae, Ceropegieae.

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#### INTRODUCTION

The genus *Heterostemma* Wight (Apocynaceae) includes 30–40 species (Rodda, 2016) distributed in Nepal, China, India, Bangladesh, continental Southeast Asia, throughout Malesia to Australia, Solomon Islands and New Caledonia (Swarupanandan *et al.*, 1989; Forster, 1992). Six species were recognized in the most recent full treatment of the genus for Thailand (Thaithong *et al.*, 2018). In 2019, three new species were described from Thailand, namely *Heterostemma ficoides* A.Kidyoo (Kidyoo, 2019), *H. barikiana* P.Agnihotri *et al.* (Agnihotri *et al.*, 2019) and *Heterostemma trilobatum* A.Kidyoo & Thaithong (Kidyoo & Thaithong, 2019). *Heterostemma trilobatum* is a synonym of *H. barikiana*. Accordingly, eight species are now recognized in Thailand.

In Laos, only three species of *Heterostemma* are recorded, *Heterostemma grandiflorum* Costantin, *H. oblongifolium* Costantin and *H. succosum* Kerr (Newman *et al.*, 2007; Jin *et al.*, 2016; Thammarong *et al.*, 2019).

During a botanical survey in Chiang Rai province, northern Thailand in 2019, an unknown *Heterostemma* species was found. Specimens were deposited in QBG and SING herbaria. The same species was also collected in Laos, Oudonxai and Houaphan provinces, in 2012 and 2013 respectively. Based on the literature (Costantin, 1912; Swarupanandan et al., 1989; Ho, 1993; Li et al., 1995; Thaithong et al., 2018), it was identified as being very similar to Heterostemma brownii Hayata, but possibly distinct because of the glabrous stems (pubescent along two lines in *H. brownii*) and with corona lobes about <sup>2</sup>/<sub>3</sub> as long as the corolla tube (vs as long as the corolla tube in H. brownii). However, upon examination of specimens of Heterostemma brownii across its distribution area at A, KUN, IBSC, TAI and online at numerous Chinese herbaria via the China Virtual Herbarium (http://www.cvh.ac.cn/) it became clear that *H. brownii* is a variable species and stem pubescence ranges from glabrous or sparsely pubescent to pubescent along two distinct lines. The corona lobes appear to be generally as long as the corolla tube in specimens from Taiwan but quite variable on specimens from elsewhere, ranging from as long as the corolla tube to  $\frac{2}{3}$  as long as the corolla tube. Therefore, there is currently no evidence to justify the separation of a new taxon based on stem pubescence and the ratio of corona lobe and tube length.

Rodda (2016) was unable to locate any duplicate of the two syntypes of *Heterostemma brownii* (Kawakumi & Mori 1373, Hayata & Mori 41). Now, however, original material of *Heterostemma brownii* has been located and a lectotype can therefore be designated.

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## **TYPIFICATION & NEW RECORD**

Heterostemma brownii Hayata, J. College Sci., Imperial Univ. Tokyo 30: 199. 1911. Type: Taiwan, Shintiku, Taitoga, 1 June 1906 [1905], *T. Kawakami* & U. Mori 1378 [1373] (lectotype **IBSC** [0005666], designated here). Fig. 1.

Climber. Stem and branches glabrous; internodes 8–11 cm long. *Leaves*: blade ovate to elliptic,  $6-16 \times$ 4-7 cm, rather fleshy, papery when dry, base broadly cuneate, apex acute, glabrous, upper surface dark green, lower surface whitish green; venation palmate with 5 basal veins; petiole 1-4 cm long, above sparsely pubescent to glabrous, below glabrous. Inflorescences umbelliform, (5-)10-18-flowered; peduncles extra axillary, 1.5-3 cm long, glabrous; pedicels filiform, 1-1.5 cm long, puberulous. Calyx lobes triangular, ca 1.5 mm long, apex acute, glabrescent. Corolla rotate, 1-1.2 cm in diam. (to 1.8 cm in diam. when fresh), yellow with reddish brown specks inside, glabrous on both sides; tube shallowly campanulate, 5-6.5 mm long; lobes ovatetriangular,  $3-4 \times 3-4$  mm, apex acute, recurved. Corona spreading, almost flat, 5-7 mm in diam., lobes red, oblong,  $2.5-3.5 \times ca 1$  mm, thicker in the middle, with a short incurved projection above; inner process acuminate, outer process triangular with a round apex. Staminal column ca 1 mm in diam. Follicles and seeds not seen.

Distribution.— Laos, Thailand, China, Taiwan, Vietnam.

Ecology and Phenology.— Evergreen forest, roadsides and along streams at 500 to 1,100 m altitude. Flowering in June and July.

Notes.— The specimen here designated as lectotype of Heterostemma brownii is a duplicate of one of the two syntypes (Kawakumi & Mori 1373; Hayata & Mori 41). The specimen is a fragment including two leaves and an inflorescence. Its label is typewritten and has two inaccuracies when compared with the protologue. The collection year is indicated as 1906 (vs. 1905 in the protologue) and the collection number is 1378 (vs. 1373 in the protologue). The same typewritten label indicates that the specimen is an isosyntype. Despite these differences, we presume that this is a fragment of a more complete specimen of Kawakumi & Mori 1373, possibly originally in TAI (now lost) and the mistakes were introduced when duplicating the label. This is currently the only original material available for lectotypification. If new evidence were to be found to indicate this specimen is not original material, and if no alternative original material is found, then the lectotypification designated here would count as an effective neotypification under Art. 9.10 of the ICN (Turland *et al.* 2018).

Selected specimens examined.- Laos, Houaphan, Prov., Xam Nua Distr., trail from Ban Houa Xieng to Tad Xam waterfall, 1096 m, 4 June 2013, Leong-Škorničková et al. JLS2289 (E [E00715044], P [P01035642], Pha Tad Ke, QBG [sheet no. 75149], SING [SING0210351]); Oudonxai Prov. Ban Fen, 729 m, 16 Jun 2012, Leong-Škorničková et al. JLS1730 (E [E00664225], NUoL, **P**[P01035641], **SING** [SING0199246, SING0205217]). Thailand, Chiang Rai, Mae Sai, Wiang Phang Kham, Pha Mi, N 20°24'02.298" E 99°51'10.456", 515 m, 11 July 2019 (fl.), Thammarong et al. 895 (QBG [sheet no. 115360], SING). China, Yunnan, Pingpien Hsien, 1,100 m, 20 June 1934, Tsai 60395 (A). Taiwan, Taipei, Wakau-Wulai, ca 100 m, 31 May 1989, Liau 46 (TAI); Taipei, Hsinten, Kwanhsinli, 3 May 1990, Ou & Kao 10857 (TAI [sheet no. 214658, 214659]); Hsinchu, Chutang, Shangpingkou, ca 200 m, 7 May 1991, Huang 4596 (TAI [sheet no. 220063, 220064, 220065]); Chiayi, Chonglun, 600 m, 14 June 1988, Yen & Kao 10694 (TAI [sheet no. 212002, 212003, 212004, 218383]).

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Figure 1. *Heterostemma brownii* Hayata in Laos: A. habit, dangling over a stream; B. inflorescences; C. flower. *Heterostemma brownii* Hayata in Thailand: D. inflorescences; E. flower. A, B, C by Michele Rodda based on *Leong-Škorničková, et al. JLS2289*; D, E by Woranart Thammarong based on *Thammarong et al. 895*.

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# The Cenozoic leaf morphotypes and palaeoclimate interpretation from the Doi Ton Formation, Mae Sot District, Tak Province, western Thailand

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#### ABSTRACT

The Cenozoic palaeovegetation and palaeoclimate of Doi Ton, western Thailand, megaflora are reconstructed based on physiognomic climate analysis, including Leaf Margin Analysis (LMA), Leaf Area Analysis (LAA), Leaf Size Index (LSI), Climate Leaf Analysis Multivariate Program (CLAMP), and systematic descriptions of each leaf morphotype. The leaf fossils were divided into 23 dicotyledonous leaf morphotypes and two unknown leaf morphotypes. The mean annual temperature results from LMA indicate  $32.3 \pm 1.17^{\circ}$ C and CLAMP shows  $21.2^{\circ}$ C. CLAMP also provides temperature data of a warm month mean temperature (WMMT) of  $27.4^{\circ}$ C and a CMMT of  $14.2^{\circ}$ C, which is similar to the present climate. The mean annual precipitation is estimated by LAA to be ~ 125 cm. CLAMP suggests precipitation in the 11 months of growing period was 154.9 cm with the three wettest months having precipitation of 73 cm, widely contrasting with 15.5 cm for the three driest months. The precipitation shows the signal of the monsoon effect. The temperature, precipitation, and LSI mirrored the vegetation of the contemporary Doi Ton area which is a semi-evergreen forest in the tropical zone. The palaeoclimatic parameters of Doi Ton are in good agreement with those of south China and northwest India from the Eocene period and the present-day Mae Sot area. Moreover, the Doi Ton flora also closely matches the humid subtropical modern vegetation of south China. Palaeoclimate and vegetation analysis support an Eocene age estimate for the Doi Ton Formation however further independent age estimates are required to test this working hypothesis.

KEYWORDS: Cenozoic, Doi Ton Formation, leaf morphotypes, Palaeoclimate, western Thailand.

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#### **INTRODUCTION**

The fossil site, Doi Ton, is located in Mae Sot Basin, 30 km north of Mae Sot district, Tak province, western Thailand and close to the frontier between Thailand and Myanmar (Fig. 1A-1B). Doi Ton is a small hill, which rose in the middle of the Mae Sot Cenozoic Basin (Fig. 2A). The leaf fossils were collected from outcrops and in-situ float rocks around Doi Ton temple (16°54'17.12"N, 98°35'56.82"E). These leaf fossils are imprinted in sandstone layers and associated with branch, tree bark, bivalve, and gastropod fossils. The stratigraphy, lithology, and palaeontology of Doi Ton, consistent and comparable with the Mae Ramat Formation of the Mae Sot Group (Fig. 3) (Ampaiwan et al., 2003), imply that age of Doi range lies between the late Mesozoic to the early Miocene. Nevertheless, many papers indicate that

this formation should be a part of Cenozoic formation. Because the exact geological age of Doi Ton Formation is still unknown, this study used leaf physiognomy and palaeoclimate estimates to try to constrain the age of the formation further as a starting point.

The adaptation of plants is clearly mirrored in leaf anatomy, which is strongly related to temperature and precipitation. Intact leaves are mostly transported short distances from the source area, so they can be excellent proxies to indicate the local land environment (Maxbauer *et al.*, 2013). For more than a century, botanists have studied the relationship between leaf characters and climatic conditions and have attempted to construct various techniques to estimate past temperatures and precipitation. Large entire margined leaves are more common in wet tropical forests with decreasing latitude, whereas

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leaves of temperate vegetation tend to be smaller with a toothed margin and/or lobes (Bailey & Sinnot, 1916; Wolfe, 1993; Burnham *et al.*, 2001; Kowalski & Dilcher, 2003; Royer *et al.*, 2005); moreover, large leaf areas show a positive correlation with increased precipitation (Givnish, 1984; Wilf *et al.*, 1998). Thus, these relationships can be used to reconstruct climatic conditions, an approach known broadly as the leaf physiognomic method (Greenwood, 2005; Green, 2006; Peppe *et al.*, 2018).

In Thailand, there have been a few studies of plant fossils in Tertiary basins, but these are mainly studies of pollen, wood or fruits for taxonomic research, and few are leaf studies (Grote, 2005). Leaf fossils in Thailand are mostly found in Cenozoic terrestrial sediments (Grote, 2005; Sawangchote, 2006; Sawangchote et al., 2010). In this study, we describe and diagnose leaf fossils to estimate climate parameters by using physiognomic method including Leaf Margin Analysis (LMA), Leaf Area Analysis (LAA), Leaf Size Index (LSI) and Climate Leaf Analysis Multivariate Program (CLAMP) (Webb, 1968; Wolf, 1979; Wing & Greenwood, 1993; Wilf et al., 1998; Yang et al., 2011; Peppe et al., 2018). This study presents a new study of a poorly known fossil flora thereby reassembling the past vegetation within Doi Ton. The comparison of modern and past vegetation can provide significant insights into the evolution and relationships of these flora assemblages.

#### **Geological Setting**

Doi Ton is located in the Mae Sot Basin, western Thailand. This basin is typically a deposit of Tertiary sediments of Mae Sot Group along the half-graben basin (Morley & Racey, 2011). This basin had been open since the Eocene to the deposition of the fluviallacustrine sediments of the Mae Ramat Formation (Charusiri & Pum-Im, 2009). At that time, the basin was widely opened to deposition of lacustrine sediments of the Mae Pa Formation, which have the potential of developing into oil shale. The uppermost formation is the Mae Sot Formation, which was deposited in lacustrine to fluvial environments (Thanomsap, 1983; Thanomsap & Sitahirun, 1992). Tantiwanit et al. (1986) established the Doi Ton Formation for the Doi Ton area, which mainly consists of conglomerate, gravelly sandstone, sandstone, and siltstone and plant fossils were preserved in white sandstone. From the lithology, the Doi Ton Formation should be equivalent to Mae Ramat Formation in early Cenozoic.

#### Stratigraphy

Doi Ton, a hill reaching 300 m elevation, has several outcrops found near the top at ca 300 m (Fig. 2B). The measured stratigraphic sections range from 160 to 480 cm in length. These sections are mainly composed of sandstone with minor conglomerate and siltstone with highly weathered and red and whitish grey fresh colour. The lower part is made



Figure 1. A. Geographic location of fossil in Doi Ton, Mae Sot, Tak, western Thailand. B. Thailand located in SE Asia.


Figure 2. A. The small hill of Doi Ton rose in the middle Mae Sot Basin with surrounded by the undulating plain. B. The outcrop section on the top of Doi Ton. C. Stratigraphic section of Doi Ton exposed at fossil leaf position.

Period	Fm.	En ror	ví- iment	Thickness (m)	Stratigrap	hy	Description	
Quaternary -	1	Fh	IV.	7		Top	soil, sand, silt, and clay	-
U		Fai	luv.	>110		Gra	ivel, sand, silt, and clay	
	Mae Sot	Offshore Lacustrine	Lacustrine	867		Sha fac	ile interbedded with mudstone and oil shale	-
Tertiary			Fluvio-Lacustrine	355		Sar turl sha	dy shale and marlstone, silty claystone, pidite rocks interbedded with shale and oil le facies	_
	Mae Pa	nal Lacustrine		525		Ma cale fac	rlstone and mudstone interbedded with careous shale, oil shale and some calcarenite ies	
		Mapoi	Margi			11 21 31	Barrier , Channel, Beach sand facies Fossiliferous limestone facies Pisolitic limestone and Peloidal facies	
ulin	Mae Ramat	Alluv Fan.	Alluvial Palin	240- 600		Rec cor cla	l bed and greyish green facies glomerate, sandstone, siltstone, coal, and ystone	Doi Ton Formation
Jurassic	1			1	mm	Ba	sement rocks	

Figure 3. Stratigraphy of the Mae Sot Group, Mae Sot's Tertiary basin. The Doi Ton Formation is equivalent to the Mae Ramat Formation.

up of thin to medium bedded sandstone to siltstone couplets. The cycles demonstrate slightly fining upward from sand to silt size. Each cycle is capped by a rippled sand layer. The plant fragments are found in the sandstone layers. In the middle part, the lithologic sequence begins with a granule conglomerate, followed by thin to medium bedded, coarse to fine grained sandstone, and topped by fine grained sandstone with ripple marks. The conglomerate shows erosive base of channels deposit in the lower part and was deposited with tree trunks. Most of the plant remains (leaves, tree barks, and branches), and a few gastropods and bivalves, were found together in the sandstone layers in this part. The primary sedimentary structures, ripple marks, and bottom structures, indicate the NW palaeocurrent direction. The uppermost part mainly includes siltstone in reddish weathered colour and greyish black fresh colour (Fig. 2C).

#### **MATERIALS & METHODS**

#### **Materials**

The leaf fossils were collected from sandstone outcrops and in-situ float rocks around Doi Ton Temple, Doi Ton Formation. All specimens in this study collected by the authors are housed at the Department of Geological Sciences, Chiang Mai University, and those collected by the Ban Nam Dib Primary School's director are housed at the school. The sample ordering in this study was started by the "DT" to represent Doi Ton (and followed by the direction alphabet N, W, E, or S if collected from floated rock) and "BD" to represent samples collected and exhibited at Ban Nam Dib school. For example, the sample number DT-W18 indicates that this leaf that was collected from the west side of Doi Ton.

## Methods

**Morphological study.** The leaf fossils specimens were photographed with a digital camera, then they were grouped into morphotypes according to their leaf architecture. The morphotype is proposed to classify leaves based on leaf morphology which is not a formal taxonomic identification. Morphotype groups are not directly related to particular species of plants but are often equivalent to biological species (Leaf Architecture Working Group, 1999). The systematic description and terminology of the dicotyledonous leaf-architecture characters follow Dilcher (1974), Leaf Architecture Working Group (1999), Ellis *et al.* (2009), Hickey (1973) and Singh (2010). The size of each leaf was measured and compared with the Raunkiaer (1934) and Webb (1959) leaf size classifications.

**Physiognomic method for climate reconstructions.** The physiognomic methodology rests on the physical character of leaves and their established correlations with climatic parameters to resolve palaeoclimate conditions. Because the plant adapts their foliar features, e. g. size, shape, margin, to survive under the land climatic conditions. Palaeobotanists use these concepts of modern leaves to calibrate the climate with the fossil leaves. The causal mechanisms underlying the relationships between leaf physiognomic characters and climate parameters remain an active area of research (Little *et al.*, 2010; Edwards *et al.*, 2016).

Leaf Margin Analysis (LMA): Temperature or mean annual temperature (MAT) is significantly correlated with the proportion of entire (smooth) leaf margin vs toothed margin of flowering dicot plants in a collection or assemblage of leaves from at least 20 different species (Peppe *et al.*, 2018). From this relationship, the MAT was estimated by used the LMA analysis of a fossil leaf assemblage. To decrease uncertainty of this method, the fossil flora must contain more than 20 different morphological types of leaf fossil (Wolfe, 1971).

In this study, we choose the linear regression equation of Su *et al.* (2010) who combined the LMA data of China's humid forest. This equation better fits with our data (in linear line) than the others equation based on the LMA equations (Peppe *et al.*, 2018).

$$MAT = 27.6P + 5.884$$
 (1)

where MAT is average annual temperature estimated using LMA and P is defined as:

$$P = \frac{r}{n}$$

where n is the number of all morphotypes, and r is the number of entire margined leaf morphotypes.

Leaf Area Analysis (LAA): This analysis uses the modern correlation of leaf area and precipitation (Givnish, 1984; Webb, 1968; Wilf *et al.*, 1998; Jacobs, 1999; Peppe *et al.*, 2018). This model uses the average natural log of leaf area in each morphotype that can be used to estimate the mean annual precipitation (MAP), which is called "Leaf Area Analysis" or LAA (Wilf *et al.*, 1998; Peppe *et al.*, 2018). The leaf area can be measured by the indirect method by assigning the leaf to a size class of the Raunkiaer-Webb leaf size scale (Leaf Architecture Working Group, 1999).

We follow the linear regression models of Peppe *et al.*, 2011 (Eq.2), who studied leaves from North and South America, Japan, and Oceania. This equation better fits with our data than the other models. Moreover, we did not use the model from China as for LMA since there has been no study about LAA modelling from the China region before (Peppe *et al.*, 2018).

$$\ln MAP = 0.283(MlnA) + 2.92$$
 (2)

where MlnA is a mean natural log (ln) of morphotype's area (Peppe et al., 2018). This value can be calculated by entering the natural log value in each size class of Raunkier-Webb (Webb, 1959) of each leaf morphotype. Then, calculating the average of the mean natural log in each leaf morphotype (if the morphotype has a various size of leaf). The mean natural log's leaf area value for each category is leptophyll: 2.12, nanophyll: 4.32, microphyll: 6.51, notophyll: 8.01, and mesophyll: 9.11. The MlnA was calculated the average of mean natural log of the entire flora to put in the Peppe *et al.*, (2011)'s equation. This method has an uncertainty for the estimate of precipitation based on this equation. The standard error for LAA is 0.572. Moreover, almost of leaf fossils in this study are broken, so the estimate can be an underestimate or an overestimate of the precipitation.

Leaf Size Index (LSI): Each leaf fossil was assigned to a size class of Raunkiaer-Webb (Leaf Architecture Working Group, 1999). The size of leaves also provides important data of forest type, which is related to climate estimation. The ratio of small leaf classes and large leaf classes (Raunkiaer, 1934; Webb, 1959) with the percentage of smoothed leaf margin (Webb, 1959; Webb, 1968) were compared with the rain forest plant in Australia of Webb (1968). Moreover, the proportion of small and large leaf sizes has the potential to be compared with equatorial Africa flora that have been measured by Jacobs (1999). The result of LSI is compared with the modern vegetation in each area of the world.

Climate Leaf Analyses Multivariate Program (CLAMP): This method is based on the combination of LMA and LAA with 31 leaf features for climate interpretation. The 31 features are associated with margin style, size (CLAMP' leaf size classification scheme), length to width ratio, lobbing, and shape: base, apex, and whole shape. Each leaf character was scored for calculation in the spreadsheet and analysed using a multidimensional tool (canonical correspondence analysis, CCA) (Wolfe, 1995; Kovach & Spicer, 1995; Spicer et al., 2004; Spicer et al., 2009). In this study the PhysgAsia2's flora data set and HiResGridMetAsia2's meteorological data were used for analysing. The best prediction of CLAMP was produced by more than 20 morphological species. The leaf character scores in this study were analysed by the online version of the CLAMP website (http:// clamp.ibcas.ac.cn/CLAMP Run Analysis.html).

# **MORPHOTYPE CATALOGUE**

The morphological study of 55 leaf fossils was classified using similar leaf characters and grouped into 25 morphotypes of 23 dicotyledonous leaves and two unknown leaves. The first sample in the material name means the reference material present in Fig. 4.

# **Dicotyledonous leaves morphotypes**

# Morphotype A.

Material: DT-0241 (Fig. 4A)

Description: Leaf moderately to poorly preserved. Lamina oblong to narrowly oblong with medial symmetry, laminar size-mesophyll, 14.50 cm long, 5.54 cm wide; length to width ratio 2.6:1. Margin entire. Apex and base unknown. Midvein stout, markedly curved approximately  $2^{\circ}$  from a straight line. Primary venation pinnate. Basal and agrophic veins not preserved. Secondary veins faint, opposite, arising from midvein at a moderately acute angle ( $50^{\circ}$ – $62^{\circ}$ ), running straight toward the margin. Higher-order veins not preserved.

# Morphotype B.

# Material: DT-D5 (Fig. 4B)

Description Leaf poorly preserved. Lamina ovate to narrowly ovate; laminar size-microphyll, 3.56 cm long, 2.13 cm wide; length to width ratio 1.7:1. Medial and basal symmetry unknown. Margin entire. Apex and base poorly preserved. Midvein stout, straight, unbranched. Venation pinnate. Basal and agrophic veins not shown. Secondary and higherorder veins not preserved.

## Morphotype C.

Material: DT-SR6 (Fig. 4F)

Description: Leaf moderately to well preserved. Lamina obovate to narrowly obovate; laminar sizenotophyll, 7.69 cm, 3.85 cm wide; length to width ratio 2:1. Medial and basal symmetry unknown. Margin entire. Apex acuminate, base missing. Midvein weak, curved markedly to the right about  $6^{\circ}$  from a straight line. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins opposite arising from midvein at a narrowly acute angle ( $26^{\circ}$ - $44^{\circ}$ ), running uniformly curved toward the apex. Venation eucamptodromous. Higher-order veins not preserved.

## Morphotype E.

Material: DT-W33, DT-BD2, DT-BD7, DT-0192 and DT-2.4 (Fig. 4G)

Description: Leaf moderately well preserved. Lamina elliptic to narrowly elliptic; laminar sizenotophyll to microphyll, 7.05–10.30 cm long, 2.78–3.60 cm wide; length to width ration 2.4–3:1. Medial and basal symmetry. Margin entire. Apex acute; base rounded with acute angle. Midvein moderately to weak sized from base to apex, markedly curved to the right approximately 7° from a straight line. Primary venation pinnate. Basal and agrophic veins not preserved. Secondary venation preserved only on one side of leaf, arising from midvein at a narrowly acute angle (38°–43°), running uniformly curved to the margin. Venation craspedodromous. Higher-order veins not preserved.

## Morphotype F.

Material: DT-5.4, DT-BD2, DT-BD3.2 and DT-N5 (Fig. 4D)

Description: Leaf moderately well preserved. Lamina elliptic to narrowly elliptic; laminar sizemicrophyll, 4.1–4.67 cm long, 1–1.53 cm wide; length to width ratio 2.7–3.7:1. Medial and basal symmetry. Margin entire. Apex acute; base narrowly cuneate. Midvein weak, straight, unbranched. Primary venation pinnate. Basal and agrophic veins not shown. Secondary and higher venation not preserved.

## Morphotype H.

# Material: DT-D1, DT-SR4, DT-W11, DT-N2 and DT-E1 (Fig. 4E)

Description: Leaf moderately well preserved. Lamina ovate to narrowly ovate; laminar sizemicrophyll to mesophyll; 7.76–12.11 cm long, 4.19–6.98 cm wide; length to width ratio: 1.5–2.5:1. Medial and basal symmetry. Margin entire. Apex unknown; base rounded with obtuse angle. Midvein stout, straight, unbranched. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins subopposite arising from midvein at a moderately acute angle (45°–47°) and running uniformly curved toward the apex. Venation eucamptodromous. Interior secondary vein space uniform. Higher-order veins not preserved.

#### Morphotype I.

Material: DT-SR4, DT-D1, DT-W11, DT-N2 and DT-E1(Fig. 4H)

Description: Leaf moderately well preserved. Lamina oblong; laminar size-microphyll, 5.3 cm long, 2.3 cm wide; length to width ratio 2.3:1. Medial symmetry, basal symmetry unknown Margin entire. Apex acute; base unknown. Midvein weak, straight, unbranched. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins faint, arising from midvein at a narrowly acute angle (30°–41°) and abruptly curved toward the apex. Venation eucamptodromous. Interior secondary vein space uniform. Higher-order veins not preserved.

#### Morphotype J.

Material: DT-D6, DT-8.1 and DT-SR7 (Fig. 4I)

Description: Leaf moderately well preserved. Blade attachment marginal with petiole. Lamina elliptic; laminar size-notophyll, 3.02–13.02 cm long, 1.19–5.36 cm wide; length to width ratio 2.4–3.6:1. Medial and basal symmetry. Margin entire. Apex acute; base narrowly acute. Midvein weak, straight, unbranched. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins only preserved on one half side of leaf, arising from midvein at a narrowly acute angle (20°–25°) and running uniformly curved toward apex. Venation weakly brochidodromous. Interior secondary vein space uniform. Higher-order veins not preserved.

# Morphotype K.

Material: DT-7.1 and DT-10.1 (Fig. 4J)

Description: Leaf moderately well preserved. Lamina oblong to linear, laminar size-nanophyll, 1.97–2.34 cm long, 0.23–1.26 cm wide; length to width ratio 1.9-8.8:1. Medial asymmetry, basal symmetry. Margin entire. Apex unknown; base rounded with an acute angle. Midvein weak, straight, unbranched. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins faintly preserved, alternate arising from midvein at a moderately acute angle (47°–48°), running abruptly curved toward the apex. Venation eucamptodromous. Higher-order veins not preserved.

# Morphotype O.

Material: DT-5.1 (Fig. 4R)

Description: Leaf poorly preserved. Lamina oblong to lanceolate; laminar size-microphyll, 10.25 cm long, 2.46 cm wide, length to width ratio 4.2:1. Medial symmetry. Margin entire. Apex acuminate with an acute angle; base unknown. Midvein weak, straight, unbranched. Primary venation; faintly preserved, pinnate. Basal and agrophic veins not shown. Secondary veins and higher-order veins not preserved.

# Morphotype P.

Material: DT-3.2 (Fig. 4S)

Description: Leaf moderately well preserved. Lamina ovate to lanceolate, laminar size-microphyll, 5.61 cm long, 1.72 cm wide; length to width ratio 3.3:1. Medial and basal symmetry unknown. Margin entire. Apex unknown; base narrowly cuneate. Midvein massive, markedly curved to the right about  $6^{\circ}$  from a straight line. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins alternate arising from midvein at a moderately acute angle ( $46^{\circ}$ – $63^{\circ}$ ), running straight toward the apex. Venation eucamptodromous. Interior secondary vein space uniform. Higher-order veins not preserved.

# Morphotype R.

Material: DT-9.7, DT-D3 and DT-W4 (Fig. 4M)

Description: Leaf moderately to well preserved. Lamina obovate to narrowly obovate, laminar sizemicrophyll to notophyll, 3.31–7.03 cm long, 1.98–3.12 cm wide; length to width ratio 1.7–2.1:1. Medial and basal symmetry. Margin entire. Apex emarginate, broadly obtuse, base narrowly cuneate. Midvein massive, markedly curved to the left about 8° from a straight line. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins subopposite, arising from midvein at a narrowly acute angle ( $46^\circ$ – $50^\circ$ ), running uniformly curved toward the apex. Venation eucamptodromous. Interior secondary vein space increasing toward base. Higher-order veins not preserved.

## Morphotype S.

## Material: DT-D9 (Fig. 4N)

Description: Leaf moderately well preserved. Lamina elliptic; laminar size-microphyll, 4.13 cm long, 2.53 cm wide; length to width ratio 1.6:1. Medial and basal symmetry unknown. Margin entire. Apex and base unknown. Midvein stout, straight, unbranched. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins opposite to subopposite arising from midvein at a narrowly acute angle  $(45^\circ-56^\circ)$ , running uniformly curved toward the apex. Venation eucamptodromous. Interior secondary vein space uniform. Higher-order veins not preserved.

## Morphotype T.

## Material: DT-BD1 (Fig. 4O)

Description: Leaf moderately well preserved. Lamina obovate to narrowly obovate; laminar sizemicrophyll, 4.2 cm long, 2.1 cm wide; length to width ratio 2:1. Medial symmetry, basal symmetry unknown. Margin entire. Apex and base unknown. Midvein weak, straight, unbranched. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins alternate, arising from midvein at a narrowly acute angle (40°–47°), running abruptly curved toward the apex. Interior secondary vein space uniform. Higher-order veins are not preserved.

## Morphotype U.

#### Material: DT-5.5, DT-7.3 (Fig. 4P)

Description: Leaf moderately well preserved. Lamina oblong to lorate; laminar size-nanophyll to microphyll, 1.75–7.97 cm long, 0.25–1.99 cm wide, length to width ratio 4–7:1. Medial and basal symmetry. Margin entire. Apex acuminate, acute angle; base unknown. Midvein weak, markedly curved to the left about 40 from a straight line. Primary venation pinnate. Basal and agrophic veins not shown. Secondary and higher-order veins not preserved.

## Morphotype V.

Material: DT-3.1 (Fig. 4Q)

Description: Leaf moderately well preserved. Lamina elliptic, laminar size-notophyll, 6.22 cm long, 3.28 cm wide; length to width ratio 1.9:1. Medial symmetry, basal asymmetry. Margin entire. Apex and base unknown. Midvein stout, markedly curved to the right about  $6^{\circ}$  from a straight line. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins opposite, arising from midvein at moderately acute angle ( $46^{\circ}$ - $56^{\circ}$ ), running uniformly curved toward the apex. Venation eucamptodromous. Interior secondary vein space uniform. Higher-order veins not preserved.

## Morphotype: W.

Material: DT-5.2 (Fig. 4L)

Description: Leaf moderately to well preserved. Lamina cordiform; laminar size-microphyll, 7 cm long, 5.1 cm wide; length to width ratio 1.4:1. Medial symmetry; basal symmetry unknown. Margin entire. Apex acuminate, acute angle; base cordate. Midvein faintly preserved, moderate size, straight, unbranched. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins random, arising from midvein at a moderately acute angle (51°–62°), running uniformly curved toward the apex. Venation eucamptodromous. Interior secondary vein space uniform. Higher-order veins not preserved.

## Morphotype X.

Material: DT-5.2 (Fig. 4T)

Description: Leaf moderately to well preserved. Lamina obovate to narrowly obovate; laminar sizenotophyll, 6.1 cm long, 3.3 cm wide; length to width ratio 1.9:1. Medial and basal symmetry. Margin entire. Apex round with obtuse angle; base narrowly cuneate. Midvein weak, straight, unbranched. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins random arising from midvein at a moderately acute angle (42°–52°), running uniformly curved toward the apex. Venation eucamptodromous. Interior secondary vein space uniform. Higher-order veins not preserved.

## Morphotype Y.

Material: DT-SR1, DT-9.8 (Fig. 4U)

Description: Leaf moderately well preserved. Lamina preserved in some parts (other parts cannot be identified); laminar size-microphyll to mesophyll, 3.5–12.54 cm long, 2.25–7.23 cm wide; length to width ratio 1.7:1. Medial and basal symmetry unknown. Margin, apex, and base unknown. Midvein weak, curved slightly toward the apex. Primary venation actinodromous, at least four veins arising from the base. Secondary veins faintly preserved, arising at a narrowly acute angle (25°–37°), running uniformly curved toward the apex. Tertiary veins opposite percurrent, slightly arched.

## Morphotype Z.

# Material: DT-5.2 (Fig. 4V)

Description: Leaf moderately well preserved. Lamina ovate to narrowly ovate; laminar sizemicrophyll, 3.71 cm long, 2.1 cm wide; length to width ratio 1.9:1. Medial symmetry unknown, basal symmetry. Margin entire. Bass broadly cuneate. Midvein weak, markedly curved to the right about 9° from a straight line. Primary venation faintly preserved, pinnate. Basal and agrophic veins not shown. Secondary veins faintly preserved, subopposite arising from midvein at a narrowly acute angle  $(40^{\circ}-43^{\circ})$ , running uniformly curved toward the apex. Venation eucamptodromous. Higher-order veins not preserved.

#### Morphotype AA.

Material: DT-D7 (Fig. 4W)

Description: Leaf moderately well preserved. Lamina elliptic to narrowly elliptic, laminar sizemicrophyll, 5.93 cm long, 1.93 cm wide; length to width ratio 3:1. Medial and basal symmetry unknown. Margin entire. Apex round, acute angle. Midvein weak, markedly curved to the right about 60. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins alternate arising from midvein at a moderately acute angle (55°–56°), running uniformly curved toward the apex. Interior secondary vein space uniform. Higher-order veins not preserved.

#### Morphotype AB.

Material: DT-4.4 (Fig. 4X)

Description: Leaf moderately well preserved. Lamina oblong, laminar size-microphyll, 5.74 cm long, 2.4 cm wide; length to width ratio 2.4:1. Medial and basal symmetry unknown. Margin toothed, crenate. Apex and base unknown. Midvein stout, straight, unbranched. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins alternate; arising from midvein at a narrowly acute angle  $(35^{\circ}-37^{\circ})$ , running uniformly curved toward the margin. Venation craspedodromous. Tertiary vein not opposite reticulate.



(Continued on next page)

Figure 4. A. Morphotype A; B. Morphotype B; C. Morphotype D; D. Morphotype F; E. Morphotype H; F. Morphotype C; G. Morphotype E; H. Morphotype I; I. Morphotype J; J. Morphotype K; K. Morphotype M; L. Morphotype W; M. Morphotype R; N. Morphotype; O. Morphotype T. P. Morphotype U; Q. Morphotype V; R. Morphotype O; S. Morphotype P; T. Morphotype X; U. Morphotype Y; V. Morphotype Z; W. Morphotype AA; X. Morphotype AB; Y. Morphotype AC. All drawn by Kobkul Keiwsanuan. (scale bar = 1 cm).

## Morphotype AC.

Material: DT-W8, DT-4.1 (Fig. 4Y)

Description: Leaf moderately well preserved. Lamina preserved in some parts (other parts cannot be identified); laminar size-microphyll to mesophyll, 3.42–8.86 cm long, 4.57–9.97 cm wide; length to width ratio 0.7–0.9:1. Medial and basal symmetry unknown. Margin, apex, and base unknown. Midvein stout, straight, unbranched. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins alternate, arising from midvein at a moderately acute angle (48°–56°), running uniformly curved toward the apex. Tertiary veins opposite, percurrent.

## Unknown leaves morphotypes

## Morphotype D.

Material: DT-W16, DT-W18, DT-2.3, DT-SR2, DT-D11, DT-2.6 and DT-5.3 (Fig. 4C)

Description: Leaf moderately well to poorly preserved. Lamina oblong to linear; laminar sizemicrophyll, 3.33–7.60 cm long, 1.38–2.53 cm wide, length to width ratio 2.5–3.4:1. Medial and basal symmetry. Margin entire. Apex unknown, base rounded, acute angle. Midvein massive, straight, unbranched. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins faintly preserved, subopposite arising from midvein at a



Figure 4. (Continued from preceding page).

widely acute angle (60°–76°), running the straight toward margin. Higher-order veins not preserved.

## Morphotype M.

## Material: DT-9.3 and DT-N13.1 (Fig. 4K)

Description: Leaf moderately well to poorly preserved. Lamina ovate to lanceolate; laminar sizemicrophyll, 5.29-7.05 cm long, 1.31-1.48 cm wide; length to width ratio 3.6-5.4:1. Medial and basal symmetry. Margin entire. Apex and base rounded, both with acute angle. Midvein weak, markedly curved to the left about 4° from a straight line. Primary venation pinnate. Basal and agrophic veins not shown. Secondary veins faintly preserved, arising from midvein at a moderately acute angle ( $70^\circ$ - $79^\circ$ ), running straight toward the margin. Interior secondary vein space uniform. Higher-order veins not preserved.

## PALAEOCLIMATE RESULTS

## Leaf Margin Analysis (LMA)

Doi Ton leaves contain a higher proportion of leaves with entire margins than toothed margins. Only one morphotype from the 23-dicot leaf morphotypes, or 4%, have toothed margins (Table 1). Following LMA this result is a high MAT estimate for the Doi Ton leaf assemblages (Wolfe, 1979; Wing & Greenwood, 1993; Wilf, 1997; Peppe *et al.*, 2018). MAT is  $32.3^{\circ}C \pm 1.17$  from equation 1 (binomial sampling error (Miller *et al.*, 2006)).

## Leaf Area Analysis (LAA)

Dicotyledonous leaf fossils of Doi Ton were compared in size with the leaf size class of Raunkier-Webb (Webb, 1959) and the natural log of each leaf size was used to calculate the MAP (Table 1). According to the univariate regression model of natural log of leaf area and natural log of MAP of Wilf *et al.*, 1998; Peppe *et al.*, 2018, these models provide the MAP estimates of Doi Ton leaf assemblages. This study used the model of Peppe *et al.* (2011) and shows a MAP of 125 cm/yr (error of this equation -57 to +105 cm, calculated by sampling error of this equation: error = [MAP-( $e^{(ln(MAP)-0.61)}$ ]

# Leaf Size Index (LSI)

Forty-two leaf sizes of dicotyledonous leaf (size category) were classified into five classes of

Raunkiaer's (1934) and Webb's (1959) leaf size classification scheme for Doi Ton. Small leaf classes are more abundant than large leaf classes: 60% are microphyll (25 samples); 7% nanophyll (three samples) and 2% leptophyll (one sample). There are two classes of large leaves comprising of 12% mesophyll (five samples) and 19% notophyll (eight samples).

# Climate Leaf Analyses Multivariate Program (CLAMP)

Multiple variable quantitative leaf physiognomy analyses of Doi Ton were made using CLAMP with the calibration of the Asian flora and climatic dataset to estimate palaeoclimate of Doi Ton leaf assemblages. The 23 leaf morphotypes were scored and analysed following CLAMP protocols. CLAMP CCA axis 1 and axis 3 biplot displays the position of the Doi Ton assemblages (red filled circle) close to the modern calibration site from East Asia and northern America (Fig. 5A to 5C). For Fig. 5, data plotted on the CCA axis 1 and axis 2, indicates that the Doi Ton is positioned among East Asia, North America, and the Caribbean modern sample localities and climates. The CCA plot between axis 2 and axis 3 shows the Doi Ton in close proximity to the site of East Asia and northern America, which is similar to CCA axis 1 and 3 plotting. Regression modelling was applied for estimating mean annual temperature (Fig. 5D), mean temperature of the three warmest and three coldest months (Fig. 5E to 5F), and precipitation of the three-wettest and three-driest months (Fig. 5G to 5H); uncertainty of the analysis is  $\pm 2$  S.D. as shown as vertical error bars from the vellow filled circles. CLAMP analysis suggests that the Doi Ton's temperatures and precipitation fall in the humid regime. The calculated temperatures of Doi Ton include MAT 21.2°C, WMMT 27.4°C, and CMMT 14.2°C. The precipitation was estimated as high. The precipitation during the growing period is 154.9 cm in 11 months. The mean precipitation during the growing months is 13.4 cm. The precipitation of the three wettest months is 73 cm, which contrasts widely 15.5 cm for the three driest months.

## DISCUSSION

The relationship between leaf characters and inhabited climatic conditions is a powerful tool for palaeoclimate reconstruction. Most of the leaf fossils

Do	i Ton Flo	ora	leaf size class (Manual of leaf architecture)					
Morphotype	%	number of specimens scored	nanophyll	microphyll	notophyll	mesophyll	MLnA	
A		1				9.11	9.11	
В		1		6.51			6.51	
С		1			8.01		8.01	
E		5		6.51	8.01		7.26	
F		3		6.51			6.51	
Н		5		6.51	8.01	9.11	7.88	
I		1		6.51			6.51	
J		3	4.32		8.01		6.17	
K		2	4.32				4.32	
0		1		6.51			6.51	
Р		1		6.51			6.51	
R		3	4.32	6.51			5.42	
S		1		6.51			6.51	
Т		1		6.51			6.51	
U		2			8.01		8.01	
V		1		6.51			6.51	
W		1		6.51			6.51	
X		1		6.51		9.11	7.81	
Y		2		6.51			6.51	
Z		1		6.51			6.51	
AA		1		6.51			6.51	
AB		1		6.51			6.51	
AC		2		6.51			6.51	
		1	0.1	0.6	0.2	0.1	6.7	

Table 1. Scores of Doi Ton leaf fossil of LMA and LAA methods.

in Doi Ton are entire margined. Ninety six percent of fossil morphotypes observed possess entire margins while 4% of leaf morphotypes show a toothed margin. This ratio is indicative a higher mean annual temperature (Bailey & Sinnott, 1916; Wolfe, 1979; Wing & Greenwood, 1993; Royer et al., 2005; Su et al., 2010; Steart et al., 2010). The range of temperatures suggests the vegetation is as in a tropical zone, such as a tropical dry forest (Murphy & Lugo, 1986). But only a single leaf in the Doi Ton leaf morphotypes has a toothed margin is a small sample size and can introduce uncertainty into the estimation of mean annual temperature. There are different calibrations based on modern vegetation in other parts of the world. For example, the Australian LMA is more appropriate for a Thailand fossil flora, as like Australia, Thailand does not experience freezing in winter and many of the samples in the Australian calibration are tropical sites (MAT 18°C–25°C) with many of these showing seasonally dry climates (Wolfe, 1979), as seen in the monsoonal forests of Thailand. One should be cautious with using the error for LMA, as original modern calibration for all modern samples has a variance of 2°C simply from the natural year to year variation seen in meteorological/weather station data, the error from the fossils cannot be smaller than 2°C. (Royer *et al.*, 2005; Su *et al.*, 2010).

Leaf size is valuable for estimating climatic conditions. Larger leaves are enriched in the mesic environment compared to the dry environment (Webb, 1968; Dilcher, 1974; Dolph & Dilcher, 1980a, b; Givnish, 1984). Following Webb (1968), who studied the leaf size and margin types of the rain forest plants in Australia for subdividing the forest types, for Doi Ton, there are 34% of the large leaf class (e.g., 13% mesophyll; 21% notophyll), 66% microphyll (small leaf class) and 96% with entire margins. The leaf size ratio and margin type agree well with data of the semi-evergreen vine thicket (SEVT) sub-formation of the rain forest. This interpretation can be used for reconstructing the palaeoforest that was a source of Doi Ton leaf fossils, which is also similar to the present day South East Asian forest type. The palaeoforest of Doi Ton had an abundance of microphyll and smaller leaf sizes. The canopy level was uneven at 4.5–9 m, with mixed evergreen, semi-evergreen and deciduous emergent to 9–18 m. This forest was in the subtropical rain forest region with lowland and lower montane forests. Moreover, the proportion of leaf sizes was used to estimate the rainfall in tropical Africa by Jacobs (1999). The study of Jacobs found that the ratio of the large leaves (notophyll + mesophyll + macrophyll)



Figure 5. CCA plots showing the relationship between the leaf fossil morphology and modern vegetation A. Axes 1 vs 3 B. Axes 1 vs 2 C. Axes 2 vs 3 D. Regression model for mean annual temperature E. Regression model for warmest month mean temperature F. Regression model for precipitation on three-wettest month H. Regression model for precipitation on three-wettest month.

vs small leaves (leptophyll + nanophyll + microphyll) was positively correlated to mean annual precipitation, that can use to interpret the palaeoenvironment of Doi Ton area. There are 31% larger leaves and 69% smaller leaves, indicating a relatively dry environment. The proportion is similar to the deciduous forest of the study sites of Africa, such as the Arabuko-Sokoke Natural Reserve deciduous forest in Kenya and the Lengwe deciduous forest in Malawi.

The forest types from LMA and LSI are very close to the present vegetation widely distributed in the Mae Sot area. Nevertheless, the large number of small leaves are of concern, because large leaves are easily broken while being transported to the deposition site. Moreover, the smaller leaves and their characters are also associated with the condition of temperature (e.g., altitude or latitude), soil character (moisture, draining, nutrient) and lightness and spaces of the forest (Jacobs, 1999; Royer *et al.*, 2005; Greenwood, 2007). Mean annual temperature and mean annual precipitation of the Doi Ton site can be used to construct the vegetation based on the Whittaker biomes classification scheme (Whittaker, 1975). Palaeoforest is matched with the seasonal tropical rain forest known as semi-evergreen forest, tropical mixed or moist deciduous forest by the data of CLAMP. The LMA and LAA analyses provide the plot slightly outside seasonal tropical rain forest's modern biomes (Fig. 6).

The wide range of precipitation of CLAMP can be the evidence of a period of aridity during the summer months. That means that the palaeoflora indicates a different distribution of precipitation throughout the year. However, the dryness data has never been supported by other leaf quantifiable analyses.

Comparing the MAT and MAP data of Doi Ton leaf assemblages with the present-day (Thai Meteorological Department, 2010), over 30 years



Figure 6. Climatic distribution of Doi Ton site. Red star is represented MAT from LMA and MAP from LAA. Yellow star is represented MAT and MAP from CLAMP. The biomes followed Wittaker (1975).

the mean annual temperature and mean annual precipitation are similar. The MAT from LMA indicates that temperatures were hotter than the present-day, in the range of  $32.3^{\circ}C \pm 1.2$  from the fossil data and 26.15°C nowadays. On the other hand, the CLAMP indicates MAT as 21.2°C. The MAT from CLAMP suggests that the climate was cooler than nowadays but the WMMT is close to MAT of Mae Sot today, which may be the effect of CLAMP uncertainty. The MAT derived from LMA ( $32.3 \pm 1.17^{\circ}$ C) and CLAMP (21.2°C) are obviously different and not close in value to each other. But, nevertheless, similar values occur in hot and tropical climatic conditions today including those existing at Mae Sot currently. Also, the precipitation, the fossil data and presentday are in very good agreement. The precipitation from the fossil data, which is derived by LAA and CLAMP, is in range of ~ 1,250 mm/yr – ~ 1,549 mm/11 months, and the present day is 1,230.9 mm/ yr. This means the climate of the LAA is more similar with the present day than the CLAMP result.

Results from CLAMP can be underestimated values when compared with the single variable model because some characters for scoring are ambiguous (Wilf, 1997; Green, 2006) and not clearly related to climate parameters. According to Wilf, 1997; Kowalski & Dilcher, 2003; Royer, 2012; and West et al., 2015, who studied the palaeoclimate by LMA, LAA, and CLAMP, MAT of CLAMP was no more precise than LMA, while precipitation is overestimated as compared with LAA. LAA and LMA analyses may both be affected by taphonomic conditions that can make a high uncertainty for estimation. Moreover, all methods use dicot plants to interpret palaeoclimate and disregarded other plant types. The study of other taxa of plants may increase the accuracy of the reconstructions.

The quantitative palaeoclimate of CLAMP results from Doi Ton were compared with the CLAMP results of Cenozoic leaf floras from the adjacent areas (China and India) because the vegetation will show a similar character when controlled by the same climate zone.

Previous study of plant fossils and palaeoclimate since the Cretaceous to Palaeocene (Wolfe & Upchurch, 1987; Spicer & Corfield, 1992; Pirrie & Marshall, 1990; Wolfe, 1990; Wilf *et al.*, 2003) do not conform together with Doi Ton climate and vegetation. Most plants in the Cretaceous to Palaeocene were deciduous and located in the cool temperate regions with a 5°C to 13°C mean annual temperature. Moreover, sedimentary rock data from the southern hemisphere suggest the palaeotemperature varied between 10°C to 20°C (Wolfe & Upchurch, 1987; Spicer & Corfield, 1992; Pirrie & Marshall, 1990).

The climate from leaf fossils of Doi Ton (MAT = 21.2°C, GSP = 154.9 cm) suggests the climate parameters maybe similar to the palaeoclimate based on Eocene data from south China; Changchang (MAT = 21.5°C, GSP = 201.35 cm) and Youganwo (middle Eocene) (MAT = 20.2°C, GSP = 233.4 cm), Huangniuling (late Eocene) (MAT = 22.35°C, GSP = 236.45 cm), and northwest India; Gurha (early Eocene) (MAT = 25.2°C, GSP = 181.5 cm) (Table 2) (Fig. 7) (Spicer *et al.*, 2016), more than the other site with leaf fossils from early Oligocene to early Pleistocene.

The geographic location of western Thailand and south China have little changed since the late Cretaceous (Spicer et al., 2014). The early Eocene climate of India was probably hotter and rainier than Doi Ton and south China because the palaeolatitude of the Indian plate was situated in southern and nearer the equator than today. After that, during the middle Eocene, the Indian plate moved northward from the southern pole (Metcalfe, 2017) and was situated at the same latitude as Doi Ton (including western Thailand) and south China (Fig. 8). Thus, the palaeoclimate correlation between northwest India, western Thailand, and south China is easy to compare and more reliable because the palaeolocation is similar. During the early Eocene, the Doi Ton climate parameters do not match with the India's climate. Doi Ton shows a lower MAT, drier than India, because at this time India was at a lower latitude, nearer to the equator, which resulted in high temperature and precipitation.

The MAT of Doi Ton disagrees with the middle Eocene of India. Doi Ton was as cold as south China, but colder than India. WMMT of Doi Ton is similar to both south China and India, but CMMT is closer to that of India than south China, which was hotter than south China. These comparisons are the only aspect of climate parameters that cannot be accurately dated to the geologic age (ideally estimated)

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ones	Age	(c)	(c)	(c)	(months)	(cm)	(cm)	(cm)	(cm)	3W/5U	(%)	Kelencinces	
Anmachal Pradesh Upper Siwalik	cPlc	25.4	28.1	20.9	12.6	189.9	15.9	97101	9.0	113	82.4	Khan et al., 2014	
Anmachal Pradesh Middle Siwalik	Pli	23.7	28.1	16.9	12.1	198.1	17.9	99.4	13.8	72	78.8	Khan et al., 2014	
Anmachal Pradesh Lower Siwalik	Mm	25.3	27.8	213	12.5	174.1	14.0	96.2	73	13.2	81.2	Khan et al., 2014	
Darjecing Lower Siwalk	WII	25.4	28.4	17.9	13.0	242.3	24.5	111.7	28.9	3.9	81.0	Khan et al., 2014	
Tirap (India)	Q	26.1	27.9	20.7	13.7	246.0	20.6	138.1	6.7	20.6	76.6	Srivastava et al., 2012	
Shangcun Flora (souther china)	8	23.1	28.2	12.0	123	225.0	23.4	103.7	20.0	52	70.8	Herman et al., 2017	
Huangniuling Upper (souther china)	Œ	24.0	28,4	15.0	12.0	240.1	25.3	114.3	26.9	42	80.1	Spicer et al., 2014	
Huangniuling Lower (souther china)	E	20.7	28.4	8.9	11.4	232.8	25.3	104.6	32.7	3.2	75.0	Spicer et al ., 2014	
Changchang 1 (souther china)	mE	21.6	28.4	11.2	11.7	200.7	19.5	87.7	21.2	4.1	68.4	Spicer et al., 2014	
Changchang 2 (souther china)	끹	213	28.4	10.8	.11.5	202.0	19.7	88.0	22.6	-39	69.0	Spicer et al ., 2014	
Youganwo (souther china)	mE	20.2	28.4	61	.113	233.4	25.7	103.7	34.9	3.0	74.4	Spicer et al., 2014	
Gurha 39 m (India)	GE	26.4	28.2	19.0	12.0	183.8	15.8	98.4	83	11.9	78.6	Shukla et al., 2014	
Gurha 72 m (India)	сE	23.9	27.2	18.2	12.0	179.2	15.3	93.8	10.6	8.8	78.0	Shukla et al ., 2014	
Doi Ton		21.2	27.4	14.2	FII	154.9	13.4	73.0	15.5	4.7	70.6	This study	



Figure 7. The CLAMP comparison of Cenozoic leaf fossils from north India, south China, and Doi Ton (red star). A. MAT comparation B. GSP comparison C. The ratio of precipitation on three-wettest month and three-driest month.

which can only be estimated independently using biostratigraphy or some chronostratigraphic method. Moreover, the fewer data of climate from leaf fossils in Thailand and neighbouring areas can be make it difficult to propose an exact age. The palaeoclimate interpretation of this work can, perhaps, shed light on the climate from Doi Ton leaf fossils allowing comparison with adjacent areas.

Moreover, Doi Ton's CLAMP data also show the Doi Ton assemblages lie close to the humid subtropical climate of present-day vegetation from southwest China (Mengla and Pingbian, Yunnan) and southeast China (Zhaoqing, Guangdong) (CLAMP website), which show a humid subtropical climate.

The difference of precipitation between wet and dry seasons of Doi Ton suggests the plants are slightly affected by monsoon phenomenon, but not to a large extent. That means Doi Ton's monsoon mirrored highly precipitation throughout the year or wetter dry period. This result can be used as a proxy to indicate the monsoon character at that time. The monsoon of SE Asia is caused by the strength of the humid wind in the summer period more than the



Figure 8. The palaeolatitude and palaeogeographic map showing of Doi Ton, India, and south China landmass at 40 Ma. (red line) with present-day (grey area) and the monsoon direction (modified from Plate Tectonic Reconstruction Service, 2011).

strength of dry wind in winter period. Doi Ton leaf fossils indicate that the monsoon at that time was weak. This suggestion conforms to that of Huber & Goldner (2012), who show weak effects by the monsoon in SE Asia during Eocene. This is caused by the lack effect of humid wind in the East Asian Monsoon during the summer period.

Leaf traits are significantly more strongly related to mean annual temperature than mean annual precipitation (Moles et al., 2014). So, the result of precipitation of Doi Ton leaf assemblages may not be of precise value. Leaf characters and leaf diversity of Doi Ton were directly affected by pre- and postdeposition processes (i.e., transportation, sorting, deposition pattern, and decay by organism or diagenesis). In fluvial environment, leaves are considered as parautochthonous, which are derived from near the location of the living plant (Gastaldo et al., 1996; Greenwood, 2005; Kunzmann & Walther, 2007; Su et al., 2010). The preservation of the flora can be an indicator of the volume of leaf character information that has been lost along the process. Leaves falling from the forest into the stream or lacustrine must originate within 50 m of the water if the leaf materials are to be transported in high quantity. Moreover, the increasing intensity of leaf fragment and clustering of leaves suggest fluvial deposit (Gastaldo et al., 1996). This means the plant growing along river or bank environments has a high chance of being deposited during a period of flooding more than plants in another environment. This suggests that the Doi Ton leaves were possibly deposited in fluvial environments.

Most of fossil leaf reports come from the Li Basin, north Thailand (Grote, 2005; Sawangchote et al., 2010). In addition, the Tertiary basins of north Thailand include Mae Moh Basin, Na Hong Basin, Mae Lamao Basin, and Chiang Muan Basin present the temperate vegetation in Oligocene - early Miocene and tropical vegetation in early-middle Miocene (Songtham et al., 2003). Temperate elements suggest that the north Thailand climate during the Oligocene - early Miocene was cooler than the present-day (Grote, 2005). The comparison of leaf fossils between Li Basin and Doi Ton is clearly different in terms of leaf characters, especially the margin character. Doi Ton leaves have a smaller proportion of toothed leaves than Li leaves, which implies that Doi Ton was hotter than Li. Vegetation types of Doi Ton and Li are similar; however, the details of climate are different. This evidence is supported by the 55 leaves morphotypes from Nong Ya Plong coal mine, western Thailand, which is the late Oligocene to early Miocene as Li Basin. Those leaves from Nong Ya Plong contain a high proportion of toothed leaves (Sawangchote, 2006). Additionally, palynological analysis from Li and Nong Ya Plong indicates the vegetation was a mix with temperate and warm species (Watanasak, 1988; Grote, 2005). That means the Doi Ton vegetation differs from the late Oligocene to early Miocene in both climatic factors and vegetation type. Vegetation of Doi Ton, Li, and Nong Ya Plong differ suggesting that they grew at different time periods. Moreover, Endo & Fujiyama (1995) examined the Miocene leaves from the oil shale in the uppermost part of the Mae Sot Group. These leaves were identified as Bauhinia sp., Podogonium Knorrii Heer, and Apocynophyllum sp. in the Miocene, which cannot compare with the Doi Ton leaf assemblage at all.

Furthermore, Doi Ton climate and vegetation also conform to the Krabi Basin. This interpretation of Krabi Basin was based on palynological study (Watanasak, 1990) and mammal fauna study (Benammi *et al.*, 2001). The vegetation and climate of Krabi Basin, late Eocene, is a tropical forest, hot and humid like the present-day. On the other hand, Doi Ton is not similar to the middle Pleistocene vegetation of northeast Thailand that comprised mixed evergreen-deciduous forest (Grote, 2006) or its climate is drier than Doi Ton.

## CONCLUSION

The Doi Ton fossil flora consists of 23 angiosperm morphotypes and two unknown morphotypes. Doi Ton fossil floras present a new point of view of palaeoclimate parameters of western Thailand, which is like the present-day. Sedimentology and palaeobotanical evidence are illustrative of a seasonal tropical environment and vegetation in a warm climate with weak monsoon conditions. This indicates the semi-evergreen forest was a major constituent of Doi Ton palaeoecology. The comparison of the Cenozoic climate data from adjacent areas indicated that Doi Ton is similar climatically to south China and northwest India in the Eocene period. Moreover, the Doi Ton fossil flora is also similar to modern vegetation of humid climatic areas of south China. Likewise, the results should be critically considered and discussed in terms of taphonomic effects, taxonomic and climatological localization, e.g., some species are tolerant in a wide range of environmental conditions. Further work with a larger flora database or collection and accurate taxonomy are needed to confirm the palaeoclimate interpretation. Furthermore, independent assessment of the age of the Doi Ton formation is now needed to test our assessment based on flora and climate that this formation was likely Eocene in age.

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# Notes on the typification of five names in Lauraceae

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#### ABSTRACT

This article deals with inadvertent lectotypifications of five names in the Lauraceae, *Cryptocarya densiflora*, *Cryptocarya impressa*, *Cylicodaphne infectoria*, *Laurus cubeba* and *Litsea castanea*, that have been previously overlooked.

KEYWORDS: Cryptocarya, lectotype, Litsea, Shenzhen Code.

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## **INTRODUCTION**

The Lauraceae is a pantropical family with a few temperate members and comprises between 2,500 and 3,500 species (Rohwer, 1993). The five names, Cryptocarya densiflora Blume, Cryptocarya impressa Miq., Cylicodaphne infectoria Blume (basionym of Cryptocarya infectoria (Blume) Miq. and synonym of Cryptocarya griffithiana Wight), Litsea castanea Hook.f. and Laurus cubeba Lour. (basionym of Litsea cubeba (Lour.) Pers.), were inadvertently lectotypified by a number of authors (Kostermans, 1970; Allen, 1938; Hyland, 1989) under Art. 7.11 of the Shenzhen Code (Turland et al., 2018; hereafter 'Code'). Later authors (Ngernsaengsaruay et al., 2005; de Kok, 2015; Singh, 2017), presumably unaware of these inadvertent typifications, either published new and superfluous lectotypifications, or, in three cases, effectively published second-step lectotypifications.

Type specimen images of all names have been studied from online resources. The curator of BO was also consulted for a type image of *Cryptocarya densiflora*. Details of the inadvertent lectotypifications are given below to ensure the correct future citation of the earliest designated lectotypes.

1. Cryptocarya densiflora Blume, Bijdr. Fl. Ned. Ind.: 556. 1826. Type: [Indonesia] Java, Mount Salak, *Blume s.n.* (lectotype **BO** [BO-1267423] photo seen, designated by Hyland, 1989: 180; isolectotypes L [L0036103, L0036104, L0036105, L0036106, L0036107, L0036111, L0036112] photos seen, U [U0002692] photo seen, NY [00355062, 00355063, 00355064] photos seen).

Notes.—Blume (1826) cited "in sylvis obscurioribus montis Salak" in the protologue. According to de Kok (2015: 323), the species was described based on two gatherings, Blume s.n. and Reinwardt s.n. I have been able to trace three specimens (L0036108, L0036109, L0036110) of Reinwardt s.n. at L which were collected from Gedokan, Java and not from montis Salak. These three specimens are not original material. There is one specimen at BO and it bears a label with the annotation 'Cryptocarya densiflora Bl' on the bottom right side and an additional label also at the bottom with the name "Kiteja" and "S" [Salak], all in Blume's own handwriting. Hyland (1989: 180) cited "Type: C. Blume, Mount Salak, Java (BO)" and the citation of 'type' should be accepted as an inadvertent lectotypification under Art. 7.11 of the Code. Later, de Kok (2015: 320) overlooked the lectotypification by Hyland (1989) and designated the specimen L0036111 as lectotype. Therefore, the lectotypification by de Kok (2015) is superfluous.

**2.** Cryptocarya griffithiana Wight, Icon. Pl. Ind. Orient. 5: t. 1830. 1852.

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Cylicodaphne infectoria Blume, Mus. Bot. 2: 11.
1856. Cryptocarya infectoria (Blume) Miq., Fl.
Ned. Ind. 1: 924. 1858. Type: [Indonesia] Archipelago
Indico, Waitz s.n. (lectotype L [first-step], designated
by Kostermans, 1970: 312; lectotype [second-step]
L [L0036159] photo seen, designated by de Kok,
2015: 323; isolectotypes L [L0036157, L0036158]
photos seen).

Notes.— *Cylicodaphne infectoria* Blume is a heterotypic synonym of *Cryptocarya griffithiana* Wight. For *Cylicodaphne infectoria*, Blume (1856) cited "In Archipelago Indico" in the protologue. Kostermans (1970: 312) cited "Typus: Arch. Ind., Herb. Waitz, fl., fr. (L, 3 sheets)" which is an inadvertent lectotypification under Art. 7.11 of the *Code*. As there are three sheets at L, it can be taken as a first-step lectotypification under Art. 9.17 of the *Code*. Later, de Kok (2015: 323) overlooked the lectotypification by Kostermans (1970) and designated *Waitz s.n.* (L0036159) as lectotype which is an effective second-step lectotypification under Art. 9.10.

**3.** Cryptocarya impressa Miq., Fl. Ned. Ind. 1: 923. 1858. Type: [Indonesia] Sumatra, 'Paja Kombo', 'Mohdang apie apie', *Teysmann 1005* (lectotype U [U0002696] photo seen, designated by Kostermans, 1970: 311; isolectotype **BO**, n.v.).

Notes.— Miquel (1858) cited "Sumatra, bij Paja Kombo (TEYSM.). – Madang api api *mal.*" in the protologue. Kostermans (1970: 311) cited "Typus: sine coll. *1005*, Payakombo, "Mohdang apie apie", fr. (U)" which is an effective lectotypification under Art. 7.11 of the *Code*. Later, de Kok (2015: 333) overlooked the lectotypification by Kostermans (1970) and designated the specimen U0002696 as lectotype. The lectotypification by de Kok (2015) is superfluous.

**4. Litsea castanea** Hook.f., Fl. Brit. Ind. 5: 171. 1886. Type: [Malaysia], Malacca, *Maingay 1269* (lectotype **K** [first-step], designated by Kostermans, 1970: 89; lectotype [second-step] **K** [K000797100] photo seen, designated by Ngernsaengsaruay *et al.*, 2005: 81; isolectotype **K** [K000797101] photo seen).

Notes.— Hooker (1886) cited "MALACCA, Maingay (Kew Distrib. 1269)" in the protologue. Kostermans (1970: 89) cited "Typus: *Maingay, Kew*  Distr. 1269 (K)" which is an inadvertent lectotypification under Art. 7.11 of the *Code*. There are two specimens at **K** but these were not distinguished into a lectotype and isolectotype so Kostermans (1970) can be taken as a first-step lectotypification. Later, Ngernsaengsaruay *et al.* (2005) overlooked the lectotypification by Kostermans (1970) and designated *Maingay 1269* (**K**) as lectotype. The specimen K000797100 bears the annotation "Lectotype of *Litsea castanea* Hook.f. selected by David Middleton in 2005". Therefore, the lectotypification by Ngernsaengsaruay *et al.* (2005) is accepted here as a second-step lectotypification under Art. 9.10 as David Middleton is one of the coauthors of the paper.

5. Litsea cubeba (Lour.) Pers., Syn. Pl. 2: 4. 1806. — Laurus cubeba Lour., Fl. Cochinch.: 252. 1790. Type: Vietnam, Cochinchina, Loureiro s.n. (lectotype BM [first-step], designated by Allen, 1938: 369; lectotype [second-step] BM [BM000793687] photo seen, designated by Singh, 2017: 1; isolectotype BM [BM000848503] photo seen).

Notes.— Loureiro (1790) cited "Habitat culta, nec rara in agris, & hortis Cochinchinae: puto, quod etiam in Chinâ" in the protologue. Allen (1938: 369) cited "FRENCH INDO-CHINA. TONKIN: *J. Loureiro* (type not seen, Brit. Mus.)" which is an inadvertent lectotypification under Art. 7.11 of the *Code*. There are two specimens at BM but these are not distinguished into a lectotype and isolectotype so Allen (1938) can be taken as a first-step lectotypification. Later, Singh (2017) overlooked the lectotypification by Allen (1938) and designated *Loureiro s.n.* (BM000793687) as lectotype. Therefore, the lectotypification by Singh (2017) is accepted here as second-step lectotypification under Art. 9.10.

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## A synopsis of Thai Piper (Piperaceae)

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#### ABSTRACT

All native and introduced Thai *Piper* are enumerated to include 46 species and two varieties. Typifications for accepted names and synonyms are made where necessary. Family and generic descriptions, based on Thai collections, are provided. A key to species and varieties and relevant synonymy are also presented. Additional morphological characters for *P. smitinandianum* are summarised. Data on the distribution, ecology, vernacular names, utilization and collections of each taxon in Thailand are presented in the standard Flora of Thailand format.

KEYWORDS: distribution, Flora of Thailand, key to species, tropical plants, taxonomy.

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#### **INTRODUCTION**

Piperaceae currently comprises five genera, namely Manekia Trel., Peperomia Ruiz & Pavon, Piper L., Verhuellia Miq. and Zippelia Blume (APG IV, 2016). Two other genera, Macropiper Miq. and Sarcorhachis Trel. have previously been recognized but are now reduced to the synonymies of Piper (Wanke et al., 2007) and Manekia (Bornstein, 1996; Arias et al., 2006) respectively. Manekia is a genus of climbing plants found in Central and South America. Peperomia, with over 1,600 species and Piper, with 1,050 species, are richly represented in tropical forests, especially in Asia and tropical America (Mabberley, 2008). Verhuellia is distributed in Cuba and Hispaniola (APG IV, 2016) while Zippelia is widely distributed in Southern China and Sout East Asia (Yongqian et al., 1999).

In general, Old World species of Piperaceae are dioecious or monoecious whereas New World species are hermaphroditic. In dioecious species, there is some variation in the size and shape of the leaves and inflorescences between male and female plants (Bornstein, 1985).

Members of *Piper* can be easily recognized on the basis of gross morphological characters. All the species are terrestrial and include woody climbers, perennial herbs, scandent shrubs and small, nonscandent shrubs. The nodes are always swollen. Climbing species ascend by means of climbing roots and the scandent shrubs have prop-roots arising from the basal part of the plant. The leaves are always simple and alternate. Many species are extremely polymorphic and have distinctive leaf shapes and sizes depending on whether the leaves are apically or basally positioned on the plant. The inflorescences are either catkins, spikes or spike-like umbels, and are single or fascicled, and compact with minute flowers. The flowers have a simple morphology, comprising a bract, stamens and/or ovary, and they lack a perianth. The infructescences are free or partly or fully connate and the fruits are drupaceous and sessile or stalked (Suwanphakdee, 2012).

Although habit and vegetative characters are highly variable, they are useful aids for identification when combined with other characters. Overall, the significant characters for identification are habit, and floral bract, infructescence and fruit morphologies,

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all of which are useful when combined with vegetative characters. Some characters are distinct for individual species identification, such as the spike-like umbels in *Piper umbellatum* L., the semi-circular, conchiform floral bracts in *P. baccatum* Blume or the 3-floral bracts in *P. ribesioides* Wall.

In Thailand Piper occurs primarily in a range of forest types at elevations ranging from sea level to 2,500 m. There are several taxonomic accounts for Piperaceae in Asia, covering Bangladesh, India, Myanmar, Nepal, Sri Lanka (Wallich, 1829–1849; Hooker, 1887; Long, 1984; Huber, 1987), China (Yongqian et al., 1999), Indochina and the Philippines (Candolle 1910, 1912 & 1923; Gardner (2006), Indonesia (Blume, 1826; Backer & Bakhuizen van Den Brink, 1963) and the Malay Peninsula (Ridley, 1924; Henderson, 1959). Thailand represents a gap in our knowledge and the present work aims to partially remedy this by providing a checklist of Piper for Thailand, including a key to species, together with distribution and utilization data which will be used for the forthcoming Flora of Thailand account.

## **MATERIAL & METHODS**

This study is based on field collections/observations and herbarium specimens. Voucher specimens are deposited in BK, BKF, KKU and QBG. Herbarium specimens and digital images were examined and consulted from the following herbaria (Thiers, 2020): A, AAU, B, BISH, BK, BKF, BM, BO, C, CMUB, DMSC, E, G, G-DC, GH, K, KKU, KEP, L, MEL, MO, NY, P, PSU, QBG, SING, TCD, U, US and WAG.

## PIPERACEAE

Giseke, Prael. Ord. Nat. Pl. 123. 1792 [Apr. 1792], nom. cons; Miq., Syst. Piperac. 1: 63. 1843; C.DC., Prodr. 16(1): 235. 1869; Hook.f., Fl. Brit. India 5: 78. 1887; C.DC. in Lecomte, Fl. Indo-Chine 1: 62. 1910; C.DC., J. Asiat. Soc. Beng. 75: 288. 1914; C.DC., Candollea 1: 65. 1923; Ridl., Fl. Malay Penins. 3: 25. 1924; Henderson, Malay. Wild Flowers Dicot. 6(3): 434. 1959; Backer & Bakh.f., Fl. Java 1: 167. 1963; Long in Grierson & Long, Fl. Bhutan 1(2): 342. 1984; Huber in Dassan., Fl. Ceyl. 6: 272.1987; Keng, Con. Fl. Sing. 1: 62.1990; Tebbs in Kubitzki, Fam. & Gen. Vas. Pl. 2: 516. 1993; Yongqian, Xia & Gilbert in Wu & Raven, Fl. China 4: 110. 1999.

Annual or perennial, aromatic, epiphytic, lithophytic or terrestial woody climbers, herbs or small shrubs/subshrubs; monoecious, dioecious or hermaphroditic. Stems  $\pm$  winged or not, variously glabrous glabrescent, puberulous, pilose, hirsute, velutinous or woolly; nodes swollen, with or without climbing roots or prop-roots; vascular bundles  $\pm$ scattered in transverse section in a monocotyledonous, atactostele-like manner. Leaves simple, variously alternate, opposite, spirally-arranged, decussate or in whorls of 3-7; stipule present,  $\pm$  adanate to petioles, or absent; petiole glabrous to glabrescent or pilose to hirsute, velutinous or pubescent; lamina  $\pm$  fleshy when fresh, chartaceous or subcoriaceous to coriaceous when dry, symmetric to asymmetric, variously orbicular, elliptic, elliptic-ovate, elliptic-oblong, ovate, deltoid, rhomboid or reniform, base variously auriculate, cuneate, rounded-cordate, rounded, acute, oblique to slightly oblique, truncate or overlapping, apex variously acute, aristate, acuminate, apiculate, caudate, obtuse, mucronate or cuspidate, emarginate or 2-cleft, surfaces glabrous to glabrescent, or variously puberulous, pilose, scabrous, hispid, hirsute, velutinous or seriaceous; venation palmate or pinnate. Inflorescences lateral or terminal, leaf-opposed or axillary, single or fascicled, comprising catkins, solitary spikes, spike-like umbels or panicles, erect to pendulous, curved or straight, cylindrical, yellowishgreen, green or white; rachis slightly to prominently thickened, glabrous or hairy, with few to many densely crowded flowers. Flowers minute, unisexual or bisexual, sessile or pedicellate, immersed, glabrous or pubescent; floral bracts subtending flower 1-6, variously rounded, orbicular, peltate, ovate, elliptic, oblong, spathulate, ovate-lanceolate or conchiform, glabrous or pubescent; sepals and petals absent. Stamens 2-12; filament short to very short, theca oblong or "D"-shaped; anthers 2-4-valved, basifixed, exserted or inserted at anthesis, dehiscence lateral or transverse. Ovary 1-locular; ovule 1, globose, elliptic,  $\pm$  rounded or triangular, style short to very short, stigma star-shaped, 1-7-lobed, filiform-like or brush-like, glabrous or hairy. Infructescences slightly to markedly pendulous or suberect to erect, cylindrical to ± rounded, glabrous or hairy; peduncle glabrous or hairy. Fruit drupaceous, glabrous or variously puberulous, pilose, velutinous, woolly or with glochidiate hairs (Piper and Zippelia) or a nutlet with ± sticky papillae (Peperomia), stipitate or sessile, free or  $\pm$  concrescent, densely or sparsely arranged

on the rachis, ripe green, dark green, yellow, orange, red, black or dark purple, floral bracts persistent, with or without persistent, spine-like style.

Three genera (*Peperomia*, *Piper* and *Zippelia*) in Thailand.

#### PIPER

L., Gen. Pl., 5: 18. 1754; Roxb., Fl. Ind. 1: 160. 1820; Blume, Verh. Batav. Gen. 11: 206. 1826; Roxb., Fl. Ind. 1: 166. 1832; Mig., Syst. Piperac. 1: 305. 1843; Miq., Ann. Bot. Mus. Lugd. Bat. 1: 136. 1863; C.DC., Prodr. 16(1): 240.1869; Benth. & Hook.f., Gen. Pl. 3: 129. 1880; Hook.f., Fl. Brit. India 5: 78. 1887; C.DC., Ann. Conserve. Jar. Gen. 2: 272. 1898; C.DC. in Lecomte, Fl. Indo-Chine 1: 74. 1910; Ridl., Fl. Malay Penins. 3: 27. 1924; Henderson, Malay. Wild Flowers Dicot. 4(3): 436. 1959; Backer & Bakh.f., Fl. Java 1: 173. 1963; Long, in Grierson & Long, Fl. Bhutan 1(2): 345. 1984; Huber in Dassan., Fl. Ceyl. 6: 274. 1987; Keng, Con. Fl. Sing. 1:62. 1990; Tebbs in Kubitzki, Fam. & Gen. Vas. Pl. 2: 518. 1993; Yongian et al. in Wu & Raven, Fl. China 4: 110. 1999.

Perennial, aromatic, woody climbers, erect herbs or small shrubs,.  $Stems \pm$  winged, glabrous or glabrescent or puberulous or pilose or hirsute, or velutinous or woolly; nodes swollen with or without climbing roots or prop roots. *Leaves* simple, alternate; stipule hood-like, lanceolate or oblong-lanceolate, caducous, glabrous, pilose or velutinous; petiole glabrous or glabrescent or pilose or hirsute or velutinous; lamina chartaceous or subcoriaceous or coriaceous, symmetric to asymmetric, variously elliptic, elliptic-ovate, elliptic-oblong, ovate or reniform, base variously auriculate, cuneate, roundedcordate, rounded, acute, oblique, truncate or overlapping, apex variously acute, aristate, acuminate, apiculate, caudate, obtuse, mucronate orcuspidate, upper lamina glabrous puberulous or pilose, lower lamina variously glabrous, glabrescent, puberulous, scabrous, pilose, hirsute or velutinous; venation palmate or pinnate. Inflorescences lateral or rarely terminal, leaf-opposed or axillary, single or fascicled, comprising catkins, solitary spikes or spike-like umbels (Piper umbellatum), erect, curved or slightly to distinctly pendulous, cylindrical, yellowish-green, green or white; rachis glabrous or hairy, with few to many densely crowded flowers. Flowers minute, mostly unisexual, dioecious, less often monoecious or bisexual, minute, dense or sparse on rachis; sepals & petals absent; floral bracts 1-3, higher or covered or lower than androecium or gynoecium, rounded or orbicular, peltate, ovate, elliptic, oblong, spathulate or semi-circular and resembling a bivalve shell, glabrous or hairy. Stamens 3-12; filaments very short, hardly visible; anthers 2-4-valved, exserted or inserted at anthesis, dehiscence lateral or transverse. Ovary elliptic,  $\pm$  rounded or triangular, style short or very short, stigma star-shaped, 3-7-lobed, filiform or brush-like, glabrous or hairy. Infructescences slightly to markedly pendulous or erect, cylindrical or  $\pm$ rounded, glabrous or hairy, peduncle glabrous or hairy. Fruit drupaceous, glabrous or variously puberulous, pilose, velutinous or woolly, stipitate or exstipitate, free or  $\pm$  concrescent, densely or sparsely arranged on the rachis, ripe green or yellow or orange or red or black or dark purple, with or without persistent, spine-like style.

Forty-six species and two varieties in Thailand.

Key to the species	
1. Inflorescence of spikes grouped in an apparently axillary umbel	44. P. umbellatum
1. Inflorescence a spike or catkin, leaf-opposed	
2. Flower subtended by a single floral bract	
3. Floral bract oblong during flowering and spathulate during fruiting	
4. Inflorescence a spike, polygamous; plant cultivated	25. P. nigrum
4. Inflorescence a catkin, not polygamous; plant not cultivated	
5. Small shrub or perennial erect herb; inflorescence and infructescence erect, or slightly pendulous w	when fruiting 15. P. kurzii
5. Woody climber; inflorescence and infructescence pendulous	
6. Fruit stalked	12. P. griffithii
6. Fruit sessile	
7. Leaf broadly cordate or ovate; infructescence 6-15 cm long; fruit ellipsoid, 2-3 mm broad, sp	barse on rachis
	31. P. porphyrophyllum
7. Leaf elliptic, ovate or elliptic-oblong; infructescence 12-21 cm long; fruit globose, 3-4mm br	road, densely arranged on
rachis	18. P. leptostachyum

3. Floral bract peltate, elliptic, elliptic-rounded, rounded or elliptic-oblong during flowering and fruiting

<ul> <li>8. Inflorescence and infructescence erect</li> <li>9. Fruit more or less concrescent</li> <li>10. Fruit fully concrescent</li> <li>11. Perenial herb and creeping; leaves chartaceous, dimorphic, veins 3 pairs, ripe fruit dark green</li> </ul>	or black; not cultivated
11. Woody climber; leaves subcoriaceous or coriaceous, monomorphic, veins 4–8 pairs; cultivated	20. P. longum 34. P. retrofractum
<ol> <li>Fruit partly concrescent</li> <li>Leaf subcoriaceous; or coriaceous; male inflorescence much longer than female; fruit 1–2 mm b</li> <li>Leaf chartaceous; male and female inflorescences subequal; fruit 2–3 mm broad</li> <li>Fruit free, stalked or sessile</li> </ol>	oroad 28. P. peepuloides 43. P. thomsonii
<ol> <li>Fruit sessile</li> <li>Woody climber, ripe fruit orange or red</li> <li>Small shrub or perennial erect herb</li> </ol>	42. P. sylvaticum
15. Fruit without persistent style 15. Fruit with persistent style looks like spine	38. P. sarmentosum
16. Plant with prop roots, leaves 16–27 by 7–16 cm, coriaceous, veins pinnate, 6–8 pairs 16. Plant without prop roots, leaves 9–13 by 6–10 cm, chartaceous, veins pinnate, 3–4 pairs	39. P. smitinandianum
<ul> <li>17. Plant glabrous, except rachis</li> <li>17. Plant woolly, velutinous or scabrous</li> <li>13. Fruit stalked</li> </ul>	29. P. penangense 37. P. rostratum
18. Woody climber; inflorescence 0.5–2.5 cm long	17. P. lanatum
<ul> <li>19. Small sinds of perchange receivers, innotescence 7 15 cm long</li> <li>19. Fruit longer than stalk</li> <li>19. Fruit shorter than stalk</li> </ul>	36. P. ridleyi 24. P. muricatum
<ol> <li>Small shrub or scandent shrub; inflorescence a spike; introduced</li> <li>Small shrub or scandent shrub; inflorescence a spike; introduced</li> </ol>	8. P. colubrinum
21. Inflorescence globose or subglobose, introduced 21. Inflorescence cylindrical, native	26. P. ornatum
<ul> <li>23. Small shrub or perennial erect herb</li> <li>24. Plant glabrous, puberulous, pilose, velutinous except terminal branches woolly; floral bra 9–25 cm long; infructescence 8–14 cm long; ripe fruit red or dark purple or black</li> <li>24a. Stems hairy; fruits fully concrescent, ripe fruit red</li> <li>5a. P. boehmeriifolium</li> <li>24b. Stems glabrous; fruits concrescent at the base or to the middle, ripe fruit dark purple or black</li> </ul>	act peltate; inflorescence 5. P. boehmeriifolium n var. boehmeriifolium lack
<ul> <li>24. Plant woolly, velutinous or pilose; floral bract rounded; inflorescence 1.5-4 cm long; infruc ripe fruit green</li> <li>23. Woody climber</li> </ul>	tescence 2.5–4 cm long; 45. P. viridescens
25. Fruit hairy 26. Floral bract margins ciliate; fruit apex conical	2. P. argyrites
<ul> <li>26. Floral bract margin glabrous; fruit apex not as above</li> <li>27. Leaf coriaceous; fruit apex acute</li> <li>27. Leaf subcoriaceous or chartaceous; fruit apex rounded</li> <li>25. Fauit observe or exercly write bairs or built apex rounded</li> </ul>	23. P. minutistigmum 4. P. betle
28. Leaf 22–27 by 14–18 cm; inflorescences and infructescences longer than 20 cm 28. Leaf less than 22–27 by 14–18 cm; inflorescence and infructescence shorter than 15 cm lo	22. P. majusculum
29. Fruit with persistent style looks like spine 29. Fruit without persistent style	11. P. durionoides
30. Plant glabrous or puberulous; fruit fully concrescent 30. Plant pilose or ramulose hairy; fruit partly concrescent	6. P. chantaranothaii
<ul> <li>31. Leaf chartaceous, pilose or velutinous with uniseriate hairs; floral bract hairy at b infructescence 5–8 cm long</li> <li>31. Leaf subcoriaceous or coriaceous, pilose or velutinous with ramulose hairs; floral infructescence 6, 13,5 cm long</li> </ul>	base and margin ciliate; 14. P. kongkandanum bract margin glabrous;
<ul> <li>22. Fruit free</li> <li>32. Fruit stalked</li> <li>33. Floral bract elliptic or elliptic-oblong, margin with long bairs: stamen transversely debised</li> </ul>	of 16 P lasticnicum
55. For the order on put of emptic-bolong, margin with long hans, stanten transversely defined	it 10.1. lacuspiculi

33. Floral bract elliptic-rounded or rounded, margin ciliate; stamen laterally dehiscent

34. Leaf palmately veined, coriaceous and thick; inflorescence 2–3 cm long; infructescence 3–4 cm long **9. P. crassipes** 34. Leaf pinnately veined, chartaceous and thin; inflorescence 5–12 cm long; infructescence 6–16 cm long

30. P. polycarpa

32. Fruit sessile	
35. Fruit 2–5 mm diam.	
36. Stem and petioles winged; fruit with persistent, spine-like style 32. I	P. quinqueangulatum
36. Stem and petioles unwinged; fruit not above	
37. Floral bract margin ciliate	
38. Leaf glabrous, puberulous and glabrescent; fruit globose or subglobose, 3-4 mm broad, r	ipe orange or red
	13. P. khaoyaiense
38. Leaf pilose or velutinous; fruit ellipsoid, 2–3 mm broad, ripe black or dark purple	1. P. arcuatum
37. Floral bract margin glabrous	
39. Leaf margin ciliate; fruit apex emarginate	41. P. sulcatum
39. Leaf margin glabrous; fruit apex acute, subacute or rounded	
40. Infructescence 2–5 cm long	
41. Plant glabrous; fruit 4–5 by 3–4 mm	19. P. lonchites
41. Plant velutinous or puberulous; fruit 2-3 by 1-2 mm	7. P. chiangdaoense
40. Infructescence 6–25 cm long	
42. Leaf 11-25 by 4-12 cm,glabrescent or glabrous; peduncle puberulous; fruit ±globos	e, ripe dark orange or
red; rugulose when dry	46. P. wallichii
42. Leaf 5-16 by 3-8 cm, puberulous or pilose; peduncle glabrous; fruit trigonoid or ellip	osoid, ripenning dark
purple or black; granuloid when dry	40. P. suipigua
35. Fruit 0.5–1.5 mm diam.	
43. Shoot, stipule and petiole puberulous, pilose or hirsute; venation palmate	21. P. macropiper
43. Shoot, stipule and petiole glabrous; vein pinnate	
44. Leaf subcoriaceous or coriaceous; infructescence 5-12 cm long; fruit ellipsoid-subglobose	10. P. doiphukaense
44. Leaf chartaceous; infructescence 8-16 cm long; fruit globose	27. P. pedicellatum
Flower subtended by 2 or 3 floral bracts	
5. Rachis glabrous; floral bracts 2, conchiform; stamens 8-12; fruit sessile	3. P. baccatum
5. Rachis hairy; floral bracts 3, ovate; stamens 3; fruit with stalk	35. P. ribesioides

1. Piper arcuatum Blume, Verh. Batav. Gen. 11: 180. 1826; Backer & Bakh.f., Fl. Java 1: 172. 1963; Suwanphakdee *et al.*, Kew Bull. 73, 33: 1. 2018. Type: Indonesia, Java, *Blume s.n.* (lectotype L [L1535955!], designated by Suwanphakdee *et al.*, 2018).

2.

— *P. zollingerianum* C.DC., Prodr. 16(1): 351. 1869. Type: Indonesia, Java, *Zollinger 1402* (lectotype **G-DC** [G00206449!], designated by Suwanphakdee *et al.*, 2018).

*— P. melanocarpum* Ridl., J. Malayan Branch Roy. Asiat. Soc. 1: 88. 1923. Type: Indonesia, Sumatra, 8 Feb. 1921, *Ridley s.n.* (holotype **K** [K000820052!]).

Thailand.—PENINSULAR: Nakhon Si Thammarat [Khao Luang NP, 2 Mar. 1962, Suvanakoses 1827 (**BKF**); 23 May 1968, van Beusekom & Phengkhlai 975 (**L**); 10 Mar. 1995, Thavorn 657 (**BKF**); 20 Mar. 2008, Suwanphakdee 29 (**BK**, **BKF**, **KKU**); 7 May 2004, Suwanphakdee 135 (**BK**, **BKF**, **KKU**); 18 Mar. 2008, Suwanphakdee 223 (**BK**, **BKF**, **KKU**); 20 Mar. 2009, Suwanphakdee 228 (**BK**, **BKF**, **KKU**); 1 Apr. 2009, Suwanphakdee 269 (**BK**, **BKF**, **KKU**); 1 Apr. 2009, Suwanphakdee 269 (**BK**, **BKF**, **KKU**); 1 Apr. 2009, Suwanphakdee 269 (**BK**, **BKF**, **KKU**); 1 Apr. 2009, Suwanphakdee 231 (**BK**, **BKF**, **KKU**); 30 (**BK**, **BKF**, **KKU**); Suwanphakdee 231 (**BK**, **BKF**, **KKU**)]; Yala [Hala Bala WS, 7 Feb. 1997, Puudjaa 324 (**BKF**)]. Distribution.— India, Sri Lanka, Malaysia. Indonesia (Java, Sumatra).

Ecology.— Uncommon in the wild, occurring near mountain summits, along streams or near waterfalls in evergreen forest; flowering and fruiting in March.

Vernacular.— Phrik khao (พริกเขา)(General).

Notes.— *Piper arcuatum* is native to southern Thailand whereas *P. nigrum* is widely cultivated throughout the country. The two species are superficially similar but *P. acruatum* can be easily recognized by its pilose or velutinous indumentum, the waviness of its leaves when fresh and their aristate apex, and inflorescences that are erect to slightly pendulous when young, becoming markedly pendulous when mature and in fruit. Moreover, the female inflorescence is longer, the floral bract is rounded and the fruits are ellipsoid and smaller (Fig. 1A).

2. Piper argyrites Ridl. ex C.DC., Rec. Bot. Surv. India 6: 25. 1912; Ridl., Fl. Malay Penins. 3: 40. 1924; Suwanphakdee & Chantaranothai, Blumea 56: 239. 2011; Suwanphakdee *et al.*, Nordic J. Bot. 34: 605. 2016. Type: Malaysia, Selangor, Gua Batu Cave, *Ridley 8176* (lectotype **SING!**, designated by Suwanphakdee & Chantaranothai, 2011; isolectotypes **G-DC** [G00219986!], **K** [K000794914!]).

— *P. nigrantherum* C.DC., Rec. Bot. Surv. India 6: 20. 1912. Type: Singapore, cultivated in Singapore Botanic Garden, 27 Dec. 1920, *Ridley s.n.* (holotype **G-DC** [G00320818!]), *Ridley s.n.* 27 Dec. 1920 (epitype **K** [K000794917!], designated by Suwanphakdee *et al.*, 2016; isoepitypes **BM** [BM000949837!], **K** (2 sheets)[K000794918!, K000794919!]).

— *P. maculaphyllum* A.Chaveer. & R.Sudmoon, Acta Phytotax. Geobot. 59: 120. Type: Thailand, Phuket, Khao Pra Thaeo WS, *Chaveerach 126* (holotype **BK**?; isotype **BKF**?).

Thailand.— SOUTH-WESTERN: Chon Buri [Sriracha, 5 Apr. 1920, Kerr 4157 (**BK**, **BM**); 8 July 1930, Kerr 19466 (**BK**); Ban Dan, 13 May 1923, Marcan 1384 (**BM**); Ban Bung, 18 July 1966, Phengklai 1272 (**BKF**, **K**)]; Rayong [Ban Kai,11 Aug. 1983, Paisooksantivatana 1248-83 (**BK**)]; Chanthaburi [Khao Soi Dao WS, 13 May 1974, Geesink et al. 6715 (**BKF**, **K**, **L**)]; Trat [Ko Chang, Klong Plu Waterfall, 14 Jan. 2005, Suwanphakdee 167 (**BK**, **BKF**, **KKU**)]; PENINSULAR: Ranong [Punyaban Waterfall, 19 June 2010, Suwanphakdee 317 (**BK**, **BKF**)]; Surat Thani [Tai Rom Yen NP, 27 Oct. 2008, Suwanphakdee 245 (**BK**, **BKF**, **KKU**); Suwanphakdee 246 (**BK**, **BKF**, **KKU**); Suwanphakdee 247 (**BK**, **BKF**, **KKU**)].

Distribution.—Malaysia, Singapore, Indonesia.

Ecology.— Along streams or near waterfalls in lowland or hill evergreen forest; flowering and fruiting October–December.

Vernacular.— Khan (ค้าน)(Surat Thani); phlu ngoen (พลูเงิน)(General).

Uses.— Has medicinal use and the plants and leaves are attractive enough to be used as ornamentals.

Notes.— Young leaves of *Piper argyrites* have white, silver, pink and purple spots or bands but become plain green when mature. The infructescence is similar to *P. betle* but differs by having fruits that are <sup>3</sup>/<sub>4</sub> to fully connate. The fruit apex has a persistent, conical style. The male and female inflorescences are shorter than in *P. betle*. The floral bract margins are hairy and 2–3 stamens are in dense clusters whereas they form a row in *P. betle* (Fig. 1B). **3. Piper baccatum** Blume, Verh. Batav. Gen. 11: 172. 1826; C.DC., Prodr. 16(1): 241. 1869; Backer & Bakh.f., Fl. Java 1: 169. 1963. Gardner, Blumea 51(3): 579. 2006; Suwanphakdee *et al.*, Nordic J. Bot. 34: 607. 2016. *Muldera baccata* (Blume) Miq., Syst. Piperac. 1: 341. 1843. Type: Indonesia, Java, *Blume 624* (lectotype L [L1535860!], designated by Suwanphakdee *et al.*, 2016; isolectotypes G-DC [G00203234!], K [K000794885!], U [U1478540!])

*— P. recurvum* Blume, Verh. Batav. Gen. 11: 176. 1826; C.DC., Prodr. 16(1): 241. 1869; Backer & Bakh.f., Fl. Java 1: 169. 1963. Type: Indonesia, Java, *Blume s.n.* (lectotype **L** [L1547132!], designated by Suwanphakdee *et al.*, 2016).*— Muldera recurva* (Blume) Miq., Syst. Piperac. 1: 342. 1843.

— *P. firmum* (Miq.) C.DC., Prodr. 16(1): 242. 1869; Ridl., Fl. Malay Penins. 3: 31. 1924.— *Muldera recurva firma* Miq., Ann. Mus. Bot. Lugduno-Batavi 1: 140. 1863. Type: Indonesia, Sumatra, *Korthals s.n.* (lectotype **L** [L1545934!] designated by Suwanphakdee *et al.*, 2016; isolectotype **G-DC** [G00314043!], **K** [K000575308!], **L** [L1545936!]).

*— P. ceylanicum* C.DC., Prodr. 16(1): 242. 1869. Types: Sri Lanka, *Thwaites* 2175 (lectotype **G** [G00203250!], designated by Suwanphakdee *et al.*, 2016; isolectotypes **K** [K000794403!], **P** [P02030045!], **P** [P02030046!], **TCD** n.v. [TCD0018339]).

*— P. pachyphyllum* Hook.f., Fl. Brit. India 5: 80. 1886. 1924; Ridl., Fl. Malay Penins. 3: 31. 1924. Type: Malaysia, *Griffith* 4427 (holotype **K** [K000575309!]).

*— P. flavimarginatum* C.DC., Rec. Bot. Surv. Ind. 6: 26. 1912; Ridl., Fl. Malay Penins. 3: 31. 1924. Type: Singapore, Bukit Timah, *Ridley 3772* (holotype **SING!**).

*— P. protrusum* Chaveer. & Tanee, J. Syst. & Evol. 49(5): 468. 2011. Type: Thailand, Phangnga, Sriphangnga NP, *Chaveerach 615* (holotype **BK**?).

Thailand.— SOUTH-EASTERN: Trat [Ko Chang, 14 Jan. 2005, Suwanphakdee 169 (**BK**, **BKF**, **KKU**)]; PENINSULAR: Ranong [Kraburi, 25 Dec. 1928, Kerr 16348 (**BK**, **BM**, **L**)]; Surat Thani [Ko Samui, 9 Apr. 1927, Kerr 12569 (**BK**, **BM**); Ko Phangan, 9 Nov. 1927, Put 1224 (**BK**, **BM**)]; Phangnga [Sri Phangnga NP, 16 Mar. 2004, Suwanphakdee 108 (**BK**, **BKF**, **KKU**); 26 Jan. 2007, Suwanphakdee 211 (**BK**, **BKF**, **KKU**)]; Nakhon Si Thammarat [Ka Rome Waterfall, 11 Nov. 2009, *Suwanphakdee 285* (**KKU**)].

Distribution.— India, Sri Lanka, Malaysia, Singapore, Indonesia, the Philippines.

Ecology.— In evergreen forest, near streams or waterfalls; flowering and fruiting in January.

Vernacular.— Thao khan (เถาค่าน)(Surat Thani); yan phrik nok (ย่านพริกนก)(Trang).

Notes.— The leaves of *Piper baccatum* are highly succulent, shiny green when fresh and coriaceous when dry; fresh petioles have red spots or bands. Based on leaf and fruit characters, this species is similar to *P. ribesioides* but has a glabrous rachis. The semi-circular floral bracts are conchiform in appearance. The stamens are positioned between the floral bracts and the fruits are sessile or shortly pedunculate (Fig. 1C).

**4. Piper betle** L., Sp. Pl. 1: 28. 1753; Hook.f., Fl. Brit. India 5: 85. 1887; Trimen, Handb. Fl. Ceylon 3: 425. 1895; C.DC. in Lecomte, Fl. Indo-Chine 1: 74. 1910; Ridl., Fl. Malay Penins. 3: 40. 1924; Backer & Bakh.f., Fl. Java 1: 170. 1963; Huber in Dassan., Fl. Ceyl. 6: 287. 1987; Yongqian, Xia & Gilbert in Wu & Raven, Fl. China 4: 120. 1999; Gardner, Blumea 51(3): 579. 2006; Suwanphakdee & Chantaranothai, Blumea 56: 239. 2011. Type: *Herb. Hermann 3: 32, No. 27* (lectotype **BM** [BM000621919!], first step designated by Huber, 1987, second step designated here).

— *P. siriboa* L., Sp. Pl.: 29. 1753. Type: *Herb. Hermann 3: 17, No. 29* (lectotype **BM**[BM000621853!], designated here).

Chavica auriculata Miq., Syst. Piperac. 1: 26.
1843. Type: Bangladesh, Sylhet, Wallich s.n.
[Numer. List 6652B] (lectotype U [U1476696!], designated here; isolectotypes K [K000794401!],
K-W (2 sheets)[K001124420!, K001124421!], U [U1476698!]).

- *C. betle* Miq., Syst. Piperac. 1: 228. 1843. Type: India orientali, *Willdenow* 686 (holotype **B** [B-W00686-000!]).

-C. siriboa Miq., Syst. Piperac. 1: 224. 1843. Piper betle var. siriboa (Miq.) C.DC., Prodr. 16(1): 359. 1869. Type: Indonesia, Java, Blume s.n. (lectotype U [U1476447!]; designated here; isolectotypes **BO!**, **G-DC** [G00206829!]). — *C. densa* Miq., Syst. Piperac. 1: 252. 1843.— *Piper betle* var. *densum* (Miq.) C.DC., Prodr. 16(1): 360. 1869. Type: Indonesia, Java, *Miquel s.n.* (lectotype **U** [U1476284!]; designated here; isolectotypes **K** (2 sheets)[K000794877!, K000794878!]).

*— Piper. philippinense* C.DC., Prodr. 16(1): 353. 1869. Type: the Philippines, *Cuming 485* (lectotype **G-DC** [G00328499!]; designated here; isolectotypes **MEL** [MEL2392163!], **P** [P01952148!]).

— *P. blancoi* Merr., Philip. J. Sci. 1: 40. 1906. Type: the Philippines, *Whitford 188* (holotype **G-DC** [G00328531!]).

— *P. rubroglandulosum* A.Chaveerach & P.Mokkamul, Act. Phytotax.Geobot. 59(2): 142. 2008. Type: Thailand, Surat Thani, Khlong Phanom NP, *Chaveerach 314* (holotype **BK**?; isotype: **BKF**?).

Thailand (only wild 'form' specimens included).-- SOUTH-EASTERN: Trat [Khao Saming, 14 Jan. 2003, Suwanphakdee 170 (BK, BKF, KKU)]; PENINSULAR: Chumphon [Khao Talu, 3 Feb. 1927, Kerr 11806 (BK, BM, L); Thung Tako, 20 Sept. 2002, Suwanphakdee 13 (BK, DMSC); 21 Feb. 2007, Suwanphakdee 197 (BKF); Lang Suan, 4 Mar. 1927, *Kerr* 12207 (**BK**, **BM**); Bang Son, *Put* 1034 (**BK**)]; Nakhon Si Thammarat [Khao Luang NP, 7 May 2004, Suwanphakdee 132 (BK, BKF, KKU); 15 July 2003, Suwanphakdee 49 (DMSC); 10 Nov. 2003, Suwanphakdee 68 (DMSC); 24 Mar. 2008, Suwanphakdee 233 (BK, BKF); 2 Apr. 2010, Suwanphakdee 268 (BK, BKF, KKU)]; Phangnga [Sri Phangnga NP, 28 Jan. 2007, Suwanphakdee 218 (BK, BKF)]; Krabi [Muang, 19 Oct. 2006, Suwanphakdee 184 (BK, BKF)]; Trang [Khao Chong, 15] Aug. 1964, Suvanakoses 2173 (BKF); 12 Mar. 1974, *Larsen & Larsen 33211* (AAU, BKF, K, L); 4 May 2003, Suwanphakdee 44 (BKF, KKU); 16 Mar. 2004, Suwanphakdee 103 (BKF, DMSC); 20 Apr. 2010, Suwanphakdee 313 (BK, BKF, KKU); Suwanphakdee 314 (BK, BKF, KKU)]; Satun [Kuan Po, 31 Dec. 1927, Kerr 13793 (BK, BM, L)].

Distribution.— India, Sri Lanka, China, Myanmar, Laos, Vietnam, Cambodia, Malaysia, Indonesia, the Philippines.

Vernacular.— Phlu (พลู)(General), phlu thean (Peninsular)(พลูเถื่อน).

Ecology.— In open areas or near streams in evergreen forest, orchards or disturbed areas; flowering March–June, fruiting May–July. Uses.— The leaves are chewed with a little lime and catechu (*Areca catechu* L.; Arecaceae) nut. It is used medicinally for treating urticaria and used culturally during religous ceremonies.

Notes.— Piper betle is common species in Southeast Asia. Huber (1987) referred to the nomenclatural types as Herb. Hermann 3: 32 and 4: 9 in BM. Although there are specimens in two volumes of the Hermann Herbarium, they all seem to have been part of a single gathering (Jarvis, 2007) and are accepted as a valid first-step lectotypification. In our second-step lectotypification we have chosen **BM** [BM000621919] in 3: 32 because it is well preserved and has good inflorescences. Piper siriboa was wrongly typified by Huber (1987) with a Rumphius plate that is not part of Linneaus' protologue and therefore not original material (Jarvis, 2007). We have lectotypified using original material in the Hermann Herbarium. Miquel (1843) described Chavica auriculata based on Wallich s.n [Numer. List 6652B] in U [U1476696 (female), U1476698 (male)]. We found other spcimens under this number in K [K000794401] and K-W [K001124420 & K001124421]). We selected the female material in U [U1476696] because it matched with original protologue and it has the inflorescence and infructescence which it informative for species identification. Miquel (1843) also described Chavica siriboa based on several syntype collections, including Blume s.n. (BO, G-DC [G00206829], L [U1476447]), Wallich s.n. (Numer. List 6659C)(K-W [K001124437]) and Cuming 485 (G-DC [G00328499]). Later, Candolle (1869) treated this species as a variety and transferred it to Piper. We selected the Blume collection in U [U1476447] as a lectotype because it well preserved and it is likely to be original material as Miquel worked in Utrecht (U). Miquel (1843) described Chavica densa based on Miquel s.n. (K [K000794877! & K000794878], U [U1476284]), Zollinger 724 (G-DC [G00206825]), Zollinger 927 (G-DC [G00206822!]) and Zollinger 974 (G-DC [G00206840!]). Later, Candolle (1869) treated it as a variety and transferred it to Piper. We selected the collection at U [U1476284] as the lectotype because it is a good candidate as original material and informative for species identification.

*Piper betle* is very common and widespread in Asia. Based on field and herbarium specimen collections in Thailand, this plant has two 'forms', namely wild and cultivated. They are minor differences between the two, such as larger and thicker leaves in female plants of cultivated form. The wild 'form' of both female and male plants are found only in south-eastern and southern parts of the country. The cultivated 'form' is common and cultivated throughout the country.

The male inflorescences are longer than female ones. The floral bract is rounded with a glabrous margin and the bracts are spirally arranged in rows alternating with a row of stamens. The fruits are fully concrescent and velutinous or woolly (Fig. 1D).

5. Piper boehmeriifolium (Miq.) Wall. ex C.DC., Prodr. 16(1): 348. 1869, as 'boehmeriaefolium'; Hook.f., Fl. Brit. India 5: 85. 1887; Ridl., Fl. Malay Penins. 3: 41. 1924; Gilbert & Xia, Novon 9(2): 191. 1999; Yonqian *et al.* in Wu & Raven, Fl. China 4: 123. 1999.— *Chavica boehmeriifolia* Miq., Syst. Piperac. 1: 265. 1843, as 'boehmeriaefolia'. Type: Bangladesh, Sylhet, Wallich s.n. [Numer. List 6654A] (lectotype U [U1476700!]; designated here; isolectotype BM [BM000950692!], E [E00313765!], G-DC [G00206475!], K [K000575313!], K-W [K001124423!], MO [MO204007!]).

— *P. boehmeriaefolium* var. *tonkiensis* A.DC. in Lecomte, Fl. Indo-Chine 5: 81. 1910. Type: Vietnam, Dans les bois, Vallee de Lankok (Mont- Bavi), *Balansa 3634* (holotype **P** [P00328761!]).

- *P. spirei* C.DC. in Lecomte, Fl. Indo-Chine 5: 87. 1910. Type: Laos, Phon thane, *Spire 258* (lectotype **P** [P01980763!], designated here; isolectotypes **G-DC** [G00322116!], **P** [P01980762!]).

— *P. spirei* var. *pilosius* C.DC. in Lecomte, Fl. Indo-Chine 5: 88. 1910. Type: Cambodia, Frequens in montibus krewahn, *Pierre 4817* (lectotype **P** [P01980769!], designated here; isolectotypes **P** (2 sheets)[P01980768!, P01980764!]).

*— P. terminaliflorum* Y.C.Tseng, Acta Phytotax. Sin. 17: 30. 1979. Type: China, Yunnan, Fengqing, *Yu 16454* (holotype **PE**; isotype **A** [A00005913!]).

#### a. var. boehmeriifolium

Thailand.— NORTHERN: Mae Hong Son [Huai Hi, 4 Feb. 1999, *Triboun s.n.*(**BK**)]; Chiang Mai [Doi Ang Khang, 8 May 1974, *Sadakorn 420* (**BK**); Doi Chang Kien, 5 Apr. 1975, *Sutheesorn 3263* (**BK**); Pang Bo-Tin Tok, 9 Mar. 1965, *Smitinand*  8674 (BK, BKF); Doi Suthep NP, 17 Feb. 1926, Collins 1208 (K), 17 May 1958, Sørensen et al. 3499 (**BKF**); 3 Feb. 1959, Sørensen et al. 6840 (**BKF**); 22 Feb. 1987, Niyomdham & Kubat 1350 (BKF, K, L); 15 Aug. 1987, Maxwell 87-824 (BKF, L); 13 Mar. 2000; Doi Inthanon NP, 11 Dec. 1933, Lakshnakara 1490 (BK); 22 Jan. 1969, Nooteboom et al. 823 (BKF); 20 Oct. 1990, Phengklai 7645 (BKF); 4 Feb. 1998, Konta & Phengklai 3952 (BKF); 18 Oct. 2003, Suwanphakdee 64 (KKU); Doi Chang, 23 Oct. 1979, Shimizu et al. T-20530 (BKF, L); Doi Chiang Dao WS, 5 June 1921, Kerr 5616 (BK, BM, K, L); 17 Feb. 1958, Smitinand 4231 (BKF); 6 Dec. 1959, Smitinand & Abbe 6228 (BKF, L); 29 Nov. 1961, Bunchuai 28 (BKF); 3 Jan. 1962, Bunchuai 1287 (BKF); 4 Jan. 1966, Tagawa et al. 4179 (BKF); 13 Sept. 1967, Tagawaet al. T-9892 (BKF, L); 15 Sept. 1967, Shimizu et al. T-10221 (BKF, L); 17 Oct. 1979, Shimizu et al. T-20933 (BKF); 9 Feb. 1983, Koyama et al. T-33241 (BKF, L), 22 Mar. 1989, Santisuk 6951 (BKF); 15 Jan. 1989, Maxwell 89-45 (BKF); 9 Nov. 1995, Maxwell 95-1133 (BKF); 29 Jan. 1996, Maxwell 96-133 (**BKF**); 15 Jan. 1998, Maxwell 89-43 (**BKF**, L); 6 Dec. 2002, Chamchamroon et al. 1756 (BKF); 20 Dec. 2003, Suwanphakdee 77 (DMSC); 10 Nov. 2009, Suwanphakdee 249 (BK, BKF, KKU); 4 Dec. 2002, Chamchamroon et al. 1708 (BKF); Mae Rim, 22 Dec. 2003, Suwanphakdee 80 (BK); 26 Jan. 2008, Jatupol 08-206 (**QBG**); Mae Wang, 19 Mar. 2004, Maxwell 04-166 (BKF); 10 Mar. 2005, Maxwell 05-212 (BKF)]; Chiang Rai [Doi Tung, 23 Oct. 1995, Pooma 1193 (BKF); Chiang Khong, Tha Torn, 2 Apr. 1932, Kerr 20848 (BK)]; Nan [Doi Phu Kha NP, 2 July 2004, Suwanphakdee 150 (KKU); 11 May 2006, Srisanga et al. 2813 (QBG)]; Lampang [Doi Luang NP, 26 Mar. 1997, Maxwell 97-236 (BKF); Chae Son NP, 1 Mar. 2003, Suwanphakdee 25 (BK); Doi Khun Tan NP, 20 Oct. 2003, Suwanphakdee 67 (KKU); 12 Feb. 2006, Suwanphakdee 177 (BK, BKF, KKU)]; Phrae [Mae Krai, 9 Jan. 1972, van Beusekom et al. 4767 (BKF, L); 23 Mar. 1961, Chantanamuk 38 (BKF); Mae Kra Ting, 11 Oct. 1995, Williams 17133 (BKF)]; Uttaradit [Phu Soi Dao NP, 12 Mar. 2003, Suwanphakdee 42 (BKF); 12 Feb. 2004, Suwanphakdee 92 (DMSC)]; Sukhothai [Ramkamhaeng NP, 29 Jan. 1995, *Maxwell* 95-49 (**BKF**)]; NORTH-EASTERN: Loei [Phu Ruea NP, 17 Sept. 1997, Pooma & Maxwell 1564 (BKF); Phu Suan Sai NP, 10 Feb. 2004, Suwanphakdee 89 (**BKF**); 12 Feb. 2004, Pornpongrungreung 439 (**KKU**); Phu Luang WS, 4 Dec. 1965, Tagawa et al. 1194 (**BKF**)]; SOUTH-WESTERN: Kanchanaburi [Sangkhlaburi, 29 Mar. 1968, van Beusekom & Phengklai 183 (**BKF**)]; SOUTH-EASTERN: Chanthaburi [Khao Soi Dao WS, 19 Dec. 1924, Kerr 9712 (**BK, BM, L**); 26 Nov. 1979, Shimizu 23715 (**BKF**)]; PENINSULAR: Ranong [Khao Pawta Chongdong, 28 Jan. 1929, Kerr 16776 (**BK, K**); Khao Pawta Luang Kaew, 30 Jan. 1929, Kerr 16897 (**BK, BM, K, L**)]; Phangnga [Tap Put, 5 Mar. 1930, Kerr 18434 (**BK, BM, K, L**)].

Distribution.— India, Sri Lanka, Bangladesh, China, Myanmar, Laos, Vietnam, Cambodia, Malaysia, Indonesia, the Philippines.

Ecology.— In lowland or hill evergreen forest, near streams or waterfalls; flowering January– March, fruiting October.

Vernacular.— Phrik kaeng (พริกแกง)(Karen-Chiangdao, Chiang Mai).

Uses.— The young leaves are locally used as a vegetable.

Notes.— Miquel (1843) published *Chavica* boehmeriifolia (as 'boehmeriaefolia') based on Wallich s.n. [Numer. List 6654A], a collection from Sylhet, Bangladesh. The specimens were deposited in U [U1476700] and there are other collections in **BM** [**BM**000950692], **E** [E00313765], **G-DC** [G00206475], **K** [K000575313], **K-W** [K001124423] and **MO** [MO204007]. We chose the collection from U [U1476700] as the lectotype because this is the only collection deposited in U and and it matches with original description in protologue. Later, Candolle (1869) transferred *C. boehmeriifolia* to *Piper boehmeriifolium* (Miq.) C.DC. (as 'boehmeriaefolium').

Piper spirei and P. spirei var. pilosius were published by Candolle (1910). The type specimens of P. spirei were collected from Phon Thane, Laos PDR and the collections of Spire 258 were kept in G and P. We chose the collection from P [P01980763] as the lectotype because it is better preserved than the one in G [G00322116] which consists of a leaf, fragmented infructescence and line drawings. The type specimen of P. spirei var. pilosius is Pierre 4817 which was collected from the Cardamom Mountains (Krâvanh Mountains), Cambodia. We found ten collections in P and chose P01980764 as the lectotype because this collection has infructescences which make it suitable for species identification. The stem of *P. boehmeriifolium* var. *boehmeriifolium* is covered with either dense or sparse hairs. The female inflorescence is shorter than the male, has fragrant flowers, and the stamens or ovaries are covered by floral bracts. The fruits are fleshy and turn red on ripe (Fig. 1E).

**b.** var. **glabricaule** (C.DC.) M.G.Gilbert & N.H.Xia, Novon 9: 191. 1999; Yongqian, Xia & Gilbert in Wu & Raven, Fl. China 4: 123. 1999.—*P. glabricaule* C.DC., Notizbl. Bot. Gart. Berlin-Dahlem 6: 477. 1917. Type: China, Yunnan, Mengzi Xian, Mengzi, *Henry* 9482A (holotype **B** [B100294885!]; isotypes **A** [A00005904!], **G-DC** [G00314823!], **K** [K000575306!], S [SG4897!], **US** [US00106402!]).

Thailand.-NORTHERN: Mae Hong Son [Mae Sariang, 12 July 1968, Larsen et al. 2392 (BKF)]; Chiang Mai [Doi Suthep NP, 10 July 1910, Kerr 1260 (BM, K, TCD); 22 Feb. 1914, Kerr 3131 (BM, K); 22 Dec. 1920, Kerr 4678 (BK, BM, K); 22 Apr. 1966, Chermsirivatthana 589 (BK); 26 Apr. 1966, Sukkri 73 (BKF); Doi Chong, 18 Feb. 1968, Hansen & Smitinand 12646 (BKF); Doi Inthanon NP, 29 Apr. 1921, Kerr 5294 (BK, BM, L); 7 Apr. 1925, Vanadorn 1364 (BK, BKF, K); 11 Dec. 1933, Lakshnakara 1490 (BK); 25 Dec. 1934, Garrett 919 (BKF, BM); 14 Apr. 1960, Smitinand & Alsterlund 6638 (BKF); 22 Mar. 1967, Smitinand 10291 (BKF, K, L); 7 Jan. 1983, Koyama et al. T-32039 (BKF); 19 Dec. 1983, Fukuoka & Ito T-35301 (BKF); 28 July 1988, Phengklai 7112 (BKF); 4 Feb. 1998, Phengklai et al. 10850 (BKF); 21 Dec. 1998, Konta et al. T-4994 (**BKF**); 14 July 1990, Phengklai 7502 (**BKF**); 16 Oct. 2003, Suwanphakdee 62 (**BK**); Doi Ang Khang, 8 Dec. 1974, Sadakorn 420 (BK); 18 Oct. 2003, Suwanphakdee 64 (BKF); Doi Chiang Dao WS, 17 Mar. 1950, Garrett 1284 (K, L); 29 Dec. 1953, Garrett 1424 (K, L); 26 Feb. 1958, Bunchuai 747 (BKF); 2 Dec. 1961, Smitinand 7261 (BKF); 29 Nov. 1961, Bunchuai 28 (BKF), 21 Dec. 1961, Bunchuai 85 (BKF), 5 Nov. 1963, Adisai 597 (**BK**); 15 Sept. 1967, Shimizu & Hutoh T-1022 (BKF); 18 Feb. 1968, Hansen & Smitinand 12646 (**BKF**, L); 16 July 1968, Larsen et al. 2542 (AAU, BKF, L); 3 June 1973, Geesink et al. 5670 (BKF, L), 4 Jan. 1979, Bjørland & Schumacher 573 (BKF); 2 Mar. 1979, Koyamaet al. 15597 (BKF); 29 Jan. 1996, Maxwell 96-133 (BKF); 4 Feb. 1998, Phengklai 10850 (BKF); 5 Apr. 2014, Prommanut & Inthachub 460 (BK)]; Chiang Rai [Mae Fang, 2 Mar. 1928, Winit 1871 (BK, BM, L); 22 June 2002, Chamchamroon et al. 1609 (BKF); Doi Chong, 18 Feb. 1968, Hansen & Smitinand 12646 (BKF); Doi Tung, 23 Oct. 1995, Pooma 1193 (BKF); Mae Chan, 25 Jan. 1970, Sutheesorn 1503 (BK); Khun Korn Waterfall, 15 Feb. 2004, Suwanphakdee 99 (KKU)]; Nan [Doi Phu Kha NP, 3 Dec. 1999, Srisanga 1204 (QBG); 14 Feb. 2004, Suwanphakdee 95 (BKF); 2 July 2004, Suwanphakdee 150 (DMSC); 12 Feb. 2006, Suwanphakdee 176 (BK)]; Tak [Mae Sot, Huai Hoi Creek, 26 Jan. 1985, Paisooksantivatana 1531-85 (**BK**); Thi Lo Su Waterfall, 16 Jan. 2004, Suwanphakdee 82 (KKU); 11 Feb. 2006, Suwanphakdee 176 (BK, BKF, KKU)]; Sukhothai [Ramkamhaeng NP, 29 Jan 1995, Maxwell 95-49 (BKF); 18 Jan. 2004, Suwanphakdee 83 (DMSC)]; NORTH-EASTERN: Loei [Phu Luang WS, 4 Dec. 1965, Tagawa et al. T-1188 (**BKF**); 19 Feb. 1983, Koyama et al. T-33708 (BKF, L); 16 Mar. 2002, Chamchamroon & Puff 1417 (BKF); Phu Ruea NP, 5 May 1997, Pooma 1564 (BKF)]; SOUTH-WESTERN: Uthai Thani [Ban Rai, 3 May 1963, Kasem 384 (BK); 25 Mar. 2004, Suwanphakdee 117 (DMSC)]; Kanchanaburi [Chalerm Rattana Kosin NP, 26 Sept. 2001, van de Bult 483 (BKF); Si Sawat, 4 Feb. 1962, Larsen & Smitinand 9459 (BKF, L); Thong Pha Phum NP, 8 Aug. 2000, Triboun 1821 (BK);10 May 2003, Suwanphakdee 70 (BK, BKF, DMSC, KKU); 13 Jan. 2004, Suwanphakdee 85 (DMSC); 1 Feb. 2004, Suwanphakdee 88 (BK); 14 Apr. 2004, Suwanphakdee 126 (**BK**); 23 Aug. 2004, Nielson et al. 1882 (**BKF**); Sangkhlaburi, 30 Jan. 1926, Kerr 10340 (BK, BM, K, L); 29 Mar. 1968, van Beusekom & Phengklai 183 (BKF, L); 1 Aug. 1968, Sangkhachand 1488 (**BK**); 7 Aug. 1968, Nimanong 250 (**BKF**)]; Phetchaburi [Kaeng Krachan NP, 13 Dec. 2002, Middleton et al. 1614 (BKF, K); 26 Jan. 2005, Williams et al. 1125 (KEP, SING); 30 Jan. 2005, Williams et al. 1218 (BKF)]; Prachuap Khiri Khan [Pa La U, 19 Jan. 2004, Middleton et al. 2254 (BKF)]; PENINSULAR: Chumphon [Kao Long, 10 Jan. 1927, Kerr 11514 (BK, BM, K, L); 7 Apr. 2004, Kaewsri 73 (BKF)]; Ranong [Nam Chut, 20 Jan. 1927, Kerr 12898 (K, L); Kraburi, 24 Dec. 1928, Kerr 16323 (BK, BM, K, L); Khao Pawta Luang Kaew, 21 Jan. 1929, Kerr 16774 (BK, BM); Khao Pawta Chongdong, 21 Jan. 1929, Kerr 16800 (BK, BM, K, L); Khao Sai Daeng, 4 May 1968, van

Beusekom & Phengkhlai 549 (L); 27 Feb. 1983, Koyama et al. T-33810 (**BKF**, L)]; Surat Thani [Chai Ya, Nong Wai, 4 Mar. 1927, Kerr 12215 (**BK**, **BM**, L); Khao Sok NP, 26 Feb. 2006, Middleton et al. 4042 (**BKF**)]; Krabi [Muang, 26 Jan 1928, Sutheesorn 5221 (**BK**)]; Trang [Khao Chong, 11 Mar. 1976, Chira 2235 (**BK**), 12 Mar. 1974, Larsen & Larsen 33239 (**BKF**, L)]; Yala [Betong, 12 Aug. 1923, Kerr 7581 (**BK**, **BM**, L)].

Distribution.— India, Sri Lanka, China, Myanmar, Laos, Vietnam, Cambodia, Malaysia, Indonesia, the Philippines.

Vernacular.— Soi hoi (ส้อยห้อย)(Karen-Chiangdao, Chiang Mai).

Ecology.— In lowland evergreen forest, hill evergreen forest or open areas near streams; flowering February–March, fruiting April.

Notes.—*Piper boehmeriifolium* var. *glabricaule* differs from the typical variety by its glabrous stems. The fruits are connate at the base and not fleshy and the ripe fruits are dark purple or black.

6. Piper chantaranothaii Suwanph. & D.A. Simpson, Kew Bull. 67 (4): 707.2012. Type: Thailand, Chiang Mai, Doi Chiang Dao WS, *Suwanphakdee* 248 (holotype **BKF**!; isotypes: **BK!**, **KKU!**, **QBG!**).

Thailand.— NORTHERN: Mae Hong Son [Pai, 18 Apr. 1995, Maxwell 95-322 (BKF)]; Chiang Mai [Doi Suthep NP, 15 Nov. 1914, Kerr 3462 (BM, K, L); Doi Inthanon NP, 1 Feb. 2007, Suwanphakdee 194 (BK, BKF, KKU, QBG); Mae Rim, 4 May 1993, Maxwell 93-363 (BKF) 20 Aug. 1995, Nanakorn et al. 9539 (QBG); 7 May 2012, Nguanchoo 485 (BK); Doi Chiang Dao WS, 2 Dec. 1961, Smitinand & Anderson 7261 (BKF); 20 June 1968, van Beusekom & Phengklai 1323 (BKF); 2 Mar. 1997, Koyama et al. 15603 (BKF); 21 Dec. 2003, Suwanphakdee 78 (BK, BKF, KKU, QBG), 10 Dec. 2008, Suwanphakdee 248 (BKF, BK, KKU, QBG); Pang Tawn, May 1881, Put 3907 (BK, BM, L)]; Chiang Rai [Mae Fa Luang, Doi Bang Nun, 17 Apr. 2008, Maxwell 08-65 (**QBG**); Doi Tung, 20 May 1991, Pooma 472 (BKF); 17 Mar. 2005, Pooma et al. 4867 (BKF)]; Nan [Doi Phu Kha NP, 11 May 2006, Srisanga 2807 (QBG); 14 Feb. 2004, Suwanphakdee 98 (KKU)]; Uttaradit [Phu Soi Dao NP, 12 Feb. 2004, Suwanphakdee 93 (BK)]; NORTH-EASTERN: Loei [Dan Sai, 3 April 1922, *Kerr* 5773 (**BK**, **BM**, **L**)]; EASTERN: Chaiyaphum [Phu Khiao WS, 12 Feb. 2010, *Suwanphakdee 289* (**BK**, **BKF**, **KKU**)].

Distribution.— Endemic.

Ecology.— Uncommon in the wild, occurring in forest or near mountain summits; flowering December–January, fruiting January–March.

Vernacular.— Cha khan (จะค้าน)(Northern); cha khan daeng (จะค้านแดง)(Chiang Mai); cha khan nuea (จะค้านเนื้อ)(Nan).

Uses.— The stem is used as an anti-cancer agent and as a carminative. It is eaten in curries and soups but is not as commonly used as *P. wallichii* (Miq.) Hand.-Mazz.

Notes.— *Piper chantaranothaii* is similar to *P. betle* but differs in its coriaceous and stiff leaves and longer female inflorescence. The infructescences are shiny-green, glabrous or puberulous in grooves, and longer and larger than *P. betle*. This species is much consumed by local people using plants taken from the wild.

7. Piper chiangdaoense Suwanph. & Chantar., Blumea 56(3): 235. 2011. Types: Thailand, Chiang Mai, Doi Chiang Dao WS, *T. Smitinand, M.E.D. Poore & R.G. Robbins 7806* (holotype **BKF!**; isotype: **E!**).

Thailand.— NORTHERN: Chiang Mai [Doi Chiang Dao WS, 4 June 1921, *Kerr 5549* (**BK**, **BM**); 10 Nov. 1962. *Smitinand et al.* 7860 (**BKF**, **E**); 20 Jan. 1968, *van Beusekom & Phengklai 1359* (**BKF**, **L**); 14 Sept. 1967, *Shimizu et al. T*-10048 (**L**)].

Distribution.— Endemic.

Ecology.— Lower montane forest, alt. 1,500–2,175 m. Flowering in May, fruiting in June.

Vernacular.— Phrik thai chiang dao (พริกไทย เชียงดาว)(General).

Notes.— *Piper chiangdaoense* is native to Thailand. The plants are very locally distributed in Doi Chiangdao, Chiang Mai province. The morphology is similar to *P. lonchites* but differs in the velutinous or puberulous stems and leaves. The fruits are also smaller (2–3 by 1–2 mm vs 4–5 by 3–4 mm in *P. lonchites*).
8. Piper colubrinum (Kunth) C.DC., Jahrb. 3: 61. 1820.— Schilleria colubrina Kunth, Linnaea 13: 684. 1840.— Artanthe colubrina (Kunth) Miq. Syst. Piperac. 1: 512. 1843. Type: Brazil, Gaude-Beaupré 86 (G-DC [G00206138!]).

Thailand.— PENINSULAR: Krabi [Muang, Rubber Research Center, 21 Oct. 2006, *Suwanphakdee 183* (**BK**, **BKF**)]; CENTRAL: Nonthaburi [Medicinal Plant Research Institute, 5 Mar. 2002, *Suwanphakdee 1* (**BK**, **BKF**, **DMSC**, **KKU**)].

Distribution.— South America. Introduced into Thailand.

Ecology.— Cultivated; flowering and fruiting all year round.

Vernacular.— Phrik thai kholu (พริกไทยโคลู) (Krabi).

Uses.— Used as grafting stock for *P. nigrum* to protect from root rot.

Notes.— Distinguishing characters include its small shrub or scandent-shrub habit, its prop roots which are produced from the basal stem, its spikelike inflorescences and its 4-valved stamens.

**9. Piper crassipes** Korth. ex Miq., Comm. Phytogr. 1: 22. 1839; C.DC., Prodr. 16(1): 344. 1869; Suwanphakdee *et al.*, Kew Bull. 73, 33: 5. 2018.— *Cubeba crassipes* (Korth. ex Miq.) Miq., Comm. Phytogr. 2: 45. 1840. Type: Indonesia, Sumatra, *Korthals 1863* (lectotype **K** [K000575314!], designated by Suwanphakdee *et al.*, 2018).

— *Cubeba neesii* Miq., Syst. Piperac.: 292. 1843. Type: not located.

*— Piper pedicellosum* Wall. ex C.DC., Prodr. 16(1): 343. 1869; Suwanphakdee & Chantaranothai, Trop. Nat. Hist. 8(2): 205. 2008. **nom. superfl**. Type: Singapore, *Wallich s.n.* [Numer. List 6646A] (holotype **K-W** [K001124404!]).

Thailand.— PENINSULAR: Surat Thani [Tha Chana, Khanthuli, 20 Jan. 1957, *Peerapat s.n.* (**BK**)]; Nakhon Si Thammarat [Tha Samet, 29 Jan. 1928, *Kerr 14336* (**BK, BM, L**)].

Distribution.— India, Myanmar, Malaysia, Singapore.

Ecology.— In swamp forest; flowering and fruiting April–May.

Vernacular.— Ta khan (ตะค้าน)(Surat Thani).

Uses.—The stems are used as a medicine.

Notes.— Based on inflorescence and infructescences morphologies, *Piper crassipes* is similar to *P. polycarpa* but it differs by having coriaceous and thick leaf. The palmately veins are differ. The inflorescences and infructescences are shorter (2–3 vs 5–12 cm long in *P. polycarpa*) and (3–4 vs 6–16 cm long), respectively. It is similar to *P. ribesioides* based on gross morphology but differs by having smaller leaves and fruit, rounded floral bracts and a non-rugulate dry fruit.

**10. Piper doiphukaense** Suwanph. & Chantar., Thai Forest Bull., Bot. 40: 31. 2012. Type: Thailand, Nan, Doi Phu Kha NP, 24 Aug. 2001, *P. Srisanga* & *C. Maknoi 2095* (holotype **QBG!**).

Thailand.— NORTHERN: Nan [Doi Phu Kha NP, 24 Aug. 2001, *Srisanga & Maknoi 2095* (**QBG**)].

Distribution.— Endemic.

Ecology.— Shaded and slightly open areas or near waterfalls in dry evergreen forest.

Vernacular.— Phrik thai phu kha (พริกไทยภูคา).

Notes.— *Piper doiphukaense* is distinguished from *P. pedicellatum* by its subcoriaceous or coriaceous and stiff leaves. The petiole is mostly glabrous. The fruits are ellipsoid to subglobose and 0.5–1 mm in size. The specific epithet refers to Doi Phu Kha NP, Nan province, where the specimen was collected.

**11. Piper durionoides** Suwanph. & Chantar., Novon 23: 230. 2014. Type: Thailand, Kanchanaburi, Thong Pha Phum NP, 10 Nov. 2003, *Suwanphakdee* 69 (holotype **BKF!**; isotypes **BK!**, **KKU!**).

Thailand.— SOUTH-WESTERN: Kanchanaburi [Sisawat, 14 Aug. 1968, Sangkhachand 1510 (**BK**); Khao Chalat, 7 Aug. 1923, Collins 927 (**BK**); Thong Pha Phum NP, 15 Apr. 2004, Suwanphakdee 128 (**BK**, **BKF**, **KKU**); 11 Aug. 1968, Nimanong & Phusomsaeng 269 (**BKF**)]; Phetchaburi [Kaeng Krachan NP, 15 May 2003, Suwanphakdee 38 (**BK**, **BKF**, **KKU**); 3 Apr. 2004, Suwanphakdee 119 (**BK**, **BKF**, **DMSC**, **KKU**); 7 Apr. 2004, Suwanphakdee 122 (**BK**, **BKF**, **KKU**)].

Distribution.— Endemic.

Vernacular.— Phlu thurian (พลูทุเรียน).

Ecology.— In evergreen forest by streams or waterfalls; flowering November–April, fruiting December–April.

Notes.— *Piper durionoides* has puberulous, pilose or velutinous branchlets, and is puberulous or pilose on both leaf surfaces. Based on infructescence and fruit morphologies, *P. durionoides* is similar to *P. chantaranothaii* but differs by having persistent style that resembles a spine. *Piper durionoides* is also similar to *P. majusculum* but differs from the latter by having smaller leaves. The inflorescences and infructescences are shorter (shorter than 15 cm vs longer than 20 cm in *P. majusculum*) and the fruits have a persistent, spine-like style. The specific epithet refers to its characteristic coalescent fruits and persistent style which are similar to *Durio zibethinus* Merr. (Fig. 1F).

**12.** Piper griffithii C.DC., J. Bot. 4: 166. 1866; Hook.f., Fl. Brit. India 5: 81. 1887. Suwanphakdee *et al.*, Kew Bull. 73, 33: 5, 2018. Type: Bangladesh "East Bengal", *Griffith 4402* (lectotype **K** [K000794378!], designated by Suwanphakdee *et al.*, 2018; isolectotype **P** [P02025591!]).

— *P. longibracteum* C.DC., Rec. Bot. Surv. Ind. 6: 16. 1912; Ridl., Fl. Malay Penins. 3: 37. 1924. Type: Malaysia, Perak, Maxwell hill, *Wray 101* (lectotype **K** [K000794925!]; isolectotype **SING!**, designated by Suwanphakdee *et al.*, 2018).

Thailand.— NORTHERN: Chiang Mai [Doi Suthep NP, 25 Jan. 1988, Maxwell 88-76 (BKF); Maxwell 88-78 (BKF)]; Nan [Doi Phu Kha NP, 27 Feb. 1921, Kerr 4956 (BK, BM, L)]; Lampang [Chae Son NP, 31 Jan. 1921, Kerr 4749 (BK, BKF, BM)]; Tak [Umphang WS, Thi Lo Su Waterfall, 16 Jan. 2004, Suwanphakdee 81 (BK, KKU); 16 Feb. 2008, Suwanphakdee 221 (BK, BKF, KKU, QBG)]; SOUTH-EASTERN: Loei [Phu Paek, 13 Jan. 1970, van *Beusekom & Phengkhlai 3014* (L)]; SOUTH-WESTERN: Kanchanaburi [Sangkhlaburi, 6 Aug. 1968, Sangkhachand 1476 (BK); 20 May 1946, Kostermans 714 (BK); 1 Apr. 1968, van Beusekom & Phengklai 249 (**BKF**, L)]; Phetchaburi [Kaeng Krachan NP, 27 June 2000, Newman et al. 1089 (BKF); 10 Aug. 2002, Middleton et al. 937 (BKF, K); 15 Dec. 2002, Middleton et al. 1684 (BKF, K); 30 Mar. 2003, Middleton et al. 1823(BKF, K); 17 May 2003, Suwanphakdee 41 (BK, DMSC, KKU); 27 Jan. 2005, Williams et al. 1147 (BKF, KEP); 3 Apr. 2004,

Suwanphakdee 118 (**BK**, **BKF**, **KKU**); 26 Dec. 2008, Suwanphakdee 255 (**BK**, **BKF**, **KKU**); Suwanphakdee 256 (**BK**, **BKF**, **KKU**); Suwanphakdee 257 (**BK**)]; Prachuap Khiri Khan [Khao Luang, Huai Yang Waterfall NP, 5 July 1924, Kerr 10865 (**BK**, **BM**); 12 Apr. 2010, Suwanphakdee 303 (**BK**, **BKF**, **KKU**)]; PENINSULAR: Ranong [Ngao Waterfall NP, 20 Feb. 2007, Suwanphakdee 195 (**BK**)]; Surat Thani [Khao Sok NP, 21 Mar. 2004, Suwanphakdee 112 (**BK**, **DMSC**); 9 Nov. 2010, Suwanphakdee 281 (**BK**, **BKF**, **KKU**)]; Phangnga [Khao Pawta Luang Kaew, 27 Nov. 1974, Geesink et al. 7640 (**BKF**, **K**, **L**)]; Krabi [Tham Suea Temple, 22 Feb. 2001, Chayamarit et al. 2641 (**BKF**)].

Distribution.—India, Bangladesh, Malaysia.

Ecology.— Shaded areas by streams or mountain summits in evergreen forest; flowering January– April, fruiting March–May.

Vernacular.— Phrik thai kan yao (พริกไทยก้านยาว).

Notes.— The general morphology of *Piper* griffithii is superficially similar to that of *P. guineense* Schum. & Thonn., a species endemic to Africa. However, *P. griffithii* differs by having glabrous nervation, a longer inflorescence and infructescence, and a glabrous floral bract, which is oblong when flowering and spathulate when fruiting. The number of stamens ranges from 5–8 and the ripe fruits are dark purple or black (Fig. 1G).

**13. Piper khaoyaiense** Suwanph. & D.A.Simpson, Thai Forest Bull., Bot. 40: 32. 2012. Type: Thailand, Nakhon Ratchasima, Khao Yai NP, 9 Apr. 2003, *Suwanphakdee 153* (holotype **BKF!**; isotypes, **BK!**, **KKU!**).

Thailand.— EASTERN: Nakhon Ratchasima [Khao Yai NP, 16 July 1962, *Smitinand 7443* (**BKF**); 9 Apr. 2003, *Suwanphakdee 52* (**BK, BKF, KKU**)]; SOUTH-EASTERN: Prachin Buri [Khao Yai NP, 10 July 2004, *Suwanphakdee 153* (**BK, BKF, KKU**); 8 Mar. 2009, *Suwanphakdee 264* (**BK, BKF, KKU**)].

Distribution.— Endemic.

Ecology.— In slightly open or shaded areas, by streams or waterfalls in evergreen forest; flowering May–August, fruiting August–September.

Vernacular.— Ta khan khao yai (ตะค้านเขาใหญ่) (Nakhon Ratchasima).

Uses.— The stems are used as a medicine.

Notes.— The vegetative parts of *Piper khaoyaiense* are similar to *P. betle* whereas the morphology of the infructescence is similar to *P. nigrum* but differs in that the inflorescence is a catkin and the bracts are rounded, ciliate and sometimes peltate with a stalk. Its fruits are smaller than those of *P. nigrum*.

**14. Piper kongkandanum** Suwanph. & Chantar., Novon 23: 232. 2014. Types: Thailand, Kanchanaburi, Sangklaburi, 5 July 2008, *Suwanphakdee 239* (holotype **BKF!**; isotypes **BK!**, **KKU!**).

Thailand.— SOUTH-WESTERN: Kanchanaburi [Kwae Noi River Basin, 28 May 1946, *Kostermans* 745 (**BK**, **SING**); Thong Pha Phum NP, 15 Apr. 2004, *Suwanphakdee 128* (**BK**, **BKF**, **KKU**); Khao Laem NP, 1 May 2009, *Suwanphakdee 273* (**BK**, **BKF**, **KKU**); Sangkhlaburi, 25 Jan. 1925, *Kerr* 10336 (**BK**, **BM**, **L**); 16 June 1946, *Kostermans 863* (**BK**)]; Phetchaburi [Kaeng Krachan NP, 3 Apr. 2004, *Suwanphakdee 119* (**BK**, **BKF**, **KKU**)].

Distribution.— Endemic.

Vernacular.— Phlu archan kong (พลูอาจารย์ก่อง) (General).

Ecology.— In shaded areas along streams or waterfalls in evergreen forest or hill evergreen forest; flowering January–Febuary, fruiting April–May.

Notes.— *Piper kongkandanum* differs from *P. ramipilum* C.DC. in having pilose or velutinous uniseriate hairs on the branchlets, larger, chartaceous leaves, hairy floral bract bases with ciliate margins and shorter inflorescences and infructescences (Fig. 1H).

**15. Piper kurzii** Ridl., J. Strait Branch Roy. Asiat. Soc. 82: 188. 1920; Ridl., Fl. Malay Penins. 3: 43. 1924; Suwanphakdee *et al.*, Kew Bull. 73, 33: 7, 2018. Type: Myanmar, Pegu, 21 Feb. 1871, *Kurz* 2220 (lectotype **K** [K000794423!], designated by Turner, Gard. Bull. Singapore 64: 253. 2012; isolectotype **CAL**).

*— P. kurzii* C.DC., Candolle 1: 198. 1923 & 2: 205. 1925., **nom. illegit.**, non *P. kurzii* Ridl.

Thailand.— NORTHERN: Chiang Mai [Doi Suthep NP, 8 May 1910, *Kerr 1169* (**BM**, **K**, **TCD**); 13 June 1967, *Bunchuai 601* (**BKF**); 24 Sept. 1987, *Maxwell 87-1037* (**BK**, **BKF**); 15 Oct. 2003, Suwanphakdee 58 (DMSC); Doi Inthanon NP, 31 May 1933, Garrett 788 (BKF, BM); 26 June 1978, Phengklai et al. 4108 (BKF); 4 Dec. 1994, Pooma 900 (BKF)]; Chiang Rai [Phu Langka, 24 June 1954, Smitinand 1733 (BKF)]; Lamphun [Mae Tha, 28 Oct. 1994, Maxwell 94-1131 (BKF)]; Lampang [Wang Nua, 21 Apr. 1997, Maxwell 97-374 (BKF)]; Tak [Muang, Maetor Distr, 3 Nov. 1984, Paisooksantivatana 1448-84 (BK)]; Phitsanulok [Nakhonthai, 17 Oct. 1921, Kerr 5854 (BK, BM); Thung Salaeng Luang NP, 12 Dec. 1965, Tagawa & Fukuoka T-2120 (BKF)]; NORTH-EASTERN: Phetchabun [Nam Nao NP, 26 Dec. 1982, Koyama et al. T-31687 (BKF); 26 Oct. 1984, Murata et al. T-51599 (BKF); Murata et al. T-51638 (BKF); 18 Jan. 2003, Kantachote 118 (KKU); 25 Jan. 2003, Suwanphakdee 20 (BKF); 30 July 2011, Suwanphakdee 372 (BK)]; Loei [Phu Kradeung NP, 3 Dec. 1965, Tagawa et al. T-1025 (BKF); 3 Sept. 1967, Shimizu et al. 883 (BKF); 30 Nov. 1968, Tagawa et al. T-918 (BKF); 10 Nov. 1970, Charoenpol et al. 4861 (BKF); 9 Sept. 1988, Takahashi & Tamura T-60626 (BKF); 12 June 1992, Niyomdham 2928 (BKF); Phu Luang WS, 3 Dec. 1965, *Tagawa et al. T-1025* (**BKF**)]; EASTERN: Chaiyaphum [Phu Khiao WS, 8 Nov. 1984, Murata et al. T-41870 (**BKF**)]; Nakhon Ratchasima [Khao Yai NP, 14 Jan. 1925, Kerr 9980 (BK, BM); 13 Dec. 1962, Phengklai 491 (BKF); 3 Jan. 1963, Phengklai 671 (BKF); 10 Aug. 1968, Larsen et al. 3239 (BKF, L); 9 Sept. 1968, Santisuk 175 (BKF, L); Salika Waterfall, 25 Oct. 1971, van Beusekom & Geesink 3351 (BKF, L); Ban Tha Chang, 24 Dec. 1930, Put 3498 (BK, BM, L)]; SOUTH-WESTERN: Uthai Thani [Huai Kha Khaeng WS, 17 Nov. 1989, Smitinand 89-11 (BKF); Ban Rai, 3 May 1963, Kasem 382 (BK)]; Kanchanaburi [Thong Pha Phum NP, 15 Nov. 2003, Suwanphakdee 71 (BK); Sangkhlaburi, 8 Aug. 1968, Nimanong 253 (BKF); 14 Aug. 1971, Phengklai 2941 (BKF); 11 Nov. 1971, van Beusekom et al. 3702 (BKF, L); 21 July 2009, Samprasong & Sonsuphab s.n. (BK)]; Phetchaburi [Kaeng Krachan NP, 7 Apr. 2004, Suwanphakdee 120 (KKU); Suwanphakdee 121 (DMSC)]; Prachuap Khiri Khan [Pa La U, 15 Aug. 2002, Middleton et al. 1079 (BKF); 16 May 2003, Suwanphakdee 36 (KKU)]; CENTRAL: Nakhon Nayok [Khao Yai NP, 26 May 2000, Chongko 73 (BKF); Nang Rong Waterfall, 13 Aug. 1968, Larsen et al. 3372 (AAU, BKF, L)]; SOUTH-EASTERN: Prachin Buri [Khao Yai NP, 11 July 1966, Larsen et al. 277 (BKF, L)]; Chanthaburi [Khao Soi

Dao WS, 29 June 2001, Chamchamroon & Puff 1103 (BKF); Khao Chamao NP, 22 Aug. 1972, Larsen et al. 32988 (BKF); Pong Nam Ron, 14 May 1974, Maxwell 74-491 (BK); 5 July 1974, Maxwell 74-665 (BK, BKF, L); 25 Dec. 1984, Paisooksantivatana Y-1512-84 (BK, BKF)]; PENINSULAR: Surat Thani [Ban Kawp Kep, 7 Apr. 1927, Kerr 13190 (BK, BM, L); Ko Samui, 15 Mar. 1928, Kerr 15743 (BK)]; Phangnga [Sri Phangnga NP, 29 Apr. 1973, Geesink & Santisuk 5073 (BKF); 22 Mar. 2004, Suwanphakdee 116 (BKF)]; Trang [Khao Chong, 14 Apr. 1928, Kerr 15207 (BK, BM); 14 June 1974, Geesink et al. 7236 (BKF, K, L); 17 Dec. 1979, Shimizu et al. T-27460 (BKF, L); 4 Sept. 1982, Shimizu et al. T-29067 (BKF); 25 Jan. 1957, Smitinand 4102 (BKF); 14 July 1969, Sangkhachand 1988 (BK)]; Satun [Thale Ban NP, 3 June 2001, Pooma et al. 1995 (BKF)]; Songkhla [Tone Ngachang WS, 18 Sept. 2003, Suwanphakdee 12 (BK); Boripat Waterfall, 18 Dec. 1979, Shimizu et al. T-27669 (BKF)]; Pattani [Khao Kala Khiri, 3 Mar. 1928, Kerr 14925 (BK, BM)]; Yala [Bunnung Star, 28 July 1928, Kerr 7384 (BK, BM)]; Narathiwat [Sri Sakorn, 26 Apr. 2001, Puudjaa 883 (BKF)].

Distribution.— India, Myanmar, Malaysia.

Vernacular.— Phrik nok (พริกนก)(Penninsular).

Ecology.— Common in shaded areas on foothills to mountain summits or along streams or waterfalls in evergreen or hill evergreen, pine and oak forest; flowering March–May, fruiting July–October.

Uses.— The stems are used as a carminative.

Notes.— The reproductive parts are similar to *Piper nigrum* but *P. kurzii* differs in its habit which is either a perennial erect herb or small shrub. It has an erect inflorescence with a terminal curve-like hook and erect infructescence which becomes slightly pendulous when mature (Fig. 2A).

**16. Piper laetispicum** C.DC., Notul. Syst. (Paris) 3: 42. 1914; Tseng, Xia & Gilbert in Wu & Raven, Fl. China 4: 117. 1999. Type: China, Hainan, Lo-Tai, *Chinese collector 469* (holotype **K** [K000794355!]; isotypes: **G-DC** [G00315972!], **P** [P02025532!]).

*— P. maclurei* Merr., Philip. J. Sci. 21: 339. 1922. Type: China, Namfung, Lo Tai, *Maclure 8531* (lectotype **C** [C10016564!]; designated here; iso lectotype **G** [G00438868!]). Thailand.— NORTHERN: Chiang Rai [Thoeng, 7 Feb. 1970, *Sutheesorn 1644* (**BK**); Khunkorn Waterfall, 26 Mar. 2010, *Suwanphakdee 292* (**BK**, **BKF**, **KKU**)]; Nan [Doi Phu Kha NP, 7 Mar. 1921, *Kerr 5032* (**BK**, **BM**, **L**); 27 May 2000, *Srisanga 1478* (**QBG**); Tham Sakoen NP, 12 May 2006, *Srisanga et al.* 2858 (**QBG**)].

Distribution.- China.

Vernacular.— Kua toi (เกือต่อย)(Nan).

Ecology.— In shaded areas along streams or waterfalls or mountain summits in hill evergreen forest; flowering and fruiting in May.

Notes.— Merrill (1922) described *Piper* maclurei, with Maclure 5831 designated as the type, without indicating where specimens were deposited. We found collections of this number in C [C10016564] and G [G00438868]. We designate G00438868 as lectotype because it is well preserved and C10016564 as an isolectotype. *Piper laetispicum* is similar to *P. polycarpa* but differs by having rounded floral bracts and margins with long hairs, coriaceous and stiff leaves, transversely dehiscent stamens and secondary veins which have less than 5 pairs (Fig. 2B).

**17. Piper lanatum** Roxb., Fl. Ind. 1: 161. 1820; Ridl., Fl. Malay Penins. 3: 38. 1924.— *Cubeba lanata* (Roxb.) Miq., Syst. Piperac. 1: 298. 1843. Type: India, *Roxburgh s.n.* (lectotype **BR**[BR0000006597801!], designated here).

— *P. lowong* Blume, Verh. Batav. Gen. 11: 161. 1826.— *Cubeba lowong* (Blume) Miq., Comm. Phytogr. 3: 33. 1840. Type: Indonesia, Java, *Blume s.n.* (lectotype **L** [AMD82238!], designated by Suwanphakdee *et al.*, 2018; isolectotypes **G-DC** [G00206348!], **K** [K000820066!]).

*— P. caninum* Blume, Verh. Batav. Gen. 11: 214. 1826; Hook.f., Fl. Brit. India 5: 82. 1887; Ridl., Fl. Malay Penins. 3: 38. 1924; Henderson, Malay. Wild Flowers Dicot. 4(3): 442. 1959; Backer & Bakh.f., Fl. Java 1: 171. 1963; Gardner, Blumea 51(3): 580. 2006; Suwanphakdee *et al.*, Thai Forest Bull., Bot. 34: 206. 2006; Suwanphakdee & Chantaranothai, Trop. Nat. Hist. 8(2): 208. 2008; Suwanphakdee *et al.*, Kew Bull. 73, 33: 5. 2018.*— Cubeba canina* (Blume) Miq., Comm. Phytogr. 3: 33. 1840. Type: Indonesia, Java, *Blume s.n.* (lectotype L [L1545499!], designated by Suwanphakdee *et al.*, 2018). *— P. javanicum* C.DC., Prodr. 16(1): 343. 1869. Type: Singapore, *Wallich s.n.* [Numer. List 6645B] (lectotype **K-W** [K001124402!], designated by Suwanphakdee *et al.*, 2018).

*— P. thwaitesii* C.DC., Prodr. 16(1): 357. 1869.*— P. caninum* Blume var. *thwaitesii* (C.DC.) Hook.f., Fl. Brit. India 6: 82. 1886. Type: Sri Lanka, *Thwaites* 2178 (lectotype **G-DC** [G00206602!], designated by Suwanphakdee *et al.*, 2018; isolectotype **K** [K000794377!]).

— *P. densibaccum* C.DC., Philipp. J. of Sci. 5(5): 454. 1910. Type: the Philippines, Lake Lanao, Camp Keithley, *Clemens s.n.* (holotype **G-DC** [G00329052!]).

— *P. pilobracteatum* A.Chaveer. & R.Sudmoon, Acta Phytotax. Sin. 44(4): 449. 2006. Type: Thailand, Phangnga, Sri Phangnga NP, *Chaveerach 63495* (holotype **BK**?).

Thailand.— PENINSULAR: Chumphon [Tha Sae, 12 Apr. 1959, Bunchuai 1145 (BKF); 26 May 1969, Sadakorn 81 (BK); 11 Apr. 1967, Sutheesorn 2172 (BK); Thung Raya Nasak WS, 29 Aug. 2002, Middleton et al. 1468 (BKF, K); Pa Toh, 28 July 2003, Suwanphakdee 55 (BK)]; Ranong [Kraburi, 1 Feb. 1927, Kerr 11747 (BK, BM, K, L); Ko Ka, 27 Jan. 1929, Kerr 16854 (BK, BM, K, L); Khao Pawta Chongdong, 19 Jan. 1929, Kerr 16732 (BK, BM, K); 21 Jan. 1929, Kerr 16804 (BK, BM, L); Bok Krai, 30 Dec. 2008, Suwanphakdee 263 (BK, BKF, KKU); Bang Son, 14 Mar. 1928, Put 1570 (BK, BM, K, L)]; Surat Thani [Khao Pra Mi, 9 Jan. 1966, Hansen & Smitinand 11855 (BKF, L); Klong Panom, 16 July 2000, *Chamchumroon* 866 (**BKF**); Ko Samui, 9 Apr. 1927, Kerr 12567 (BK, BM, K, L); Ko Tao, 21 Sept. 1928, Kerr 16060 (BK, BM, L); Ban Kawp Kep, 12 Apr. 1927, Kerr 13312 (BK, BM, K, L); Khao Sok NP, 29 Mar. 1993, Chantaranothai et al. 1527, (TCD); 21 Mar. 2004, Suwanphakdee 114 (DMSC); 9 Nov. 2010, Suwanphakdee 283 (BK, BKF, KKU)]; Phangnga [Kuraburi, 27 Aug. 1929, Kerr 16854 (BK); Bang Tor, 19 Feb. 1929, Kerr 17155 (BK, BM, K, L); Tap Pud, 3 Mar. 1930, Kerr 18347 (BK, BM); 5 Mar. 1930, Kerr 18375 (BK); Sri Phangnga NP, 6 Apr. 2006, Suwanphakdee 179 (BK, BKF); 28 Jan. 2007, Suwanphakdee 217 (BK, BKF)]; Krabi [Ao Luk, 15 Mar. 1930, Kerr 18561 (BK, L); 31 Mar. 1930, Kerr 18792 (BK, BM, L); Khao Panom, 31 Mar. 1930, Kerr 18742 (BK); 18 June 2006, Williams et al. 1899 (BKF)]; Nakhon Si Thammarat [Khao Luang NP, 5 Mar. 1983, Koyama et al. T-34049 (BKF, L); 24 Nov. 1984, Maxwell 84-482 (BKF, PSU); 9 May 1985, Ramsri 63 (L); 24 Oct. 1951, Smitinand 1001 (BKF); 7 May 2004, Suwanphakdee 137 (BK); same locality and date, Suwanphakdee 139 (BKF); 26 Oct. 2006, Triboun 3688 (BK); 18 Mar. 2008, Suwanphakdee 222 (BK, BKF); 19 Apr. 2010, Suwanphakdee 308 (BK, BKF, KKU); Si Chon, 25 Feb. 1987, Maxwell 87-216 (BKF, L, PSU); 21 June 1951, Suvanakoses 148 (**BKF**); 21 Dec. 2006, *Pooma et al.* 6519 (**BKF**); 26 Jan. 1956, Thavorn 531 (BKF); 4 Dec. 1957, Thavorn 973 (BKF); Yong Waterfall, 31 Aug. 1982, Shimizu et al. T-28978 (BKF)]; Phatthalung [Na Wong, 19 Apr. 1928, Kerr 15321 (BK, BM, L)]; Trang [Khao Chong, 7 Mar. 1920, Chermsirivattana & Larsen 1649 (BK, BKF); 1 Apr. 1969, Sangkhachand 1827 (**BK**); 9 Oct. 1970, *Charoenphol et al. 3506* (**BKF**); 12 Aug. 1975, Maxwell 75-771 (BK); Maxwell 75-801 (**BK**); 17 Dec. 1979, Shimizu et al. T-27467 (**BKF**); 8 July 2000, Middleton et al. 322 (BKF); 16 Mar. 2004, Suwanphakdee 104 (BKF)]; Satun [Khao Keo Kaenge, 13 Mar. 1928, Kerr 14544 (BK, BM)]; Songkhla [Ton Nga Chang WS, 24 Dec. 1927, Kerr 13663 (BK, BM, K, L); 8 Dec. 1985, Maxwell 85-1085 (BKF, L, PSU); 19 Jan. 1986, Maxwell 86-31 (**BKF**, **L**, **PSU**); *Pooma et al.1941* (**BKF**); 19 Mar. 2004, Suwanphakdee 111 (KKU); Rattapoom, 9 Nov. 1984, Maxwell 84-410 (BKF, PSU); 13 Nov. 1984, Maxwell 84-424 (BKF, PSU); 4 Jan. 1985, Maxwell 85-20 (BKF, PSU); Ko Hong Hill, Hat Yai, 9 Jan. 1986, Maxwell 86-32 (L)]; Pattani [Khao Kala Khiri, 3 Apr. 1928, Kerr 15000 (BK, BM, K, L)]; Yala [Betong, 23 Aug. 1923, Kerr 7640 (BK, BM, L)].

Distribution.— India, Sri Lanka, Malaysia, Singapore, Indonesia, the Philippines.

Vernacular.— Phrik nok (พริกนก)(Trang).

Ecology.— Common in the wild or in plantations, occurring from the lowlands to mountain summits, growing in open or shaded areas by streams or waterfalls in lowland or hill evergreen forest; flowering and fruiting all year round.

Notes.— Suwanphakdee et al. (2018) incorrectly applied the Piper caninum to this species. However, P. lanatum is an earliest available name and therefore, the one that should be used by priority. Piper lanatum is a slender woody climber. The leaves are highly variable in size, shape and indumentum. The inflorescences are slender and the infructescences are erect. The fruits have a short stalk and the ripe fruits are succulent and attractive with shiny, dark orange or red coloration (Fig. 2C).

**18. Piper leptostachyum** Wall. ex Miq., Syst. Piperac. 1: 315. 1843; Hook.f., Fl. Brit. India 5: 95. 1887. Suwanphakdee *et al.*, Nordic J. Bot. 2016. 34: 610; Mukherjee, Phytotaxa 338(1): 23. 2018; Mukherjee, Phytotaxa 441(3): 267. 2020. Type: Myanmar, Nidaun/Ataran river, *Wallich s.n.* [Numer. List 6649] (holotype **K-W** [K001124408!]).

— *P. indicum* C.DC., Prodr. 16(1): 362. 1869. Type: MyanmaSr, Nidaun/Ataran river, *Wallich s.n.* [Numer. List 6649](holotype **G-DC** [G00206817!]).

*— P. rhytidocarpum* Hook.f., Fl. Brit. India 5: 92. 1886; Long in Grierson & Long, Fl. Bhutan 1(2): 347. 1984; Gilbert & Xia, Novon 9(2): 194. 1999; Yongqian, Xia & Gilbert in Wu & Raven, Fl. China 4: 7. 1999; Mukherjee, Phytotaxa 338(1): 27. 2018.

— *Piper nigrum* var. *macrostachyum* C.DC., Prodr. 16(1): 363. 1869. Type: India, Meghalaya, Khasia mountains, *Hooker & Thomson s.n.* (holotype **G-DC** [G00207056!]; isotypes **CAL**, **K** [K000794409!]).

— *P. chaudocanum* C.DC., Ann. Conserv. Jard. Bot. Gen. 2: 274. 1898, as '*chandocanum*'; C.DC. in Lecomte, Fl. Indo-Chine 1: 91. 1910; Yongqian, Xia & Gilbert in Wu & Raven, Fl. China 4: 8. 1999. Type: Vietnam, Monte Chandoe, *Harmand 536* (holotype **G-DC** [G00329209!]).

Thailand.- NORTHERN: Chiang Rai [Chiang Kham, 25 Jan. 1954, Sangkhachand 113 (BKF)]; Nakhon Sawan [Khlong Khlung, 2 June 1922, Kerr 6047 (BK, BM, L)]; NORTH-EASTERN: Loei [Phuluang WS, 10 Oct. 1998, Chaveevach 7 (BK)]; EASTERN: Nakhon Ratchasima [Khao Yai NP, 18 Aug. 1964, Sutheesorn 9 (BK); 20 Oct. 2004, Suwanphakdee 160 (BK, DMSC)]; SOUTH-WESTERN: Kanchanaburi [Khao Tawng, 5 Nov. 1930, Kerr 19744 (BK)]; Phetchaburi [Kaeng Krachan NP, 12 Dec. 2002, Middleton et al. 1593 (BKF); 16 May 2003, Suwanphakdee 37 (DMSC, KKU); 17 May 2003, Suwanphakdee 40 (BK, BKF); 5 Apr. 2004, Suwanphakdee 124 (BK, BKF, DMSC)]; Prachuap Khiri Khan [Pa La U, 16 May 2003, Suwanphakdee 37 (BK); Huai Yang Waterfall NP, 7 Oct. 1980, Put 3236 (BK, BM); 19 Feb. 1921, Winit 618 (BKF); 4 Aug. 1995, Larsen et al. 45395 (BKF); 26 Aug. 2002, Middleton et al. 1344 (BKF, K); 18 Feb. 2006, Middleton et al. 3774 (BKF); 11 Apr. 2010, Suwanphakdee 299 (BK, KKU)]; CENTRAL: Saraburi [Muak Lek, 30 Aug. 1924, Kerr 9062 (BK, BM); Kerr 9069 (BK, BM); Sam Lahn, 18 May 1974, Geesink et al. 6805 (BKF, K, L); 19 May 1974, Maxwell 74-527 (BK, BKF); 16 June 1974, Maxwell 74-615 (BK, BKF, L); 4 Aug. 1992, Larsen et al. 43766 (BKF); 17 Feb. 2003, Suwanphakdee 22 (BK); 20 Oct. 2004, Suwanphakdee 161 (DMSC)]; Nakhon Nayok [Nang Rong Waterfall, 13 May 1954, Suvattabhandu s.n. (BK); 4 Aug. 1992, Puudjaa 68 (BKF)]; SOUTH-EASTERN: Prachin Buri [Krabin, 8 Nov. 1930, Kerr 19794 (BK, L)]; Chon Buri [Sriracha, 5 Apr. 1920, Kerr 4158 (BK, BM); Khao Khiao WS, 9 Sept. 2000, Phengklai 12961 (BKF); Phengklai 12790 (BKF); Chan Tathen, 17 Dec. 1974, Chermsirivatana & Sangkhachand 1933 (BK); 5 Apr. 1976, Vacharee 3 (BK); 10 July 1976, Maxwell 76-425 (BK); 16 Nov. 2003, Suwanphakdee 73 (DMSC); Ban Bung, 18 July 1966, Phengklai 1272 (BKF, C, K, L, P)]; Chanthaburi [Ma Kham, 2 July 1930, Kerr 19466 (BK, BM); 26 Nov. 1930, Lakhanakara, 26 Nov. 1930 (BK); Pong Nam Ron, 9 Feb. 1958, Bunpheng 1072 (BKF, SING); 20 June 1973, Phengklai 3236 (BKF, L); Khao Soi Dao WS, 28 Nov. 1979, Shimizu et al. T-23872 (BKF); 10 Nov. 1969, van Beusekom & Smitinand 2084 (BKF, L)]; Trat [Ko Chang, 24 Mar. 2001, Chayamarit et al. 2912 (BKF); PENINSULAR: Chumphon [Lang Suan, 19 June 1828, Put 1741 (BK, BM, L)].

Distribution.— India, Bangladesh, China, Myanmar, Laos, Vietnam.

Ecology.— In open or slightly shaded areas, by streams or waterfalls in lowland or hill evergreen forest; flowering February, fruiting March–May.

Vernacular.— Sa khan nu (สะค้านหนู)(Saraburi).

Uses.— Stems are used as medicine.

Notes.— Piper rhytidocarpum is treated here as a synonym of P. leptostachyum, following Suwanphakdee et al. (2016). Gilbert & Xia (1999) lectotypified P. rhytidocarpum with Hooker & Thomson s.n. (lectotype K [K000794414!]). However, Mukherjee (2018) pointed out that P. rhytidiocarpum is a replacement name for P. nigrum var. macrostachyum (C.Presl) DC. This was described from a single collection made by Hooker & Thomson. Under Article 7.4 of the International Code for Algae, Fungi and Plants (Turland *et al.* 2018) 'a replacement name is typified by the type of the replaced synonym'. In this case, it is the holotype indicated above.

*Piper leptostachyum* is similar to *P. nigrum* but differs in its leaf shape and texture, the catkintype inflorescence, transversely dehiscent stamens and larger fruit. The ripe fruits are dark purple or black (Fig. 2D).

19. Piper lonchites Roem. & Schult., Mant. 1: 241.
1822; Miq., Syst. Piperac. 2: 331. 1844. Hook.f., Fl. Brit. India 5: 90. 1887; Ridl., Fl. Malay Penins.
3: 49. 1924. Type: Malaysia, Penang, *Wallich s.n.* [Numer.List6644B](lectotype K-W [K001124400!]; designated here; isolectotype BR (2 sheets) [BR0000006598273! & BR0000006598280!], G-DC (3 sheets)[G00206582!, G00320150! & G00206592!], K (3 sheets)[K000820949!, K000794896! & K000842460!], L [L0929297!], U [U1476319!]).

— *P. lonchites* Wall. ex C.DC., J. Asiat. Soc. Beng. 75: 306. 1914, **nom. illeg**.

Thailand.— NORTHERN: Tak [Umphang, Thung Yai WS, 14 Jan. 2011, Suwanphakdee 365 (BK)]; Phitsanulok [Thung Salaeng Luang NP, 18 Nov. 2010, Suwanphakdee 356 (BK)]; NORTH-EASTERN: Phetchabun [Muang, 27 Mar. 1922, Kerr 5684 (BK, BM, L); Khao Keo Ngoi, 13 Apr. 1922, Kerr 5759 (BK, BM, K, L); Nam Nao NP, 27 Dec. 1982, Koyama et al. T-31828 (BKF, L), 30 May 2003, Suwanphakdee 131 (BK, BKF, KKU)]; Loei [Phu Luang WS, 5 Dec. 1965, Tagawa et al. T-1536 (BKF); Phu Ruea NP, 21 May 2004, Bunwong 199 (KKU); Phu Suansai NP, 10 Feb. 2004, Suwanphakdee 91 (BK, BKF, KKU)]; Nakhon Phanom [Tha Utain, 15 Feb. 1924, Kerr 8451 (BK, BM, L)]; EASTERN: Chaiyaphum [Phu Khiao WS, 23 May 1974, Geesink et al. 6878 (BKF, L); 12 Feb. 2010, Suwanphakdee 290 (**BK**, **BKF**, **KKU**)]; SOUTH-WESTERN: Kanchanaburi [Sri Sawat, 29 June 1974, Larsen & Larsen 33927 (**BKF**, **K**, **L**); Thong Pha Phum NP, 1 Apr. 2005, Suwanphakdee 164 (BK, BKF, DMSC, **KKU**)]; Phetchaburi [Kaeng Krachan NP, 26 Jan. 2005, Williams et al. 1108 (BKF); 27 Dec. 2008, Suwanphakdee 260 (BK, BKF, KKU)]; SOUTH-EASTERN: Chanthaburi [Khao Soi Dao WS, 26 Nov. 1979, Shimizu et al., T-23682 (BKF); 12 Jan. 1969, van Beusekom & Smitinand 2151 (BKF, L); Khao Khitchakut NP, 9 Apr. 2008, Phonsena 5920 (BK); Pong Nam Ron, 4 Feb. 1959, *Smitinand 5471* (**BKF**)]; PENINSULAR: Nakhon Si Thammarat [Khao Luang NP, 20 Apr. 2010, *Suwanphakdee 311* (**BK**, **BKF**, **KKU**)].

Distribution.- India, Malaysia.

Ecology.— In open areas on mountain summits or shaded areas along streams or near waterfalls in lowland evergreen, hill evergreen or freshwater swamp forest; flowering May–April, fruiting June–August.

Vernacular.—Phrik thai pa (พริกไทยป่า)(General).

Notes.— Roemer & Schultes published *Piper lonchites* without indicating a type specimen. Later, Miquel (1844) cited *Wallich s.n.* [Numer. List 6644B] as the type specimen with an explanation that it refered to "the material on the left hand and lower right-hand specimens" (Fig. 3). We found *Wallich s.n.* [Numer. List 6644B] [K001124400] in **K-W** and have chosen this specimen as the lectotype. The other specimens deposited in **BR**, **G-DC**, **K** and **L** are isolectotypes. *Piper lonchites* is similar to *P. nigrum* but differs in its chartaceous leaves, catkintype inflorescence, rounded floral bracts which are spirally arranged in rows and the alternating rows of stamens.The ripe fruits are dark green or black (Fig. 2E).

**20. Piper longum** L., Sp. Pl. 1: 29. 1753; Hook.f., Fl. Brit. India 5: 83. 1887; C.DC. in Lecomte, Fl. Indo-Chine 1: 74. 1910; Long in Grierson & Long, Fl. Bhutan 1(2): 348. 1984; Yongqian, Xia & Gilbert in Wu & Raven, Fl. China 4: 119. 1999; Suwanphakdee *et al.*, Kew Bull. 73 art. 33: 7. 2018. Type: *Herb. Hermann 4: 48* (lectotype **BM** [BM000621029!], designated by Huber 1987).

— *Chavica roxburghii* Miq., Syst. Piperac. 1: 239. 1843. Type: India, Guapara, *Wallich s.n.* [Numer. List 6640D] (lectotype **K-W** [K000794337!], designated by Suwanphakdee *et al.*, 2018).

Thailand.— NORTHERN: Mae Hong Son [Mae Lanoi, 29 Feb. 2004, *Pongamornkul 1815* (**QBG**); Mae Sariang, 1 May 2003, *Pongamornkul 1817* (**QBG**)]; Chiang Mai [Doi Saket, 21 July 2007, *Warintorn 07-049* (**QBG**)]; Lampang [Chae Son NP, 22 Aug. 1995, *Maxwell 95-527* (**BKF**)]; Tak [Sam Ngao, 10 Nov. 1920, *Kerr 4588* (**BK, BM, K, L**); Mae Sot, 19 Aug. 1994, *Maxwell 94-899* (**BKF**]; SOUTH-EASTERN: Phetchabun [Lom Sak, 8 Aug.



Figure 1. A. Piper arcuatum Blume; B. P. argyrites Ridl. ex C.DC.; C. P. baccatum Blume; D. P. betle L.; E. P. boehmeriifolium (Miq.) C.DC. var. boehmeriifolium; F. P. durionoides Suwanph. & Chantar.; G. P. griffithii C.DC.; H. P. kongkandanum Suwanph. & Chantar. (photos by Suwanphakdee).



Figure 2. A. Piper kurzii Ridl.; B. P. laetispicum C.DC.; C. P. lanatum Roxb.; D. P. leptostachyum Wall. ex Miq.; E. P. lonchites Roem. & Schult.; F. P. peepuloides Roxb.; G. P. rostratum Roxb.; H. P. smitinandianum Suwanph. & Chantar. (photos by Suwanphakdee).



Figure 3. Type of Piper lonchites Roem. & Schult.

2002, Suwanphakdee 10 (**BKF**)]; Loei [Phu Kradueng NP, 29 Oct. 1984, Murata et al. T-51750 (**BKF**)]; SOUTH-WESTERN: Phetchaburi [Ban Huai Sok, 22 Aug. 2002, Suwanphakdee 11 (**BK,BKF, KKU**, **DMSC**)]; PENINSULAR: Trang [Khao Chong, 15 July 2003, Suwanphakdee 48 (**BK, BKF, DMSC, KKU**)].

Distribution.— India, Sri Lanka, Bhutan, China, Myanmar, Laos, Vietnam, Cambodia, Malaysia, Indonesia, the Philippines.

Ecology.— In open or disturbed areas, or margins of all forest types; flowering July–August, fruiting August–September.

Vernacular.— Phrik hang (พริกหาง)(Central).

Uses.—All parts, especially the fruit, are used for a medicine.

Notes.— The leaves of *Piper longum* are dimorphic, being cordate or auriculate on sterile shoots and sagittate or ovate on fertile shoots. Fertile (flowering and fruiting) shoots are erect and sterile shoots are creeping. This species is often confused with *P. sarmentosum* but it differs in size, auriculate base leaf, inflorescence size, and fruits which are fully connate.

**21. Piper macropiper** Pennant, Outl. Globe. 4: 242. 1800; Gardner, Blumea 51(3): 582. 2006.— *P. arborescens* Roxb., [Hort. Beng.: 80. 1814, **nom. nud.** ex] Fl. Ind. 1: 161. 1820. Type: Rumphius, Herb. Amb. 5: 46, t. 28, f. 1. 1747.

*— P. moluccanum* Spreng., Syst. Veg. 1: 112. 1817. Type: not located.

*— P. lanceolatum* Roxb., Fl. Ind. 1: 159. 1820. Type: India, *Roxburgh s.n.* (holotype **G** [G00386489!]).

*— P. miniatum* Blume, Verh. Batav. Gen. 11: 166. 1826; Hook.f., Fl. Brit. India 5: 85. 1887; Ridl., Fl. Malay Penins. 3: 39. 1924; Henderson, Malay. Wild Flowers Dicot. 4(3): 440. 1959; Backer & Bakh.f., Fl. Java 1: 171. 1963.*— Chavica miniata* (Blume) Miq., Syst. Piperac. 1: 234. 1843. Type: Indonesia, Java, *Blume s.n.* (lectotype L [L1546296!]; designated here; isolectotypes **BO!**, **G-DC** [G00206627!], **K** [K000794888!]).

*— P. auriculatum* Blume, Verh. Batav. Gen. 11: 171. 1826. Type: not located.

*— P. glandulosum* Opiz in Presl, Rel. Haenk. 158. 1828. Type: not located.

— *Chavica macrostachya* Miq., Syst. Piperac. 1: 236. 1843. Type: Indonesia, Java, *Blume s.n.* (holo-type **BO!**; isotypes: **G-DC** [G00320869!], **L** [L1546169!]).

Thailand.— PENINSULAR: Trang [Thung Khai Botanical Garden, 17 Mar. 2004, *Suwanphakdee 109* (**BK**, **BKF**, **KKU**), *Suwanphakdee 315* (**BK**, **BKF**, **KKU**)]; Narathiwat [Tak Bai, Phu Kok Ku, 17 Apr. 1986, *Niyomdham 1198* (**BKF**, **K**, **L**)].

Distribution.— India, Malaysia, Indonesia, the Philippines.

Vernacular.— Phlu pa (พลูป่า)(Narathiwat).

Ecology.— In peat swamp forest; flowering and fruiting April–September.

Notes.— Blume (1826) described *Piper* miniatum without indicating type specimens. Later, Miquel (1843) transferred it to the genus *Chavica* and refered to *Blume s.n.* in **BO**, **G-DC** [G00206627], **K** [K000794888] **L** [L1546296] and *Cuming 841* (**G-DC** [G00206626!], **TCD** [TCD18340]) as types. We designate the Blume collection in **L** (L1546296) as the lectotype and the others as isolectotypes. In Thailand, *P. macropiper* is distributed mainly in swamp forest of the southern region. The fruits are the smallest in the genus. The palmately patterned leaf venation is showy.

**22. Piper majusculum** Blume, Verh. Batav. Gen. 11: 210. 1826; Backer & Bakh.f., Fl. Java 1: 171. 1963; Gardner, Blumea 51(3): 582. 2006; Suwanphakdee *et al.*, Nordic J. Bot. 2016. 34: 611.— *Chavica majuscula* (Blume) Miq., Syst. Piperac. 271. 1843. Type: Indonesia, Java, *Blume s.n.* (lectotype L [L1546892!], designated by Suwanphakdee *et al.*, 2016; isolectotype G-DC [G00206465!]).

— *P. rotundistigmum* C.DC., Philip. J. Sci. 5: 425. 1910. Type: the Philippines, Mindanao, Lake Lanao, Camp Keithley, *Clemens* 58341-2 (holotype **G-DC** [G00322943!], drawing).

— *P. febrifugum* C.DC., Rec. Bot. Surv. Ind. 6: 10. 1912; Ridl., Fl. Malay Penins. 3: 39. 1924. Type: Malaysia, Sunjei Ujong, Atrar Sang Trap, *Alvin 1867* (lectotype **SING!**, designated by Suwanphakdee *et al.*, 2016; isolectotypes **BM** [BM000949838!], **K** [K000794923!]).

*— P. kraense* Ridl., J. Fed. Mal. States Mus. 10: 112. 1919, as '*kraensis*'. Type: Thailand, Ranong, Kra

Isthmus, *Kloss 7045* (lectotype **K** [K000794895!], designated by Suwanphakdee *et al.*, 2016; isolecto-type **SING!**).

*— P. subgrande* Ridl., Fl. Malay Penins. 5: 329. 1925. Type: Malaysia, Batu caves, *Ridley 14013* (holotype **K** [K000794913!]).

— *P. amboinense* (Miq.) C.DC., Prodr. 16(1): 347. 1869.— *Chavica amboinensis* Miq., Ann. Mus. Bot. Lugduno-Batavi 1: 134. 1863. Type: Indonesia, Amboina, *Forsten s.n.* (lectotype U [U1476512!], designated by Suwanphakdee *et al.*, 2016; isolectotypes L (2 sheets)[L15360006!, L1536005!], U [U1476511!]).

Thailand.— SOUTH-WESTERN: Phetchaburi [Kaeng Krachan NP, 13 May 2005, *Middleton et al.* 3428 (**BKF**)]; PENINSULAR: Chumphon [Ngao NP, Klong Prao Waterfall, 27 Sept. 2003, *Suwanphakdee* 54 (**BK, BKF, DMSC, KKU**); 20 Feb. 2007, *Suwanphakdee 196* (**BKF**); 19 June 2010, *Suwanphakdee 318* (**BK, BKF, DMSC, KKU**); 31 Dec. 2008, *Suwanphakdee 262* (**BK, BKF, KKU**); 14 Nov. 2010, *Suwanphakdee 287* (**BK, BKF, KKU**)].

Distribution.— India, Myanmar, Malaysia, Indonesia, the Philippines.

Ecology.— In shaded or open areas along streams or near waterfalls in evergreen forest; flowering August to September.

Vernacular.— Tue (ตือ)(Phangnga).

Notes.— The leaves of *P. majusculum* are the largest, and the inflorescences the longest, in the woody climbing species of Thai *Piper*.

**23.** Piper minutistigmum C.DC., Rec. Bot. Surv. Ind. 6: 9. 1912; Ridl., Fl. Malay Penins. 3: 43. 1924. Type: Malaysia, Perak, Larut, *Kunstler 2388* (lectotype **G-DC** [G00320785!], designated here).

Thailand.— PENINSULAR: Narathiwat [Tak Bai, 15 Sept. 1985, *Niyomdham 995* (**BKF**, **K**, **L**)].

Distribution.— India, Malaysia, Indonesia, the Philippines.

Ecology.— In peat swamp forest; flowering and fruiting April–September.

Vernacular.— Ta khan nok (ตะค้านนก) (Narathiwat).

Notes.— Candolle (1912) described *Kunstler* 2388 and *Scortechini s.n.* as a syntypes of *Piper* 

*minutistigmum*. We located *Kunstler* 2388 in **G-DC** [G00320785] and, as this specimen was well preserved, we have selected it as the lectotype. *Piper minutistigmum* is similar to *P. betle* but differs in its thick leaves that are coriaceous when dry, and its larger infructescences. In Thailand, this species is found only in swamp forest in the southern region.

**24.** Piper muricatum Blume, Verh. Batav. Gen. 11: 219. 1826; Hook.f., Fl. Brit. India 5: 82. 1887; Ridl., Fl. Malay Penins. 3: 32. 1924; Henderson, Malay. Wild Flowers Dicot. 4(3): 441. 1959; Backer & Bakh.f., Fl. Java 1: 169. 1963; Suwanphakdee *et al.*, Thai Forest Bull., Bot. 34: 209. 2006; Suwanphakdee *et al.*, Kew Bull. 73, 33: 7, 2018. Type: Indonesia, *Blume s.n.*, (lectotype L [L1547468!], designated by Suwanphakdee *et al.*, 2018).

— *P. birmanicum* var. *macrostachyon* C.DC. in A.DC., Prodr. 16(1): 338. 1869. Type: Malaysia, Maluccas, *Griffith* 4408 (holotype **K** [K000794931!]).

— *P. muricatum* f. *peninsulare* C.DC., Rec. Bot. Surv. Ind. 6: 18. 1912. Type: Malaysia, Selangor, *Ridley 8531* (lectotype **SING**!, designated by Suwanphakdee *et al.*, 2018; isolectotype **CAL** [CAL0000025054!]).

Thailand.— PENINSULAR: Yala [Betong, 1 Aug. 1923, *Kerr 7443* (**BK**); Khao Cha Bor, 27 Apr. 1931, *Lakshnakara 820* (**BK**)]; Narathiwat [Hala Bala, 16 Aug. 1995, *Larsen et al. 5678* (**AAU**, **BKF**); 18 Nov. 1971, *Sathaphon 210* (**BKF**, **L**); 22 Nov. 1971, *C.S.S. 276* (**BKF**); 14 Oct. 2005, *Chongko & Boonkongchart 389* (**CMUB**); Waeng, 3 Mar. 1974, *Larsen & Larsen 32890* (**AAU**, **BKF**, **K**, **L**)].

Distribution.— India, Malaysia, Indonesia, the Philippines.

Ecology.— In evergreen forest by streams; flowering and fruiting May.

Vernacular.— Phum nara (พุ่มนรา)(General).

Notes.—*Piper muricatum* is similar to *P. ridleyi* but differs by having stipes which are longer than the fruit. In Thailand, this species is mainly distributed in the area around the Thai-Malaysian border.

**25.** Piper nigrum L., Sp.Pl. 1: 308. 1753; Hook.f., Fl. Brit. India 5: 90. 1887; C.DC. in Lecomte, Fl. Indo-Chine 1: 88. 1910; Backer & Bakh.f., Fl. Java

1: 169. 1963; Yonqian *et al.* in Wu & Raven, Fl. China 4: 115. 1999. Type: *Herb. Hermann 3: 21, No 26* (lectotype **BM**! [BM000621872], first step designated by Huber in Dassanayake & Fosberg (ed.), Revised Handb. Fl. Ceylon 6: 283. 1987, second step designated here).

— *P. laxum* Vahl, Enum. 1: 326. 1804. Type: not located.

*— P. nigrum* var. *trioicum* C.DC., Prodr. 16(1): 363. 1869. Type: Bangladesh, *Griffith* 4423 (**K** (3 sheets) [K000794415!, K000794412! & K000794407!]).

*— Muldera wightiana* Miq., London J. Bot. 5: 557. 1846. Type: India, Courtellum, *Wight 2624* (lectotype **E** [E00313757!], designated here).

*— M. multinervis* Miq., London J. Bot. 5: 558. 1846.— Type: India, Malabar, *Wight 3017* (holotype **K** [K000794416!]).

Thailand.— Cultivated; Chonburi [Sriracha, 18 Aug. 1924, *Collins 1010* (**BK**, **L**)]; Chanthaburi [Khao Ploi Wen, 9 Dec. 1927, *Kerr 18052* (**BK**, **BM**); 19 Jan. 1958, *Larsen & Hansen 561* (**BKF**), Makham, 29 Nov. 2010, *Suwanphakdee 353* (**BK**)]; Chumphon [Thung Tako, 20 Sept. 2002, *Suwanphakdee 14* (**DMSC**)]; Ranong [Kraburi, 25 Dec. 1928, *Kerr 16348* (**BK**)].

Distribution.— Native to India. Introduced into Thailand, other Asian countries and parts of tropical South America, West Africa and Caribbean Islands.

Ecology.— Cultivated; flowering and fruiting all year round.

Vernacular.— Phrik thai (พริกไทย)(General).

Uses.— Cultivated for the production of peppercorns, the well known and widely used spice. Also used as a medicinal plant.

Notes.— Huber (1987) refered to the nomenclatural type of *Piper nigrum* as *Herb. Hermann 3:* 21 and 4: 11 in **BM**. Although there are specimens in two volumes of the Hermann Herbarium, they are part of a single gathering (Jarvis, 2007) and are accepted as a valid first-step lectotypification. In our second-step lectotypification we have chosen **BM** [BM000621872] in 3: 21 because it well preserved. *Piper nigrum* is well known and of high economic value as a spice. The inflorescence of *P. nigrum* consists of unisexual, bisexual or polygamous flowers. The floral bract is oblong when flowering and spathulate when fruiting. The four stamens are transversely dehiscent. The fruits are globose and ripe fruits are dark orange or red.

**26. Piper ornatum** N.E.Br., Gard. Chron. 2: 424. 1884. Type: Sulawesi [Celebes], 8 Sept. 1884, *Curtis s.n.* (holotype **K** [K000820056!]).

Thailand.— Cultivated [Bangkok, Suan Luang Rama IX, 15 Aug. 2004, *Suwanphakdee 159* (**BK**, **DMSC**, **KKU**); Nonthaburi [Bang Yai, 8 Dec. 2010, *Suwanphakdee 355* (**BK**)].

Distribution.— Native to Sulawesi. Introduced into Thailand and elsewhere.

Vernacular.— Phlu long ya (พลูลงยา)(General).

Ecology.— Cultivated in shaded areas with high humidity; flowering and fruiting all year round.

Uses.— Used as an ornamental plant.

Notes.— In Thailand, *Piper ornatum* was orginally recorded as *P. crocatum*, a small shrub with hairs on stems and leaves, and erect and cylindrical inflorescences, native to tropical western South America. *Piper ornatum* is very popular as an ornamental plant as its leaves have many spots or bands and colors such as white, pink, red and purple when young. The globose inflorescence is useful for identification.

**27.** Piper pedicellatum C.DC., J. Bot. 4: 164. 1866; C.DC. in Lecomte, Fl. Indo-Chine 1: 73. 1910; Long in Grierson & Long, Fl. Bhutan 1(2): 349. 1984; Yongqian, Xia & Gilbert in Wu & Raven, Fl. China 4: 124. 1999; Mukherjee, Phytotaxa 338(1): 25. 2018; Suwanphakdee *et al.*, Kew Bull. 73, 33: 7, 2018. Type: "Bengalria orient" *Griffith* 4404 (lectotype **K** [K000794428!]; designated by Gilbert & Xia, 1999; isolectotype **P** [P01656299!]).

— *P. curtipedunculum* C.DC., Notizbl, Konigl. Bot. Gart. Berlin-Dehlem.6: 481. 1917. Type: China, Yunnan, Mengzi, *Henry 10438* (lectotype **B** [B100294777!]; designated here; isolectotypes **A** [A00005900!],**E**[E00318488!],**G-DC**[G00314149!], **K** [K000794373!], **MO** [MO150824!], **US** [US00105456!]).

— *P. clarkei* C.DC., Candollea 1: 186. 1923. Type: India, Darjeeling, *Clarke 9164* (lectotype **K**  [K000794426!], designated by Suwanphakdee *et al.*, 2018; isolectotype **BM** [**BM**000950691!]).

— *P. pedicellatum* C.DC. var. *eglandulatum* Chaveer. & Mokkamul, Acta Phytotax. Geobot. 58(1): 35. 2007. Type: Thailand. Chiang Mai, Doi Inthanon NP, *Chaveerach 48* (holotype **BK!**).

Thailand.— NORTHERN: Chiang Mai [Doi Inthanon NP, 9 Mar. 1931, Garrett 660 (**BKF**, L), San Kamphaeng, 5 Mar. 1996, Maxwell 97-207 (**BKF**)]; Nan [Doi Phu Kha NP, 21 Nov. 1993, Larsen et al. 44694 (**AAU**, **K**, **PSU**), 9 Aug. 1991, Pooma439 (**BKF**), 24 Sept. 1989, Paisooksantivatana Y-2499-89 (**BK**), 2 July 2004, Suwanphakdee 151 (**BK**, **BKF**, **KKU**), 11 Feb. 2006, Suwanphakdee 175 (**BK**, **BKF**, **KKU**)]; Phitsanulok [Phu Hin Rongkla NP, 17 July 2004, Suwanphakdee 156 (**BK**, **BKF**, **KKU**)]; SOUTH-WESTERN: Kanchanaburi [Kwae Noi River Basin, 13 June 1946, Kostermans 863 (**BK**, L); Sangkhlaburi, 1 Apr. 1968, van Beusekom & Phengklai 260 (**BKF**, L)].

Distribution.— Bangladesh, China.

Ecology.— In shaded areas on mountain summits or by streams in evergreen forest; flowering February to March, fruiting July.

Vernacular.— Plu na haeo (พลูนาแห้ว)(General).

Notes.— Candolle (1919) indicated *Henry 10438* as being the type. We found collections in several herbaria (**A**, **B**, **E**, **G-DC**, **MO**, **K**, **US**) and we designated a specimen in **B** [B100294777] as the lectotype because it is informative for species identification. Plants of *Piper pedicellatum* are generally glabrous and the fruits are the smallest of the Thai species.

**28.** Piper peepuloides Roxb., [Hort. Bengal.: 4. 1814, nom. nud. ex] Fl. Ind. 1: 159. 1820; Hook.f., Fl. Brit. India 5: 83. 1887. Suwanphakdee *et al.*, Nordic J. Bot. 34: 613. 2016; Mukherjee, Phytotaxa 338(1): 25. 2018; Mukherjee, Phytotaxa 441(3): 268. 2020.— *Chavica peepuloides* (Roxb.) Miq., Syst. Piperac. 1: 237. 1843. Type: Bangladesh, Sylhet, *Roxburgh. Icon. Pl. 2169* (lectotype K!, designated by Mukherjee, 2020; isolectotype CAL).

*— P. mullesua* Buch-Ham. ex D.Don, Prodr. Fl. Nepal: 20. 1825; Long in Grierson & Long, Fl. Bhutan 1(2): 347. 1984; Yonqian *et al.* in Wu & Raven, Fl. China 4: 115. 1999; Mukherjee, Phytotaxa 338(1): 23. 2018.— *Chavica mullesua* (Buch-Ham. ex D.Don) Miq., Syst. Piperac. 1: 280. 1843. Type: Nepal, Naranhetty, 17 Jan. 1803, *Hamilton s.n.* (lectotype **BM** [BM000950696!], designated by Mukherjee, 2018; isolectotypes **BM** [BM000895997!], **CAL**).

*— P. guigual* Buch-Ham. ex D.Don, Prodr. Fl. Nepal: 20. 1825; Mukherjee, Phytotaxa 338(1): 23. 2018. *Chavica mullesua guigual* (Buch-Ham. ex D.Don ) Miq., Syst. Piperac. 1: 280. 1843. Type. *—* Nepal, Narainhetty, 6 Feb. 1803, *Buchanan-Hamilton s.n.* (lectotype **BM**[BM000950728!], designated by Mukherjee, 2018; isolectotype **CAL**).

— *Chavica neesiana* Miq., Syst. Piperac. 249. 1843; Mukherjee, Phytotaxa 441(3): 268. 2020.— Types: Nepal, *Wallich s.n.* [Numer. List 6656] (lectotype **U** [U1476536!], left-hand specimen on sheet, first step designated (as holotype) by Suwanphakdee *et al.*, 2016, second step designated by Mukherjee, 2020).

— *C. sphaerostachya* Miq., Syst. Piperac. 1: 278. 1843. Type: Nepal, *Wallich s.n.* [Numer. List 6656] (lectotype U [U1476536!], right-hand specimen on sheet, designated by Suwanphakdee *et al.*, 2016; isolectotype **K** [K000794464!]).

— Piper brachystachyum Hook.f., Fl. Brit. India 5:
87. 1886. Type: Nepal, Wallich s.n. [Numer. List 6656] (lectotype K-W [K001124432!]; isolectotype K-W [K001124429!], BM [BM000950695!], G-DC [G00207123!], designated by Suwanphakdee et al., 2016).
— P. vasculosum Wall., nom. nud.

Thailand.—NORTHERN: Chiang Mai [Doi Inthanon NP, 4 Nov. 1994, *Pooma 898* (**BKF**)]; Chiang Rai [Doi Tung, 23 Oct. 1995, *Pooma 1211* (**BKF**)]; Nan [Doi Phu Kha NP, 10 Nov. 1991, *Pooma 551* (**BKF**); 14 Nov. 2001, *Srisanga 2249* (**QBG**); 12 Aug. 2001, *Srisanga & Maknoi 2006* (**QBG**)].

Distribution.— India, Sri Lanka, Nepal, China.

Ecology.— In evergreen, lower montane, forest and hill evergreen forests by streams or on granite of cliffs near waterfalls; flowering and fruiting February.

Vernacular.— Phrik pha (พริกผา)(General).

Uses.— Fresh or dried roots are soaked in spirit alcohol and drunk as a tonic, young leaves are locally used as a vegetable.

Notes.— There has been confusion over the typification of *Piper peepuloides*. Suwanphakdee *et al.* (2016) designated *Wallich s.n.* [Numer. list 6650A] (U [U1476553]) as the lectotype while Mukherjee (2018), apparently unaware of the earlier lectotypification, designated *Wallich s.n.* [Numer. List 6650A] (K [K000794359]) as the lectotype. Mukherjee (2020) provided evidence to demonstrate that both lectotypifications were erroneous and proposed a new lectotypification based on a Roxburgh drawing in K. We accept this here.

Miquel (1843) described *Chavica neesiana* and indicated that it formed the major part of *Wallich s.n.* [Numer. List 6656]. Suwanphakdee *et al.* (2016) selected the specimen on the left-hand side of a sheet in U [U1476536] as the holotype of *C. neesiana* However, Mukherjee (2018) lectotypified *C. neesiana* with *Wallich s.n.* [Numer. List 6656] **K-W** [K001124432], a specimen earlier selected as the lectotype of *Piper brachystachyum* by Suwanphakdee *et al.* (2016). Mukherjee (2020) subsequently cited the left-hand specimen on U14765636 as the lectotype of *C. neesiana*, which we accept. As indicated above, Mukherjee (2020) is designated as a second-step lectotypification.

Some authors (e.g. Mukherjee, 2020) treat *Piper mullesua* as as distinct species from *P. peepuloides* on the basis of differences in the characters of the female spikes. However, we treat them here as conspecific. They are minor differences between the male and female plant, such as leaf shape, larger and thicker leaves in female plants. The male inflorescences are longer than female.

Suwanphakdee et al. (2016) lectotypified Chavica sphaerostachya it with the right-hand specimen on Wallich s.n. [Numer. List 6656](U [U1476536]). Mukherjee (2018), placed it in the synonymy of Piper mullesua and lectotypified it with U1476536, without distinguishing the left or right-hand specimens and citing an earlier barcode (U0016199) attached to the sheet. However, the earlier lectotypification of Suwanphakdee et al. (2016) has prority and is followed here. Suwanphakdee et al. (2016) also lectotypified P. brachystachyum with Nepal, Wallich s.n. [Numer. List 6656](K-W [K001124432!]). Mukherjee (2018) placed P. brachystachyum in the synonymy of P. mullesua and lectotypified with a different specimen, namely Wallich s.n. [Numer. List 6656] (BM [BM1088832]). Again, the earlier lectotypification of Suwanphakdee *et al.* (2016) has prority and is followed here.

*Wallich s.n.* [Numer. List 6656] is notoriously mixed. The collections consist of male and/or female plants and there only minor differences between the sexes. Often, there are more than two specimens on a single herbarium sheet and more than ten sheets in in a wide range of herbaria herbaria such as **BM**, **G**, **K**, **K-W**, **L**, **U** and **MO**. Many determinations have been placed on the sheets, adding to the confusion. We were able to examine nearly all the collections and have concluded that they are conspecific and the typifications indicated above are sound.

*Piper peepuloides* is distinguished by having globose or subglobose erect infructescences, fruits that are very small, dense and connate at the base in some collections, with a spike-like inflorescences in some collections, and young leaves that have a sugary odour when bruised. This species often grows on rocks or cliffs (Fig. 2F).

**29. Piper penangense** (Miq.) C.DC., Prodr. 16(1): 353. 1869; Hook.f., Fl. Brit. India 5: 88. 1887; Ridl., Fl. Malay Penins. 3: 42. 1924; Suwanphakdee & Chantaranothai, Nat. Hist. of Chula. Univ. 8(2): 206. 2009.— *Chavica penangensis* Miq., Syst. Piperac. 1: 279. 1843. Types: Malaysia, Penang, *Wallich s.n.* [Numer. List 6642B] (lectotype L [L0940196!], designated here; isolectotype G-DC (2 sheets) [G00321984!, G00321985!], K (2 sheets) [K000794905!, K000842407!], L [L0940195!]).

Thailand.— PENINSULAR: Yala [Bannang Star, 10 Oct. 1991, *Larsen et al. 42293* (**BKF**); Betong, 23 Feb. 2003, *Niyomdham et al. 6053* (**BKF**); 23 May 2005, *Middleton et al. 3622* (**BKF**); Tan To Waterfall, Ban Chulaphon Phatthana 7 area, 9 Feb. 2004, *Middleton et al. 2857* (**BKF**)].

Distribution.- India, Malaysia.

Vernacular.— Cha phlu pinang (ชะพลูปีนัง) (General).

Ecology.— In shaded areas, along streams, near waterfalls or in open areas on mountain summit and in lowland and hill evergreen forest; flowering and fruiting in May.

Notes.— Miquel (1843) published *Chavica* penangensis based on *Wallich s.n.* [Numer. List 6642B].Later, *C. penangense* was transferred to *Piper penangense* by Candolle (1896). We found two collections of *Wallich s.n.* [Numer. List 6642B] in L and others in G and K. We designate the collection in L [L0940196] as the lectotype because it is the best preserved and most informative for species identification. The distinctive character of *P. penangense* is its style-like fruit spine. This species is similar to *P. sarmentosum* in gross morphology but differs in the style-like fruit spine and the free fruit.

**30. Piper polycarpa** Ridl., J. Fed. Malay States Mus. 9: 112. 1919; Suwanphakdee & Chantaranothai, Nat. Hist. J. Chula. Univ. 8(2): 208. 2008. Type: Thailand, Tasan, Kra Isth, *Kloss 6888* (holotype **K** [K000794894!]).

*— Chavica venosa* Miq. Pl. Jungh. 1: 295. 1854. Type: not located.

*— Piper venosum* (Miq.) C.DC., Prodr. 16(1): 340. 1869. Type: not located.

— *P. dominantinervium* A.Chaveer. & P.Mokkamul, Acta Phytotax. Sin. 44(4): 447. 2006. Type: Thailand, Phangnga, Sri Phangnga NP, *Chaveerach 63498-500* (**BK**?, **KKU**?).

Thailand.—PENINSULAR: Ranong [Kraburi, 1 Feb. 1927, Kerr 11742 (BK, BM, K, L); Kerr 11742A (BK, BM, L); Bok Krai Waterfall, 30 Dec. 2008, Suwanphakdee 261 (BK, BKF, KKU); Khao Pra Mi, 8 Jan. 1966, Hansen & Smitinand 11844 (BKF, L); 27 Feb. 1968, Vacharapong 152 (BK); 8 Jan. 1966, Sutheesorn 766 (BK); Khlong Na Kha WS, 26 Jan. 2007, Suwanphakdee 207 (BKF); 209 (BKF); 19 June 2010, Suwanphakdee 316 (BK, **KKU**); 29 Sept. 2003, Suwanphakdee 56 (**BK**)]; Phangnga [Kuraburi, 29 April 1973, Geesink & Santisuk 5040 (BKF, L); Thap Put, 5 Mar. 1930, Kerr 18375 (BK, BM, L); Ta Kua Pa, 3 Feb. 1929, Kerr 17061 (BK, BM, K, L); Sri Phangnga NP, 22 Mar. 2004, Suwanphakdee 115 (DMSC); 6 Apr. 2006, Suwanphakdee 180 (BKF); 8 Nov. 2009, Suwanphakdee 279 (BK, BKF, KKU)]; Trang [Khao Chong, 9 July 2000, Middleton et al. 333 (**BKF**); 17 Mar. 2004, Suwanphakdee 106 (**BKF**); Suwanphakdee 107 (KKU)]; Narathiwat [Ba Cho, 17 Dec. 1968, Sangkhachand 1580 (BK)].

Distribution.- Malaysia, Indonesia.

Ecology.— In open or shaded areas, along streams or near waterfalls to mountain summits in

evergreen forest; flowering February–March, fruiting March–September.

Vernacular.— Phlu kae (พลูแก)(Ranong); phlu nang khao (พลูหนังเขา)(Phangnga).

Notes.—*Piper polycarpa* has zigzag stems and its leaf venation is pinnate with 5–12 pairs of veins. Based on vegetative characters, this species differs from *P. laetispicum* in the higher number of secondary veins and the subcoriaceous leaf. The floral bracts are rounded and have sparsely ciliate margins.

**31. Piper porphyrophyllum** N.E.Br., Gard. Chron. 22: 438. 1884; Ridl., Fl. Malay Penins. 3: 45. 1924; Suwanphakdee *et al.*, Kew Bull.73: art. 33: p. 7, 2018. Type: Malaysia, Penang, *Wallich s.n.* [Numer. List 6643E] (lectotype **K-W** [K000794902!], designated by Suwanphakdee *et al.*, 2018; isolecto-type **K** [K000794900!]).

*— P. leptonema* Hook.f., Fl. Brit. India 5: 91. 1886. Type: Malaysia, *Maingay* 1335 (holotype **K** [K000794898!]).

Thailand.— PENINSULAR: Surat Thani [Khao Sok NP, 9 Nov. 2009, *Suwanphakdee 282* (**BKF**, **KKU**)]; Yala [Hala Bala WS, 4 Oct. 1999, *Niyomdham et al. 5917* (**BKF**)].

Distribution.- Malaysia, Singapore.

Ecology.— In shaded areas near streams in evergreen forest.

Vernacular.— Phlu tuk kae (พลูตุ๊กแก)(Yala).

Uses.— Potentially an ornamental plant.

Notes.—Young leaves of *Piper porphyrophyllum* have red, pink, purple, white and shiny black spots or bands which are similar to those of *P. ornatum*. However, it differs in its mature leaves which turn to plain green and are coriaceous or subcoriaceous when dry. Its floral bracts and fruit are similar to those of *P. nigrum* but it differs in the inflorescence which is a catkin, and the fruit is smaller and loose on the rachis.

**32. Piper quinqueangulatum** Miq. in Zoll., Syst. Verz. 2: 85. 1854; Backer & Bakh.f., Fl. Java 1: 170. 1963; Gardner, Blumea 51(3): 583. 2006; Suwanphakdee *et al.*, Nordic J. Bot. 34: 615. 2016. Type: Indonesia, Java, *Zollinger 1233* (holotype **P** [P01952129!]).

— *P. korthalsii* Miq., Ann. Mus. Bot. Lugd. Bat. 1: 139. 1863. Type: Indonesia, Sumatra, *Korthals s.n.* (lectotype **L** [L1547158!], designated by Suwanphakdee *et al.*, 2016; isolectotype **K** [K000820065!]).

— *P. cristatum* C.DC. in Elmer, Leaflets Philipp. Bot 3: 770. 1910. Type: The Philippines, Mindanao, *Elmer 10703* (lectotype **G-DC** [G00329641!], designated by Suwanphakdee *et al.*, 2016; isolectotype **BISH** [BISH1004059!], **E** [E00504353!], **GH** [GH00005949!], **K** [K000587330!], **MO** [MO-022706!], **NY** [NY00283898!], **US** [US00105445!]).

— *P. magnibaccum* C.DC., Rec. Bot. Surv. Ind. 6: 5. 1912; Ridl., Fl. Malay Penins. 3: 46. 1924; Henderson, Malay. Wild Flowers Dicot. 4(3): 439. 1959; Suwanphakdee *et al.*, Thai Forest Bull., Bot. 34: 207. 2006. Type: Malaysia, Perak, Maxwell Hill, *Ridley 5480* (lectotype **SING!**, designated by Suwanphakdee *et al.*, 2006; isolectotype **G-DC** [G00320017!]).

*— P. amphibracteatum* C.DC., J. Linn. Soc. Bot. 42: 128. 1914. Type: Malaysia, *Gibbs s.n.* Feb. 1910 (holotype **BM** [BM000624277!]).

— *P. salticola* Ridl., J. Asiat. Soc. Mal. 1: 88. 1923. Type: Indonesia, Sumatra, *Ridley s.n.*, Feb. 1921 (lectotype **K** [K000820064!], designated by Suwanphakdee *et al.*, 2016; isolectotype **K** (2 sheets) [K000575307! & K000820063!]).

Thailand.— SOUTH-WESTERN: Phetchaburi [Kaeng Krachan NP, 9 May 2005, *Middleton et al. 3332* (**BKF**)]; PENINSULAR: Chumphon [Khao Nom Sao, Patoh, 8 Dec. 2011, *Suwanphakdee 374* (**BKF**, **BK**, **KKU**)]; Nakhon Si Thammarat [Khao Luang NP, 25 Jan. 1966, *Hansen & Smitinand 12055* (**BKF**); 17 May 1968, *van Beusekom & Phengklai 831* (**BKF,L**); 7 May 2004, *Suwanphakdee 140* (**DMSC**); 20 Mar. 2008, *Suwanphakdee 225* (**BK**, **BKF, KKU, QBG**); *Suwanphakdee 226* (**BK, BKF**, **KKU, QBG**); 2 Apr. 2010, *Suwanphakdee 271* (**BK**, **BKF, KKU, QBG**)]; Yala [Khao Han Kut, 25 Mar. 1998, *Niyomdham 5332* (**BKF, K**)].

Distribution.— India, Malaysia, Indonesia and the Philippines.

Ecology.— In freshwater swamps by streams or near waterfalls; flowering and fruiting March– April.

Vernacular.— Phlu chet pik (พลูเจ็ดปีก)(General).

Notes.— The 7-winged stem and petiole are diagnostic and have a superficial resemblance to *Dioscorea* (Dioscoreaceae). The fruit apex is style-like and both pointed and curved.

**33. Piper ramipilum** C.DC., Rec. Bot. Surv. Ind. 6(1): 3. 1912; Ridl., Fl. Malay Penins. 3: 39. 1924; Suwanphakdee *et al.*, Thai Forest Bull., Bot. 34: 209. 2006. Type: Malaysia, Penang, Balik Palau, *Curtis* 792 (lectotype **SING**!, designated by Suwanphakdee *et al.*, 2006; isolectotype **K** [K000794922!]).

*— Chavica frustrata* Miq., Pl. Jungh. 1: 16. 1852. Type: not located.

Thailand.— PENINSULAR: Chumphon [Tha Sae, Ka Poh Waterfall, 12 Apr. 1967, Sutheesorn 2201 (BK), 9 Feb. 1979, Koyama et al. 15337 (BKF)]; Nakhon Si Thammarat [Khao Luang NP, 29 July 1994, Smitinand 781 (BKF); 7 May 2004, Suwanphakdee 136 (BK, BKF, DMSC, KKU); 2 Apr. 2010, Suwanphakdee 270 (BK, BKF, KKU); 19 Apr. 2010, Suwanphakdee 309 (BK, BKF, KKU); 20 Apr. 2010, Suwanphakdee 312 (BK, BKF, KKU)]; Phatthalung [Khao Pu Khao Ya NP, 22 Mar. 1986, Maxwell 86-192 (BKF)]; Trang [Khao Chong, 16 Aug. 1964, Suvarnakoses 2180 (BKF); 13 Mar. 1966, Bunnab 469 (BKF); 23 Mar. 1966, Bunnab 470 (**BKF**); 19 July 1969, Sangkhachand 1997 (BK); 16 Mar. 2004, Suwanphakdee 105 (BK, BKF, KKU)]; Songkhla [Ton Nga Chang WS, 19 Mar. 2004, Suwanphakdee 110 (DMSC, KKU); 11 Nov. 2009, Suwanphakdee 284 (BK, BKF, KKU)]; Yala [Bannang Star, 10 Oct. 1991, Larsen et al. 42295 (BKF); Betong, 20 July 2004, Pooma et al. 4459 (BKF)]; Narathiwat [Bacho Waterfall, 18 June 1992, Larsen et al. 42983 (BKF)].

Distribution.- India, Malaysia.

Ecology.— Open areas or disturbed areas in evergreen forest; flowering March, fruiting May.

Vernacular.— Phrik khao (พริกเขา)(Nakhon Si Thammarat).

Notes.—*Piper ramipilum* has uniquely ramulose hairs on all parts except the fruit. The rows of floral bracts are alternately arranged with the rows of stamens.

**34.** Piper retrofractum Vahl, Enum. Pl. 1: 314. 1804; C.DC. in Lecomte, Fl. Indo-Chine 1: 83. 1910;

Backer & Bakh.f., Fl. Java 1: 172. 1963; Yongqian, Xia & Gilbert in Wu & Raven, Fl. China 4: 128; 1999; Gardner, Blumea 51(3): 583. 2006.— *Chavica retrofracta* (Vahl) Miq., Syst. Piperac. 1: 275. 1843. Type: 'Habitat in India orientali', *unknown collector s.n.* (lectotype C [C10016619!], first step designated by Gardner, 2006, second step designated here).

*— P. longum* Blume, Verh. Batav. Gen. 11: 197. 1826. Type: not located.

— *P. chaba* Hunter, As. Res. 9: 391. 1809. Type: not located.

*— P. parvifolium* Blanco, Fl. Filip. 1: 23. 1837. Type: not located.— *Chavica parviflora* Hassk., in Fl. 47: 59. 1864. Type: not located.

*P. officinarum* (Miq.) C.DC., Prodr. 16(1): 356.
1869. *Chavica officinarum* Miq., Syst. Piperac.
1: 256. 1843. Type: Indonesia, Java, *Blume s.n.* (K
[K000820050!]).

Thailand.— Cultivated: NORTHERN: Chiang Mai [Mae Sa, 4 Jan. 1989, Pooma 137 (BKF, CMUB)]; CENTRAL: Saraburi [Phu Kae, 10 Jan. 1989, Santisuk 6880 (BKF)]; Bangkok [Bangkhen, 4 May 1924, Kerr 8960 (BK, L); 8 Aug. 1974, Maxwell 74-748 (BK)]; Nonthaburi [Medicinal Plant Research Institute, 1 Apr. 2002, Suwanphakdee 3 (KKU, DMSC)]; SOUTH-EASTERN: Chanthaburi [Muang, 14 July 2003, Maxwell 03-194 (BKF, CMUB)]; Trat [Ban Kadan, 21 Nov. 1971, Vidal 5796 (BKF)]; Rayong [Ban Pa, 2 Sept. 1979, Sirisuk 343 (CMUB)]; Chon Buri [Sattahip, 5 Nov. 1969, Maxwell s.n. 5 Nov. 1969 (BK)]; SOUTH-WESTERN: Ratchaburi [Ban Ping, 15 Oct. 1916, Winit 424 (BKF)]; PENINSULAR: Chumphon [Sawee, 23 Aug. 1988, Vacharee 684 (BK)]; Suratthani [Wiangsa, 8 Aug. 2005, Pooma et al. 5551 (BKF); Tha Chana, 13 June 2006, Williams et al., 1708 (BKF)]; Phattalung [Khuan Khanun, 24 Dec. 2006, Pooma et al. 6617 (BKF)]; Nakhon Si Thammarat [Thung Song, 27 July 1929, Bunnak 222 (BK, BM, L)]; Satun [Muang, 10 Mar. 2006, Middleton et al. 4195 (BKF)].

Distribution.— Bangladesh to the Philippines.

Vernacular.— Di pli (ดีปลี)(General); di pli chueak (ดีปลีเชือก)(Peninsular).

Ecology.— Cultivated, flowering and fruiting all year around.

Uses.— Economic plant used for spice and seasoning throughout Asia; also used for medicine.

Notes.— The plants all have fully connate fruits and erect infructescences. Male inflorescence collections are only known from the Philippines. The cultivated plant in Thailand is female only but can form fruits as this species can be parthenocarpic.

**35.** Piper ribesioides Wall., Pl. As. Rar. 1(4): 79. 1830; C.DC., Prodr. 16(1): 342. 1869; Hook.f., Fl. Brit. India 5: 81. 1887; Ridl., Fl. Malay Penins. 3: 34. 1924; Henderson, Malay.Wild Flow.Dicot. 4(3): 442. 1959; *Suwanphakdee et al.*, Kew Bull.73, 33: 14. 2018. Type: Myanmar, Chappedong, *Wallich s.n.* [Numer. List 6637] (lectotype **K-W** [K001124357!], designated by Suwanphakdee *et al.*, 2018; isolectotypes **BM** [BM000949830!], **G** [G00438866!], **G-DC** [G00206359!], **K** (4 sheets)[K000061828!, K000794384!, K000794385!, K000794386!]).

— *P. sumatranum (Miq.)* C.DC., Prodr. 16(1): 343. 1869; Hook.f., Fl. Brit. India 5: 81. 1887.— *Chavica sumatrana* Miq., Comm. Phyt.: 3: 33. 1840. Type: Malaysia Penang, *Wallich s.n.* [Numer. List 6646B] (lectotype **K-W** [K001124405!], designated by Suwanphakdee *et al.*, 2018; isolectotype **BM** [BM000949828!]).

Thailand.— EASTERN: Nakhon Ratchasima [Ka Tok, 30 Dec. 1943, Kerr 8183 (BK, BM, K, L); Ban Rai, 23 Nov. 1924, Kerr 9455 (BK, BM, K); Khao Yai NP, 19 Mar. 1965, Kasem 447 (BK); 14 Mar. 1968, van Beusekom & Phengklai 42 (BKF, L)]; Ubon Ratchathani [Phu Chong Na Yoi NP, 5 Dec. 2003, Suwanphakdee 74 (DMSC)]; SOUTH-EASTERN: Prachinburi [Khao Yai NP, 27 Mar. 1998, Wongprasert s.n. (BKF)]; Chon Buri [Khao Khieo WS, 5 Jan. 1975, Maxwell 75-4 (BK, L); 28 Mar. 1976, *Maxwell* 76-166 (**BK**, **L**)]; SOUTH-WESTERN: Kanchanaburi [Thong Pha Phum NP, 31 Jan. 2004, Suwanphakdee 86 (BK); same locality, 13 Apr. 2004, Suwanphakdee 125 (KKU); Suwanphakdee 127 (DMSC)]; CENTRAL: Nakhon Nayok [Khao Yai NP, 17 Mar. 2000, Charoenchai 896 (BKF); 25 Apr. 2001,. Maxwell 01-271 (BKF); 8 May 2006, Maxwell 06-308 (**QBG**)]; PENINSULAR: Chumphon [Pa Toh, 27 Feb. 1927, Kerr 12140 (BK, BM, K)]; Ranong [Khlong Na Kha WS, 4 Nov. 1974, Geesink et al. 7570 (BKF, K, L); Muang Len, 11 Jan. 1966, Hansen & Smitinand 11902 (BKF, L); 29 Sept.

2003, Suwanphakdee 56 (KKU); Suwanphakdee 57 (DMSC); 26 Jan. 2007, Suwanphakdee 210 (BK)]; Phangnga [Sri Phangnga NP, 22 Mar. 2004, Suwanphakdee 116 (KKU); 10 Dec. 2003, Pooma et al.3764 (BKF)]; Krabi [Muang, 20 Oct. 2006, Suwanphakdee 185 (BK)]; Nakhon Si Thammarat [Khao Luang NP, 23 Jan. 1966, Sutheesorn 871 (BK); 25 Mar. 1993, Chantaranothai et al. 1371, (TCD); 7 May 2004, Suwanphakdee 133 (KKU); Suwanphakdee 134 (DMSC); 19 Apr. 2010, Suwanphakdee 310 (BK, BKF, KKU); 2 Apr. 2010, Suwanphakdee 267 (BK, BKF, KKU)]; Phatthalung [Khao Pu Khao Ya NP, Riang Tong Waterfall, 23 Mar. 1986, Maxwell 86-213 (BKF, L)]; Trang [Yan Ta Khao, Khao Chong, 9 Mar. 1976, Chermsirivattana & Sangkhachand 2210 (BK); 24 Nov. 1985, Bunnab 185 (BKF); 17 May 2004, Suwanphakdee 106 (BKF); 9 Nov. 1988, Paisooksantivatana Y-2293-88 (**BK**)]; Yala [Betong, 26 July 1928, Kerr 7330 (**BK**, BM, K, L)].

Distribution.— India, Myanmar, Laos, Vietnam, Cambodia, Malaysia, Indonesia, the Philippines.

Ecology.— Common in lowland and hill evergreen forest; flowering March, fruiting May.

Vernacular.— Ta khan lek (ตะค้านเล็ก)(Trat); ta khan yuak (ตะค้านหยวก)(Nakhon Si Thammarat).

Uses.- The stems are used for medicine.

Notes.— The fresh leaves of *Piper ribesioides* are the thickest of any Thai *Piper* spp. and are strongly coriaceous when dry. Leaf size and shape are variable and differ between those on the ground and those on the climbing part of the plant. The inflorescences can be single or in clusters of 2–3 inflorescences, and there are 3-ovate floral bracts surrounding the stamens or ovary. The fruits are globose, free with a long stalk (3–7 mm long) and shiny. The ripe fruits are dark orange to red and rugose when dry.

**36.** Piper ridleyi C.DC., Rec. Bot. Surv. Ind. 6: 19. 1912; Ridl., Fl. Malay Penins. 3: 33. 1924; Suwanphakdee *et al.*, Thai Forest Bull., Bot. 34: 210. 2006; Suwanphakdee *et al.*, Kew Bull. 73, 33: 14. 2018. Type: Malaysia, Selangor, Suiting Peras, *Ridley 7609* (lectotype **SING!**, designated by Suwanphakdee *et al.*, 2018; isolectotype **CAL** [CAL0000020946!]).

— *P. velutibracteatum* C.DC., Ann. Cons. Jard. Bot. Gen. 21: 289. 1920. Type: North Borneo, Labuk Bay, *Ridley s.n.* (holotype **SING**!).

*— P. malaccense* C.DC., Rec. Bot. Surv. Ind. 6: 12. 1912; Ridl., Fl. Malay Penins. 3: 33. 1924. Type: Malaysia, Moluccas, *Merliman 1617* (lectotype **K** [K000794929!], designated by Suwanphakdee *et al.*, 2018).

Thailand.— PENINSULAR: Yala [Betong, 6 Aug. 1923, *Kerr 7443* (**BK**, **BM**, **K**, **L**); 9 Aug. 1923, *Kerr 7903* (**K**); Kao Cha Bor, 27 Apr. 1931, *Lakshnakara 820* (**BK**, **BM**, **K**); 19 July 2004, *Pooma et al. 4427* (**BKF**)]; Narathiwat [Sungai Kolok, 3 Mar. 1974, *Larsen & Larsen 32890* (**BKF**); 7 Apr. 1997, *Niyomdham & Puudjaa 4978* (**BKF**); Waeng, 18 Nov. 1971, *C.S.S. 210* (**BKF**); Hala Bala WS, 5 May 2004, *Suwanphakdee 144* (**BKF**, **DMSC**)].

Distribution.— India, Malaysia, Indonesia, the Philippines.

Ecology.— In evergreen forest; flowering and fruiting May.

Vernacular.— Phlu rit le (พลูริดเลย์)(General).

Notes.— *Piper ridleyi* is an undershrub or small shrub and all its parts are covered with dense woolly or pilose hairs. The stipe of *P. ridleyi* is shorter than the fruit.

**37. Piper rostratum** Roxb., Fl. Ind. 1: 162. 1820; Hook.f., Fl. Brit. India 5: 87. 1887; Suwanphakdee & Chantaranothai, Trop. Nat. Hist. 8(2): 206. 2008; Suwanphakdee *et al.*, Kew Bull. 73, 33: 14. 2018.— *Peperomia rostrata* (Roxb.) A.Dietr., Sp. Pl. 1: 153. 1831. Type: Malaysia, Malacca, *Roxburgh 2675* (holotype **BM** [BM000939635!]).

*— Rhyncholepis roxburghii* Miq., Syst. Piperac. 1: 284. 1843. Type: Malaysia, Maluccas, *Roxburgh* 2675 (holotype **BM** [BM000939635!]).

— *Piper stylosum* Miq., Ann. Bot. Mus. Lugd. Bat. 1: 139. 1863; Ridl., Fl. Malay Penins. 3: 42. 1924; Henderson, Malay. Wild Flowers Dicot. 4(3): 440. 1959. Type: Indonesia, Sumatra, *Korthals s.n.* (lectotype L [L1547514!], designated by Suwanphakdee *et al.*, 2018; isolectotype K [K000820049!], L [L1547518!]).

— *P. birmanicum* C.DC., J. Bot. 4: 163. 1866. Type: Malaysia, Moluccas, *Griffith* 4414 (lectotype **K**  [K000794910!], designated by Suwanphakdee *et al.*, 2018; isolectotype **K** (2 sheets)[K000794908! & K000790909!]).

Thailand.— PENINSULAR: Trang [Yan Ta Khao, Phu Pha Mek, 6 Apr. 2003, *Middleton et al. 1953* (**BKF**)]; Yala [Betong, 15 July 1923, *Kerr 7202* (**BK, BM, K**); 11 Aug. 1923, *Kerr 7571* (**BK, BM, K**); 12 Aug. 1923, *Kerr 7903A* (**K**), 19 July 2004, *Pooma et al. 4424* (**BKF**); Hala Bala WS, 1 May 2004, *Suwanphakdee 141* (**BK, DMSC**)]; Narathiwat [Hala Bala WS, 9 Mar. 2004, *Chongko 255* (**CMUB**); Khao Pi Sat, 30 Apr. 1998, *Niyomdham & Puudjaa 5457* (**BKF**)].

Distribution.-Malaysia, Singapore, Indonesia.

Ecology.— In lowland or hill evergreen forest; flowering and fruiting May.

Vernacular.— Cha phlu khon (ชะพลูขน)(General).

Notes.— *Piper rostratum* resembles *P. sarmentosum* but differs in having woolly, velutinous or scabrous hairs. Generally, the inflorescence is a catkin and sometimes spike-like. The fruits are free with a style-like spine at the apex (Fig. 2G).

**38. Piper sarmentosum** Roxb. in Hunter, As. Res. 11: 565. 1810; Ridl., Fl. Malay Penins. 3: 40. 1924; Backer & Bakh.f., Fl. Java 1: 172. 1963; Yongqian *et al.* in Wu & Raven, Fl. China 4: 119. 1999. Type: India, Calcutta, *Roxburgh 1267* (lectotype **BM** [BM000950704!]; designated by Gilbert & Xia, 1999).— *Chavica sarmentosum* (Roxb.) Miq., Syst. Piperac. 1: 242. 1843.

— *P. brevicaule* C.DC., Ann. Conserv. Jard. Bot. Gen. 2: 272. 1898; C.DC. in Lecomte, Fl. Indo-Chine 1: 71. 1910. Type: Vietnam, Tonkin, village de Tchontiao, *Balansa 3631* (lectotype **P** [P02030064!]; isolectotype **P**[P02030063!], designated by Gilbert & Xia, 1999)

- P. lolot C.DC., Ann. Conserv. Jard. Bot. Gen. 2: 272. 1898; C.DC. in Lecomte, Fl. Indo-Chine 1: 86. 1910. Type: Vietnam, Tonkin, Environs de Quang-Yen, Balansa 539 (holotype P!).

*— P. albispicum* C.DC. in Lecomte, Fl. Indo-Chine 5: 85. 1910. Type: Vietnam, Tonkin, meridional, *Bon* 983 (holotype **G-DC** [G00317821!]).

— *P. gymnostachyum* C.DC. in Lecomte, Fl. Indo-Chine 5: 72. 1910. Type: Cambodia, Phuocthan, *Thorel "T" s.n.* (holotype **P** [P02025575!]). — *P. pierrei* C.DC. in Lecomte, Fl. Indo-Chine 5: 78. 1910. Type: Vietnam, In Sylvis at Baochiang in austro cochinchine, *Pierre 1042* (lectotype **P** [P01656234!]; designated here; isolectotypes **G-DC** [G00322055!], **P** [P01656235!]).

— *P. saigonense* C.DC. in Lecomte, Fl. Indo-Chine 5: 79. 1910. Type: Vietnam, Ad urbem Saigon in austro Cochinchine, *Pierre 1142* (lectotype **P** [P01980655!], designated here; isolectotypes **C** [C10016632!], **G-DC** [G00323001!], **MO** [MO204016!], **P**(2 sheets)[P01980654!, P01980647!]).

— *P. siassiense* C.DC., Philip. J. Sci. 5: 443. 1910. Type: the Philippines, Siassi Island, *Merrill 5311* (lectotype **G-DC** [G00322960!]; designated here; isolectotype **NY** [NY00283930!], **P** [P02029921], **US** [US00107083!]).

Thailand.—NORTHERN: Chiang Mai [Muang, 9 July 1991, Pooma 504 (BKF); Doi Chiang Dao WS, 4 Feb. 1979, Bjørland & Schumacher 563 (BKF)]; Phayao [Doi Luang NP, 11 Aug. 1997, Detrmitr 72 (BKF)]; Lampang [Mae Salop, 25 Sept. 1925, Winit 1464 (BK, BKF); Muang Bahn, 29 Oct. 1996, Maxwell 96-1423 (BKF); Muang, 15 Apr. 2004, Kietinum et al. 16 (BKF)]; Phitsanulok [Thung Salaeng Luang NP, 20 July 1966, Larsen et al. 556 (BKF, L)]; NORTH-EASTERN: Loei [Chiang Karn, 3 Sept. 1968, Phengnaren 589 (BKF); Phu Luang WS, 29 Sept. 1990, Chantaranothai et al. 90/435 (KKU, TCD)]; Nakhon Panom [Muang, 4 Nov. 1982, Vacharee 407 (BK)]; EASTERN: Nakhon Ratchasima [Khao Yai NP, 23 May 2002, Detrmitr 520 (**BKF**); 10 July 2004, Suwanphakdee154 (BKF)]; SOUTH-WESTERN: Uthai Thani [Huai Kha Khaeng WS, 18 Nov. 1989, Smitinand 89-35 (BKF)]; Kanchanaburi [Kwae Noi River Basin, 2 May 1946, Wichian 321 (BK, L); Sai Yok, 6 Nov. 1979, Shimizu et al. T-21792 (BKF); 3 July 1963, Larsen 10481 (BKF); Sangklaburi, 13 Aug. 1993, Maxwell 93-893 (BKF)]; CENTRAL: Lop Buri [Wang Kan Leung Waterfall, 19 Nov. 1984, Murata et al. T-51033 (BKF)]; Ang Thong [Muang, 17 Sept. 1972, Maxwell 72-392 (BK)]; Saraburi [Sam Lan Waterfall, 29 July 1974, Maxwell 74-745 (BK, L); 2 Nov. 1974, Maxwell 74-960 (BK, L)]; Nonthaburi [Medicinal Plant Research Institute, 1 Apr. 2002, Suwanphakdee 2 (**BKF,DMSC**)]; Bangkok [Bang Khen, 9 Oct. 1921, Lakhanakhara 213 (BK, L); 5 Sept. 1924, Kerr 11041 (BK); 28 June 2004, Suwanphakdee 147 (BK)]; SOUTH-EASTERN : Chon Buri [Sriracha, 26

Aug. 1924, *Collins 1009* (**BK**)]; Chanthaburi [Khao Soi Dao Wildlife Sacntuary, 24 Aug. 1972, *Larsen et al. 31934* (**BKF**); Priw Waterfall, 19 Jan. 1958, *Sørensen et al. 541* (**BKF**, L)]; PENINSULAR: Surat Thani [Ko Samui, 8 Apr. 1927, *Kerr 12535* (**BK**, **BM**); 3 Dec. 1974, *Geesink et al. 7741* (**BKF**, K); 14 July 2003, *Suwanphakdee 47* (**KKU**); Oct. 1915, *Vanpruk 777* (**BKF**, K)].

Distribution.— India, Sri Lanka, Myanmar, China, Laos, Vietnam, Cambodia, Malaysia, Indonesia, the Philippines.

Ecology.— Common or in disturbed areas or cultivated; flowering and fruiting all year round.

Vernacular.— Cha phlu (ชะพลู)(General).

Uses.— The leaves are used locally as a vegetable and the roots are used for medicine.

Notes.— This species is common in Southeast Asia and has a number of synonyms. *Piper saigonense* was named by Candolle (1910), with *Pierre 1142* as the type. We found several collections under this number and chose the collection from **P** [P01980655] as the lectotype because it is the best preserved. The Philippine species, *P. siassiense* was also published by Candolle (1910) and was based on *Merrill 5311*. We again found several collections and chose the specimen from **G-DC** [G00322960] as the lectotype, as it is the best available material.

*Piper sarmentosum* is markedly variable in leaf shape and size, and they also differ between male and female plants. In general, the inflorescence is a catkin but can sometimes be a spike. The male inflorescence is longer than the female and is fragrant. Both male and female inflorescences, as well as the infructescences, are erect. The fruits are free or sometimes connate at the base and are dark purple or black when ripe.

**39. Piper smitinandianum** Suwanp. & Chantar., Thai Forest Bull., Bot. 40: 34. 2012. Type: Narathiwat, Waeng, 12 June 1970, *Smitinand 10907* (holotype **BKF**!).

Thailand.— PENINSULAR: Narathiwat [Waeng, 20 Sept. 1965, *Phengklai & Smitinand 1188* (**BKF**), 12 June 1970, *Smitinand 10907* (**BKF**), 22 Nov. 1971, *C.S.S. 268* (**BKF**), same locality, 28 Oct. 2017, *Suwanphakdee 553* (**BK, BKF, QBG**), same date, *Suwanphakdee 554* (**BKF**)]. Distribution.— Endemic.

Ecology.—Along streams in evergreen forest; flowering September–November, fruiting November– June.

Vernacular.— Prik thai a chan tem (พริกไทย อาจารย์เต็ม)(General).

Notes.— Suwanphakdee *et al.* (2012) published *Piper smitinandianum* as a new species based on herbarium specimens deposited in **BKF**. Later, the first author revisited the type locality, collected living specimens and found a male plant, which allowed further morphological characters to be added to the species description. The plant has prop-roots from the nodes. The male inflorescence is cylindrical and 3–5 cm long. The male flower has a rounded floral bract 1.5–2 mm in diameter. The anthers are 1–1.5 mm long with 1 mm long filaments. The peduncle is 1–1.5 cm long. The inflorescence is 1.5–4 by 1–1.5 cm (Fig. 2H).

**40. Piper suipigua** Buch-Ham. ex D.Don, Prodr. Fl. Nepal. 20. 1825; Long in Grierson & Long, Fl. Bhutan 1(2): 350. 1984; Yongqian *et al.* in Wu & Raven, Fl. China 4: 128. 1999; Mukherjee, Phytotaxa 338(1): 28. 2018.— *Chavica suipigua* (Buch-Ham. ex D.Don) Miq., Syst. Piperac. 1: 275. 1843. Type: Nepal, Naranhetty, 21 Aug. 1802, *Buchanan s.n.* (holotype **BM** [BM000950698!]; isotype **G-DC** [G00206597]!).

— *P. nepalense* Miq., Syst. Piperac. 1: 318. 1843. Type: Nepal, *Wallich s.n.* [Numer. List 6650B] (lectotype U [U1476540!], designated by Mukherjee, 2018; isolectotypes **BR** [BR0000006599409!], **C** [C10016600!], **CAL**, **G-DC** (3 sheets)[G00206597!, G00206598! & G00206595!], **GZU** (2 sheets) [GZU000256215! & GZU000256228!], **K** [K000794463!], **K-W** [K001124409!]).

Thailand.— NORTHERN: Mae Hong Son [Mae Surin NP, 20 Oct. 2009, *Suwanphakdee 276* (**BK**, **BKF**, **KKU**)]; Chiang Mai [San Kamphaeng, 5 Oct. 1995, *Maxwell 95-841* (**BKF**); Doi Suthep NP, 26 July 1914, *Kerr 3306* (**BM**, **L**); 30 Oct. 1994, *Nanakorn et al.* 2597 (**QBG**); 28 May 1988, *Maxwell 88-693* (**BKF**, **L**); 12 Aug. 1988, *Maxwell 88-987* (**BKF**, **L**); 14 July 1988, *Koyama T-61908* (**BKF**); 10 May 1999, *Nanakorn s.n.* (**QBG**); 19 Oct. 2003, *Suwanphakdee 66* (**BK**, **BKF**, **KKU**); Mae On, 5 Oct. 1995, *Maxwell 93-841* (**BKF**); 23 Oct 2005, Maxwell 05-596 (BKF); Khun Awn, 31 June 1921, Kerr 4741 (BK, BM, L); Doi Inthanon NP, 7 Nov. 1980, Put 3394 (BK, BM, L), 11 Dec. 2007, Tanaka 8146 (QBG); 3 Aug. 1988, Phengklai 7477 (BKF), 26 July 1988, Koyama T-61136 (BKF), 26 July 1988, Takahashi T-62546 (BKF); 10 Dec. 1969, van Beusekom & Phengklai 2444 (BKF, L); 26 June 1978, Phengklai et al. 4107 (BKF); 8 Dec. 1981, Koyama & Phengklai T-49903 (BKF); 5 Dec. 1984, Mitsuta et al. T-43155 (BKF); 8 Dec. 1984, Nagamasu T-50068 (BKF); 29 Nov. 1991, Pooma 621 (BKF); 10 Sept. 1994, Palee 253 (BKF); 16 Sept. 1995, Larsen et al. 46521 (BKF); 16 Oct. 2001, Srisanga & Maknoi 2188 (QBG); 9 Apr. 2004, Suwanphakdee 59 (BK, BKF, KKU); 30 May 1979, Vidal et al.6181 (BKF); Doi Chiang Dao WS, 14 Sept. 1967, Shimizu T-10048 (BKF); 10 Nov. 1972, Smitinand 7806 (BKF); 26 Jan 1996, Maxwell 96-85 (**BKF**); 21 Dec. 2003, Suwanphakdee 79 (**BK**, **BKF**, KKU); 4 Aug. 2007, Watthana 2428 (QBG); 12 Dec. 2008, Suwanphakdee 254 (BK, BKF, KKU); Mae Chaem, 18 Dec. 1998, Konta et al. 4751 (BKF); 28 July 1988, Phengklai 7075 (BKF); Huai Namdang NP, 27 May 1977, Santisuk 1065 (BKF); Mae Rim, 3 Jan. 1972, Smitinand 11544 (BKF); 17 Dec. 2006, Pongamornkul 1910 (**QBG**); 14 Oct. 2010, Suwanphakdee 343 (BK, BKF, KKU)]; Chiang Rai [Kun Chae NP, 18 July 1997, Chayamarit 824 (BKF); Khunkorn Waterfall, 26 Mar. 2010, Suwanphakdee 292 (BK, BKF, KKU)]; Nan [Doi Phu Kha NP, 14 Feb. 2004, Suwanphakdee 97 (BK, BKF, KKU); 11 Feb. 2006, Suwanphakdee 173 (BK, BKF, KKU); 4 Oct. 2010, Suwanphakdee 321 (BK, BKF, KKU); Suwanphakdee 322 (BK, BKF, KKU); 8 Oct. 2010, Suwanphakdee 338 (BK, BKF, KKU)]; Lamphun [Doi Khun Tan NP, 4 Sept. 1967, Tagawa et al. T-9158 (BKF, L); Mae Tha, 25 Sept. 1993, Maxwell 93-1115 (BKF)]; Lampang [Chae Son NP, 22 June 1996, Maxwell 96-849 (BKF); Muang Pan, 1 Dec. 1995, Maxwell 95-1215 (BKF)]; Uttaradit [Phu Soi Dao NP, 14 Nov. 2010, Suwanphakdee 348 (BK, BKF, KKU)]; Tak [Mae Tun, 3 July 1922, Kerr 6221 (BK, BM, L); Thung Yai Naresuan WS, 14 Jan. 2011, Suwanphakdee 365 (BK, BKF, KKU)]; Sukhothai [Ramkamhaeng NP, 8 Dec. 1987, Paisooksantivatana & Sangkhachand Y-2201-87 (BK); 18 Jan. 2004, Suwanphakdee 84 (BK, BKF, KKU); 29 Jan. 1995, Maxwell 95-53 (BKF)]; Phitsanulok [Thung Salaeng Luang NP, 10 May 2004, Kudjabnak & Watanachaiyingcharoen *BRT 0077* (**BKF**); 18 Nov. 2010, *Suwanphakdee* 356 (**BKF**, **KKU**); Phu Hin Rongkla NP, 17 July 2004, *Suwanphakdee 157* (**BK**, **BKF**, **KKU**); *Suwanphakdee 158* (**BK**)]; NORTH-EASTERN: Loei [Phu Kradeung NP, 6 May 1948, *Nakkan 2* (**BKF**); 24 Dec. 1971, *van Beusekom et al. 4516* (**BKF**, **L**), 2 Sept. 1988, *Takahashi T-63531* (**BKF**); 16 June 2004, *Suwanphakdee 145* (**BK**, **BKF**, **KKU**); 8 Nov. 2010, *Suwanphakdee 347* (**BK**, **BKF**, **KKU**)].

Distribution.- Nepal, China, Myanmar.

Ecology.— In high altitudes and mountain summits in pine and oak forest; flowering June– August, fruiting October–December.

Vernacular.— Chak khan hua wok (จักค้านหัววอก) (General).

Uses.— Used as a medicinal plant.

Notes.— This species is similar to the introduced *Piper nigrum* but is native and differs in its leaf indumentum, catkins, rounded floral bract and stamen number. The fruit is smaller than *P. nigrum* and ovoid, trigonoid or ellipsoid. The dry fruit has a granuloid surface.

**41. Piper sulcatum** Blume, Verh. Batav. Gen. 11: 158. 1826; Backer & Bakh.f., Fl. Java 1: 172. 1963. Suwanphakdee *et al.*, Nordic J. Bot. 34: 617. 2016. Type: Indonesia, Java, *Blume s.n.* (lectotype L [L1542853!], designated by Suwanphakdee *et al.*, 2016; isolectotype G-DC [G00206472!]).

— *P. nigrescens* Blume, Verh. Batav. Gen. 11: 161. 1826.— *Cubeba nigrescens* (Blume) Miq., Comm. Phytogr.: 33. 1840. Type: Indonesia, Java, *Blume s.n.* (lectotype L [L1542854!], designated by Suwanphakdee *et al.*, 2016; isolectotype **BO**!).

Thailand.— SOUTH-WESTERN: Phetchaburi [Kaeng Krachan NP, 28 Mar. 2003, *Middleton et al.1759* (**BKF**, **K**)]; SOUTH-EASTERN: Chanthaburi [Khao Soi Dao WS, 26 Nov. 1979, *Shimizu et al. T-23715* (**BKF**, **L**)]; PENINSULAR: Chumphon [Muang, 26 Feb. 1983, *Koyama et al. T-33751* (**BKF**, **L**); Thung Tako, 27 Sept. 2003, *Suwanphakdee* 53 (**BK, BKF, DMSC, KKU**); Lang Suan, 19 June 1928, *Put 1741* (**BK**)]; Ranong [Khlong Nakha WS, 2 May 1974, *Larsen & Larsen 33570* (**AAU, BKF**, **L**)]; Phangnga [Sri Phangnga NP, 8 Nov. 2009, *Suwanphakdee 280* (**BK, BKF, KKU**)]; Narathiwat [Hala Bala WS, 20 Mar. 2008, *Pertmitr 777* (**CMUB**)]. Distribution.— India, Malaysia, Indonesia, the Philippines.

Ecology.— In evergreen forest by streams or near waterfalls; flowering September, fruiting October to December.

Vernacular.— Prik thai khon (พริกไทยขน) (General).

Notes.—Generally, the fruits of *Piper sulcatum* look like those of *P. nigrum*. However, *P. sulcatum* native to Thailand and differs in being a slender woody climber possessing chartaceous leaves with velutinous or pilose indumentum and hairy leaf margins. The inflorescence is a catkin and the floral bract is rounded. The male inflorescence is longer than the female one, and the fruit apex is retuse when dry.

**42. Piper sylvaticum** Roxb., [Hort. Bengal.: 4. 1814, **nom. nud.** ex] Fl. Ind. 1: 158. 1820; Hook.f., Fl. Brit. India 5: 83. 1887; Long in Grierson & Long, Fl. Bhutan 1(2): 348. 1984; Yongqian, Xia & Gilbert in Wu & Raven, Fl. China 4: 121. 1999; Mukherjee, Phytotaxa 338(1): 29. 2018; Suwanphakdee *et al.*, Kew Bull. 73, 33: 17. 2018.— *Chavica sylvatica* (Roxb.) Miq., Syst. Piperac.1: 248. 1843. Type: India, 'mountains on the northwest border of Bengal' *Roxburgh s.n.* (lectotype Icones Roxburghianae Ineditae, Plate 2168, **K**!, designated by Mukherjee, 2018; isolectotype Plate 2168A **CAL**).

— *P. petiolatum* C.DC., J. Bot. 4: 161. 1866.— *Chavica petiolata* (C.DC.) C.DC., Prodr. 16(1): 389. 1869. Type: India, Bangladesh, "East Bengal" *Griffith 4405* (lectotype **K** [K000794631!], designated by Suwanphakdee *et al.*, 2018; isolectotype **K** [K000794632!]).

- *P. bavinum* C.DC., Ann. Conserv. Jar. Bot. Gen. 2: 270. 1898; C.DC. in Lecomte, Fl. Indo-Chine 1: 80. 1910. Type: Vietnam, Lambok, *Balansa 3630* (lectotype **P** [P02030119!], designated by Gilbert & Xia, 1999).

— *P. punctulinevum* C.DC. in Lecomte, Fl. Indo-Chine 5: 77. 1910. Type: Lao PDR, Luang Prabang. *Thorel s.n.* (lectotype **P** [P01655983!], designated by Gilbert & Xia, 1999).

— *P. punctulinevum* var. *panifolium* C.DC. in Lecomte, Fl. Indo-Chine 5: 77. 1910. Type: Laos PDR, Paklai, *Thorel s.n.* (holotype **P** [P01655982!]). — *P. thomsonii* (C.DC.) Hook.f. var. *trichostigma* Chaveerach & Sudmoon, Act. Phytotax.et Geobot. 58(1): 35–38. 2007. Type: Thailand, Mae Hong Son, Mae Sariang, *A. Chaveerach 49* (holotype **BK!**).

— *P. trichostigma* (Chaveerach & Sudmoon) Suwanph. & Chantar., Blumea 43 (3): 235. 2011. Type: Thailand, Phetchaburi, Kaeng Krachan NP, *Suwanphakdee 259* (epitype **BK!** designated by Suwanphakdee *et al.*, 2011; isoepitypes **BKF!**, **KKU!**, **QBG!**).

Thailand.— NORTHERN: Chiang Mai [Doi Chiang Dao WS, 19 Apr. 1956, Suvarnakoses 1155 (BKF, L); 16 July 1968, Larsen et al. 2554 (BKF), 5 June 1973, Geesink et al. 5703 (BKF, L); 8 Apr. 1989, Maxwell 89-428 (BKF, L); 14 Aug. 1995, Maxwell 95-498 (BKF); Mae Taeng, 30 July 1997, Maxwell 97-796 (BKF)]; Chiang Rai [Doi Luang NP, 18 June 2002, Chamchamroon et al. 1484 (BKF); Mae Sai, 2 June 2007, Maxwell 07-372 (OBG)]; Nan [Doi Pha Chang WS, 4 Aug. 1998, Maxwell 98-803 (BKF); Doi Phu Kha NP, 21 Nov. 1993, Larsen et al. 44671 (AAU, BKF, K, PSU); 25 Sept. 2000, Srisanga 1699 (QBG); 14 Feb. 2004, Suwanphakdee 94 (BK, BKF, KKU); 2 July 2004, Suwanphakdee 152 (BK, BKF, KKU); Khun Nan NP, 5 Apr. 2010, Suwanphakdee 324 (BK)]; Payao [Doi Luang NP, 28 Mar. 2010, Suwanphakdee 293 (**BK**, **BKF**, **KKU**)]; Phrae [Huai Hom, 20 Mar. 1961, Adisai 48 (BKF)]; Tak [Doi Muser, 12 Apr. 1985, Paisooksantivatana 1565-85 (BK); Mae Sot, 12 May 1960, Smitinand6007 (BKF); Thi Lo Su Waterfall, Umphang WS, 20 Mar. 2003, Suwanphakdee130 (BK, BKF)]; NORTH-EASTERN: Loei [Phu Luang WS, 12 Apr. 1968, Chemsirivathana 824 (BK); May 1998, Chayamarit 1326 (BKF)]; CENTRAL: Nakhon Nayok [Nang Rong Waterfall, 13 Aug. 1968, Larsen et al. 3053 (AAU, BKF, L)]; SOUTH-WESTERN: Kanchanaburi [Thong Pha Phum NP, 26 Jan. 2003, van de Bult 621 (BKF); 15 Apr. 2004, Suwanphakdee 129 (**BK**, **BKF**, **KKU**); Khao Lam NP, 1 May 2009, Suwanphakdee 274 (BK, BKF, KKU); Sangkhlaburi, 8 May 1946, Kostermans 351 (BK, SING); Kostermans 351a (BK, SING); 21 May 1946, Bloombergen 619 (BK); 27 Mar. 1968, van Beusekom & Phengklai 136 (BKF, L); 1 Apr. 1968, van Beusekom & Phengklai 250 (BKF, L); 1 Aug. 1968, Sangkhachand 1450 (**BK**); 14 Aug. 1971, Phengklai et al. 2940 (BKF); 29 Apr. 2002, Suwanphakdee 4 (BK, BKF, KKU, QBG); 11 Mar. 2003, Suwanphakdee 31 (BK,

BKF, KKU); 31 Mar. 2005, Suwanphakdee163 (BK,
BKF, KKU); 1 Apr. 2005, Suwanphakdee165 (BK,BKF, KKU)]; Phetchaburi [Kaeng Krachan NP, 4 Dec. 1993, Larsen et al. 45041 (AAU, K,
PSU); 30 Jan. 1995, Williams et al. 1221(BKF), 14 Dec. 2002, Middleton et al. 1644 (BKF, K); 7 Apr. 2004, Suwanphakdee 123 (BK, BKF, KKU, QBG); 26 Dec. 2008, Suwanphakdee 259 (BK, BKF, KKU, QBG)]; PENINSULAR: Chumphon [Pha To, 6 July 1992, Larsen et al. 43153 (BKF, PSU)]; Ranong [Khao Pawta Chongdong, 21 Jan. 1929, Kerr 16804 (BK)]; Phangnga [Khao Lak, Takua Pa, 5 May 1973, Geesink & Santisuk 5195 (BKF, L)]; Krabi [Khao Phanom, 31 Mar. 1930, Kerr 15792 (BK)].

Distribution.— India, Sri Lanka, Bangladesh, China, Myanmar, Laos.

Ecology.— In shaded or partially open areas by streams or waterfalls in evergreen forest; flowering March–April, fruiting March–May.

Vernacular.—Sakhandong(สะค้านดง)(Kanchanaburi).

Uses.— Eaten locally as a vegetable.

Notes.— The lower surface of the leaf in *Piper* sylvaticum is pale yellow and the netted venation is very showy.Inflorescence length is variable but the male inflorescence is slender and much longer than the female. The infructescences are erect or slightly erect. The fruit is free, densely arranged and sessile, and the ripe fruits are dark orange or slightly pale red.

**43. Piper thomsonii** Hook.f., Fl. Brit. India 5: 87. 1885; Yongqian *et al.* in Wu & Raven, Fl. China 4: 120. 1999.— *Chavica thomsonii* C.DC., Prodr. 16(1): 389. 1869. Type: Sikkim, Khasia mountain, *Hooker & Thomson 18* (holotype **K** [K000794638!]).

Thailand.— NORTH-EASTERN: Loei [Phu Luang WS, 12 Apr. 1928, *Chermsirivatana* 824 (**BK**); 16 Mar. 2002, *Chamchamroon & Puff* 1413 (**BKF**)]; Nong Khai [Phon Phisai, 7 June 1963, *Adisai* 480 (**BK**)]; Sakon Nakhon [Phu Phan NP, not record, *Chantaranothai* 537 (**KKU**); 10 May 1997, *Pooma* 1635 (**BKF**)]; Kalasin [Kuchinarai, 7 Aug. 1963, *Prachit* 362 (**BK**)]; Nakhon Phanom [Dong Bang-I, 15 May 1932, *Kerr* 21473 (**BK, BM**)]; EASTERN: Chaiyaphum [Phu Khiao WS, 23 June 1970, *Sangkhachand & Bunchuai* 1670 (**BKF**); 12 Dec. 1971, van Beusekom et al. 4193 (**BKF, L**); 3 Aug. 1972, Larsen et al. 31316 (**BKF**); 25 June 1974, Geesink et al. 6957 (**BKF**, **K**, **L**); 14 Jan. 1983, Nanakorn 158 (**BKF**)]; Nakhon Ratchasima [Khao Yai NP, 10 Aug. 1968, Larsen et al. 3258 (**AAU**, **BKF**, **L**)]; SOUTH-EASTERN: Sa Kaeo [Khao Ta Kiap, 22 May 2003, Suwanphakdee 46/1 (**KKU**)]; Chon Buri [Sriraha, Ban Don, 30 Mar. 1920, Kerr 4125 (**BM**, **L**); Khao Khieo WS, 24 June 1975, Maxwell 75-663 (**BK**)].

Distribution.- India, China.

Ecology.— In open or disturbed areas in mixed deciduous or dry evergreen forest; flowering March– May, fruiting June–August.

Vernacular.— Phlu thomson (พลูทอมสัน) (General).

Notes.— *Piper thomsonii* is a slender woody climber. The inflorescence and infructescence are subglobose or globose and erect. Each infructes-cence contains 5–8 fruits which are densely crowded along the rachis and connate at the base in some specimens.

**44. Piper umbellatum** L., Sp. Pl.: 43. 1753; C.DC. in Lecomte, Fl. Indo-Chine 1: 67. 1910; Ridl., Fl. Malay Penins. 3: 51. 1924; Henderson, Malay. Wild Flowers Dicot. 4(3): 438. 1959; Yongqian *et al.* in Wu & Raven, Fl. China 4: 128. 1999.— *Pothomorphe umbellata* (L.) Miq., Comm. Phytogr.: 36. 1840.— *Lepianthes umbellatum* (L.) Raf., Sylva Tellur.: 85. 1838.— *Heckaria umbellata* (L.) Kunth, Linnaea 13: 569. 1839. Type: "Saururus arborescens, foliis amplis, cordatis non umbilicatis" in Plumier, Descr. Pl. Amér.: 55, t. 73. 1693 (lectotype, designated by Huber, 1987).

— *P. peltatum* L., Sp. Pl.: 42. 1753.— *Pothomorphe peltata* (L.) Miq., Comm. Phytogr.: 37. 1840; Backer & Bakh.f., Fl. Java 1: 168. 1963. Type: "*Saururus arborescens* foliis amplis rotundis et umbilicatis" in Plumier, Descr. Pl. Amér., 56, t. 74. 1693 (lectotype, designated by Howard, 1973).

*— P. subpeltatum* Willd., Sp. Pl., ed. 4 [Willdenow] 1(1): 166. 1797.*— Heckeria subpeltata* (Willd.) Kunth, Linnaea 13: 571. 1839.*— Piper subpeltata* (Willd.) Miq., Comm. Phyt.: 36. 1840; Backer & Bakh.f., Fl. Java 1: 168. 1963.*— P. umbellatum* L. var. *subpeltatum* (Willd.) C.DC., Candollea 1: 170. 1923. Type: not located. *— P. reniforme* Poir., Encycl. (Lam.) 5: 465. 1804. Type: not located.

— *P. dombeyanum* C.DC., Prodr. 16(1): 332. 1869. Type: Peru, *Poeping 1389* (holotype **G-DC** [G00206096!]).

Thailand.—NORTHERN: Chiang Mai [Doi Chiang Dao WS, 21 Dec. 1940, Garrett 1213, (TCD); 2 Nov. 1961, Bunchuai 1167 (BKF); 27 Nov. 1962, Bunchuai 1232 (BKF); 3 June 1973, Geesink et al. 5648 (BKF, L); 12 Feb. 1989, Maxwell 89-200 (BKF, CMUB); 8 Oct. 1995, Maxwell 95-849 (BKF, CMUB)]; Chiang Rai [Mae Chaem, 27 Jan. 1970, Sutheesorn 1547 (BK); Mae Fa Luang, 8 Sept. 2006, Maxwell 06-657 (CMUB)]; Phayao [Doi Luang NP, 7 May 1997, Maxwell 97-471 (CMUB)]; Nan [Pua, Hue Sala, 10 Mar. 1921, Kerr 5073 (BK, BKF, BM, K); Na Noi, 26 July 1992, Larsen et al. 43595 (BKF); 16 Aug. 1995, Pooma1078 (BKF); Doi Phachang, 4 Aug. 1998, Maxwell 98-804 (BKF, CMUB)]; Payao [Doi Luang NP, 7 May 1997, Maxwell 97-471 (BKF)]; Lampang [Mae Ngao, 4 Sept. 1922, Winit 763 (BK, BKF, K); Chae Son NP, 26 July 1996, Maxwell 56-1021 (BKF); Chae Hom, 7 Jan. 1992, Maxwell 92-12 (CMUB); Muang Bahn, 23 May 1996, Panatkool 61 (CMUB); Wang Nua, 26 July 1996, Maxwell 96-1021 (CMUB)]; Tak [Muang, 3 Nov. 1984, Paisooksantivatana 1464-84 (BK); Mae Sot, 22 July 1959, Smitinand & Flonto 5999 (BKF); Doi Mu Sor, 7 Dec. 1960, Umpai 3 (BK)]; SOUTH-WESTERN: Uthai Thani [Ban Rai, 3 May 1963, Kasem 371 (BK)]; Kanchanaburi [Sisawat, 25 May 1962, Kasem 176 (BK); Thong Pha Phum NP, 5 Feb. 1972, Larsen & Smitinand 9571 (BKF); 24 Aug. 1999, Wongprasert s.n., 24Aug 1999 (**BKF**); 18 Dec. 2003, Suwanphakdee 76 (KKU, DMSC); Sangkhlaburi, 6 Aug. 1968, Sangkhachand 1478 (BK); 14 Aug. 1971, Phengklai et al. 2946 (BKF); 11 Oct. 1993, Maxwell 93-1216 (CMUB)]; Phetchaburi [Kaeng Krachan NP, 12 Aug. 2002, *Middleton et al. 1017* (**BKF**, **CMUB**); Middleton et al. 3320 (BKF)]; Prachuap Khiri Khan [Phraek Ta Khraw Waterfall, 19 Jan. 2004, Middleton et al. 2259 (BKF); Khao Luang, Huai Yang Waterfall NP, 12 Apr. 2010, Suwanphakdee 301 (BK, KKU)]; SOUTH-WESTERN: Prachin Buri [Krabin Buri, 27 Mar, 1975, Sutheesorn 3203 (BK)]; Chanthaburi [Khao Soi Dao WS, 13 May 1974, Geesink et al. 6714 (**BKF**, **K**, **L**)]; PENINSULAR: Surat Thani [Khlong Phanom, 21 Feb. 2001, Chayamarit et al. 2615 (**BKF**); Ko Samui, 11 Mar. 1930, Kerr 12542 (**BK**)]; Phangnga [Bang Toi, 11 Mar. 1930, Kerr 18542 (BK, BM, K)]; Nakhon Si Thammarat [Khao Luang NP, 8 Mar. 1922, Smith 688 (BK, BM, K); 17 Jan. 1966, Tagawa et al. T-4536 (BKF, L); 25 Jan. 1966, Hansen & Smitinand 12051 (BKF); 30 Jan. 1966, Sutheesorn 844 (BK); 15 Dec. 1989, Maxwell 85-1135 (BKF); 25 Mar. 1993, Chantaranothai et al. 1381 (TCD); 17 Dec. 1994, Ploenchit 222 (BKF); 7 May 2004, Suwanphakdee 138 (DMSC); 20 Mar. 2008, Suwanphakdee 227 (BK, BKF); 1 Apr. 2009, Suwanphakdee 265 (BK)]; Trang [Khao Chong, 13 Mar. 1974, Larsen & Larsen 33274 (BKF, L); 10 Oct. 1970, Charoenpol et al. 3600 (BKF, K, L); 13 July 1985, Maxwell 85-706 (BKF)]; Songkhla [Ton Nga Chang WS, 27 May 1985, Maxwell 85-544 (BKF)]; Yala [Betong, 8 July 1928, Kerr 7428 (BK, BM, K),14 Feb. 2004, Middleton et al. 3079 (BKF, **KEP**)].

Distribution.— India, Sri Lanka, China, Laos, Vietnam, Cambodia, Malaysia, Indonesia, the Philippines.

Ecology.— In disturbed areas; flowering March–April, fruiting April.

Vernacular.— Han mu (หานหมู)(Northern); rok chang (รกช้าง)(Nakhon Si Thammarat).

Uses.— Young leaves are used locally as a vegetable (Nakhon Si Thammarat).

Notes.— The inflorescence of *Piper umbellatum* is characteristically a spike-like umbel originating from leaf-axils. The fruits appear similar to *Peperomia* in dry specimens but are obviously drupes in fresh material. Some botanists place this species in the genus *Potomorphe*.

**45. Piper viridescens** Suwanph. & Chantar. Nordic J. Bot. 32(4): 459. 2014. Type: Thailand, Nan, Khun Nan NP, 5 August 2010, *Suwanphakdee 325* (holotype **BKF!**; isotypes: **BK!**, **KKU!**, **QBG!**).

Thailand.—NORTHERN: Nan [Khun Nan NP, 5 Aug. 2010, Suwanphakdee 325 (**BK**, **BKF**); same locality, 8 Oct. 2010, Suwanphakdee 337 (**BK**, **BKF**); same locality, 7 Jan. 2013, Suwanphakdee 382 (**BK**, **BKF**); Suwanphakdee 383 (**BK**, **BKF**); Suwanphakdee 384 (**BK**, **BKF**)].

Distribution.— Endemic.

Vernacular.— Di pli din (ดีปลีดิน)(General).

Ecology.—In evergreen forest by streams or waterfalls; flowering January–February, fruiting March–May.

Notes.—This plant is similar to *Piper boehm*eriifolium var. boehmeriifolium but is smaller and also differs in its woolly velutinous orpilose and glabrescent stem. The inflorescence and infructescence are shorter than *P. boehmeriifolium* var. boehmeriifolium. The floral bract is rounded. The infructescence is fully concrescent and the ripe fruit is dark green.

**46. Piper wallichii** (Miq.) Hand.-Mazz., Symb. Sin. Pt. 7: 155. 1929; Gilbert & Xia, Novon 9(2): 191. 1999; Yongqian *et al.* in Wu & Raven, Fl. China 4: 126. 1999; Mukherjee, Phytotaxa 338(1): 30. 2018.— *Chavica wallichii* Miq., Syst. Piperac. 1: 254. 1843.— *Piper aurantiacum* Wall. ex C.DC., Prodr. 16(1): 357. 1869; Hook.f., Fl. Brit. India 5: 86. 1887. **nom. illegit.** Type: Nepal, *Wallich s.n.* [Numer.List6658A](lectotype **K-W**[K000639619!], designated by Gilbert & Xia, 1999; isolectotypes **BM** [BM000950694!],**E**[E00313749!],**K**[K001124433!], **P**[P00624877!]).

— *P. chawya* (Miq.) C.DC., Prodr. 16(1): 351. 1869, as '*chuvya*'.— *Chavica chuvya* Miq., Syst. Piperac. 1: 267. 1843. Type: India, Gongachora, *Wallich s.n.* [Numer. List6650C] (holotype **K-W** [K001124412!]).

*— P. henryei* C.DC., Ann. Conserv. Jard. Bot. Gen.: 271. 1898. Type: China, Hupei, *Henry 3311* (holo-type **G-DC** [G00438864!]; isotypes **GH**, **MEL**).

— P. aurantiacum Wall. ex C.DC. var. hupeense C.DC., Notizbl, Konigl. Bot. Gart. Berlin-Dehlem 6: 478. 1917.— P. wallichii var. hupeense (C.DC.) Handel-Mazetti, Symb.Sin.7: 155. 1929. Type: China, Hupei, *Henry 3893* (lectotype **B**, designated by Gilbert & Xia, 1999; isolectotype **G-DC** [G00328146!], **GH**, **K** [K000794339!]).

— *P. ichangense* C.DC., Notizbl, Konigl. Bot. Gart. Berlin-Dehlem 6: 480. 1917. Type: China, Hubei, Hupeh occidentalis, *Wilson 499 "489*" (holotype **B** (photo)[B100294754!]; isotypes **A**, **K** [K000794340!], **P** [P01980615!]).

— *P. flaviflorum* C.DC., Notizbl, Konigl. Bot. Gart. Berlin-Dehlem 6: 477. 1917. Type: China, Yunnan, *Henry 12931* (holotype **K** [K000794372!]).

-P. martinii C.DC., Notul. Syst. (Paris) 3: 41. 1914.

1923. Type: China, Guizhou (Kouy Teheou), *L Martin & E. Bodinier 2298* (lectotype **P**?; isolectotype **E** [E00318482!], **G-DC** [G00320393!], designated by Gilbert & Nian He, 1999).

*— P. emeiense* Y.C.Tseng, Acta phytotax. Sin. 24: 385. 1986. Type: China, Sichuan, *Hsiung 32838* (**IBSC**).

Thailand.— NORTHERN: Chiang Mai [Doi Suthep NP, 2 June 1914, Kerr 3260 (BM, K, L); 7 July 1988, Maxwell 88-848 (BKF, L); Mae Tang, 3 June 1989, Paisooksantivatana & Chuaycharoen Y-615-81 (BK); Mae Rim, 25 May 1994, Nanakorn 707 (OBG); 20 Jan. 2008, Jatupol 08-188 (OBG); same locality, 4 Aug. 2005, Suwanphakdee 166 (BK, BKF, DMSC); 18 Oct. 2009, Suwanphakdee 275 (BK, BKF, KKU); 24 Mar. 2010, Suwanphakdee 291 (BK, BKF, KKU); Mae Taeng, 26 Nov. 1994, Pooma 902/1 (BKF, CMUB); Huai Namdang NP, 18 Oct. 2009, Suwanphakdee 277 (BK, BKF, KKU); Doi Chiang Dao, Ban Tham, 12 Dec. 2008, Suwanphakdee 253 (BK)]; Chiang Rai [Doi Tung Palace, 16 Feb. 2004, Suwanphakdee 101 (BK, KKU, DMSC); same locality and date, Suwanphakdee 102 (BK, BKF, DMSC, KKU)]; Nan [Doi Phu Kha NP, 24 Sept. 2000, Srisanga 1689 (QBG)]; Lampang [Wang Nua, 10 July 1997, Maxwell 97-715 (BKF)]; Uttaradit [Phu Soi Dao NP, 22 Dec. 2007, Suwanphakdee 205 (BK, BKF, KKU)]; Tak [Pa Charoen Waterfall, 25 Apr. 2004, Pooma et al. 3949 (BKF); Thi Lo Su Waterfall, 16 Feb. 2008, Suwanphakdee 220 (BK, BKF, KKU)]; Phitsanulok [Ban Rom Klao, 16 Dec. 2010, Suwanphakdee 350 (BK)]; NORTH-EASTERN: Loei [Wang Sapung, 16 Apr. 2491, Din 164 (BKF)]; EASTERN: Chaiyaphum [Nong Bau Daeng, 14 May 2008, Norsaengsri 3816 (QBG)]; SOUTH-WESTERN: Kanchanaburi [South-West of Kanchanaburi, without data, Phengklai 296 (**BKF**); Thong Pha Phum NP, 15 May 2003, Suwanphakdee72 (BK, BKF, KKU)].

Distribution.— India, Nepal, China, Myanmar, Laos.

Ecology.— In open or shaded areas, by streams or waterfalls or mountain summits in evergreen forest, or cultivated; flowering December–January, fruiting January–March.

Vernacular.— Cha khan (จะค้าน)(Northern); cha khan khao (จะค้านขาว)(Chiang Rai); phlu ling (พลูลิง)(Chiang Mai). Uses.— Stems are used for spicy curry and it has anti-tumour and carminative properties.

Notes.— The infructescence of *P. wallichii* resembles *P. nigrum* but it is native and differs by its larger leaves, catkins and rounded floral bracts. The lower surface of leaf is glaucous and puberulous, and its infructescence length is variable.

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## Dimetra (Oleaceae), a new genus record for Lao PDR

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#### ABSTRACT

The monotypic genus *Dimetra*, represented by *D. craibiana*, was previously known to be endemic to Thailand. A specimen from Xaignabouri Province, Lao PDR is reported here as new generic record for Lao PDR; a detailed description and photographs are provided.

KEYWORDS: *Dimetra craibiana*, Lamiales, Myxopyreae, taxonomy, Xaignabouri. Accepted for publication: 15 August 2020. Published online: 11 September 2020

#### **INTRODUCTION**

The genus Dimetra Kerr, contains only one species, D. craibiana Kerr, and was established by Kerr (1938) based on a single specimen collected by himself from the North-Eastern region of Thailand. Initially, Dimetra was first assigned to Oleaceae-Jasmineae by Kerr (1938) but subsequently suggested to belong to Verbenaceae (Airy Shaw, 1952; Stant, 1952; Johnson, 1957). In the Flora of Thailand, *Dimetra* was not treated in Oleaceae but rather suggested to belong to Nyctanthaceae in conjunction with Nyctanthes L. (Green, 2000). However, in the new classification by Wallander & Albert (2000), Dimetra was classified in Oleaceae-Myxopyreae based on molecular evidence and supported by morphology. Tribe Myxopyreae consists of Dimetra, Myxopyrum Blume and Nyctanthes, and these genera share the apomorphic character of ascending ovules (Wallander & Albert, 2000).

During exploration in Xaignabouri Province, in the northern part of Lao PDR in May–August 2019, two specimens of Oleaceae were collected and deposited in the Queen Sirikit Botanic Garden Herbarium (QBG) and, after consulting the relevant literature (Green, 2000; Newman, 2013), they were identified as *Dimetra craibiana*. The genus *Dimetra*  was previously known to be endemic to the North-Eastern and Eastern regions of Thailand (Green, 2004; Newman, 2013); *Dimetra* has never been reported in Lao PDR (Newman *et al.*, 2007a; Newman *et al.*, 2007b; Lee, 2016). Therefore, these collections represent a new genus and species record for Lao PDR, and a description, distribution and colour photographs based on the Lao material are provided below for their easier recognition.

### DESCRIPTION

Dimetra craibiana Kerr, Bull. Misc. Inform. Kew 1938: 127. 1938; Fl. Siam 2: 408. 1939; Newman, Fl. Thailand 13(3): 525. 2017. Type: Thailand, Nong BuaLamphu, *Kerr 8611* (holotype **BM**[BM000604671!] seen on digital image; isotypes **BK**, **K** [K000979298!] seen on digital image). Fig. 1.

Subshrub or perennial herb with woody rootstock. *Rootstock* terete, numerous, single or fewbranched. *Stem* erect, ca 20 cm tall; branchlets 4-angled, scabrid-pilose. *Leaves* simple, opposite; petiole 3–6 mm long, strigose; lamina lanceolate or elliptic, 2.2–4 × 1.2–2 cm, chartaceous, upper surface shortly scabrid-hispid, green, lower surface densely strigose, grayish green, base narrowly cuneate, apex acute or subacute; midrib slightly raised above,

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prominent below, whitish, secondary veins often 3 on each side of the midrib, almost reaching the margin. Inflorescences axillary, cymose-capitate, 5–9-flowered; peduncle 1.2–4 cm long, strigose; outer bracts linear-oblanceolate,  $7-8 \times 1-1.5$  mm, greenish, apex acute or acuminate, densely pilose outside, sparsely, shortly pilose inside, inner bracts similar but smaller.  $5-6.5 \times ca 0.75$  mm. Flowers sessile or subsessile. Calyx deeply 4-lobed, divided to the base, persistent, greenish, densely pilose outside, sparsely, shortly pilose inside; tube very short, ca 0.5 mm; lobes linear,  $4-6.5 \times 0.2-0.5$  mm. Corolla hypocrateriform, white with yellow at throat, sparsely, shortly pilose outside; tube yellow at 3/4 from the base of the corolla tube with white at above of corolla tube, gradually widening above, 3-5 mm long, velutinate inside; lobes 4 or 5, white, rounded, ca  $4.5 \times 4$  mm, margins obscurely crenulate, imbricate in bud. Stamens 2, epipetalous; filament 0.5–1 mm long; anthers oblong, 1.5–2 mm long, shortly apiculate, dehiscing laterally. *Ovary* bilocular, divided to the base, ca 1 mm long, apex flat to convex, glabrous; style ca 3 mm long, glabrous; stigma bilobed, lobes ca 0.4 mm long, glabrous; ovules 1 each locule. *Fruit* not seen.

Distribution.— Laos, Thailand.

Specimens examined.—Lao PDR: Xaignabouri Province [Ban Na Kha, Botene District, alt. ca 300 m, 30 May 2019, *Maknoi et al. L17-079* (**QBG!**); same locality, 28 Aug. 2019, *Maknoi et al. L18-128* (**QBG!**)].

Ecology & Phenology.— This species grows on open area of deciduous forest, alt. ca 300 m; flowering: May–August.

Notes.— *Dimetra craibiana* is easily distinguishable by the subshrub or perennial herb habit to 20 cm tall, simple and opposite leaves with scabrous surface, and the white hypocrateriform corolla with



Figure 1. *Dimetra craibiana* Kerr: A. inflorescence; B. flower; C. flower with all petals removed, showing inner bract, calyx and ovary; D. corolla, showing inside of corolla tube and two stamens. Scale bar 2 mm (C, D). Photos taken by C. Maknoi (A, B) and S. Rakarcha (C, D).

yellow throat. Now, with this new record, the distribution of *D. craibiana* is in the mountain ranges of Thailand that extend to the border of Lao PDR. A good illustration of *D. craibiana* was provided by Kerr (1938, p. 128).

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# Cardamine occulta (Brassicaceae), a new name for the Flora of Thailand

HANS-JOACHIM ESSER<sup>1</sup>

#### ABSTRACT

The common Thai species of *Cardamine*, treated as *C. hirsuta* in the Flora of Thailand, is discussed. The correct name should be *C. occulta* according to recent publications. New data and collections are added.

KEYWORDS: Cruciferae, neophytes, weeds.

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### **INTRODUCTION**

Brassicaceae (or Cruciferae) are a cosmopolitan family consisting mainly of herbs, and many of them are weedy in temperate regions. They were treated by Hedge (1997) for the Flora of Thailand. In addition to several cultivated taxa, such as cabbage or pak choi in the genus *Brassica* L., Hedge reported only six native or introduced species in two genera in Thailand. One of these genera, *Cardamine* L., has white flowers and narrowly linear, compressed fruits with smooth seeds. The common weed of *Cardamine* present in Thailand was treated as *C. hirsuta* L. by Hedge (1997), recognizable by pinnate leaves (the rare *C. circaeoides* Hook.f. & Thomson has entire leaves).

Several species of this genus are annual widespread weeds that are morphologically similar and at the same time variable in numerous characters. Only in recent years their names have been clarified in several publications (Cheo *et al.*, 2003; Lihová *et al.*, 2006; Marhold *et al.*, 2016; Šlenker *et al.*, 2018, 2019). In particular, collections of *C. hirsuta* and *C. flexuosa* With. have been confused in China (Cheo *et al.*, 2003).

Cardamine hirsuta is sufficiently distinguished by, e.g., indumentum and stamen number. Cardamine flexuosa and C. occulta Hornem. are superficially very similar, and were sometimes treated as separate varieties or synonyms of a single species. Cheo et al. (2003: 105) stated that "Cardamine occulta ... represents only a minor variant of C. flexuosa." Later publications disagreed, based on molecular and more detailed morphological studies. Šlenker *et al.* (2018) published a key to similar species that had been confused before, copied slightly simplified here, and Šlenker et al. (2019) added comparative illustrations of C. flexuosa, C. hirsuta and C. occulta. Among these, the first two have a temperate distribution but were erroneously reported for tropical Asia including Thailand before, and only C. occulta occurs here.

KEY TO CARDAMINE OCCULTA AND SIMILAR SPECIES

<sup>1.</sup> Whole plant glabrous, except for few hairs at the base of stem leaves; basal leaf rosette compact; stamens four, the lateral pair often absent, rarely five or six C. hirsuta

<sup>1.</sup> At least some hairs on stem or on stem leaves; basal leaf rosette absent or not compact; stamens six

<sup>2.</sup> Middle stem leaflets predominantly glabrous on the upper surface; basal leaves not rosulate; stem hairy or glabrous basally, glabrous or rarely sparsely hairy in the upper part; terminal leaflet of the middle stem leaf (1–)3–5(–7)-lobed with deep and sharp sinuses; petals more than two times wider than sepals **C. occulta** 

<sup>2.</sup> Middle stem leaflets strikingly hairy on the upper surface; basal leaves rosulate; stem markedly hairy; terminal leaflet of the middle stem leaf 1–7(–9)-lobed with both deep and shallow sinuses; petals less than two times wider than sepals **C. flexuosa** 

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## TAXONOMY

Cardamine occulta Hornem., Hort. Bot. Hafn. Suppl.: 71. 1819; Marhold *et al.*, Phytokeys 62: 60. 2016; Šlenker *et al.*, Bot. J. Linn. Soc. 187: 468, 473. 2018; Bull. Slov. Bot. Spoločn. 41: 13, fig. 1A.— *Cardamine flexuosa* var. *occulta* (Hornem.) O.E.Schulz, Bot. Jahrb. Syst. 32: 479. 1903. Type: '*Cardamine occulta* mihi, sponte provenit in terra e China alata [?], ex h. b. Hafn.' [spontaneous in the Copenhagen Botanical Garden, in soil from China], 1817, *J.W. Hornemann s.n.* (lectotype C, designated by Marhold *et al.*, 2016: 60, or perhaps holotype); China, Zhejiang Province, Linhai County, Kuocang Mountains, 18 Apr. 2014, *K. Marhold*, *Y.P. Zhao & M. Jiang CH18/12/20148* (epitype SAV, designated by Marhold *et al.*, 2016: 60). Fig. 1.

— *Cardamine flexuosa* auct. non With.: T.Y.Cheo *et al.*, Fl. China 8: 105. 2003, p.p.

*— Cardamine hirsuta* auct. non L.: Hosseus, Beih. Bot. Centralbl. 28: 390. 1911; Craib, Fl. Siam.: 76. 1931; Hedge, Fl. Thailand 6(3): 180. 1997; Pooma & Suddee, Thai Plant Names rev. ed.: 113. 2014.

Erect to partially decumbent herb, to 25 cm tall, often branched from the base, bright green, stems usually glabrous, rarely few hairs near base. Leaves alternate, basal leaf rosette absent; petiole 5-15 mm long, blade thin, 15-30(-50) by 15-30 mm, pinnate with 2-3(-4) pairs of smaller lateral pinnae of irregularly elliptic shape, sometimes lobed, and a larger apical pinna, this 10-15 by 6-10(-15)mm and distinctly (1-)3-5(-7)-lobed with (shallow to) deep sinuses, glabrous at least above. Flowers with a pedicel of 1 mm length, sepals ca 2 mm long, petals 2.5-3 by ca 1 mm, white, but further characters not seen (the petals are wider than the sepals but exact measurements difficult, see notes), stamens 6. Fruits erect, 15-17 by 0.8-1 mm, dehiscent. Seeds ca 1 by 0.7 mm, brown, smooth.

Thailand.— NORTHERN: Chiang Mai [Chiang Dao, Tin Tok, 8 Mar. 1965, *Chermsirivathana 295* (**BK**); Doi Inthanon NP, car park on mountain top, ca 2,500 m, 30 Sep. 2005, *Esser et al. 05-40* (**BKF**, **M**); Doi Suthep, unterhalb Wat Doi Suthep, 1,050 m, 14 Apr. 1905, *Hosseus 492a* (**M**); Mae On valley, 29 Jan. 1921, *Kerr 4704* (**BK, TCD**); Chiang Dao district, Huai Nam Ru, Doi Sahm Meun, 1,550 m, 01 Feb. 1990, *Maxwell 90-149* (**L**); Samoeng, Pang

Ha Sta., 500 m, 11 Nov. 1980, Paisooksantavatana 437-80 (**BK**); Chom Thong, Ban Meo Khunglang, 1,200 m, 22 Dec. 1985, Paisooksantavatana 1671A-85 (BK); Fang, 1,500 m, 17 Feb. 1975, Sadakorn 465 (**BK**); Phu Ping, 05 Jan. 1972, Umpai 438 (**BK**)]; Chiang Rai [Ban Phami, Mae Sai, 557 m, 15 Feb. 2012, Norsaengsri & Tathana 8997 (BKF); Mae Chan, Ban Pang Sa, 550 m, 22 Jan. 1980, Paisooksantavatana 526-81 (BK); Phu Chi Fa NP, 22 Sep. 1999, S.C. 326 (BKF)]; NORTH-EASTERN: Loei [Mueang, Klong river, 217 m, 26 Dec. 2011, Norsaengsri & Tathana 8528 (BKF]; SOUTH-WESTERN: Kanchanaburi [Thong Pha Phum, Tha Kha-nun, Suan Ruen Rom view raft resort, 270 m, 03 Aug. 2019, Esser et al. 19-03 (BKF, M)]; CENTRAL: Krung Thep [Bangkok, 19 Aug. 1926, Kerr 11024 (BK)].

Ecology.— Found in open areas of secondary forest and disturbed anthropogenic places, paddy fields, along pavements, in flower pots and nurseries, often in garden earth; sea level to 2,500 m alt. Probably flowering and fruiting throughout the year.

Distribution.— Earliest records from East Asia (type originating from China), from man-made habitats, and from South-East Asia; recently invasive in North America and Europe, the earliest European records known are from 1993 (Marhold *et al.*, 2016).

Conservation status.— Although not often collected, it is a common weed in disturbed places and not threatened.

Vernacular.— Lao ko (เล่ากอ)(Central).

Notes.— Flowers ripen into fruits very soon when pressed, so that no good flowering material was available in the herbaria consulted, but the leaves are sufficient to characterize this species, because they are glabrous above with a larger, lobed apical pinna.

Hedge (1997: 180) used a basal leaf rosette as species character for '*C. hirsuta*' in his key, however, a rosette is absent in all Thai specimens studied. Perhaps he included this character because a leaf rosette would be typical for the true *C. hirsuta*.

Lihová *et al.* (2006) had already reported the species for Thailand, citing two collections from Chiang Mai, *Koch s.n.* (**HEID**) and *Maxwell 90-149* (**MO**), but they discussed it as 'Asian *C. flexuosa*', at that time still without a formal name.



Figure 1. Cardamine occulta Hornem. A. habit; B. flower; C. fruit. After S.C. 326 (BKF).

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# Geraniaceae in Thailand

#### PIYAKASET SUKSATHAN<sup>1</sup>

#### ABSTRACT

Members of the geranium family (Geraniaceae) native to Thailand are enumerated. Two genera, Geranium (3 species) and Pelargonium (1 species) are recognized. Pelargonium is a new genus record for Thailand and Asia Major (except Asia Minor-Anatolia). Keys to the Thai species, descriptions, information on distribution and ecology, as well as conservation status, are provided.

KEYWORDS: Geraniales, Doi Chiang Dao, endemic species, disjunct distribution, taxonomy. Accepted for publication: 5 August 2020. Published online: 2 October 2020

## **INTRODUCTION**

Geraniaceae is a family of ca 835 species mainly distributed in temperate and subtropical regions worldwide (Albers & van der Walt 2007). Except in Hypseocharis J.Rémy, the family is uniquely characterized by its schizocarpic fruit with styles united around a central column and generally breaks up elastically at maturity (Chant, 1993; Albers & van der Walt, 2007). According to Stevens (2001 onwards) there are five genera in Geraniaceae, i.e., Geranium Tourn. ex L. (ca 430 spp.), Pelargonium L'Hér. ex Aiton (ca 280 spp.), Erodium L'Hér. ex Aiton (ca 80 spp.), Monsonia L. (ca 40 spp.: inc. Sarcocaulon Sweet), and Hypseocharis (1–3 spp.).

Geraniaceae representatives in Thailand are uncommon and always occur in high altitude areas or mountain summits, especially in the north. Before 2000, there were only two Geranium species reported: G. lambertii Sweet subsp. siamense (Craib) T.Shimizu and G. nepalense Sweet (Craib, 1926; Shimizu, 1970). Subsequently, an additional species, G. ocellatum Jacquem. ex Cambess. was noticed (Aedo et al., 2016). During research on this family for the Flora of Thailand treatment based on both herbarium specimens worldwide, e.g., BK, BKF, E, K, L, P, SING, QBG, and additional field work, one more species was discovered and reported for the first time in Thailand - Pelargonium apetalum P.Taylor, an east African species, as the result of a very longdistance dispersal from its known areas in Malawi, Tanzania, and Zimbabwe. The genus Pelargonium was formerly known only from Africa, Asia Minor, and Australia (Albers & van der Walt, 2007; Fiz et al., 2008). This discovery in Thailand represents a new genus record outside its known distribution range. In total, two genera with four native species of Geraniaceae are recognized for the country.

# **TAXONOMY**

#### KEY TO THAI GERANIACEAE SPECIES

1. Leaves 3-8 deeply lobed, subtriangular, pentagonal, suborbicular, to subreniform in outline; flower actinomorphic; hypanthium absent

2. Flower 1–3.2 cm across; petals present; fertile stamens 10	
3. Flower 2.8–3.2 cm across; Petals $\pm$ twice as long as sepals, 7–9 veined	1. Geranium lambertii subsp. siamense
3. Flower 1–1.3 cm across; Petals slightly longer than sepals, 3–5 veined	2. Geranium nepalense

2. Flower 0.4-0.6 cm across; petals absent; fertile stamens 5

1. Leaves unlobed to very shallowly 3-5(-7)-lobed, ovate to cordate in outline; flower zygomorphic; hypanthium present

3. Geranium ocellatum 4. Pelargonium apetalum

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ALTERNATE KEY TO THAI SPECIES (FROM FRUITS)

1. Awns generally ± recurved at maturity, not spirally coiled

2. Mericarp glabrous, with 8-10, prominent, parallel, transverse ribs

2. Mericarp hairy, surface smooth without any ribs

3. Awns densely hairy; hairs to 1 mm long; mericarps 4.1–4.3 mm long

3. Awns subglabrous to hairy; hairs to 0.4 mm long; mericarps 2.2-3.3 mm long

1. Awns spirally coiled (in dry condition) at maturity

1. Geranium lambertii Sweet subsp. siamense (Craib) T.Shimizu, Tonan Ajia Kenkyu (The Southeast Asian Studies) 8(2): 180. 1970.— *G. siamense* Craib, Bull. Misc. Inform. Kew 4: 158. 1926; Smitinand, Nat. Hist. Bull. Siam. Soc. 21: 102. 1966. Type: Thailand, Chiang Mai, Doi Chiang Dao, 2,100 m alt., 6 Nov. 1922, *Kerr 6601*, (holotype K!; isotype BK!). Figs. 1E & 2D.

Perennial, decumbent to ascending herbs, with a few branches, almost all part especially the young ones covered with rigid, patent to retrorse, eglandular, yellowish-white hairs, 1-2.5 mm long, becoming glabrous with age. Stems to 70 cm long, ca 2 mm in diam, densely pilose when young. Leaves palmatifid, generally opposite, rarely alternate; stipules free or basally connate, ovate-lanceolate, broadly lanceolate, to oblanceolate, 2.5-6 by 2-4.7 mm, apex acuminate,  $\pm$  pilose; petiole 0.8–3.1(–20) cm long, densely pilose in the upper part; blades pentagonal to pentagonalreniform, or subtriangular in outline, (1-)3.6-4.2(-6.4)by (1-)4-5(-8.4) cm, deeply divided about  $\frac{3}{5}-\frac{4}{5}$  of the radius into (3–)5–7 palmately segments, chartaceous, upper surface sparsely pubescent, lower surface  $\pm$ densely pilose especially along veins; segments obovate, obliquely obovate, to rhomboid in outline, mid-segment largest, becoming smaller toward both ends, (0.5-)1-2.1 by (0.3-)0.5-1.9 cm, apex acute to rounded, margin with 1-3(-4) lobe(s) in each side; lobes 1-4 mm wide, apex mucronate. Inflorescences a 1-2-flowered cymule; peduncles absent in 1-flowered cymules, or 5-9 cm long in 2-flowered cymules, densely pilose; bracts and bracteoles narrowly triangulate-lanceolate, 4-5(-8.5)by 1–2 mm, apex obtuse, acute, or to 0.8 mm long mucronate, abaxially sparsely to densely pilose. Flowers actinomorphic, rose pink to pale pink with dark veins, 2.8-3.2 cm across; pedicels 1.5-4 cm long, densely pilose. Sepals 5, oblong to broadly lanceolate, 7–10 by 4–4.5 mm, enlarging in fruit, 5 veined, adaxially glabrous, abaxially long pilose especially along veins, hairs to 2.5 mm long, apex abruptly constricted in to a 1.7-2.2 mm long mucro. Petals 5, obovate to broadly obovate, 14-18 by 8–11.5 mm, apex rounded to slightly emarginate, base cuneate, 7–9 veined, glabrous on both sides except yellowish-green pilose at the inner base. *Stamens* 10; filament pinkish, 8–10 mm long, dorsally densely pubescent in the lower-half; anther yellowishbrown, sometimes with a purplish-blue ring along margin, elliptic-oblong, ca 1 mm long. *Ovary* ca 1 mm long, densely pubescent; style 5–8 mm long, pubescent; stigma 5-lobed, purplish-red, filiform, 3–5 mm long. *Fruits* ca 2.6 cm long; columella pubescent; awn ca 1.4 cm long, outer surface densely pubescent; mericarps pale brown, subellipsoid-oblong, 4.1–4.3 mm long, ca 2.5 mm in diam., pilose. *Seeds* pale brown, ca 3.4 mm long, glabrous.

Thailand.— NORTHERN: Chiang Mai [Doi Chiang Dao (Doi Cheng Duo), 2,100 m, 6 Nov. 1922, *Kerr 6601*, (**K**, **BK**); ibid., 2,100–2,200 m., 3 Dec. 1961, *Smitinand & Anderson 7292* (**BKF**, **K**); ibid, *Shimizu et al. T4378*; ibid., 14 Sept. 1967, *Shimizu et al. T10143* (**BKF**, **KYO** not seen); ibid., 26 Sept. 1971, *Murata et al. T15287* (**BKF**); ibid., 1 Dec. 1984, *Koyama et al. T39750* (**BKF**); ibid., 2,100 m, 21 Nov. 1999, *Suksathan 2211* (**QBG**); ibid., 2,225 m, 15 Oct. 2000, *Suksathan 2859* (**QBG**).

Distribution.— Endemic to Northern Thailand, known only from the type locality.

Ecology.— Scattered in open rocky-grassy slopes and ridges between 1,900–2,225 m alt. Flowering and fruiting September–January.

Vernacular.— Che ra nium chiang dao (เจราเนียม เชียงดาว)(General).

Conservation status.— This endemic taxon occurs only at higher elevations of Doi Chiang Dao (extent of occurrence <100 km<sup>2</sup>) with an area of occupancy estimated less than 2.5 km<sup>2</sup> in total. In the last decade, high ridges and summit of this mountain have been heavily destroyed by annual fires causing expansion of an alien weed, *Ageratina adenophora* (Spreng.) R.M.King & H.Rob. Therefore, the status is assessed as Critically Endangered (CR): B1ab (iii); B2ab (iii) (IUCN 2019).

3. Geranium ocellatum

4. Pelargonium apetalum

1. Geranium lambertii subsp. siamense 2. Geranium nepalense
Notes.— Geranium lambertii subsp. siamense differs from typical G. lambertii by having no glandular hairs (vs glandular hairs presented on pedicels and sepals in typical G. lambertii), and pale pink filaments (vs dark pink in typical G. lambertii) (Shimizu, 1970).

2. Geranium nepalense Sweet, Geraniaceae. 1: t. 12. 1820; Edgeworth & Hook.f., Fl. Brit. India 1: 430. 1875; Tardieu-Blot, Fl. Indo-Chine 1: 551. 1945; A.J.C.Grierson & D.G.Long, Fl. Bhutan 1(3): 79. 1987; R.Knuth in Engl., Pflanzenr. IV-129, 53: 192. 1912; Hara, Fl. East. Himal. 167. 1966; T.Shimizu, Tonan Ajia Kenkyu (The Southeast Asian Studies) 8(2): 180. 1970; L.Xu & C.Aedo, Fl. China 11: 15, 2008. Type: Nepal, cult, in Chelsea, *W. Anderson s.n.* (CGE? not seen), cited by Veldkamp & Moerman (1978). Figs. 1F & 2E.

*— Geranium radicans* DC., Prodr. [A.P. de Candolle] 1: 639. 1824. Type: Nepal, *Wallich s.n.* (lectotype **GDC!**, designated by Veldkamp & Moerman, 1978; isolectotypes **K** not seen, **NY!**, **W** not seen.).

— *Geranium lavergneanum* H.Lév., Bull. Soc. Agric. Sarthe ser. 2, 31(4): 319. 1904. Type: China. Yunnan, Hin-y-hie, 10 Apr. 1897, *Bodinier 1534* (lectotype **E**!, designated by Lauener, 1967; isolectotype **P**!).

— Geranium fangii R.Knuth, Repert. Spec. Nov. Regni Veg. 40: 218. 1936. Type: China. Szetschuan, Nanchuan Hsien, 2,400–2,700 m alt., 1928, Fang 834 (lectotype E!, designated by Aedo in 2006 [http://data.rbge.org.uk/herb/E00216777], cited in "Geranium Taxonomic Information System" (Aedo, 2020); isolectotypes GH!, P!).

*— Geranium oliganthum* C.C.Huang, Acta Phytotax. Sin. 1(2): 161. 1951.*— Geranium nepalense* var. *oliganthum* (C.C.Huang) C.C.Huang & L.R.Xu, Fl. Reipubl. Popularis Sin. 43(1): 35. 1998. Type: China. Hebei (Hopei), near Eastern Tombs, 770 m alt., 17 Jun 1931, *K.M.Liou 331* (holotype **PE?** not seen).

*— Geranium jinchuanense* Z.M.Tan, Bull. Bot. Res., Harbin 14: 232. 1994. Type: China. Jinchuan County, by the road, near the town, 2,150 m alt., 4 June 1979, *Jinchuan Exped. 322* (holotype **SM** not seen).

Perennial, decumbent to ascending herbs, with a few branches, often rooting at nodes. *Stems* green to reddish, terete, to 50 cm long, 1–2 mm in diam., sparsely to densely pilose especially when young, with patent to retrorse, eglandular, yellowish-white hairs, to 1 mm long. Leaves palmatifid, basally deciduous rosette, cauline ones opposite, rarely alternate; stipules lanceolate to narrowly lanceolate, to 10 by 2.5 mm, apex long attenuate, sparsely to densely pilose; petioles 0.2-21 cm long, with patent, eglandular hairs, ca 0.5 mm long; blades pentagonal, reniform, to subtriangular in outline, 1.9-5.6 by 2.2–5.9 cm, deeply divided about  $\frac{1}{3}-\frac{3}{4}$  of the radius in to 3-5(-7) palmately segments, chartaceous, upper surface sparsely pubescent with short stiff white hairs, ca 0.2 mm long, lower surface long pubescent especially along veins; segments obovate, broadly oblanceolate, to rhomboid in outline, each  $\pm$  equal in size or mid-segment largest, 0.5-2 by 0.3-1.5 cm, apex acute to rounded, margin with 1-6 lobes in each side; lobes 0.5-3.5 mm wide, apex abruptly mucronate. Inflorescences a 1-2-flowered cymules; peduncles 2.2-8 cm long, pubescent with patent, eglandular hairs; bracts and bracteoles narrowly lanceolate, 2-5 by 0.5-1 mm, apex acuminate. Flowers actinomorphic, pale pink to bluish-pink with dark veins, 1–1.3 cm across; pedicels 1.5–3 cm long, pubescent with patent, eglandular hairs. Sepals 5, oblong to elliptic, 4.5–5.5 by 1.3–2.8 mm, enlarging in fruit, 3-5 veined, adaxially glabrous, abaxially pubescent especially along veins and margins, apex abruptly constricted in a 0.5-1 mm long mucro. Petals 5, obovate to narrowly obovate, 5.5–8 by 3–4 mm, base cuneate, 3-5 veined, glabrous on both sides except pubescent inner base. Stamens 10; filament light green to white, ca 3.3 mm long, dorsally densely pubescent in the lower-half; anther purple, round-oblong, ca 0.8 mm long. Ovary ca 1 mm long, densely pubescent; style ca 1 mm long, subglabrous to sparsely pubescent; stigma 5-lobed, purplish-red, filiform, ca 1.3 mm long. Fruits ca 1.3 cm long; columella glabrous; awn 1–1.4 cm long, outer surface subglabrous to sparsely or densely covered with patent, eglandular hairs, 0.1-0.4 mm long; mericarps brown, subellipsoid, 2.8-3.2 mm long, ca 1.5 mm in diam., densely covered with long patent hairs. Seeds ca 2.5 mm long.

Thailand.— NORTHERN: Chiang Mai [Chom Thong, Mae Klang Luang (Doi Inthanon), 1 Feb. 1983, *Somkit 440* (**BKF**); Fang, Doi Angkhang, 1,500 m, 3 Dec. 1974, *Sadakorn 365* (**BK**); ibid., 1,650 m, 6 May 1974, *Sadakorn 318* (**BK**); Fang, Mae Ngon, Ban Luang, ca 1,200 m, 5 Feb. 1986, Paisooksantivatana Y1787-86 (**BK**, **BKF**)]; Phitsanulok [Phu Rom Rot, Phu Miang, 1,200–1,600 m, 3 Oct. 1967, *Shimizu et al. T11524* (**BKF**, **K**, **KYO** not seen); Phu Hin Rong Kla, 1,600 m, *Suksathan* (pers. obs.)].

Distribution.— Afghanistan, Pakistan, Nepal (type), Bhutan, India, Sri Lanka, China, Korea, Myanmar, Laos, Vietnam, Indonesia (Sumatra).

Ecology.— Growing by roadsides, paddy fields or edges of hill evergreen forest between 1,200–2,500 m alt. Flowering and fruiting September–February.

Vernacular.— Lakueiko (ละก็ยค่อ)(Karen-Chiang Mai); che ra nium pa (เจราเนียมป่า), che ra nium ne pan (เจราเนียมเนปาล)(General).

Conservation status.— This species is widely distributed in eastern Asia from the west Himalaya to Korea and southward to Sumatra. It is assessed as Least Concern (LC) (IUCN 2019).

Notes.— *Geranium nepalense* is characterized by having small pinkish to bluish white flowers. Even though it is a widespread species in northern Thailand, it is not so common.

**3. Geranium ocellatum** Jacquem. ex Cambess., Voy. Inde [Jacquemont] 4 (Bot.): 33. t. 38. 1841; Edgeworth & Hook.f., Fl. Brit. India 1: 433. 1875; Nasir, Y.J., Fl. Pakistan 149: 7. 1983; L.Xu & C.Aedo, Fl. China 11: 10. 2008; Aedo *et al.*, Syst. Bot. 41(2): 369. 2016. Type: India, Jammu & Kashmir, Pentapotamide, pagum Sera, 26–27 Apr. 1831, *V. Jacquemont s.n.* (lectotype **P!** [*Jacquemont* 203?], designated by Kokwaro, 1971a; isolectotypes: **K** not seen, **MPU** not seen). Figs. 1A–D & 2A–C.

— *G. ocellatum* var. *himalaicum* R.Knuth in Engl., Pflanzenr. IV-129, 53: 62. 1912.— *G. mascatense* var. *himalaicum* (R.Knuth) Babu ex Raizada, Suppl. Duthie's Fl. Upper Gangetic Plain 4: 36. 1976. Type: India, Manipur, Khongui valley, *G. Watt 6313* (lectotype: **P**!, designated by Aedo *et al.*, 2016; isolectotypes **E**!, **K**!).

— G. ocellatum var. yunnanense R.Knuth in Engl., Pflanzenr. IV–129, 53: 62. 1912.— G. mascatense var. yunnanense (R.Knuth) Raizada, Suppl. Duthie's Fl. Upper Gangetic Plain 36. 1976.— Geranium tapintzense C.C.Huang, Notes Roy. Bot. Gard. Edinburgh 42(2): 326. 1985, **nom. nov.** Type: China, Yunnan, bei Tapin-tze, 1883–1885, *P.J. Delavay* 2491 (holotype: **B** destroyed; isotypes: **BM** not seen, **E**!, **G** not seen, **MPU** not seen, **P**!). For more type information see Aedo *et al.*, (2016).

— *G. kweichowense* C.C.Huang, Notes Roy. Bot. Gard. Edinburgh 42(2): 325. 1985. Type: China, Guizhou, Kweichow province, Lo-fou, Mar. 1909, *J. Cavalerie* 3615 (holotype: **E!**; isotypes: **K!**, **P!**).

Annual, suberect, decumbent, to ascending herbs, with a few branches. Stems terete, to 60 cm long, up to 1 mm in diam., densely pubescent with patent to retrorse, glandular hairs, 0.1-0.7 mm long, sometimes sparsely interspersed with longer glandular hair, 1.2-3 mm long. Leaves palmatifid, basally rosette, cauline ones opposite; stipules narrowly triangulate to lanceolate, 2.1-8 by 0.5-2 mm, apex long attenuate, abaxially sparsely to densely covered with glandular hairs, margins long ciliate, to 0.7 mm long; petioles 0.8-13.5 cm long, with patent glandular hairs, to 0.5 mm long; blades reniform to suborbicular in outline, (0.4-)1.3-2.8 by (0.3-)1.7-3.1 cm, deeply divided about  $\frac{1}{3}-\frac{1}{2}$  of the radius in to 5-7(-9)palmately segments, thin chartaceous, both surface sparsely to densely pubescent with short glandular hairs, 0.1-0.3 mm long especially along veins and margins; segments spatulate-flabellate to oblanceolate, rarely oblong in outline, mid-segment largest, (2.8–)6.5–12.5 by (1.4–)3.8–12 mm, apex divided ca <sup>1</sup>/<sub>3</sub> of its length in to 2–3 sub-segments, each with (0-)2-3 lobes at margin; lobes 0.4-1.2 x 0.4-1.1 mm, apex abruptly mucronate. Inflorescences a pseudo umbel, (1-)2-6(-8)-flowered, usually subtended by 2-6 long petiolate, 3-5-lobed, reduced leaves; peduncle absent to 3.5 mm long, densely glandular; bracts and bracteoles lanceolate, narrowly lanceolate to linear, 0.8-2.2 by 0.1-0.5 mm, apex acuminate to attenuate, outer surface and margin with long glandular hairs, to 0.5 mm long. Flowers very small, ± actinomorphic, 4–6 mm across; pedicels 1-6.7 mm long, densely glandular. Sepal 5, subulate to oblong-lanceolate, 2.7-3 by 1-1.5 mm, enlarging in fruit, 3-veined, adaxially glabrous, abaxially subglabrous to pubescent with glandular hairs, to 0.5 mm long especially along veins, margins hyaline, glabrous, apex abruptly constricted in a 0.2-0.3 mm long mucro. Petals absent. Stamens 5; filament filiform, ca 1.3 mm long, glabrous; anther oblong, ca 0.2 by 0.1 mm. Ovary ca 0.5 mm long, glabrous; style ca 0.5 mm long, densely pubescent; stigma 5-lobed, short and stout, ca 0.5 mm long. *Fruits* 1.2–1.4 cm long; columella glabrous; awn lanceolateoblong, 8–8.2 by 3 mm, outer surface sparsely to densely glandular, to 0.1 mm long; mericarps dark brown, oblong-ellipsoid, 1.8–2 mm long, 1–1.2 mm in diam., glabrous, with 8–10, prominent, parallel, transverse ribs; basal prong spinelike, 2–3 mm long. *Seeds* glabrous, ca 1.5 mm long.

Thailand.— NORTHERN: Chiang Mai [Doi Chiang Dao, 5 Dec. 2002, 2,000 m, *Chamchumroon et al. VC.1709* (**BKF**); ibid., 21 Dec. 1931, *Put 4463* (**BK, C** not seen, **GH** not seen, **K, P**)].

Distribution.— Afghanistan, Pakistan, India (type), Nepal, China.

Ecology.— Open grassy slope near summit, at about 2,000 m alt. Flowering and fruiting November–December.

Vernacular.— Che ra nium nu (เจราเนียมหนู) (General).

Conservation status.— Even though *Geranium* ocellatum is widely distributed from Afghanistan eastward to China and should be assessed as Least Concern (LC) (IUCN 2019), in Thailand it is rare and has been collected only twice in 1931 and 2002 around the summit area of Doi Chiang Dao, the place where forest fires often unusually disturbed, therefore the Thai population is under threat.

Notes.— Generally, *Geranium ocellatum* is easily recognized by having purple petals with a dark purplish-red base, and mericarps with 8–14 parallel, transverse ribs (Aedo *et al.*, 2016). In Thai plants, however, the petals are absent and the stamen number is also reduced from 10 to 5. These characters are commonly known in cleistogamous flowers of *Geranium* sect. *Trilopha* (Aedo *et al.*, 2016); it is worth noting that chasmogamous or open flowers, so far, have not been observed in any Thai specimens. I have not seen a specimen of *Koyama et al.* 39750 kept at **GH** that was cited under this species by Aedo *et al.* (2016), but the same specimen number kept at **BK** is clearly not *G. ocellatum* but *G. lambertii* subsp. *siamense*.

**4. Pelargonium apetalum** P.Taylor, Hooker's Icon. Pl. 36: t. 3579. 1962; Müller, T., Fl. Zambesiaca 2(1): 145. 1963; Kokwaro, J., Fl. Trop. E. Afr.: 1. 1971. Types: Tanganyika, Songea District, Matengo Hills, near R. Luhekea about 1–5 km. NE. of Mpapa, *Milne-Redhead & Taylor 10377B* (holotype K!; isotypes B!, BM not seen, BP not seen, BR!, EA!, LISC not seen, P!, SRGH!). Figs. 1G & 2F–G.

Annual, short ascending to prostrate herbs, 15-50 cm long, almost all part covered with sessile to short glandular hairs to 0.08 mm long interspersed with white, long stiff patent hairs, 0.4–2 mm long. Stems terete, 2-4 mm in diam., with a few branches, glandular and pilose. Leaves simple, generally opposite, one in each pair usually smaller than the other, occasionally basally alternate; stipule ovatelanceolate to subtriangular, 3-5 by 1-2.5 mm, apex obtuse to long apiculate, base cuneate to broadly cuneate, membranous, both surfaces subglabrous to sparsely pubescent, margins long ciliate; petioles terete, to 2.5-56 mm long, glandular and  $\pm$  pilose; blades simple, ovate, cordate, to compressed cordate, 0.8-2.6(-3.5) by 0.6-1.4(-3.7) cm, unlobed to shallowly 3-5(-7)-lobed, apex obtuse, base truncate to cordate-cuneate, chartaceous, margin coarsely serrate, sparsely hispid and glandular in both surfaces especially along veins. Inflorescences a pseudo-umbel, (1-)2-4-flowered; peduncles up to 1.5 cm long,  $\pm$ pilose with glandular and eglandular hairs; bracts and bracteoles free or basally connate in a pair, each lanceolate, ca 3.5 by 1.5 mm, apex acuminatemucronate. Flowers very small, green to dull red, zygomorphic; pedicels 3-9 mm, with glandular and  $\pm$  eglandular hairs. *Hypanthium* 2–2.5 mm long, reddish, densely glandular. Sepals 5, light green with white margins, elliptic-lanceolate, posterior one largest, not or slightly reflexed, other 4 smaller, subequal,  $\pm$  strongly reflexed, 3.5–5 by 1.5–2 mm, adaxially subglabrous to sparsely glandular, adaxially densely hispid and glandular apex mucronate up to 0.2 mm long, margins ciliate, enlarging and inflexing in fruit. Petals absent. Stamens 10, 5 antheriferous. other 5 reduced without anthers; fertile filaments white, acicular, ca 2 mm long, sparsely pilose, base adnate and connate; sterile filaments narrower and slightly longer; anthers pale pink, short, ca 0.4 mm long. Ovary densely pubescent, ca 1 mm long, style ca 0.5 mm long, densely pubescent, stigma pinkishred, 5-lobed, ca 0.5 mm long. Fruits 2.2-3.4 cm long; columella densely short-pubescent; awn 1-1.7 cm long, outer surface glabrous, inner surface with long, thin, white, caducous hairs, to 7 mm long; mericarps pale brown with black mottles, subellipsoid, ca 3 mm long, 1.2 mm in diam., densely pubescent. Seeds pale brown, ca 2 mm long, glabrous.



Figure 1. A–D: Geranium ocellatum Jacquem. ex Cambess.: A. habit; B. flower; C. inflorescence and infructescence; D. mericarp with awn. [Chamchumroon et al. VC 1710 (**BKF**)]; E. G. lambertii Sweet subsp. siamense (Craib) T.Shimizu: mericarp with awn. [Suksathan 2859 (**QBG**)]; F. G. nepalense Sweet: mericarp with awn. [Paisooksantivatana Y1787-86 (**BKF**)]; G. Pelargonium apetalum P.Teylor: mericarp with awn [Schanzer N03-065 (**BKF**)]. Drawn by Piyakaset Suksathan.



Figure 2. A–C: *Geranium ocellatum* Jacquem. ex Cambess.: A. habit; B. flower (scale bar = 2 mm); C. infructescence; D. *G. lambertii* Sweet subsp. *siamense* (Craib) T.Shimizu: habit & flowers; E. *G. nepalense* Sweet: flower; F–G: *Pelargonium apetalum* P.Teylor: F. flower; G. mature infructescence. Photos A, C by Voradol Chamchumroon, B, E, F by Piyakaset Suksathan, D, G by Pramote Triboun.

Thailand.— NORTHERN: Chiang Mai, Doi Chiang Dao, ca 2,000 m, 5 Dec. 2002, *Schanzer N03-065* (**BKF**); ibid, 2,000 m, 5 Dec. 2002, *Chamchumroon et al. VC1710* (**BKF**); ibid, 2,100 m, 15 Oct. 2000, *Suksathan 2943* (**QBG**).

Distribution.— Eastern Africa (Malawi, Tanzania (type), Zimbabwe).

Ecology.— Terrestrial in open grassy slopes or on rock, near the summit of Doi Chiang Dao at 2,000–2,200 m alt. Flowering and fruiting October–December.

Vernacular.— Long klai (หลงไกล)(General).

Conservation status.—*Pelargonium apetalum* is known from eastern Africa with a disjunct distribution to Doi Chiang Dao in Northern Thailand where it was collected only twice. At Doi Chiang Dao, this rare species occurs around the summit area (less than 0.2 km<sup>2</sup>) and is threatened by annual fire and invasive weeds, but since we do not know its current status in eastern Africa, it is assessed as Data Deficient (DD).

Notes.— Pelargonium apetalum belongs to section Peristera DC. because of its slender, annual habit with small flowers (Bakker et al., 1998; Röschenbleck et al., 2014). This section has disjunct distribution from southern Africa to Australia. The new occurrence in Northern Thailand could also be another representative evidence supporting a recent long-distance dispersal theory for its section (Bakker et al., 1998) that can undertake long dispersal events. Morphologically, the Thai and African plants are almost identical except more variation found in African plants e.g., petals are not always absent but sometimes present in Zimbabwe plants, stamens vary from 9 to 10 with 2-3(-5) fertile (Müller, 1963; Kokwaro, 1971b). Its autogamy is noticed from plants growing at Queen Sirikit Botanic Garden's nursery which is also a mechanism employed by most Australian Peristera (Meve, 1995).

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# Terminalia santisukiana (Combretaceae), a new species from North-Eastern Thailand

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#### ABSTRACT

A new species of *Terminalia*, *T. santisukiana* (Combretaceae) from fresh water swamp forest in North-Eastern Thailand is described and illustrated. The new species is similar to *Terminalia nigrovenulosa*, having similar leaves with glands on the leaf margin near the base and paniculate inflorescences, but it is mainly distinguished by the loose panicles with dense indumentum on the flowers and the 4–5-winged fruits. It is also similar to *Terminalia polyantha*, having 4–5-winged fruits, but differs by the dense indumentum on the flowers and asymmetrical fruits.

KEYWORDS: Fresh water swamp forest, Sakon Nakhon, *Terminalia nigrovenulosa*, *Terminalia polyantha*. Accepted for publication: 1 November 2020. Published online: 4 November 2020

### **INTRODUCTION**

The genus *Terminalia* L. is the second largest genus of Combretaceae, belonging to subfamily Combretoideae Engl. & Diels, tribe Combreteae DC., subtribe Terminaliinae (DC.) Exell & Stace (Stace, 2007). It comprises about 190 species and is widely distributed pantropically with a centre in Asia (Stace, 2007, 2010). The genus is characterised by having spiral, alternate and opposite to subopposite leaves, or crowded into pseudowhorls at the apices of branchlets; flowers having a receptacle without bracteoles, and petals are absent; and by showing a notable variation of fruit types, ranging from fleshy and drupe-like, to dry and leathery or corky, and often longitudinally 2–5-winged or ridged.

Recently, as part of a recent study on the phylogeny of the subtribe Terminaliinae, *Anogeissus* (DC.) Wall., *Buchenavia* Eichler and *Pteleopsis* Engl. were transferred to *Terminalia* (Maurin *et al.*, 2017). Consequently, one of the two Thai species of *Anogeissus*, *A. acuminata* (Roxb. ex DC.) Guill. & Perr. was included as a synonym under *Terminalia phillyreifolia* (Van Heurck & Müll.Arg.) Gere & Boatwr., and *A. rivularis* (Gagnep.) O.Lecompte was recombined as *T. rivularis* (Gagnep.) Gere & Boatwr. (Maurin *et al.*, 2017). In Thailand, the genus *Terminalia* was enumerated by Craib (1931) and Nanakorn (1984, 1985) with 21 species and 17 species (3 varieties; 1 introduced species) included, respectively. Gardner *et al.* (2015) additionally recorded *Terminalia phellocarpa* King from Peninsular Thailand.

In the study of Combretaceae for the Flora of Thailand by the first author, specimens collected from fresh water swamp forest, along the Nam Un River, a branch of the Songkhram River in Sakon Nakhon, North-Eastern Thailand, by the second author could not be matched with any previously known *Terminalia*. We here describe it as a new species, *Terminalia santisukiana* Patthar. & Poopath.

# TAXONOMY

### Terminalia santisukiana Patthar. & Poopath, sp. nov.

Similar to *Terminalia nigrovenulosa* Pierre by similar leaves with glands on their margin near the base and paniculate inflorescences, but differing in its outer bark being smooth or scaly outside, inner bark yellowish brown, loose panicles with a dense indumentum, whitish flowers that are densely pubescent on the outside at the base of the receptacle (lower receptacle) and pubescent inside towards the

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apex of the receptacle (upper receptacle), and ovoid to broadly ellipsoid (4-)5-winged fruits (versus smooth outer bark with shallow longitudinal streaks, bright orange-red inner bark, compact panicles, pale yellow flowers that are glabrous outside at the base of the receptacle, and oblong, (2-)3-winged fruits in T. nigrovenulosa). It is also similar to Terminalia polyantha C.Presl, from the Philippines, in having 4-5-winged fruits, but it differs in flowers with a dense indumentum on the apex of the receptacle, asymmetrical fruits, and growing in fresh water swamp forest (versus flowers glabrous at the apex of the receptacle, symmetrical fruits, and growing in dry thickets and secondary forests). Type: Thailand, Sakon Nakhon, Phanna Nikhom, Ban Non Sai Kham, 165 m alt., 25 Apr. 2017, Poopath, Karaket, Khammongkol & Jirakorn FP160 (holotype BKF!; isotypes BKF!, K!). Figs. 1-2.

Trees 5–10 m tall; bark smooth or scaly, greyish brown; inner bark yellowish brown. Leaves opposite or subopposite, coriaceous, obovate-oblong, oblong, or obovate to narrowly elliptic,  $2-7 \times 1.2-2.8$  cm, glabrous or slightly pubescent on the midrib of the upper surface towards the base, glabrous,  $\pm$  glaucous on the lower surface; base obtuse or  $\pm$  cuneate, symmetrical or obscurely oblique, with glands on margins near the base; apex obtuse, acute to acuminate, margin entire or slightly undulate, midrib prominent on the lower surface; secondary veins 6-11 on each side; petioles 5-8(-10) mm long, sometimes persistent and thorn-like, sparsely pubescent to glabrous. Inflorescences paniculate, axillary to terminal, loose, 2-8 cm long; peduncle 0.8-1.5 cm long, pubescent. Flowers (4-)5-merous, whitish; ca 6.5 mm long (length of the receptacle, also including stamens), ca 3 mm in diam.; lower receptacle 1-1.5 mm long, densely pubescent outside, base densely tomentose inside; upper receptacle campanulate, 2-3 mm long, glabrous outside, pubescent inside; calyx lobes triangular, ca 0.5 mm long, apex acute, puberulous inside; bracts caducous, oblong, ca 1.5 mm long, margins ciliate. Stamens (8-)10, exserted at base and near middle of upper receptacle, arranged into 2 rows; filaments white, 3.4-4 mm long; anthers pale vellow, versatile. Ovules 2. Style white, 4-4.5 mm long. Fruits (4-)5-winged, unequal, ovoid to broadly ellipsoid, 2.5-3 cm long; wings 5-8 mm wide, coriaceous, glabrous; young fruits light green, tinted reddish purple, turning reddish brown with age.

Thailand.— NORTH-EASTERN: Sakon Nakhon [Phanna Nikhom, *Poopath et al. FP160* (**BKF**, **K**)].

Distribution.— Known from the type locality only.

Ecology.— Fresh water swamp forest, along the Nam Un River, branch of the Songkhram River, a tributary of the Mekong River; ca 150 m alt. Flowering and fruiting April–May.

Vernacular.— Khi ai nam (ขี้อ้ายน้า), saeng kham tham (แสงคำทาม), saen kham tham (แสนคำทาม) (General).

Etymology.— The species is named in honour of the late Prof. Dr Thawatchai Santisuk (1944–2020), who was an editor of the Thai Forest Bulletin (Botany) (1991–2013) and Editor-in-Chief of the Flora of Thailand (1997–2013).

Proposed IUCN conservation status.— Data Deficient (DD), this species is only known from one locality and its population size is unknown.

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Figure 1. *Terminalia santisukiana* Patthar. & Poopath: A. habit; B. gland on margin near base (×20); C. inflorescence; D. flower bud and bract; E. flower, side view (a. lower receptacle, b. upper receptacle); F. dissected flower; G. 4- and 5-winged fruits, top view. All from *Poopath et al. FP160* (**BKF**). Drawn by Mahsarahka Rungkrajang.



Figure 2. *Terminalia santisukiana* Patthar. & Poopath: A. habitat, the tree is the largest trunk (arrow); B. bark; C. lower surface of glaucous leaves; D. inflorescences; E. infructescences. Photos by Manop Poopath.

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# Lectotypification of Porpax scaposa (Orchidaceae)

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#### ABSTRACT

*Porpax scaposa* is lectotypified. This species is endemic to northern Thailand, and was based on *Garrett 717* (BKF, K) when published. We here select the Kew sheet, K000913725, as the lectotype.

KEYWORDS: Lectotype, taxonomy, Thailand.

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### **INTRODUCTION**

The genus Porpax Lindl. (Orchidaceae, tribe Podochileae) was established by Lindley (1845) based on Porpax reticulata Lindl. Recently, Ng et al. (2018) published a phylogenetic tree of Podochileae based on molecular data and accepted Porpax as a valid genus while expanding it to include Conchidium Griff. and Stolzia Schltr. Govaerts et al. (2020) listed 52 species under Porpax in the World Checklist of Selected Plant Families (WCSP). Seidenfaden (1977) revised Porpax sensu stricto (i.e., excluding Conchidium and Stolzia), recognising 10 species, including two new species. Subsequently, he published one more new species from Thailand (Seidenfaden, 1981) and prepared a synopsis of this genus for Thailand with a total of seven species (Seidenfaden, 1986).

*Porpax scaposa* Seidenf. was published in 1977 based on *Garret 717* (**BKF**, **K**) from Doi Pha Khao, Chiang Mai, Thailand, which was collected on 3 September 1931. According to the International Code of Nomenclature for algae, fungi, and plants (ICN), the name needs lectotypification.

### LECTOTYPIFICATION

**Porpax scaposa** Seidenf., Bot. Tidsskr. 72: 11, Fig. 10. 1977; Opera Bot. 89: 123, fig. 75. 1986. Type: Thailand, Chiang Mai, Doi Inthanon National Park,

Doi Pha Khao, 1,450–1,560 m, *Garrett 717* (lectotype K [K000913725!], selected here (Fig.1); isolectotype BKF!).

Note.— We select the sheet in K [K000913725] as the lectotype of *Porpax scaposa*, because it is a better sheet with more pseudobulbs, leaves and flowers.

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Figure 1. Lectotype of Porpax scaposa Seidenf. Image © The Trustees of the Royal Botanic Gardens, Kew.

# Stemona fimbritepala (Stemonaceae), a new species from northern Laos

#### SARAYUT RAKARCHA<sup>1,\*</sup>, WITTAYA PONGAMORNKUL<sup>1</sup>, WORANART THAMMARONG<sup>1</sup>, CHARUN MAKNOI<sup>2</sup> & KEOOUDONE SOUVANNAKHOUMMANE<sup>3</sup>

### ABSTRACT

*Stemona fimbritepala* (Stemonaceae), a new species from northern Laos, is described and illustrated. It is morphologically similar to *S. hirtella* and *S. kerrii* but clearly differs in longer peduncle, longer tepals, longer petaloid outgrowth of the connective and fimbriate margin of inner tepals. A detailed description, distribution, ecology, etymology, preliminary conservation status and photographs of this species are provided. A key to discriminate between the three hairy species is presented.

KEYWORDS: fimbriate, new taxon, Stemonaceae, *Stemona fimbritepala*, taxonomy. Accepted for publication: 25 September 2020. Published online: 17 November 2020

### **INTRODUCTION**

Stemona Lour. is a small genus in the family Stemonaceae, with approximately 20 species, distributed in China and Japan, through eastern Malesia to Australia (Duyfjes & Inthachub, 2011). In a Checklist of the Vascular Plants of Lao PDR (Newman *et al.*, 2007), six species of this genus were reported.

The Botanical Garden Organization, Thailand collaborated with Pha Tad Ke Botanical Garden and the Ministry of Agriculture and Forestry, Laos PDR to conduct botanical expeditions in northern Laos between 2014 and 2020. In 2014, an interesting specimen of unknown *Stemona* was collected and photographed by Charun Maknoi and Wittaya Pongamornkul during botanical exploration in Louangphrabang Province. Later, the authors rechecked the unidentified specimen of *Stemona* in Laos, and after carefully consulting the relevant literature (Hooker, 1894; Wright, 1896; Gagnepain, 1934; Telford, 1986; Duyfjes, 1993; Chuakul, 2000; Ji & Duyfjes, 2000; Inthachub, 2008; Inthachub *et al.*, 2010; Duyfjes & Inthachub, 2011; De Wilde & Duyfjes, 2019), comparison of its morphological characters with the protologues and study of the type specimens, we found that it did not match with any known species and that it clearly represents an undescribed species.

In this paper, *Stemona fimbritepala* from Louangphrabang Province of northern Laos, is described and illustrated below. The description is based on both herbarium specimens and field observations. Terminology used here follows Inthachub *et al.* (2010), Duyfjes & Inthachub (2011) and De Wilde & Duyfjes (2019).

### DESCRIPTION

**Stemona fimbritepala** Rakarcha, Pongamornkul & Thammar., **sp. nov.** 

Stemona fimbritepala is similar to S. hirtella W.J.de Wilde & Duyfjes and S. kerrii Craib by its hairiness on nearly all parts of the plant, but clearly differs in longer peduncle, longer tepals, longer petaloid outgrowth of the connective and fimbriate margin of inner tepals instead of entire margin in

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*S. hirtella* and *S. kerrii*. The twiner habit and pedunculate inflorescence of *S. fimbritepala* is similar to *S. kerrii*, but *S. hirtella* is an erect herb with sessile inflorescence. The abaxial surface of tepals of *S. fimbritepala* is glabrous but hairy in *S. hirtella* and *S. kerrii*. Type: Laos. Louangphrabang Province: Xieng Ngeun District, Ban Lak Sib, Phou Souang Protected Nature Reserve, 19°51.635'N, 102°11.331'E, 21 July 2014, *C. Maknoi, W. Pongamornkul & P. Yadee L3-238* (holotype **QBG!** [sheet no. 86234]; isotypes **BKF!, HNL!**). Figs. 1 & 2.

Twiner ca 1 m tall. Stem terete, greenish, with sparse hairs when young, becoming glabrous when older. Leaves simple, alternate; petiole 1.5-3.2 cm long, hairy; lamina ovate-lanceolate,  $6-16.5 \times 2.5-6$ cm, bullate, apex acuminate, mucronate up to 2 cm long, base cordate, margin entire, adaxial surface glabrous, abaxial surface hairy on veins, basal veins 9. Inflorescences with apically a dense raceme, 2-9-flowered, axillary; peduncle 2.5-5.5 cm long, filiform, hairy; bracts triangular-ovate, sessile, 4-6  $\times$  0.5–1 mm, apex acute, adaxial surface glabrous, abaxial surface hairy. Flowers: pedicel 5-15 mm long, filiform, sparsely hairy at base, becoming less hairy towards the apex, or glabrous. Tepals 4, lanceolate,  $13-20 \times 2.5-7$  mm, veins 7–9, glabrous; outer tepals 2, adaxial side dark brownish-red at basal part with a yellowish-green at apex when young, becoming dark brownish-red when mature, abaxial side yellowish-green with green stripes from the base towards the apex, margin entire; inner tepals 2, adaxial side dark brownish-red at basal part with a yellowish-green at apex when young, becoming dark brownish-red when mature, abaxial side yellowishgreen with brownish-red tinge towards the margin, margin fimbriate. Stamens 4, dark brownish-red with a yellowish-green apex when young, becoming dark brownish-red when mature,  $15-20 \times ca 0.5 \text{ mm}$ , abaxial surface conspicuously squamulose-rugose; filaments ca 1.5 mm long, basally connate; anthers 3-5 mm long with a longitudinal ridge separating the thecae ca 0.5 mm high, the surface squamuloserugose, continuing above the thecae on the outgrowth of the connective with a distal, ca  $2 \times 1$  mm, patent, elongate, yellowish-green, succulent body; petaloid outgrowth of the connective 12-15 mm long, margin involute at base and patent at the apex, with squamulose-rugose surface; additional appendage absent. *Ovary* superior, ovoid, ca  $1 \times 0.5$  mm, style absent, stigma inconspicuous. *Fruits* ellipsoid, ca  $18 \times 10$  mm, glabrous. *Seeds* 3–4, ellipsoid, 5–7.5  $\times$  4.5–6 mm, base surrounded by finger-like aril.

Distribution.—Northern Laos: Louangphrabang Province.

Ecology.— Found on limestone under semishade, climbing on other plants, at 860 m alt. Flowering and fruiting from July to August.

Etymology.— The specific epithet '*fimbritepala*' refers to the fimbriate margin of the two inner tepals (Fig. 2H).

Preliminary conservation status.— *Stemona fimbritepala* is endemic to Laos and currently known only from one locality. The extent of occurrence was estimated to be less than 100 km<sup>2</sup>. The number of mature individuals is less than 50 in three populations within Phou Souang Protected Nature Reserve and the species occurs in an area at risk of human disturbance because of trails used in the region. Therefore, the conservation status is provisionally evaluated as Critically Endangered, CR B2ab(iii); D, according to IUCN Standards and Petitions Committee (2019).

Notes.— *Stemona fimbritepala* is easy to distinguish from other species of *Stemona* in the combination of the presence of hairs on many of the vegetative and reproductive organs, dark brownish-red flowers, glabrous tepals and fimbriate margin of the two inner tepals. *Stemona fimbritepala*, *S. hirtella* and *S. kerrii* all are hairy on nearly all parts of the plant, and *S. fimbritepala* is compared to these taxa in Table 1.

The description of 'body' on the outgrowth of the connective (Figs. 1D & 2F) as described above follows Inthachub *et al.* (2010) and Duyfjes & Inthachub (2011). These authors noticed that it resembles an additional thecae-appendage, but that it is not connected with the apices of the thecae. The fleshy succulent body of *S. fimbritepala* is attached far from thecae, and about 7 mm from the apex of the outgrowth of the connective (Fig. 2F). Later, the body is caducous. This feature can also be found in other *Stemona* species, like *S. kerrii*.

#### KEY FOR THREE HAIRY SPECIES OF STEMONA

1. Inflorescences sessile. Erect herb, 30-40 cm tall

S. hirtella

1. Inflorescences pedunculate. Twiner, 50-100 cm tall or more

2. Adaxial surface of leaves and abaxial surface of tepals hairy. Margin of two inner tepals entire with short hairs S. kerrii

2. Adaxial surface of leaves and abaxial surface of tepals glabrous. Margin of two inner tepals fimbriate S. fimbritepala

Table 1. Morphological comparison between *Stemona fimbritepala* and *S. hirtella* (from De Wilde & Duyfjes, 2019), and *S. kerrii* (from Inthachub, 2008; Inthachub *et al.*, 2010; Duyfjes & Inthachub, 2011).

Characters	S. fimbritepala	S. hirtella	S. kerrii
Habit	twiner	erect herb	twiner
Indumentum	simple hairs	simple hairs	simple hairs
Leaves:			
shape	ovate-lanceolate	ovate	broadly ovate
size (cm)	$6 - 16.5 \times 2.5 - 6$	$11 - 16 \times 5.5 - 9$	$4-7 \times 3-5$
apex	acuminate	acute-acuminate	acuminate
base	cordate	cordate	cordate
Inflorescence:			
no. of flowers	2–9	1–4	1–4
length of peduncle (cm)	2.5-5.5	sessile	1–2.5
Tepals:			
colour	dark brownish-red	violet with white	yellowish-purple
shape	lanceolate	narrowly ovate to lanceolate	narrowly ovate
size (mm)	$13-20 \times 2.5-7$	10–11 × (2–)3	$10-12 \times 3-4$
abaxial surface	glabrous	hairy	hairy
margin of inner tepals	fimbriate and glabrous	entire	entire with short hairs
Stamens:			
colour	dark brownish-red	unreported	dark purple or maroon
length (mm)	15–20	ca 12	8–12
anther length (mm)	3–5	ca 8	2–4
petaloid outgrowth of the connective length (mm)	12–15	ca 5	ca 6
additional appendage	absent	present	absent
Distribution	Laos	Vietnam	China, Laos, Thailand

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Figure 1. *Stemona fimbritepala* Rakarcha, Pongamornkul & Thammar.: A. habit; B. part of twig showing adaxial surface of leaves; C. idem, showing abaxial surface of leaves; D. younger flower, showing yellowish-green bodies; E. mature flower; F. fruit. Photos by W. Pongamornkul.



Figure 2. *Stemona fimbritepala* Rakarcha, Pongamornkul & Thammar.: A. stem; B. abaxial surface of leaf; C. peduncle; D. bract; E. abaxial surface of petaloid outgrowth of connectives in dry specimen; F. & I. younger flower, tepals removed, note connectives with bodies; G. seed, note finger-like aril; H. inner tepal. Photos by S. Rakarcha from *Maknoi et al. L3-238*.

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# Ten new species of Globba section Globba from continental South-East Asia

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#### ABSTRACT

Ten new species of *Globba* from Thailand and Vietnam are described and illustrated; *Globba amnicola, G. amplectens, G. conferta, G. dasycarpa, G. grandis, G. hilaris, G. impar, G. nitida, G. verecunda* and *G. williamsiana*. Distribution maps and IUCN provisional assessments of each species are provided.

KEYWORDS: Dancing lady, ginger, Thailand, Vietnam, Zingiberaceae. Accepted for publication: 30 October 2020. Published online: 20 November 2020

### **INTRODUCTION**

*Globba* L. is a genus of perennial herbs in the tribe Globbeae, Zingiberaceae, distributed in Sri Lanka and India, the Himalaya, southern China, all countries of South-East Asia and northern Australia. They are often encountered in savannas and forests, particularly along watercourses and at the margins of forest gaps. Most species are deciduous, losing their above ground parts in the dry season, though section *Sempervirens* K.J.Williams consists of evergreen species found in aseasonal forests.

About 100 species are reported (Mabberley, 2017) but new species are being described every year and the number expected is likely to reach ca 120 (see numbers in each section below).

*Globba* species are among the smaller of plants of the Zingiberaceae, normally from 40–70 cm tall though a few species reach 1 m tall or slightly taller. They are easy to recognise by their small, delicate flowers which have a very long filament arching over the labellum. Most Zingiberaceae have trilocular ovaries with axile placentation while *Globba* species generally have unilocular ovaries with basal placentation. Bulbils commonly form on the inflorescences of *Globba*, though not in all species. These bulbils fall easily from the plant and are often missing from herbarium specimens. Bulbil morphology seems to be taxonomically informative but our knowledge is too patchy at present to be sure of this.

Infrageneric classification of *Globba* has placed great emphasis on the number of appendages on the anther which may be zero, two or four (Horaninow, 1862; Schumann, 1904; Larsen, 1972). The most recent classification of *Globba* incorporates information from morphology and molecular systematics and recognises seven sections in three subgenera (Williams *et al.*, 2004), as follows:

Subgenus Globba section Globba. Approx. 40 species

Subgenus *Globba* section *Nudae* K.Larsen. Approx. 30 species

Subgenus *Globba* section *Sempervirens* K.J.Williams. Approx. 15 species

Subgenus *Ceratanthera* section *Ceratanthera* (Horan.) Petersen. Approx. 20 species

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Subgenus *Haplanthera* section *Haplanthera* (Horan.) Petersen. Approx. 10 species

Subgenus *Haplanthera* section *Substrigosae* K.J.Williams. Two species

Subgenus *Haplanthera* section *Mantisia* (Sims) K.J.Williams Four species

Two subsections of *Globba* section *Nudae* have recently been revised throughout their range (Sangvirotjanapat *et al.*, 2019a, 2019b) and further revisions of infrageneric taxa are under way.

While preparing a revision of the Zingiberaceae for the Flora of Thailand, and a monographic treatment of *Globba* section *Globba*, ten new species have been found and are described here. Five of these species were collected during an expedition carried out in north and north-eastern Thailand by staff of BKF, QBG, E and Charles University, Prague in 2013, and earlier collections of four of these species were subsequently found in herbaria. Another was collected in Vietnam as part of Sud Expert Plantes Project 350 in 2008. The remainder were found during research visits to herbaria aimed at a revision of *Globba*. All specimens cited in this paper have been seen by the authors.

All the new species belong in Globba section Globba which is the largest section in the genus and includes the type species, Globba marantina L. Members of this section are easily recognised by the presence of four appendages on the anther, occasionally with a minute appendage between each pair (Cao et al., 2018). Globba section Sempervirens also has anthers with four appendages but, while section Globba has short peduncles without sterile bracts, section Sempervirens has long peduncles bearing sterile bracts. In addition, there is very little overlap in the ranges of the two sections. Globba section Globba has its centre of diversity in continental SE Asia and is confined to the north of the Isthmus of Kra (Williams et al., 2004) while section Sempervirens has its centre of diversity in Peninsular Malaysia, and hardly occurs north of the Isthmus of Kra.

### DESCRIPTIONS

#### Globba amnicola M.F.Newman & Sangvir., sp. nov.

Similar to *Globba dasycarpa* M.F.Newman in its small habit about 15 cm tall on average, small inflorescence with green bracts but differing by its cream flower with red spot on labellum (vs rich orange flower with no coloured spot) and verrucose fruit (vs softly prickly fruit). Type: Thailand. Mae Hong Son, Mae Sariang District, Salawin National Park, 420 m, 2 Aug. 2013, *Newman, Sangvirotjanapat, Wongnak, Fér, Záveská & Pospíšilová 2588* (holotype **BKF!**; isotypes **E!**, **QBG!**). Fig. 1. & Map 1.

Herb 13–20 cm tall. Leaf sheaths ca 3, sparsely pubescent; ligule ca 5 mm long, bilobed, lobes acute; blades 5–6, elliptic or ovate,  $3-10 \times 1-3$  cm, base obtuse, apex acuminate, slightly plicate, pubescent and glaucous below, sessile. Inflorescence pendent, conical, ca  $3 \times 3$  cm; peduncle ca 1 cm long beyond leaf sheaths, pale green; rachis pale green, densely pubescent; bracts persistent, elliptic, ca  $13 \times 9$  mm, green, wrapping around cincinni, apex acute or acuminate, sparsely ciliate; cincinni ca 10 mm long, flowers 3–10 per cincinnus; bracteoles caducous, elliptic,  $5-10 \times 1-6$  mm, keeled, yellowish green, semitransparent, apex acute. Flowers ca 2.7 cm long; ovary ellipsoid,  $2 \times 1$  mm, pale yellow; calyx infundibuliform, ca 6 mm long, cream or green, lobes acute; floral tube ca 14 mm long, inflated above, cream, hairy; dorsal corolla lobe hooded, elliptic, ca  $5 \times 1.5$  mm, cream, apex acute; lateral corolla lobes slightly smaller than dorsal lobe, shallowly hooded, cream; lateral staminodes elliptic, ca  $7 \times 3.5$  mm, slightly longer than corolla lobes, cream, apex acute; labellum obtriangular, ca  $8 \times 8$  mm, cream with brown-red spot on labellum, base truncate, apex bilobed, lobes acute; nectar tube ca 4 mm long; stamen: filament ca 15 mm long, cream; anther nearly round, ca  $1.5 \times 1.2$  mm, connective tissue cream, semitransparent; appendages 4, triangular, ca  $2 \times 1$  mm, cream, apex acuminate. Fruit globose, ca 8 mm in diam., verrucose, yellowish green; seeds not seen. Bulbils present in basal bracts, ovoid, ca  $5 \times 2$  mm, corky.

Thailand.— NORTHERN: Mae Hong Son [Mae Sariang District, Salawin National Park, 420 m, 2 Aug. 2013, *Newman et al.* 2588 (**BKF**, **E**, **QBG**)].

Distribution.— Endemic to Thailand.

Ecology. — Growing in shade with high humidity along streams or by waterfalls.

Etymology.— Latin, *amnis*, a river and *-cola*, a dweller, referring to the wet, streamside habitat of this species.

Proposed IUCN conservation status.— *Globba* amnicola is endemic to Thailand. The Area of



Figure 1. *Globba amnicola* M.F.Newman & Sangvir. (*Newman et al.* 2588) A. Habit; B. Habitat; C. Inflorescence; D. Bract (left) and bracteole (right); E.–G. Flower; H. Infructescence; I. Bulbils (indicated by black arrows). Scale bars; A= 5 cm; C.–I. = 1 cm. All photographed by S. Sangvirotjanapat.

Occupancy (AOO) of the species is 8 km<sup>2</sup>, including a new locality recently found in Tak but it still seems likely that the AOO is underestimated. It is only known from two protected areas situated in tourist hot spots and thus in danger of disturbance. *Globba amnicola* is assessed as of Least Concern (LC) but more studies are needed to estimate potential threats.

Notes.— This species is found in western Thailand and probably also occurs in adjacent Burma. The diagnostic characters are small-sized plants and cream-coloured flowers with a red spot on the labellum.

#### Globba amplectens M.F.Newman, sp. nov.

Similar to *G. schomburgkii* Hook.f. in its green imbricate bracts and pendent inflorescence (Fig. 2A) but differing by its short cincinni (vs elongate cincinni) and pale yellow flower with brown spot on the labellum (vs bright yellow with a red spot on labellum). Type: Accession BRG 2000-145, cultivated at Smithsonian Institution, Department of Botany Research Greenhouses, 24 July 2001, *Kress & Bordelon 01-6990* (holotype **US** [00605346!]). Originally collected in Phitsanulok Province, Thailand. Fig. 3 & Map 1.

Herb to 40 cm tall. Leaf sheaths 12, green with clear margins, glabrous; ligule bilobed, 13-14 mm long, glabrous; blades 9, broadly elliptic,  $12-16 \times$ 6-9.5 cm, green with silver patches below, base decurrent, apex acuminate, entirely glabrous; petiole ca 12 mm long, glabrous. Inflorescence recurved, downward pointing, 9 cm long; peduncle 4 cm long beyond leaf sheaths, with 1-2 sterile bracts; rachis 5 cm long, green, glabrous; bracts persistent, glaucous green, wrapping round and enclosing the rachis and cincinni, broadly ovate with shortly acuminate apex,  $22 \times 23$  mm at basal cincinnus to  $15 \times 12$  mm at apex, glabrous; cincinni 1 mm thick, 8-9 mm to first flower, pedicel 2-3 mm long, flowers 3-4; bracteoles persistent, broadly ovate, 11 × 10 mm at base of cincinnus, becoming smaller towards apex, green, thin, glabrous. Flowers: ovary ovoid, 2-3 mm, sparsely granular, perhaps with cystoliths; calyx broadly infundibuliform,  $5.5-6.5 \times 3-4$  mm, sparsely granular, lobes acute; floral tube 9-10 mm longer than calyx, yellow, coarsely patent hairy, lobes glabrous, dorsal corolla lobe elliptic, boat-shaped, ca 7 mm long, with narrow apical spur, yellow, lateral corolla lobes slightly smaller, without spurs, yellow; lateral staminodes elliptic, slightly longer than corolla lobes, yellow; labellum obtriangular, shortly bilobed, not reaching corolla, light yellow with dark spot on labellum; stamen: filament yellow, length unknown (specimen lacks fully open flowers); anther 3.5 mm long with 4 acute appendages, 2 mm long. *Fruit* not seen. *Bulbils* present in basal bracts, frequently sprouting on mother plant.

Thailand.— NORTHERN: Phitsanulok (original) [Accession BRG 2000-145, cultivated at Smithsonian Institution, Department of Botany Research Greenhouses, 24 July 2001, *Kress & Bordelon 01-*6990 (**US**)].

Distribution.— Endemic to Thailand, known only from Phitsanulok province.

Ecology. - Unknown.

Etymology.— Latin, *amplectens*, clasping or embracing, in reference to the bracts which embrace the cincinni.

Proposed IUCN conservation status.— The type locality is unknown and there are no other collections so *Globba amplectens* must be assessed DD until further information comes to hand.

Notes.— The original material was a living collection made by the late Mark Collins at an unknown locality in Phitsanulok province. This was cultivated at the Smithsonian Institution, Department of Botany Research Greenhouses under accession number BRG 2000-145. When this accession flowered in 2001, Kress & Bordelon made a herbarium specimen from it which is now the holotype. Field survey work must be carried out to discover the wild population in Phitsanulok. There are no open flowers on the type, which is the only known specimen so the dimensions given, which are taken from a bud, must be regarded as approximate.

#### Globba conferta M.F.Newman, sp. nov.

Similar to *Globba candida* Gagnep. in its condensed inflorescence, ca 3 × 3 cm and no bulbil production but differing by its dark red bracts and bracteoles (vs white bracts and bracteoles), bright yellowish orange flowers (vs yellow flowers with white filament and anther appendages) as well as red, trisulcate and smooth fruits (vs white, globose and verrucose fruits). Type: Thailand. Sakon Nakhon, Phu Phan National Park, 350 m, 31 July 1999, *Newman 942* (holotype **BKF!**; isotype **E!**). Fig. 4. & Map 1.

Herb 25-70 cm tall. Leaf sheaths 9-10, reddish, especially at base, lower ones glabrescent, upper ones pubescent with densely ciliate margins; ligule rounded, 1 mm long, densely glandular hairy; blades 4–7, narrowly elliptic,  $7-13.5 \times 1.5-2.3$  cm, plain green, base cuneate, apex long acuminate, indumentum densely pubescent below, glabrous to sparsely pubescent above; petiole 5–10 mm, longer on upper leaves, pubescent. Inflorescence compact, held roughly at right angles to stem, 2-3 cm long; peduncle ca 5 mm long beyond leaf sheaths, usually without sterile bracts; rachis 0.8-1.0 cm, green, pubescent; bracts persistent, ovate, acute, lowermost to  $1.5 \times 1.0$  cm, red, minutely pubescent; cincinni enclosed in bracts, 2-3 mm to first flower, pedicel ca 1 mm long, flowers 2-3 per cincinnus; bracteoles persistent, ovate, to  $10 \times 7$  mm, white at base, red at tips, minutely pubescent. Flowers ca 3 cm long; ovary ovoid, ca 1 mm diameter, minutely pubescent; calyx narrowly tubular, 4 mm long, minutely pubescent, lobes ca 1 mm long, acute; floral tube 12-13 mm longer than calyx, yellow, minutely pubescent, dorsal corolla lobe deeply boatshaped with cucullate apex,  $4-5 \times 3$  mm, yellow, minutely pubescent, lateral corolla lobes more shallowly boat-shaped, not cucullate, to 4 mm long, vellow; lateral staminodes oblong, apex often emarginate,  $8-9 \times 3-3.5$  mm, considerably longer than corolla lobes, yellow, glabrous; labellum narrowly obtriangular, lobes sometimes slightly divergent, usually emarginate,  $8 \times 3.5$  mm, not reaching ends of lateral corolla lobes, yellow with no spot; stamen: filament 20 mm long, yellow, glabrous; anther  $2 \times 1$  mm; appendages 4, yellow, proximal pair smaller, ca 2 mm long, distal pair larger, 3 mm long. *Fruit* trisulcate, smooth, red; seeds not seen. *Bulbils* absent.

Thailand.— NORTH-EASTERN: Sakon Nakhon [Phu Phan National Park, Sakon Nakhon side, 350 m, 31 July 1999, *Newman 942* (**BKF**, **E**); ibid., Aug. 1987, *Yuktathat 137* (**E**)].

Distribution.— Endemic to Thailand.

Ecology. — On wet seepage among sandstone boulders at 350 m altitude.

Etymology.— Latin, *confertus*, densely crowded, in reference to the small, dense inflorescence.

Proposed IUCN conservation status.— *Globba conferta* is endemic to Thailand. The AAO is 8 km<sup>2</sup>, suggesting a status of Critically Endangered but it grows in a protected area and the records seem to underestimate the AOO so it is here assessed as of Least Concern (LC). A further survey is needed to reassess the conservation status.

Notes.— Globba conferta has often been determined in herbaria as Globba annamensis Gagnep. but the Thai material does not match the type of Globba annamensis from Vietnam. This species is recognised by its red bracts and rich yellow flowers. It may be misidentified as G. candida Gagnep., which has a very similar inflorescence but with white bracts and flower parts yellow and white (Fig. 2B).



Figure 2. A. Globba schomburgkii Hook.f.; B. G. candida Gagnep. Photographs by S. Sangvirotjanapat.



Figure 3. *Globba amplectens* M.F.Newman A. Habit; B. Inflorescence at stage of bulbil production; C. Flower in front view; D. Flower in side view. Scale bars = 1 cm. Photographs courtesy of the Smithsonian's National Museum of Natural History Botany Research Greenhouses.



Figure 4. *Globba conferta* M.F.Newman A. Inflorescence with fruit; B. Flower in front view; C. Flower in side view. Scale bars = 1 cm. Photographed by A. P. Suksathan; B.–C. by S. Ruchisansakun.



Map 1. Distribution of *Globba amnicola* M.F.Newman & Sangvir. (■); *G. amplectens* M.F.Newman (★); *G. conferta* M.F.Newman (●).

#### Globba dasycarpa M.F.Newman, sp. nov.

Similar to *Globba amnicola* in its size (ca 15 cm tall) and inflorescence (ca 2 cm long) but differing by its ovate bracts and bracteoles (vs elliptic bracts and bracteoles) and softly prickly fruit (vs verrucose fruit). Type: Thailand. Phitsanulok, Chat Trakan District, Chat Trakan Waterfalls National Park, 250 m, 19 June 2006, *Poulsen & Suksathan 2395* (holotype **BKF!**; isotypes **E!**, **QBG!**). Fig. 5 & Map 2.

Herb 10–32 cm tall. *Leaf sheaths* 6–9, purplish to green, pubescent throughout to ciliate at margins only; ligule truncate, 2–3 mm long, pubescent to ciliate; blades 4–8, elliptic, 6–10×3–4 cm, variegated silvery green with dark green centre above, purple below, base rounded, apex shortly acuminate, sparsely to densely pubescent on both surfaces; petiole absent. *Inflorescence* dense, globose, pendent, 2–4 cm long; peduncle < 1 cm long, decurved just above uppermost sheaths, sterile bracts 0–2, slightly longer and narrower than fertile bracts, 13–17 × 8–10 mm; rachis 1–3 cm long, densely pubescent, sometimes with one branch at base; bracts persistent, ovate, concave, slightly broader than long,  $12 \times 15$ mm at base of inflorescence, gradually diminishing in size, green, sparsely pubescent, especially at margins and apex; cincinni enclosed in bracts, ca 3 mm to first flower, flowers 1-4, sessile, sometimes with 1 or 2 additional buds which never develop; bracteoles as bracts but proportionately smaller. Flowers: ovary globose, 2 mm diam., densely covered with soft, flat, triangular prickles, whitish green; calyx green, tubular, slightly inflated, 4-4.5 mm long, glabrous, lobes 3, slightly incurved; floral tube 10-11 mm, yellow, sparsely patent pubescent; dorsal corolla lobe boat-shaped, 5 mm long, yellow; lateral corolla lobes elliptic, almost flat,  $4.5 \times 2.5$  mm, yellow; lateral staminodes obovate, widest near truncate apex,  $8.5-9 \times 4$  mm, much larger than corolla lobes, yellow; labellum obtriangular with two short, acute lobes,  $7.5-8 \times 6$  mm, hardly reaching point of attachment of corolla, yellow without coloured spot; stamen: filament 17–18 mm, yellow; anther 2.3  $\times$ 1.3 mm; appendages 4, 2.5 mm long, distal pair broader at base and forked, yellow, semitransparent. Fruit globose, 7-8 mm diam., green or yellowish green, softly prickly; seeds not seen. Bulbils present in basal bracts, ovoid,  $15 \times 6$  mm, corky.

Thailand.— NORTHERN: Phitsanulok [Chat Trakan Waterfalls National Park, Chat Trakan Waterfall, 19 June 2006, *Poulsen & Suksathan 2395* (**BKF, E, QBG**); Thung Salaeng Luang National Park, 21 July 1966, *Larsen et al.* 675 (**AAU, BKF**); 1 May 1961, *Chantamuk 123* (**BKF, C, K**)]. NORTH-EASTERN: Phetchabun [Phu Hin Rong Kla National Park, 10 May 2002, *Maknoi 219* (**QBG**); ibid., 8 Aug. 2013, *Newman et al. 2625* (**QBG**)].

Distribution.— Endemic to Thailand.

Ecology.— Grows in deciduous forest at 250–1,090 m alt.

Etymology.— Greek, *dasy*- and *carpos*, meaning 'hairy fruit'.

Proposed IUCN conservation status.— *Globba dasycarpa* is endemic to Thailand. Its AOO is small, 28 km<sup>2</sup>, suggesting a status of Endangered. The main localities are in Phitsanulok and Phetchabun whereas the single collection from Hod District, Chiang Mai is doubtful. We have found three duplicates of *Chantamuk 123*. Those at **C** and **K** are labelled as being from Thung Salaeng Luang in Phitsanulok while the one at BKF is labelled from Khaem Son

(Pine Camp), Hot District, Chiang Mai. It is not clear whether there has been a mistake in labelling or collection numbering, or whether *Globba dasycarpa* existed in Hot District in 1961. It has never been collected in this district since then, and the exact location of Pine Camp is unknown. It is reasonable to assume that the habitat has been lost though surveys should continue for *Globba dasycarpa* in Chiang Mai Province. In this assessment, we consider the populations in Phetchabun and Phitsanulok alone. The collecting localities all occur in protected areas. Areas accessible to tourists may impose a threat but, since the species occurs in protected areas, it is assessed as of Least Concern (LC).

Note.— *Globba dasycarpa* is recognised by its small size, variegated leaves, compact inflorescence and rich yellow flowers. The soft prickles on the fruit are unique and of diagnostic value.



Figure 5. *Globba dasycarpa* M.F.Newman A. Habit; B. Flower from front view; C. Dissection of flower; D. Inflorescence with fruit; E. Bracts; F. Fruit; G. Bulbil. Scale bars = 1 cm. All photographs by S. Sangvirotjanapat.

# Globba grandis Sangvir., sp. nov.

Similar to *Globba sherwoodiana* W.J.Kress & V.Gowda in its lax and pendent inflorescence and white reflexed bracts but differing by its plain orange flowers (vs orange flower with red spot on labellum), caducous bracts (vs persistent bracts) and occurrence

of scaly bulbils (vs bulbils lacking). Type: Thailand. Phetchabun, Nam Nao National Park, 9 Aug. 2013, 890 m, *Newman, Sangvirotjanapat, Sirimongkol, Fér, Záveská & Pospíšilová 2635* (holotype **BKF!**; isotypes **E!**, **QBG!**, **SING!**). Fig. 6 & Map 2.



Figure 6. *Globba grandis* Sangvir. A. Habit & habitat; B. Inflorescence; C. Bracts; D. Cincinnus with bracteoles; E. Flower in side view; F. Dissection of flower; G. Anther thecae with appendages; H. Bulbils. All scale bars = 1 cm. All photographed by S. Sangvirotjanapat.

Herb 32-130 cm tall. Leaf sheaths ca 4, bladeless, pubescent; blades 7-8, linear or elliptic, 13-28  $\times$  1.5–5.5 cm, plicate, pubescent below and above, sessile, base cuneate or obtuse, apex acuminate. Inflorescence pendent, lax, conical,  $7-13 \times 3-5.5$  cm; peduncle 1–5 cm long beyond leaf sheaths, green; rachis green, densely pubescent; bracts persistent, reflexed, elliptic,  $1.5-4.5 \times 0.4-1.8$  cm, apex mucronate, margin undulate, white or greenish white; bracteoles caducous, elliptic,  $6-10 \times 3-6$  mm, yellowish orange, apex acute, keeled; cincinni held at ca 45° to rachis, with flowers crowded at tip, 8–12 mm to first flower. Flowers 3.2-3.4 cm long; ovary ellipsoid, 2-3 mm long, white; calyx infundibuliform, ca 5 mm long, trilobed with acute apices; floral tube ca 12 mm long, orange, hairy; dorsal corolla lobe hooded, elliptic, ca  $8 \times 1.5$  mm, orange; lateral corolla lobes hooded, elliptic, ca  $6 \times 1$  mm, orange, apex obtuse; lateral staminodes oblong to slightly curved, ca  $11 \times 4$  mm, orange, apex acute or obtuse, twice as long as lateral corolla lobes; labellum obtriangular, ca  $10 \times 7$  mm, pure orange, base truncate, apex bilobed, lobes acute, nectar tube ca 5 mm long; stamen: filament ca 27 mm long, orange; anther elliptic, ca  $1.5 \times 1$  mm, connective tissue orange, semitransparent; appendages 4, triangular, ca  $2 \times 1$ mm, orange, upper pair bigger, base broader, lower pair narrower, apex acuminate. Fruit globose, ca 8 mm in diam., orange, verrucose; seeds not seen. Bulbils present along peduncle and lower bracts, ovoid or globose,  $7-15 \times 6-13$  mm, green turning brown at maturity, scaly.

Thailand.—NORTH-EASTERN: Khon Kaen [Pha Nok Khao, 500 m, 9 Sept. 1963, Smitinand & Sleumer 1118 (AAU, BKF, C, K, L); Route to Phanokkao, 257 m, 24 July 2010, Norsaengsri & Thongsorn 6896 (QBG); Phuphaman National Park, Chum Phae District, 23 Aug. 2011, Norsaengsri et al. 8070 (QBG); ibid., 427 m, 14 Aug. 2012, Norsaengsri et al. 9874 (QBG)]; Loei [Wang Saphung District, Ban Si Than, 23 June, Bunpheng 20 (BKF, C); Phu Kradung, 1,300 m, 22 June 1950, Bunpheng 294 (BKF, K, C); ibid., 1,040 m, 17 July 1950, Bunpheng 303 (BKF, C); ibid., 4 Oct. 1947, Bunpheng 5 (BKF, C); ibid., 1 Sept. 1953, Bunpheng 669 (AAU, C); ibid., 930 m, 3 Sept. 1967, Shimizu et al. T 8776 (AAU, BKF); ibid., Ban Simain, 300 m, 25 Aug. 1988, Wongprasert sn. (**BKF**)]; Phetchabun [Nam Nao National Park, 30 July 1964, Bunchuai 163 (AAU, BKF); ibid., 950 m, 28 July 1999, Newman 940 (BKF, E); ibid., 600 m, 21 May 1951, Smitinand & Suwannakoset 500 (**BKF**, **P**); ibid., Sam Bon Station, 890 m, 9 Aug. 2013, Newman et al. 2635 (**E**, **QBG**, **SING**); ibid., Tham Yai (Yai cave), 4 Sept. 2013, Khattiyot 425 (**QBG**); ibid., 5 Sept. 2013, Khattiyot 460 (**QBG**); ibid., 17 July 2013, Maknoi 6133 (**QBG**); ibid., 2 Sept. 2014, Maknoi 7111 (**QBG**); ibid., Phu Pha Jit, 19 June 2014, Maknoi 7064 (**QBG**); ibid., Tham Pha Hong (Pha Hong cave), 4 Sept. 2014, Maknoi 7204 (**QBG**); Lom Kao, 27 July 1964, Bunchuai 151 (**BKF**)]. EASTERN: Chaiyaphum [Thung Kramang, 900 m, 9 Aug. 1972, Larsen et al. 31594 (**AAU**, **K**, **P**)].

Distribution.— Endemic to Thailand.

Ecology.— Grows in deciduous forest at 250–1,040 m alt.

Etymology.— Latin, *grandis*, large, referring to its habit, which can be to 1.3 m tall. This is the tallest species in *Globba* section *Globba*.

Proposed IUCN conservation status.— *Globba* grandis is endemic to Thailand. The AOO of 28 km<sup>2</sup> is small, suggesting a status of Endangered. As all known localities are in protected areas and there is



Map 2. Distribution of *Globba dasycarpa* M.F.Newman (■); *G. grandis* Sangvir. (○).

no immediate threat, it is assessed as of Least Concern (LC).

Notes.— *Globba grandis* has ornamental potential, as has *G. sherwoodiana* (Fig. 7A). The big inflorescence and up to 1.3 m tall, robust stems are desirable attributes for horticulture. *Globba grandis* is recognised by its imbricate white bracts with rich orange flowers. The bulbils are scaly, a character otherwise not found in *Globba* section *Globba*.

#### Globba hilaris Sangvir., sp. nov.

Similar to *Globba laeta* K.Larsen in its pendent inflorescence, white reflexed bracts, and yellow flower with red spot on the labellum but differing by the small size of its inflorescence, to 6 cm long (vs 15 cm long), verrucose fruit (vs smooth with three furrows) and corky bulbils (vs bulbils lacking). Type: Thailand. Phetchabun, Nam Nao National Park, 870 m, 8Aug. 2013, *Newman, Sangvirotjanapat,* 



Figure 7. A. Globba sherwoodiana W.J.Kress & V.Gowda; B. G. hilaris Sangvir.; C. G. laeta K.Larsen; D. G. winitii C.H.Wright. All photographs by S. Sangvirotjanapat.

Sirimongkol, Fér, Záveská & Pospíšilová 2629 (holotype **BKF!**; isotypes **E!**, **QBG!**, **SING!**). Figs. 7B, 8 & Map 3.

Herb 15–60 cm tall. *Leaf sheaths* dark red, ca 3, sparsely puberulent, to 1 cm in diam.; ligule bilobed, ca 3 mm long; blades 5–9, elliptic,  $5-22 \times 2-6$  cm, puberulent and usually dark red below, base cuneate,

apex acuminate, sessile. *Inflorescence* pendent, compact, conical,  $2-5.5 \times 1.5-2.5$  cm; peduncle to 1 cm beyond leaf sheaths, pale green; rachis pale green or white, densely pubescent; bracts persistent, patent, ovate to elliptic,  $10-20 \times 5-12$  mm, greenish white, apex mucronate; cincinni short, to 5 mm long; bracteoles elliptic, ca  $8 \times 3$  mm, white, apex acuminate.



Figure 8. *Globba hilaris* Sangvir. (*Newman et al. 2629*) A. Habit & habitat; B. Inflorescence; C. Bracts; D. Infructescence; E. Dissection of flower; F. Anther thecae with appendages; G. Bulbils. Scale bars; A. = 10 cm; B.–E. = 1 cm; F.= 3 mm; G.= 5 mm. All photographs by S. Sangvirotjanapat.

*Flowers* ca 3 cm long; ovary ellipsoid,  $2 \times 1$  mm, white; calyx infundibuliform, ca 6 mm long, narrow, with 3 ribs ending in the calyx lobes, white; floral tube ca 10 mm long, pale orange, hairy; dorsal corolla lobe hooded, elliptic, ca  $4 \times 1.5$  mm, pale orange, apex shortly mucronate; lateral corolla lobes hooded, elliptic, ca 3 × 1 mm, pale orange, apex acute; lateral staminodes oblong to slightly curved, ca  $7 \times 2$  mm, orange, apex acute; labellum obtriangular, ca  $8 \times 5$ mm, orange with red spot, base truncate, apex bilobed, lobes acute; nectar tube ca 4 mm long; stamen: filament ca 25 mm long, pale orange; anther elliptic, ca  $2 \times$ 1.2 mm, connective tissue orange, semitransparent; appendages 4, semitransparent, triangular, ca  $3 \times 1$ mm, orange, apex acuminate. Fruit globose, ca 8 mm in diam., white, verrucose; seeds not seen. Bulbils ovoid, ca  $7 \times 5$  mm, in axils of lower bracts, corky.

Thailand.-NORTHERN: Nan [Bo Kluea, Sapan waterfall, a few km N of Ban Bo Kluea, E of road 1081, 600 m, 7 Sept. 1995, Larsen et al. 46181 (AAU, BKF); ibid., 850 m, 6 July 2001, Srisanga 1944 (**BKF**, **E**, **QBG**); Doi Phu Kha, Phu Wae, 1,400 m, 3 July 1999, Srisanga et al. 897 (BKF, E, QBG)]; NORTH-EASTERN: Udon Thani [Non Sang, 27 May 1968, Bunchuai 1668 (BKF, C, E, K, L, P)]; Phetchabun [Chulaphorn Dam, 600 m, 5 Aug. 1972, Larsen et al. 31444 (AAU)]; Nam Nao National Park, Chum Phae District, 850 m, 11 Oct. 1979, Shimizu et al. T18280 (BKF)] ibid., 870 m, 8 Aug. 2013, Newman et al. 2629 (E, QBG, SING)]; EASTERN: Chaiyaphum [Phu Khiao, Thung Kramang, 4 Aug. 1972, Larsen et al. 31378 (AAU); ibid., Oct 1999, Phengklai 12267 (BKF)]; Nakhon Ratchasima [Khao Yai National Park, km 80 at the Korat-Sattahip Highway, 300 m, 10 Aug. 1968, Larsen et al. 3255 (AAU, BKF, E); ibid., Heo Suwat Falls, 750 m, 8 July 1966, Larsen et al. 117 (AAU, BKF, K); ibid., 650 m, 9 Sept. 2002, Maxwell 02-336 (A, BKF); Korat-Kabin, 9 Sept. 1968, Santisuk 203 (BKF, P)]; SOUTH-EASTERN: Chanthaburi [Khao Soi Dao, Bo Nam Ron District, 300 m, 6 July 1974 Maxwell 74-691 (AAU, BK); Pong Nam Ron, Hindat, 220 m, 30 Aug. 1956, Smitinand 3457 (AAU, BKF, C)]; Chonburi [Khao Kum Pang, Bo Thong District, 300 m, 14 July 1999, Puudjaa & Cholkulchana 594 (BKF)]; CENTRAL: Nakhon Nayok [6 Aug. 1970, Phengklai 3735 (A, BKF)].

Cambodia.—Unspecified locality, *Martin 708* (**P**).

Laos.— Louangphabang: Bane Phuay Say Khao, 726 m, 14 June 2012, *Leong-Škorničková et al. 1712* (**P**, **QBG**, **SING**).

Distribution.— Cambodia, Lao PDR and Thailand.

Ecology. — Grows in deciduous forest in shaded areas or near streams at 40–850 alt m.

Etymology.—Latin, *hilaris*, meaning cheerful, referring to the appearance of the inflorescence.

Proposed IUCN conservation status.— *Globba hilaris* is a very widespread species with an extent of occurrence of 168,000 km<sup>2</sup> and AOO of 66 km<sup>2</sup>. The three localities of this species are in protected areas in three regions of Thailand; north, north-east and centre. These localities have no major threats and the species usually occurs in large populations of more than 250 mature individuals. It is therefore assessed as of Least Concern (LC).

Notes.— *Globba hilaris* is recognised by the following characters: condensed inflorescences composed of greenish white bracts, yellow-orange flowers with an obvious dark-red spot on the labellum, and mature inflorescences producing a few bulbils at the lower bracts. When growing in conditions of high humidity, the inflorescence can lengthen (Fig. 7B) resembling *G. laeta* (Fig. 7C). *Globba hilaris* and *G. laeta* are distinguished by having vertucose and smooth fruits, respectively.

#### Globba impar M.F.Newman & H.D.Trần, sp. nov.

Similar to the white form of *Globba williamsiana* M.F.Newman & Sangvir. by its pendent inflorescence and white bracts but differing by its large white bracteoles (vs small yellow bracteoles), and ca 3 mm wide lateral corolla lobes (vs ca 1.5 mm wide corolla lobes). Type: Vietnam, Đắk Lắk province, Buôn Đôn District, Bản Đôn, 12° 54′ 48″ N, 107° 50′ 21″ E, 219 m alt., 25 June 2008, *Trần, Leong-Škorničková, Cecilio, Newman, Thi, Dang, Lý & Lamxay 79* (holotype **VNM!**; isotypes **E!**, **P!**, **RUPP!**, **SING!**). (Fig. 9 & Map 3).

Herb to 30 cm tall. *Leaf sheaths* to 10, sometimes reddish, sparsely pubescent; ligule bilobed, 1.5-2 mm long, ciliate; blades 3–5, elliptic, 10–19 × 2.7–4.5 cm, densely pubescent below, glabrescent above, base cuneate, apex acuminate; petiole 0.8–2.3 cm long, pubescent. *Inflorescence* pendent, ca 7–8 cm long; peduncle ca 1 cm beyond leaf sheaths, without sterile bracts; rachis 6-7 cm long, pubescent; bracts persistent, broadly elliptic,  $3.5 \times 2.0$  cm at base diminishing to  $1.3 \times 0.9$  cm at apex of inflorescence, white or pink, shiny, sparsely ciliate at apex; cincinni 7–9 in the inflorescence, to 1.6 cm long to first flower, with ca 8–9 sessile, yellow flowers; bracteoles as

bracts but slightly smaller. *Flowers* ca 3 cm long; ovary ovoid,  $3 \times 2$  mm, white, verrucose; calyx somewhat urceolate, 4 mm long, white, glabrous; floral tube ca 9 mm long, pale orange, minutely pubescent, lobes ovate, concave, pale orange, acute; dorsal corolla lobe  $5 \times 3$  mm; lateral corolla lobes  $4 \times 3$  mm; lateral staminodes narrowly ovate,



Figure 9. *Globba impar* M.F.Newman & H.D.Trần (*Trần et al. 79*) A. Habitat ; B. Habit; C. Dissection of flower; D. Flower from side view; E. anther thecae with appendages. Scale bars B = 1 cm; C. & E. = 5 mm; D = 1 cm. Photographs by A., C.–E.: Trần Hữu Đăng; B. V. Lamxay.

acuminate,  $6 \times 2$  mm, orange, slightly longer than corolla lobes; labellum more or less rectangular, 8–9  $\times$  3.5 mm, orange without coloured spot, bilobed, each lobe emarginate, shorter than corolla lobes; stamen: filament 16 mm long, orange; anther 2.5 mm long with two acute appendages on each side and sometimes a third, minute one between them, distal appendages often with 2–3 minute teeth at apex; nectary glands 2, subulate. *Fruit* globose, 6–8 mm diam., verucose; seeds not seen. *Bulbils* absent.

Distribution.- Endemic to Vietnam.

Ecology.— Seasonally dry dipterocarp savanna, among bushes and low, open vegetation, on coarse sandy soil.

Etymology.— Latin, *impar* means unequal or dissimilar, referring to the size of the bracts.

Proposed IUCN conservation status.— This species is only known from the type collection made in 2008. It may occur in the nearby Yok Đôn National Park but a search by the second author in 2019 was unsuccessful. The population found in 2008 had an AOO of  $< 4 \text{ km}^2$  but the preferred habitat type is fairly common in the area. Bản Đôn is a scenic area, which attracts tourists. While this may protect the habitat to a certain degree, it may also lead to urbanization. With current knowledge, *Globba impar* must be assessed data deficient (DD) but surveys should be carried out to gather data for a more precise assessment. An ex situ collection of *Globba impar* is held at the Royal Botanic Garden Edinburgh under accession number 20081114A.

Notes.— *Globba impar* grows on flat land along the Srepok River in a district which borders Mondulkiri Province of Cambodia. It may occur in similar soil types on the Cambodian side of the border.

#### Globba nitida M.F.Newman & Sangvir., sp. nov.

Similar to *Globba sherwoodiana* W.J.Kress & V.Gowda in its pendent inflorescence with white reflexed bracts, and yellow flower with orange-red spot on labellum but differing by its flat, oval and caducous bracteoles (vs infundibuliform and persistent bracteoles). Type: Thailand. Krabi, Khao Phanom Bencha, 1,150 m, 19 June 2006, *Williams, Pooma, Chamchumroon & Seasin 1977* (holotype **BKF!**; isotypes **A!**, **E!**). Fig. 10 & Map 3.

Herb 70 cm tall. Leaf sheaths red, glabrous; ligule truncate, 2 mm long, minutely pubescent; blades ca 5, narrowly elliptic,  $18.5-19.5 \times 3.2-3.5$ cm, plain green, plicate, glabrous, base cuneate, apex long caudate; petiole to 3 mm long, glabrous. Inflorescence hanging vertically, conical, 4-9 cm long; peduncle short, to 1.5 cm beyond leaf sheaths, with 2-3 sterile bracts; rachis pubescent; bracts persistent, reflexed, oval, ca  $16 \times 9$  mm at base of inflorescence, diminishing gradually towards apex, white, plastic-like, shining, minutely pubescent; cincinni slender, 5-9 mm long to first flower, flowers 2-3 per cincinnus, sessile; bracteoles caducous, oval, ca  $9 \times 7$  mm, enfolding ovary and calyx, white, glabrous. *Flowers* ca 3 cm long; ovary ovoid,  $3 \times$ 1.5 mm, minutely verrucose; calyx 3 mm long, pale yellow, glabrous, with 3 acute lobes; floral tube 8 mm long, yellow, glabrous, lobes hooded, lateral lobes 5 mm long, dorsal lobe slightly larger; lateral staminodes oblong, 5 mm long, yellow, slightly longer than corolla lobes; labellum obtriangular, 11  $\times$  5 mm, yellow with red spot, lobes acute; stamen: filament 20 mm long, pale yellow; anther 2.5 mm long, appendages 2 on each theca with a minute 3rd tooth between them. Fruit unknown. Bulbils lacking.

Thailand.— SOUTH-WESTERN: Phetchaburi [Kaeng Krachan National Park, Summit of Khao Phanoen Thung, 1,240 m, 8 May 2005, *Middleton et al. 3279* (**BKF**, **E**)]; PENINSULAR: Krabi [Khao Phanom Bencha, trail from Ban San to summit of Khao Phanom Bencha, 1,150 m, 19 June 2006, *Williams et al. 1977* (**A**, **BKF**, **E**)].

Distribution.— Endemic to Thailand.

Ecology. — Grows in dappled sunlight at 1,150–1,240 m alt.

Etymology.— Latin, *nitidus*, shining, referring to the shiny bracts.

Proposed IUCN conservation status.— *Globba nitida* is restricted to a vulnerable habitat type at high elevation, 1,150–1,240 m alt. with an AOO estimated under 10 km<sup>2</sup>. The two localities are situated in protected areas for which reason this species is assessed as of Least Concern (LC). Further surveys are required in particular in the area between the known locations; if other subpopulations are found, a reassessment will be needed.


Figure 10. *Globba nitida* M.F.Newman & Sangvir. (*Williams et al. 1977*) A. Habit & habitat; B. Inflorescence; C. & D. Holotype at **BKF**. Photographs A.–B. by M. Poopath; C.–D. by S. Sangvirotjanapat.



Map 3. Distribution of *Globba hilaris* Sangvir. (■), unspecific locality in Cambodia excluded from this map; *G. impar* M.F.Newman & H.Đ.Trần (★); *G. nitida* M.F.Newman & Sangvir. (○).

Notes.— *Globba nitida* is recognised by its pendent inflorescence with reflexed, white and shiny, plastic-like bracts. It shares these characters with *G. sherwoodiana* but differs from this species by having caducous, flat, elliptic bracteoles (vs persistent, infundibuliform bracteoles)(Fig. 7A). The differences between *G. nitida* and *G. grandis* are in the colour of the bracteoles and flowers. *Globba nitida* has white bracteoles and yellow flowers whereas *G. grandis* has yellow-orange bracteoles and rich orange flowers.

## Globba verecunda M.F.Newman & Sangvir., sp. nov.

Similar to *Globba marantina* L. in its compact inflorescence, yellowish orange flower with red spot on labellum and verrucose fruit but differing by its pendent inflorescence hidden by the leaves (vs erect or horizontal inflorescence which is easily seen) and lack of bulbils (vs bulbils many). Type: Thailand. Phitsanulok, Chat Trakan Waterfalls National Park, 185 m, 6 Aug. 2013, *Newman, Sangvirotjanapat, Sirimongkol, Fér, Záveská & Pospíšilová 2614*  (holotype **BKF**!; isotypes **E**!, **QBG**!, **SING**!). Fig. 11 & Map 4.

Herb 16-60 cm tall, growing in soil among limestone rocks under light shade. Leaf sheaths 4-9, green, densely patent hairy along midline and margins, 1-2.5 cm thick, forming distinctly flattened stems at tip; blades 4–9, elliptic, rather large,  $12-30 \times$ 3.5–8.5 cm, plain green, plicate in life, glabrous above, densely patent hairy below, base cuneate, apex long acuminate; petiole absent or very short on lower leaves, to 3 cm long on upper leaves, hirsute. Inflorescence condensed, pendent,  $2-6.5 \times 1.5-3.5$ cm; peduncle to 3 cm beyond leaf sheaths, without sterile bracts; rachis 2-3 cm long, green, hairy; bracts persistent, elliptic,  $26 \times 17$  mm at base, diminishing to  $10 \times 5$  mm at apex of inflorescence, green or white, densely hairy; cincinni 2.0-2.5 mm thick, 4.5-8.0 mm long to first flower, second order pedicel 1.0–1.5 mm long, with 3–6 orange-yellow flowers; bracteoles persistent, elliptic, somewhat boatshaped,  $17-18 \times 10-11$  mm at base of cincinnus, becoming smaller towards apex, greenish yellow or white, minutely pubescent. Flowers ca 3 cm long; ovary globose, 1.5 mm, finely granular; calyx 6 mm long, narrow, pubescent, orange or white, with 3 ribs ending in the calyx lobes, lobes curving inwards at apices; floral tube ca 15 mm long, orange, dorsal corolla lobe strongly boat-shaped, 7 mm long, orange, pubescent, acute, shortly cucullate, lateral corolla lobes shallowly boat-shaped, 5 mm long, orange, pubescent; lateral staminodes spreading, oblong to slightly curved,  $6 \times 2$  mm, orange, slightly longer than corolla lobes; labellum obtriangular,  $7 \times 4$  mm, orange with orange-red spot, shorter than lateral corolla lobes; stamen: filament 20 mm long; anther 2.5 mm long, appendages 4, 3 mm long, orange, slightly diverging. Fruit globose, 8 × 11 mm, surface verrucose, white to orange; seeds not seen. Bulbils absent.

Thailand.— NORTHERN: Phitsanulok [Chat Trakan Waterfalls National Park, Chat Trakan Waterfall, 1<sup>st</sup> level, Maliwan, 185 m, 6 Aug. 2013, *Newman et al. 2614* (**E, QBG, SING**); ibid., 400 m, 13 Aug. 2000, *Suksathan 2669* (**QBG**); Phu Suan Sai National Park, Chat Trakan District, 1,300 m, 21 June 2006, *Poulsen & Suksathan 2404* (**AAU**, **BKF, E, QBG**); Phu Soi Dao, 500 m, 14 Aug. 2000, *Suksathan 2674* (**QBG**); Tha Pla, Sirikit Dam, 178 m, 29 June 2012, *Norsaengsri & Tathana 9687* (**QBG**)]; Uttaradit [Phu Soi Dao, Nam Pat, path by waterfall towards pine forest, 680 m, 7 Aug. 2013, *Newman et al. 2619* (**E**, **QBG**); ibid., 700 m, 20 June 2006, *Poulsen & Suksathan 2398* (**A**, **AAU**, **BKF**, **E**, **QBG**); Phumiang-Phuthong Wildlife Sanctuary, Nam Pat District, 300 m, 13 Sept. 2011, *Romklao*  *Botanical Garden 3382554* (**QBG**); ibid., 340 m, 24 Sept. 2010, *Romklao Botanical Garden 1322553* (**QBG**); ibid., 443 m, 13 June 2012, *Romklao Botanical Garden 4852555* (**QBG**)]; NORTH-EASTERN: Loei [Phu Suan Sai, route to Hueang Nga, Na Haeo District, 8 July 2008, *Maknoi 2442* (**QBG**)].



Figure 11. *Globba verecunda* M.F.Newman & Sangvir. A. Habit & habitat; B. Ligule (left) & Inflorescence (right); C. Inflorescence with young fruit; D. Inflorescence (white form); E. Bracts of orange form; F. Dissection of flower; G. Infructescence at maturity. Scale bars = 1 cm. All photographs by S. Sangvirotjanapat.

#### Distribution.— Endemic to Thailand.

Ecology. — Deciduous forest, growing along the trails near streams at 180–800 m alt.

Etymology.—Latin, *verecundus*, meaning coy or modest, in reference to the inflorescence which is hidden by the leaves.

Proposed IUCN conservation status.— *Globba verecunda* is endemic to Thailand, where it is restricted to three localities in Phitsanulok, Uttaradit and Loei. All localities are situated in protected areas, which are not under serious threat but vulnerable to tourists activities. This species is assessed here as Least Concern (LC).

Notes.— *Globba verecunda* is a large plant with large leaves which hide its small inflorescence. The inflorescence can vary in colour from orange to white. The orange form has green bracts, yellowish-orange bracteoles and orange calyces (Fig. 11C) while the white form has white bracts, bracteoles and calyces (Fig. 11D).

# Globba williamsiana M.F.Newman & Sangvir., sp. nov.

Similar to *Globba winitii* C.H.Wright in its pendent inflorescence with persistent, reflexed bracts but differing by its cuneate leaf bases (vs cordate leaf bases), sessile leaves (vs petiolate), and yellowish orange flower with no spot on labellum (vs yellow with brown spot on labellum). Type: Thailand. Prachinburi, Kabinburi district, Ban Nong Plakhayaeng, 10 Aug. 2009, *Sangvirotjanapat 607* (holotype **QBG!**). Fig. 12 & Map 4.

Herb 30–50 cm tall. *Leaf sheaths* ca 3, sparsely puberulent; ligule bilobed, ca 5 mm long; blades 5–6, elliptic, ca  $15 \times 2.5$  cm, slightly plicate, glabrous below and above, sessile, base cuneate, apex acuminate. *Inflorescence* pendent, conical, ca  $8 \times 8$  cm; peduncle pale green, to 4 cm beyond leaf sheaths; rachis pale green, puberulent; bracts persistent, elliptic, ca  $2 \times$ 1 cm, white or pink, reflexed, apex acute; cincinni ca 1–4 cm long, >10 per inflorescence, 5–10 flowers per cincinnus; bracteoles caducous, elliptic, ca  $12 \times$ 6 mm, yellowish green, semitransparent, keeled, apex acute. *Flowers* ca 3 cm long; ovary ellipsoid, ca  $2 \times 1$  mm, pale yellow; calyx infundibuliform, ca 6 mm long, yellow, lobes acute; floral tube ca 10 mm long, yellowish orange, hairy; dorsal corolla lobe hooded, elliptic,  $3-5 \times 1.5$  mm, yellowish orange, apex acute, lateral corolla lobes shallowly hooded, elliptic, ca  $3 \times 1.5$  mm, yellowish orange, apex acute; lateral staminodes oblong, ca  $8 \times 1.5$  mm, yellowish orange, longer than corolla lobes, apex acute; labellum obtriangular, ca  $8 \times 5$  mm, yellowish orange with orange spot, base truncate, apex bilobed, lobes acute; nectar tube ca 4 mm long; stamen: filament ca 20 mm long, orange; anther elliptic, ca  $2 \times 1.2$  mm, appendages 4, triangular, ca  $3 \times 1$  mm, apex acuminate. *Fruit* globose, ca 8 mm in diam., yellowish green, verrucose; seeds not seen. *Bulbils* produced along peduncle, corky.

Thailand.— SOUTH-EASTERN: Sa Kaeo [Khao Takrup, 600 m, 6 Nov. 1993, *Larsen et al.* 44241 (**AAU**)]; Prachinburi [Kabinburi District, Ban Nong Plakhayaeng, 10 Aug. 2009, *Sangvirotjanapat* 607 (**QBG**)]; CULTIVATION VOUCHER: 15 June 2000, *Suksathan 2936* (**QBG**); *Mood M94P24* (**AAU**); 17 July 2013, *Muangyen 0060* (**QBG**), 9 July 2014, *Sangvirotjanapat* 688 (**QBG**).

Distribution.- Endemic to Thailand.

Ecology. — Growing on limestone mountains or in decidous forest.



Map 4. Distribution of *Globba verecunda* M.F.Newman & Sangvir. (■); *G. williamsiana* M.F.Newman & Sangvir. (○).

Vernacular.— Dok khao phansa (ดอกเข้าพรรษา).

Etymology.— In honour of Kyle Williams whose PhD thesis at Duke University, and published papers contain great insights into the systematics and evolution of *Globba*. Proposed IUCN conservation status.— *Globba williamsiana* is endemic to Thailand. The AOO is estimated at 8 km<sup>2</sup>, suggesting a status of Critically Endangered. The habitat in SE Thailand has been cleared for rubber plantations. The most recent



Figure 12. *Globba williamsiana* M.F.Newman & Sangvir. (*Sangvirotjanapat 688*) A. Habit; B. Inflorescence with white bracts; C. Inflorescence with pink bracts; D. Bracts; E. Cincinnus; F. Bracteoles; G. Dissection of flower; H. Fruit. Scale bars; A. = 10 cm; B.-C. = 5 mm; D.-E. & G. = 1 cm; F. & H. = 5 mm. All photographs by S. Sangvirotjanapat.

collection of this species in the wild was made in 2009, so further survey work is required to establish whether it is still extant in nature. The species is cultivated for cut flowers. With the information available at present, it is assessed as Endangered, EN B1ab(i,iii)+B2ab (i,iii).

Notes.— *Globba williamsiana* is well known as an ornamental plant with large and brightly coloured bracts. Individuals selected from the wild have been used to breed artificial hybrids for the horticultural trade. These hybrids are commonly seen in flower markets, indicating that interspecific hybrids can occur in sect. *Globba*. The inflorescence structure and colour of the bracts and bracteoles resemble those of *Globba winitii* (Fig. 7D) very closely and the two species are sometimes confused but the cordate leaf bases of *G. winitii* are highly diagnostic; *G. williamsiana* always has cuneate leaf bases.

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#### Notes on taxonomy of the genus Argostemma (Rubiaceae) from Vietnam

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#### ABSTRACT

*Argostemma pictum* (Rubiaceae), a species occurring in Myanmar, Thailand, Laos and Peninsular Malaysia, is newly reported for the flora of Vietnam; a description, photographs, information on ecology and taxonomic notes are also presented. In order to facilitate identification, we provide an identification key and checklist to the 10 known *Argostemma* species in Vietnam.

KEYWORDS: Argostemmateae, checklist, new record, Rubiaceae, Vietnam, Gentianales. Accepted for publication: 4 November 2020. Published online: 3 December 2020

#### **INTRODUCTION**

The genus Argostemma Wall. is the largest genus of the tribe Argostemmateae (Rubioideae, Rubiaceae) with about 220 species, distributed mainly in tropical and subtropical Asia, and with two species are endemic to west tropical Africa (Bremer, 1989; Bremer & Manen, 2000). However, the taxonomically complicated genus that has yet to be studied in detail and so knowledge of the genus is still poor. Although several taxonomic treatments of the genus were published for geographical areas, e.g. the Malay peninsula and peninsular Thailand (Ridley, 1923; Sridith, 1999, 2007; Sridith & Puff, 2000), Laos (Lanorsavanh & Chantaranothai, 2013, 2019), China (Chen et al., 2011), and Vietnam (Pitard, 1923; Pham, 2003), a worldwide monographic study has not yet been attempted. The Malay Peninsula, Peninsular Thailand and Borneo were considered as centres of diversity of Argostemma; 31 species were recorded for the flora of Thailand (Sridith, 2007).

During a recent investigation on the flora of Ta Dung National Park in Dak Nong province, southern Vietnam, we collected some flowering specimens belonging to Argostemma. Detailed examination of the specimens and studies on the protologues and type specimens of previously known species revealed that the morphological characters of these specimens match with those of Argostemma pictum Wall. - a species distributed mainly in Myanmar, Thailand, Peninsular Malaysia, and Laos (Sridith, 2007; Lanorsavanh & Chantaranothai, 2019), however, this species has not yet been reported for Vietnam in previous treatments (Pitard, 1923; Pham, 2003; Choudhary et al., 2013; Govaerts et al., 2017; Nuraliev et al., 2017; Quang et al., 2019; Do et al., 2020). Therefore, we report here A. pictum as a new record for the flora of Vietnam bringing the number of species in the genus to 10, of which, six species, i.e. A. annamiticum Ridl., A. bachmaense T.V.Do, A. bariense Pierre ex Pit., A. cordatum Nuraliev, A. glabra Joongku Lee, T.B. Tran & R.K. Choudhary

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and A. vietnamicum B.H.Quang, Joongku Lee & R.K.Choudhary, are endemic to Vietnam. Moreover, Central and Central Highland Regions of Vietnam are considered as the centres of diversity of Argostemma

in the country. In order to facilitate identification, we here provide a key and checklist to *Argostemma* species in Vietnam.

#### KEY TO THE SPECIES OF ARGOSTEMMA IN VIETNAM

. Plant glabrous	1. A. glabra
. Plant pubescent	
2. Leaves verticillate	2. A. verticillatum
2. Leaves not verticillate	
3. Leaves strongly anisophyllous	
4. Inflorescence exclusively 1-flowered	3. A. uniflorum
4. Inflorescence 1-many-flowered	
5. Leaves sessile; inflorescence umbel-like	4. A. cordatum
5. Leaves petiolate; inflorescence racemose	
6. Inflorescence axis 4–7 cm long; pedicel 0.8–1.5 cm long	5. A. bariense
6. Inflorescence axis up to 1.5 cm long; pedicel up to 0.5 cm long	6. A. annamiticum
3. Leaves isophyllous or slightly anisophyllous	
7. Large leaves more than 5 cm long; inflorescence umbel-like, 5-10-flowered	
8. Leaves ovate; petioles 1–2 cm long	7. A. borragineum
8. Leaves ovate or triangular; petioles sessile	8. A. pictum
7. Leaves up to 4 cm long; inflorescence solitary or laxly corymbiform, 1-4-flowered	
9. Leaves oblanceolate to spathulate, attenuate at base; inflorescence 1-flowered; bracts absent	9. A. bachmaense
9. Leaves rounded to obovate, rounded at base; inflorescence 1–4-flowered; bracts triangular to lance	ceolate

10. A. vietnamicum

#### A CHECKLIST TO THE SPECIES OF ARGOSTEMMA IN VIETNAM

**1. Argostemma glabra** Joongku Lee, T.B.Tran & R.K.Choudhary, Ann. Bot. Fennici 50(4): 258. 2013. Type: Vietnam, Khanh Hoa, Hon Ba Nature Reserve, 11 Apr. 2011, *Lee et al. HIKK 285* (holotype **HN!**; isotype **KRIB!**).

Ecology and phenology.— Growing in pristine mixed evergreen and sub-temperate forests on a moss-rich hillock, ca 1,305 m alt. Flowering in April.

Distribution.— Endemic to southern Vietnam (Khanh Hoa).

2. Argostemma verticillatum Wall., Fl. Ind. (Carey & Wallich, ed.), 2: 325. 1824. Type: Nepal, Moreko, July 1821, *Wallich s.n, Numer. List 8394A* (holotype K-W [K001125376, image seen]).

*A. acutum* Wall. ex Hook.f., Fl. Brit. India 3(7):43. 1880. Type: Unknown.

— A. glaberrimum Dalzell, Hooker's J. Bot. Kew Gard. Misc. 3: 345. 1851. Type: India, Bombay, *Dalzell s.n.* (holotype **K** [K001325261, image seen]).

Ecology and phenology.- Growing on moist

rocks along streams or near small waterfall in evergreen forests, 1,200–1,500 m alt. Flowering June to July.

Distribution.— India, Nepal, Myanmar, Thailand, Laos, southern Vietnam.

**3. Argostemma uniflorum** Blume ex DC., Prodr. 4: 418. 1830. Type: Indonesia, Java, *Blume s.n.* (holotype L [L0063029, image seen]).

Ecology and phenology.— Growing on moist soil near streams in evergreen forest, 900–2,000 m alt. Flowering May to June, fruiting July to August.

Distribution.— Vietnam (Thua Thien Hue, Dak Lak), Indonesia.

**4. Argostemma cordatum** Nuraliev, Phytotaxa 317(1): 43. 2017. Type: Vietnam, Dak Lak, Lak, Bong Krang, Chu Yang Sin National Park, 11 km South-eastern of Krong Kmar village, 12°24′ 53″N, 108°22′56″E, 22 May 2014, *Nuraliev et al. 960* (holotype **MW** [MW0595623!]).

Ecology and phenology.— Growing on shady stream banks in mixed forests and inhabits vertical granite rock surfaces, 950–1,250 m alt. Flowering May to June. Distribution.— Endemic to southern Vietnam (Dak Lak).

**5. Argostemma bariense** Pierre ex Pit. in Lecomte, Fl. Indo-Chine 3: 79. 1922. Type. Vietnam, in montibus densy ad Baria, 2–300 m alt., 1 Aug. 1866, *Pierre 5480* (holotype **P** [P00077330!]; isotype **P** [P00077331!]).

Ecology and phenology.— Growing on moist soil near streams in evergreen forest, 1,500–1,700 m alt. Flowering August to October, fruiting November to December.

Distribution.— Endemic to Vietnam (Thua Thien Hue, Da Nang, Kon Tum, Ba Ria-Vung Tau).

**6. Argostemma annamiticum** Ridl., J. Bot. 65: 40. 1927. Type: Vietnam, Thua Thien Hue (unknown).

Ecology and phenology.— Growing on the moist sites in evergreen forest, 800–1,200 m alt. Flowering April to May.

Distribution.— Endemic to central Vietnam (Thua Thien Hue).

7. Argostemma borragineum Blume ex DC., Prodr. 4: 417. 1830. Type: Indonesia, Sumatra, 6 Aug. 1921, *Kloss s.n.* (holotype **K** [K000760145!]).

Ecology and phenology.— Growing on moist rocks along streams or near small waterfall in evergreen forests, 1,200–1,600 m alt. Flowering September to October.

Distribution.— India, Nepal, Myanmar, Vietnam (Lao Cai, Ha Tinh, Kon Tum, Dak Lak, Lam Dong), Indonesia, Peninsular Malaysia.

8. Argostemma pictum Wall. in Roxb., Fl. Ind. (Carey & Wallich, ed.) 2: 327. 1824. Type: Malaysia, Penang, 1822, *Wallich s.n., Numer. List 8392* (lectotype **K-Hook.** [K000172892, image seen]; isolectotype **K-Benth.** [K000172894, image seen], **K-W** [K001125373, image seen]), designated by Sridith, 1999)(Fig. 1A–E).

— *A. bifolium* Ridl., Fl. Malay. Penins. 5: 314. 1925. Type: Malaysia, Perak, Maxwell's Hill, Dec. 1892, *Ridley s.n.* (holotype **K** [K000760231, image seen]).

*—A. rotundifolium* E.T.Geddes, Bull. Misc. Inform. Kew 1927(4): 168. 1927. Type: Thailand, Yala, Betong (formerly in Pattani), 2 Aug. 1923, *Kerr* 7470 (lectotype **K** [K000760185, image seen]; isolectotypes **BM** [BM000028699, image seen], **K** [K000760184, image seen], **SING** [SING0058412, image seen]), designated by Sridith, 1999).

Herb, to 9–14 cm tall; stems erect, 6–9 cm long, pubescent. Stipules ovate, ca 3 by 3 mm, bifid tip, pubescent. Petioles sessile. Leaves opposite, 1 pair, rarely 2 pairs, slightly anisophyllous or sometimes isophyllous when young; lamina membranaceous, ovate or triangular, larger one 6-8 by 3-4 cm, smaller one 3-4 by 1-2 cm, base truncate, rounded or occasionally cordate, apex acute or slightly rounded, lower surface light grey, sparsely to densely hairy, upper surface dark green, sparsely hairy; lateral veins 4-5 pairs, venation slightly sunken above and prominent and raised below. Inflorescences 6-12-flowered, umbel-like; peduncles 3-5 cm long, sparsely hairy; bracts 4-5, basally fused, forming a cup-like involucrum, linear or ovate, 2-3 by 1-2 mm, green, outside pubescent. Flowers 5-merous, actinomorphic; pedicels 3-10 mm long, glabrescent to pubescent. Calyx green; lobes ovate, triangular, 1-2 by 0.5-1 mm, raphides conspicuous. Corolla white, star-shaped, outside densely covered with very short hairs, inside glabrous; tube 0.6-1.1 mm long; lobes triangular, 2-3 by 1-2 mm, strongly recurved and tip very coiled. Stamens 5, insert at base of the corolla tube; filament free, ca 1.5 mm long, broad and thick, swollen connective; anthers connivent into an anther cone, pale yellow, basifixed, oblong, 3.8-4.2 mm long, with short appendages, opening by longitudinal slits. Ovary pubescent; style filiform, 4-5 mm long, long exserted, glabrous; stigma capitate. Capsule not seen.

Ecology and phenology.— Growing on moist sandstone rocks with soil in evergreen forests, 450–500 m alt. Flowering May to June.

Distribution.—Myanmar, Thailand, Peninsular Malaysia, Laos, and new to Vietnam (Dak Nong).

Specimens examined. Vietnam.—Dak Nong [Ta Dung National Park, 23 May 2019, *Nguyen Quang Hung et al. 323* (HN!, VNMN!)].

Notes.— Argostemma pictum is morphologically similar to A. neurocalyx Miq. (occuring in Thailand and Laos) by having an ovate or triangular leaves, slightly anisophyllous or sometimes isophyllous when young and umbel-like inflorescence but it clearly differs by having 1-paired leaves, rarely 2-paired (vs. always 2-paired), conspicuously white veins on upper leaf surface (vs. green veins), sessile petioles (vs. conspicuous, 3–5 mm long), 5-merous flowers with star-shaped corolla (vs. 4-merous with bell-shaped corolla).

**9.** Argostemma bachmaense T.V.Do, Nord. J. Bot. 8(7): 02765. 2020. Type: Vietnam, Thua Thien Hue province, Bach Ma National Park, Do Quyen waterfall, 16°11′27.32″N, 107°51′15.62″E, 1 July 2019, *Yang et al. NWC-201951* (holotype **VNMN!**; isotype **KUN!**).



Figure 1. *Argostemma pictum* Wall. (A–E.): A. Habitat; B. Leaves and inflorescence; C. Lower leaf surface; D. Frontal view of flowers; E. Dorsal view of flowers (*Nguyen Quang Hung et al. 323*).— *A. neurocalyx* Miq.: F. Habitat, leaves, and calyx.— *A. cordatum* Nuraliev: G. Habitat, leaveas, and inflorescence. A–E. photos by Do Van Truong; F. photo by Tony Rood; G. photo by Maxim Nuraliev.

Ecology and phenology.— Growing on moist rocks near small waterfall or along the rapid stream in evergreen forest, 1,000–1,100 m alt. Flowering June to August.

Distribution.— Endemic to central Vietnam (Thua Thien Hue).

**10.** Argostemma vietnamicum B.H.Quang, Joongku Lee & R.K.Choudhary, Ann. Bot. Fennici 56(1–3): 27. 2018. Type: Thua Thien Hue, Bach Ma National Park, 1190 m alt., 16°11'34.4"N, 107°51'16.7"E, 19 Apr. 2013, *Quang 85* (holotype **HN!**; isotype **HN!**).

Ecology and phenology.— Growing on the wetlands (mostly near streams) of the primary and temperate forest, 1,190 m alt. Flowering April to May.

Distribution.— Endemic to central Vietnam (Thua Thien Hue).

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