VARIATIONS IN THE *HOYA VERTICILLATA* COMPLEX IN THAILAND

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Abstract

Hoya verticillata (Vahl) G.Don *s.l.* is a climbing epiphyte belonging to the family Apocynaceae. At present, the taxonomic status of this species in Thailand is still uncertain due to the great variability of size, shape and colour of leaf and flower. Morphological variations were explored in 500 fresh plants collected from 50 sites throughout the country. The collected specimens represent the *H. verticillata* complex, including two polymorphic species, namely *H. verticillata s.l.* and closely related species, *H. rigida* Kerr. Based on qualitative macro- and micro-morphological characters, the *H. verticillata* complex can be divided into nine groups. They can be distinguished by leaf shape, leaf base, venation pattern, leaf indumentum, and shapes of sepal, corona and corpusculum. Group I matched with the characteristics of *H. rigida* Kerr, which has ovate leaves with cordate base, 3-5 prominent nerves running from base to apex; indumentum absent on the abaxial surface; and lanceolate sepals. In contrast, Group II is an unidentified taxon that is close to *H. verticillata* (Vahl) G. Don var. *citrina* (Ridl.) Veldkamp. It is charaterized by broad ovate leaves with cordate base, 3-5 prominent nerves running from base to apex; and narrowly oblanceolate-oblong corpusculum. Groups III and IV have distinctly different vegetative characters and do not correspond to the previously described varieties of *H. verticillata*. Their leaf venation is acrodromous, with 3 prominent nerves running from leaf base parallel to the midrib and reaching the apex, but they are different in their shape of leaf and coronal scale. Group III has ovate leaves with subcordate base and elliptic coronal scale, while Group IV has elliptic-oblong leaves with cuneate base and ovate-lanceolate corona. Groups V-IX are still of weak validity, having slightly discontinuity in leaf shape, base and venation; and shape of coronal scale. They are treated in this paper as variable groups within *H. verticillata* var. *verticillata.*

Introduction

Hoya verticillata (Vahl) G.Don (Apocynaceae: Asclepioideae) is one of the most common members of the section *Hoya* (Hooker *f.*, 1883). It is relatively widespread, occurring from E. India-Assam through Myanmar, Thailand, Indo-China, Malay Peninsula, and Sumatra to N. Borneo (Rintz, 1978). The most recent taxonomic study of the species (Kiew, 1995; Veldkamp *et al.*, 1995) included three varieties: *H. verticillata* var. *verticillata*, *H. verticillata* var. *citrina* and *H. verticillata* var. *hendersonii.* These varieties can be distinguished from each other by leaf characters and habitat. *H. verticillata* var. *verticillata* is distinguished from the other two varieties by its elliptic leaf, cuneate base, obscure veins with the lowest pair extending about halfway to apex. The other two varieties are similar in having an ovate leaf with slightly cordate base, but with conspicuous veins and the lowest vein pair extending to apex. As for habitat, var. *hendersonii* grows in lower montane forest between 1,200 and 1,260 m altitude, while the other two are lowland varieties (Kiew, 1995).

In Thailand, *H. verticillata s.l.* is the most common hoya, and is an extremely variable species. There is variation in texture, shape, size and venation of leaves, the size of the flower and shape of corolla lobes (Kerr, 1951). These plants were later named "the *H. verticillata* complex" (Thaithong, 1995). However, variations within this complex did not match properly with the three fomerly recognized infraspecific taxa. Additional intensive research into relationships within this difficult group of plants has not been carried out for many years.

Moreover, previously distinct species, *H. ridleyi* and *H. rigida* have been taxonomically confused with *H. verticillata s.l. H. ridleyi* is found in peninsular Thailand (Ridley, 1923), but has also been recognized as *H. parasitica* var. *parasitica*, the synonym of *H. verticillata* var. *verticillata* (Rintz, 1978). Then, Veldkamp *et al.* (1995) suggested that *H. rigida,* a species endemic to Thailand, may be included in *H. verticillata s.l.*. Thus, the taxonomic status of *H. verticillata* complex in Thailand is still uncertain and needs to be reinvestigated.

We suspect that *H. verticillata* complex in Thailand is composed of several undescribed taxa. We have explored all the available variables in the complex and have determined macro- and micro-morphological variations of each group. In this paper, we have (1) described the overall qualitative morphological variations of characters in the complex, (2) classified the variations into groups, and (3) described morphological characters, geographical distribution and ecological features of each recognized group.

We then (4) discuss the taxonomic treatment of these recognized groups as compared with the previous classification.

Materials and methods

Plant Morphology

Plant materials used in this study were collected from 50 sites throughout Thailand during 2002-2003 (Table 1, Fig. 1) and all were raised in the same conditions in a greenhouse at the Department of Botany, Faculty of Science, Chulalongkorn University. Flower and leaf materials were then gathered from the living collection. These were preserved in 70% ethanol for further morphological studies. In general, the morphological characters of leaves and flowers were examined using light microscopy (LM). Leaf indumentum on both surfaces was observed under LM and scanning electron microscopy (SEM).

Habitat and Distribution

Habitats of *H. verticillata* complex were studied and their location recorded using GPS. Collection sites were plotted on an outline map, thus showing their distribution, in relation to forest types and elevation, and characterizing the habitat of particular member of the complex.

Results

General description of *Hoya verticillata* complex (Fig. 2–4)

Glabrous **twiner,** epiphyte, with long internodes. **Leaves** opposite or whorled; *lamina* ovate or elliptic to oblong, glabrous or papillate on abaxial surface; *texture* coriaceous to succulently coriaceous, depending somewhat on habitat; *venation* with three or five principal veins (nerves) arising near the junction of lamina and petiole; *nectary glands* present at the junction of petiole and lamina; *petioles* usually thick and stout, occasionally slender in mature leaves. **Inflorescences** axillary, negative geotropic umbels with almost equal pedicel; **flower** actinomorphic, 5-merous; *pedicels* slender; *calyx* glabrous or covered with hairs on abaxial surface and margin, with a small gland alternately arranged between calyx lobes; *corolla* rotate, abaxial surface glabrous, covered with minute hairs on adaxial surface, reflexed when in full bloom, becoming closed at the end of flowering period; *corolla lobe* ovate-triangular with acute or acuminate apex, inflexed (bent inwards) between corona scales; *corona* longer than corolla tube, coronal scale ovate-elliptic or ovate-lanceolate; the first inner angle abruptly apiculate, slightly raised, the outer angle broadly or narrowly acute, concave on the upper

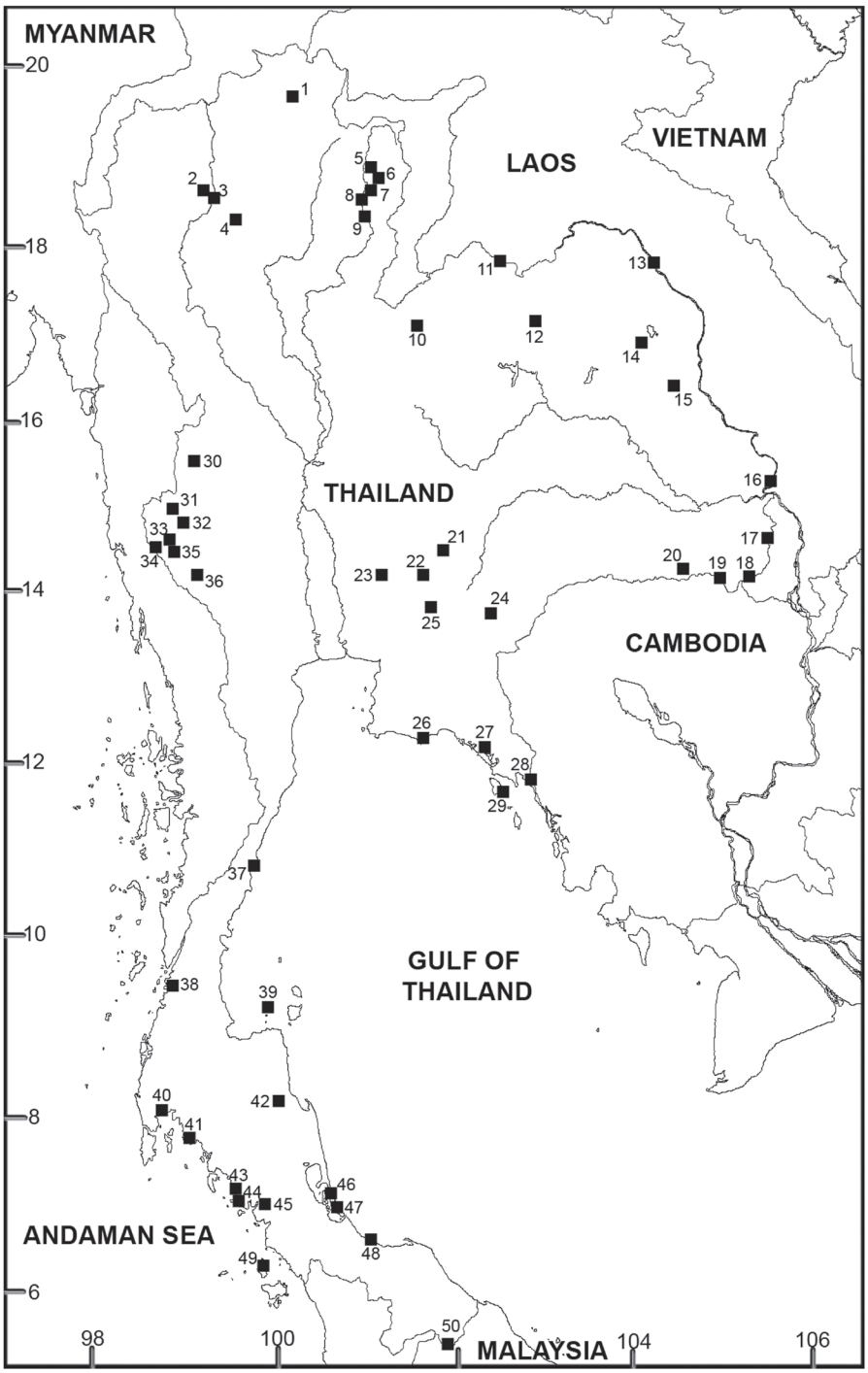

Fig. 1. Sampling sites of *Hoya verticillata* complex in Thailand.

Table 1. Locality and collected groups of the *Hoya verticillata* complex in Thailand.

Site no.[a]	Locality	Group[b]
1.	Mueang, Chiang Rai Province	V
2.	Wang Bua Ban Waterfall, Chiang Mai Province	V, IX
3.	Haew Keaw, Mueang, Chiang Mai Province	VI
4.	Doi Khun Tan National Park, Lampang Province	IX
5.	Silaphet Waterfall, Pua, Nan Province	III, VII
6.	Tat Laung Waterfall, Pua, Nan Province	VII
7.	Ban Muang Wang Nhua, Phu Phiang, Nan Province	IX
8.	Phasing, Mueang, Nan Province	V
9.	Lhinan, Na Noi, Nan Province	VII, IX
10.	Pla Ba Waterfall, Phu Ruea, Loei Province	IX
11.	Than Thong Waterfall, Sri Chiang Mai, Nong Khai Province	IX
12.	Than Ngam Waterfall, Nong Wua So, Udon Thani Province	IX
13.	Tat Kham Waterfall, Ban Phaeng, Nakhon Phanom Province	IX
14.	Phu Phan National Park, Sakon Nakhon Province	IX
15.	Tat Ton Waterfall, Mukdahan Province	IX
16.	Soi Sawan Waterfall, Ubon Ratchathani Province	IX
17.	Huai Sai Yai waterfall, Sirinthon, Ubon Ratchathani Province	IX
18.	Phu Chongna Yoi National Park, Ubon Ratchathani Province	IX
19.	Tat Hai Waterfall, Nam Yuen, Ubon Ratchathani Province	IX
20.	Sam Long Kiat Waterfall, Khun Han, Si Sa Ket Province	IX
21.	Phu Wa Kiew Waterfall, Nakhon Ratchasima Province	IX
22.	Khao Yai National Park, Nakhon Ratchasima Province	I, IX
23.	Pu Kae, Saraburi Province	IX
24.	Pang Sida National Park, Sa Kaeo Province	IX
25.	Prachantakham, Prachin Buri Province	VIII

Site no.[a]	Locality	Group[b]
26.	Ban Pe, Rayong Province	VIII
27.	Nam Tok Phriu National Park, Chanthaburi Province	VIII
28.	Mueang, Trat Province	VIII
29.	Ko Chang, Trat Province	VIII
30.	Thi Lo Su waterfall, Tak Province	IX
31.	Sangkhla Buri, Kanchanaburi Province	IX
32.	Koeng Kra Wia Waterfall, Kanchanaburi Province	IX
33.	Pong Ron, Thong Pha Phum, Kanchanaburi Province	IX
34.	Pha Suk Pass,Thong Pha Phum, Kanchanaburi Province	I
35.	Ban Thamadua, Thong Pha Phum, Kanchanaburi Province	IX
36.	Sai Yok National Park, Kanchanaburi Province	IX
37.	Bang Saphan, Prachuap Khiri Khan Province	VIII
38.	Namtok Ngao National Park, Ranong Province	IX
39.	Ko Wua Ta Lub, Suratthani Province	VIII
40.	Mueang, Phangnga Province	VIII
41.	Noppharat Thara Beach, Krabi Province	VIII
42.	Khao Luang National Park, Nakhon Si Thammarat Province	I
43.	Pakmeng, Trang Province	VIII
44.	Hat Chao Mai National Park, Trang Province	VIII
45.	Thung Kai, Trang Province	VIII
46.	Sathing Phra, Songkhla Province	VIII
47.	Singhanakhon, Songkhla Province	VIII
48.	Pak Bang Sakom Beach, Songkhla Province	VIII
49.	Tarutao National Park, Satun Province	IV, VIII
50.	Sirinthon Waterfall, Waeng, Narathiwat Province	II

a = Site numbers correspond to those in Fig.1; b = Nine groups distinguished in this study.

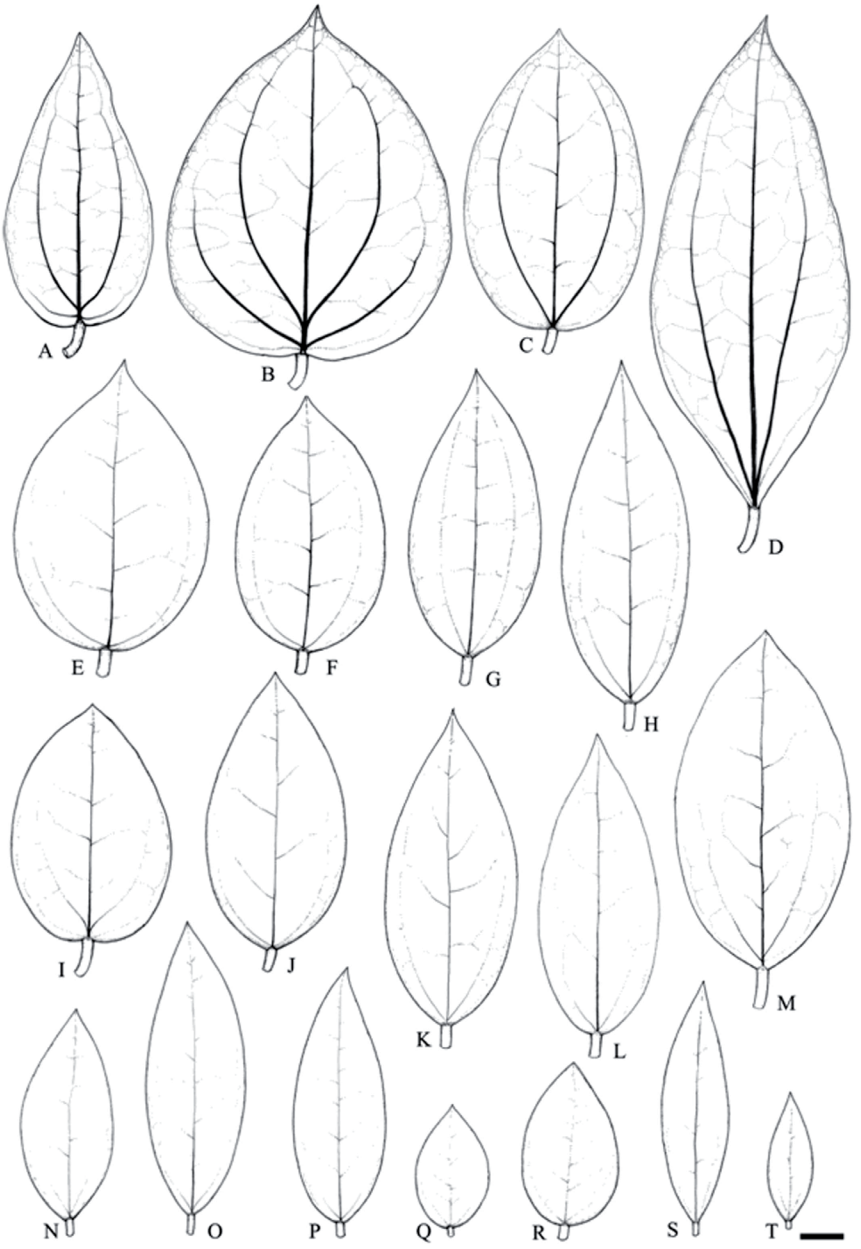

Fig. 2. Leaves of *Hoya verticillata* complex. A: Group I, site 42 (166). B: Group II, site 50 (303). C: Group III, site 5 (380). D: Group IV, site 49 (320). E-F: Group V, E. site 1 (404), F. site 8 (378). G-H: Group VII, G. site 6 (385), H. site 5 (384). I: Group VI, site 3 (289). J-M: Group IX, J. site 11 (559), K. site 14 (436), L. site 24 (3), M. site 33 (258). N-T: Group VIII, N. site 27 (120), O. site 40 (670), P. site 45 (66), Q. site 39 (585), R. site 46(243), S. site 47 (213), T. site 49 (202). Numbers in parenthesis denote the collector number. Bar = 2 cm.

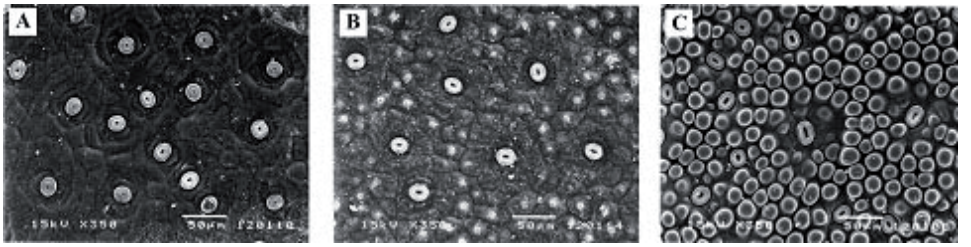

Fig. 3. Scanning electron micrographs of the abaxial surface of leaves of *Hoya verticillata* complex. A: Group I (absent indumentum); B: Group II (minute and scattered indumentum); C: groups III-IX (dense indumentum). Bar = 50 μm.

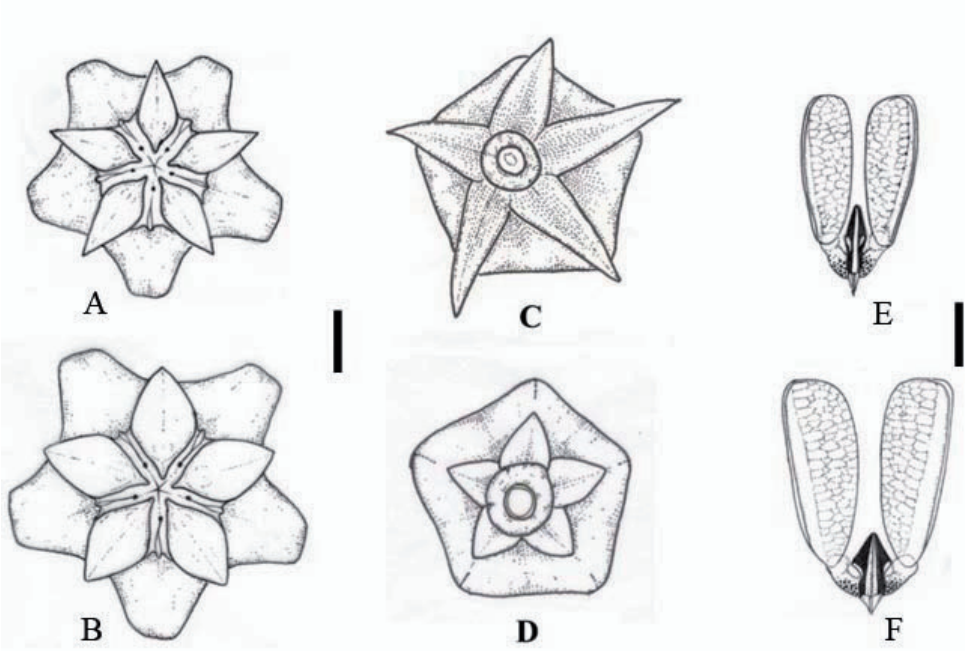

Fig. 4. Flower and flower parts of *Hoya verticillata* complex. A-B (top view of flower), A: Groups II, IV, VI,VIII and IX (coronal scales ovate-lanceolate); B: Group I, III, V, VII (coronal scales broad ovate or ovate-elliptic); C-D (bottom view of flower), C: Group I (sepal lanceolate); D: Group II-IX (sepal ovate); E-F (polinaria), E: Group II (corpuscles oblanceolate-oblong); F: Groups I, III-IX (corpuscles triangular-oblong). A-D: Bar = 2 mm; E-F: Bar = 0.2 mm.

surface usually with a median ridge; *anthers* 5, lying just below the inner coronal angle, each producing two pollen masses or pollinia, each pollen mass from adjacent anther lobes connected by short translator arms with a corpusculum, forming a pollinarium; *pollinium* flattened, oblong, truncate at the top, with narrow translucent longitudinal wing; *corpusculum* dark brown or black. **Fruits** a follicle, pod-like, straight and glabrous.

Comparative morphology

Despite the great observed variations (i.e., habitat, leaf shape, forms of leaf base, venation pattern of leaf, forms of sepal and corona), we can tentatively classify the variations of the complex into nine groups by a comparison of qualitative morphological characters. These groups are then named as Group I-IX (IX being the residual group). A key to the Groups and descriptions of the Groups are presented below.

Key to Groups of wild *H. verticillata* complex in Thailand

1. Sepals lanceolate, longer than the corolla tubes, leaves glabrous (Fig. 3A, 4C) ..... **Group I**
1. Sepals ovate, equal in length or shorter than corolla tubes, leaves papillate on abaxial surface (Fig. 3B-C, 4D)

    2. Leaves with prominent basal nerves, extending from base to apex, veins conspicuous (Fig. 1A-D)

        3. Leaves ovate, base rounded to cordate

            4. Coronal scales ovate-lanceolate (Fig. 4A), corpusculum narrowly oblanceolate-oblong (Fig. 4E) ..... **Group II**
            4. Coronal scales ovate-elliptic (Fig. 4B), corpusculum broadly triangular-oblong (Fig. 4F) ..... **Group III**

        3. Leaves ovate-oblong, base cuneate ..... **Group IV**

    2. Leaves with unclear basal nerves, mostly extending about half way to apex, veins obscure (Fig. 1E-T)

        5. Leaf base rounded to subcordate

            6. Coronal scales ovate-elliptic, petioles stout ..... **Group V**
            6. Coronal scales ovate-lanceolate, petioles slender ..... **Group VI**

5. Leaf base cuneate to obtuse

   7. Coronal scales ovate-elliptic ..... **Group VII**
   7. Coronal scales ovate-lanceolate

   8. Leaves relatively narrow, 1.8-(3.8)-5.8 cm wide, base cuneate. Littoral plants ..... **GroupVIII**
   8. Leaves broad, 4-(5.8)-8.6 cm wide, base variable. Inland plant found throughout Thailand ..... **Group IX**

Group I

Leaves rigidly coriaceous, broad ovate to oblong with rounded to cordate base, 13.8-(17.8)-19.1 cm long, 6.8-(8.7)-10.1 wide; nerves 3-5, prominent, extending from base to apex, the other veins conspicuous; glabrous on both surface; petiole slender, 2.7-(3.4)-3.9 cm long. Umbel 7-(30)-65 flowered, peduncle 1.5-(2.9)-4.7 cm long; pedicel glabrous, 2-(2.3)-3 cm long. Sepal lanceolate, longer than corolla tube, 4.9-(5.4)-5.6 mm long, 2-(2.1)-2.2 mm wide. Corolla creamy white, 1.6-(1.9)-2.1 cm diam. Coronal scale broad ovate, 4.2-(4.5)-4.8 mm long, 2.2-(2.4)-2.6 mm wide, the outer angle slightly erected and white, apiculus of the inner angle raised and pink. Pollinia oblong, 0.62-(0.63)-0.64 mm long, 0.21-(0.23)-0.24 mm wide; translator short; corpusculum triangular-oblong, 0.16-0.18 mm long, 0.12-0.13 mm wide.

Ecology and distribution: A long climbing epiphyte, usually on trees along stream banks, in moist evergreen forest, in the eastern, western and southern parts of the country at 700-900 m elevation.
Specimens examined: Kanchanaburi - Thong Pha Phum, *Manit Kidyue 464, 465, 466, 467, 468, 469*. Nakhon Ratchasima - Khao Yai, *Manit Kidyue 360, 361, 997*. Nakhon Si Thammarat - Khao Luang, *Manit Kidyue 166*.

Group II

Leaves coriaceous, broadly ovate or rhombic with cordate base, 14.7–(15.9)–16.7 cm long, 11.3–(12.3)–13.2 cm wide; nerves 3–5, prominent, extending from base to apex, veins conspicuous; hairs minute, scattering on the abaxial surface; petiole slender, 1.8–(2.1)–2.2cm long. Umbel 10–(26)–49 flowered, peduncle 2.5–(3.3)–4.3 cm long; pedicel glabrous, 1.7–(1.9)–2.0 cm long. Sepal ovate, 1.8–(1.9)–2.0 mm long, 1.5–(1.7)–1.8 mm wide. Corolla creamy white, 1.4–1.5 cm diam. Coronal scale ovate-

lanceolate, 3.5–(3.8)–4.0 mm long, 1.5–(1.6)–1.7 mm wide, the outer angle flattened and pinkish white, apiculus of the inner angle raised and pink. Pollinium oblong, 0.45–0.46 mm long, 0.15–0.16 mm wide; translator short; corpusculum narrowly oblanceolate-oblong, 0.2–0.22 mm long, 0.07–0.08 mm wide.

Ecology and distribution: A long climbing epiphyte in moist evergreen forest, usually on trees along stream banks, restricted to Bala forest, peninsular Thailand at about 200 m elevation.
Specimens examined: Narathiwat - Sirinthon Waterfall, *Manit Kidyue 128, 303, 304, 305, 306, 688*.

Group III

Leaves rigidly coriaceous, broadly ovate with subcordate base, 14–(14.6)–15.3 cm long, 5.9–(7.4)–8 wide; nerves 3, prominent, extending from base to apex, veins conspicuous; covered with dense hairs on abaxial surface; petiole stout, 1.1–(1.9)–2.1 cm long. Umbel 22–(43)–59 flowered, peduncle 3.1–(4.5)–7.4 cm long; pedicel sparsely pubescent, 1.9-(2.2)-2.4 cm long. Sepal ovate, 1.8–(1.9)–2 mm long, 1.4–(1.6)–1.8 mm wide. Corolla yellowish white, 1.4–1.5 cm diam. Coronal scale ovate-elliptic, 3.5–(3.6)–3.8 mm long, 1.7–(2.0)–2.2 mm wide, the outer angle slightly erect and white, apiculus of inner angle raised and pink. Pollinium oblong, 0.5–0.6 mm long, 0.19–0.22 mm wide; translator short; corpusculum triangular-oblong, 0.17–0.19 mm long, 0.11–0.12 mm wide.

Ecology and distribution: A long climbing epiphyte in mixed deciduous forest, or on rocks along stream banks, at about 400 m elevations, confined to northern Thailand.
Specimens examined: Nan - Silaphet Waterfall, *Manit Kidyue 380, 381, 382*.

Group IV

Leaves large coriaceous, elliptic-oblong, with cuneate base, 18–(19.3)–20.4 cm long, 7.3–(7.7)-8 cm wide; nerves 3, prominent, extending from base to apex, veins conspicuous; covered with dense hairs on abaxial surface; petiole slender, 2–(2.5)–2.9 cm long. Umbel 65–(68)–71 flowered, peduncles 5.6–(7.3)–9.1 cm long; pedicel glabrous, 2–(2.2)–2.3 cm long. Sepal small ovate, 1.7–1.8 mm long, 1.5-1.6 mm wide. Corolla creamy white, 1.2–1.3 cm diam. Coronal scale ovate-lanceolate, 3.4–(3.5)-3.6 mm long, 1.82-(1.86)–1.91 mm wide, the outer angle slightly erect and white, apiculus of the inner angle

short raised and pink. Pollinium oblong, 0.45–0.46 mm long, 0.17–0.18 mm wide; translator short; corpusculum triangular-oblong, 0.16–0.17 mm long, 0.11–0.12 mm wide.

Ecology and distribution: A long climbing epiphyte on tree branches along stream banks in evergreen forest, restricted to Tarutao Island, peninsular Thailand.
Specimens examined: Satun - Tarutao National Park, *Manit Kidyue 320, 321*.

Group V

Leaves coriaceous to succulently coriaceous, ovate with round to subcordate base, 8.6–(12.5)–16.2 cm long, 5–(7.1)–10 cm wide; nerves 3, extending about half way to apex or slightly longer, veins obscure; covered with dense hairs on abaxial surface; petiole stout, 0.5–(1.2)-2.9 cm long. Umbel 21–(43)–87 flowered, peduncle 0.6-(3.0)-6.5 cm long; pedicel glabrous to pubescent, 1.9–(2.3)–2.8 cm long. Sepal ovate, 1.45–(1.8)–2.1 mm long, 1.4–(1.6)-1.9 mm wide. Corolla creamy white, 1.3–(1.5)–1.6 cm diam. Coronal scale ovate-elliptic, 3.1-(3.7)–4.4 mm long, 1.9–(2.2)–2.4 mm wide, the outer angle slightly erect to erect and white, apiculus of inner angle short raised and pink. Pollinium oblong, 0.51–(0.55)–0.64 mm long, 0.18–(0.2)–0.21 mm wide; translator short; corpusculum triangular-oblong, 0.15–(0.19)–0.23 mm long, 0.11–(0.12)–0.14 mm wide.

Ecology and distribution: On tree branches by stream banks in mixed deciduous to dry dipterocarp forests, northern Thailand at about 300-600 m elevation.
Specimens examined: Chiang Rai – Mueang, *Manit Kidyue 404, 405, 406, 407, 407/2, 407/3, 408, 409, 409/2, 409/3, 409/4*; Chiang Mai - Wang Bua Ban Waterfall, *Manit Kidyue 281, 282, 283, 284, 285, 292, 293, 294, 295, 296, 312, 313, 411, 413, 414, 414/2, 415, 416, 417, 417/2, 417/3, 418, 419, 425*; Nan – Meang, *Manit Kidyue 331, 332, 333, 378, 378/2, 378/3, 378/4, 378/5, 378/6, 378/7, 379, 379/2, 379/3, 379/4, 379/5, 379/6, 379/7, 379/8, 379/9, 379/10.*

Group VI

Leaves succulently coriaceous, broadly ovate, subcordate at base, 11–(11.2)–11.6 cm long, 7.4–(8.0)–8.3 cm wide, indistinct acrodromous venation, the lowest pair extending about half way to apex; veins obscure; covered with dense hairs on abaxial surface; petiole slender, 1.5–(2.2)–3 cm

long. Umbel 26–(29)–30 flowered, peduncle 3.5–(5.8)–7.1 cm long; pedicel pubescent, 1.7–(1.8)–1.9 cm long. Sepal ovate, 2–(2.2)–2.3 mm long, 1.6–(1.7)–1.8 mm wide. Corolla creamy white, 1.3–(1.4)–1.5 cm diam. Corona scale ovate-lanceolate, 3.6–(3.7)–3.8 mm long, 1.8-1.9 mm wide, the outer angle slightly erect and white, apiculus of inner angle short raised and pink. Pollinium oblong, 0.49–(0.5)–0.54 mm long, 0.17–0.18 mm wide; translator short; corpusculums triangular-oblong, 0.17–0.19 mm long, 0.11–0.12 mm wide.

Ecology and distribution: On tree branches in dry dipterocarp forests at 350 m elevation, northern Thailand.
Specimens examined: Chiang Mai - Haew Keaw, *Manit Kidyue 288, 289, 290, 291*.

Group VII

Leaves coriaceous to succulently coriaceous, ovate-oblong with cuneate to obtuse base, 10.4–(13.9)–17.9 cm long, 4.3–(5.6)–7.8 cm wide; 3 nerves, extending about half way to apex or slightly longer, veins obscure; covered with dense hairs on abaxial surface; petiole stout, 0.8–(1.4)–2.1 cm long. Umbel 9–(31)–52 flowered, peduncle 0.6–(3.4)–8.1 cm long; pedicel glabrous to pubescent, 1.8–(2.3)–2.6 cm long. Sepal ovate, 1.5–(1.9)–2.4 mm long, 1.4–(1.6)–2.0 mm wide. Corolla creamy white, 1.5–(1.6)–1.8 cm diam. Coronal scale ovate-elliptic, 3.4–(3.7)–4.1 mm long, 2.1–(2.2)–2.5 mm wide, the outer angle erect and white, apiculus of inner angle short raised and pink. Pollinium oblong, 0.54–(0.58)–0.62 mm long, 0.19–(0.2)–0.24 mm wide; translator short; corpusculum triangular-oblong, 0.16–(0.18)–0.21 mm long, 0.11–(0.12)–0.15.

Ecology and distribution: On tree branches by stream banks in mixed deciduous to dry dipterocarp forests at about 300-600 m elevation, northern Thailand.
Specimens examined: Nan - Silaphet Waterfall, *Manit Kidyue 325, 326, 327, 328, 329, 383, 384/1, 384/2, 384/3, 384/4, 384/5, 384/6*, Tat Laung Waterfall, *Manit Kidyue 342, 343, 344, 345, 385, 385/2, 386, 387*, Lhinan, *Manit Kidyue 391, 392, 393, 394, 395, 391, 392, 393, 394, 396, 396, 402, 402, 403*.

Group VIII

Leaves succulently coriaceous, narrowly ovate or elliptic to oblong, cuneate or rarely obtuse at base, 5–(9.6)–15 cm long, 1.8–(3.8)–5.8 cm wide, in-

distinct acrodromous venation, the lowest pair extending about half way to apex; veins obscure; covered with dense hairs on abaxial surface; petiole stout, 0.3–(1.2)–2.8 cm long. Umbel 10-(28)–77 flowered, peduncle 0.8–(3.8)–11.4 cm long; pedicel glabrous to pubescent, 1.2–(1.7)–2.6 cm long. Sepal ovate, 1.4–(2.0)-2.9 mm long, 1.1–(1.7)-2.6 mm wide. Corolla creamy white, 1.1–(1.3)–1.6 cm diam. Coronal scale ovate-lanceolate, 2.9–(3.5)–4.2 mm long, 1.5–(1.7)–2.1 mm wide, the outer angle variable from flattened to erect and white, apiculus of inner angle short raised and white to pink. Pollinium oblong, 0.40–(0.48)–0.56 mm long, 0.15–(0.18)–0.2 mm wide; translator short; corpusculum triangular-oblong, 0.13-(0.16)-0.2 mm long, 0.10–(0.12)–0.14 mm wide.

Ecology and distribution: A littoral plant, on tree branches or on rocks, common in beach forest, coastal areas of islands, or mainland in eastern and peninsular Thailand.
Specimens examined: Rayong - Ban Pe, *Manit Kidyue 80, 81, 82, 83, 84, 85, 94, 95, 96, 99, 100*; Chanthaburi - Nam Tok Phriu National Park, *Manit Kidyue 110, 111, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 132, 133, 134, 135, 136*; Trat – Mueang, *Manit Kidyue 163, 164, 250*, Ko Chang *Manit Kidyue 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668*; Prachuap Khiri Khan - Bang Saphan, *Manit Kidyue 622, 623, 624*; Suratthani - Ko Wua Ta Lub, *Manit Kidyue 584, 585, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595*; Phangnga – Mueang, *Manit Kidyue 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 671, 672, 673, 674, 675, 676, 677, 678*; Krabi [Noppharat Thara Beach, *Manit Kidyue 579, 580, 581, 582, 583, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643*]; Trang [Pakmeng, *Manit Kidyue 693, 694, 695, 696, 697*], [Hat Chao Mai National Park, *Manit Kidyue 628, 629, 630, 631, 632, 633*], [Thung Kai, *Manit Kidyue 66, 67, 68, 69, 70, 71, 72, 73, 74*]; Songkhla [Sathing Phra, *Manit Kidyue 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 240, 241, 242, 243, 244, 245, 246, 247, 248*], [Singhanakorn, *Manit Kidyue 212, 213, 216, 217, 218, 219, 220, 221, 222*], [Pak Bang Sakom Beach, *Manit Kidyue 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618*]; Satun [Tarutao National Park, *Manit Kidyue 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 596, 597, 598, 599, 600, 602, 603, 604, 605, 606*].

Group IX (residual group)

Leaves coriaceous to succulently coriaceous, ovate or elliptic to oblong, cuneate or obtuse at base, 7.7–(12.9)–18.6 cm long, 4–(5.8)–8.6 cm wide,

indistinctly acrodromous venation, the lowest pair extending about half way to apex; veins obscure; covered with dense hairs on abaxial surface; petiole stout, 0.5–(1.5)–3.2 cm long. Umbel 5–(27)–75 flowered, peduncle 0.3–(3.8)–14.3 cm long; pedicel glabrous to pubescent, 1.3–(2.0)–2.9 cm long. Sepal ovate, 1.3–(1.9)–3 mm long, 1.1–(1.6)–2.1 mm wide. Corolla creamy white, 1.1–(1.4)–1.8 cm diam. Coronal scale ovate to ovate-lanceolate, 2.8–(3.5)–4.4 mm long, 1.5–(1.9)–2.4 mm wide, the outer angle slightly erect to erect and white, apiculus of inner angle short raised and white to pink. Pollinium oblong, 0.41–(0.51)-6.43 mm long, 0.16–(0.19)–0.22 mm wide; translator short; corpusculums triangular-oblong, 0.14–(0.17)–0.21 mm long, 0.10–(0.12)–0.15 mm wide.

Ecology and distribution: Along stream banks in mixed deciduous to dry dipterocarp forests at about 100-600 m elevation. Occurs sporadically throughout northern, north-eastern, eastern, and western to peninsular Thailand.

Specimens examined: Chiang Mai - Wang Bua Ban Waterfall, *Manit Kidyue 299, 300, 301, 412*; Lampang - Doi Khun Tan National Park, *Manit Kidyue 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 380, 410*; Nan [Phu Pieng, *Manit Kidyue 388, 389, 390*], [Rhinan, *Manit Kidyue 398, 399*], Loei [Pla Ba Waterfall, *Manit Kidyue 689, 690, 691, 692*]; Nong Khai [Than Thong Waterfall, *Manit Kidyue 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568*]; Udon Thani [Than Ngam Waterfall, *Manit Kidyue 420, 421, 422, 423, 424*]; Nakhon Phanom [Tat Kham Waterfall, *Manit Kidyue 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505*]; Sakon Nakhon [Phu Phan National Park, *Manit Kidyue 427, 228, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441*]; Mukdahan [Tat Ton Waterfall, *Manit Kidyue 484, 485, 486, 487, 488, 489, 490, 491, 492*]; Ubon Ratchathani [Soi Sawan Waterfall, *Manit Kidyue 540, 541, 542, 543, 544*], [Huai Sai Yai Waterfall, *Manit Kidyue 479, 480, 481, 482, 483*], [Phu Chongna Yoi National Park, *Manit Kidyue 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528*], [Tat Hai Waterfall, *Manit Kidyue 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539*]; Sri Sa Ket [Sam Long Kiat Waterfall, *Manit Kidyue 506, 507, 508, 509, 510, 511*]; Nakhon Rat Chasima [Phu Wa Kiew Waterfall, *Manit Kidyue 545, 546, 547, 548, 549, 550*], [Khao Yai National Park, *Manit Kidyue 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377*]; Saraburi [Pu Kae, *Manit Kidyue 307, 308, 309*]; Prachin Buri [Prachantakham, *Manit Kidyue 315,316,317,318*]; Sa Kaeo [Pang Sida National Park, *Manit Kidyue 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30*]; Tak [Thi Lo Su Waterfall, *Manit Kidyue 570*]; Kanchanaburi [Sangkhla Buri, Manit Kidyue 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 458, 460, 461, 462, 463], [Koeng

Kra Wia Waterfall, *Manit Kidyue 475, 476*], [Pong Ron, Thong Pha Phum, *Manit Kidyue 258, 259, 442, 443, 444, 445, 446*], [Ban Thamadua, Thong Pha Phum, *Manit Kidyue 140, 141, 142, 158, ,165, 473, 474*], [Sai Yok National Park, *Manit Kidyue 150, 151, 152, 153, 155, 156, 157, 159, 160, 162*]; Ranong [Namtok Ngao National Park, *Manit Kidyue 644, 645, 646, 647, 648*].

Discussion

Hoya verticillata has long been recognized as a taxonomically confusing group in the genus. Many authors have discerned differently the taxa within the species complex. The confusion was partly due to the great variations exhibited by the plants in their natural habitats. The results from this present study indicate that nine morphological groups can be recognized based on leaf shape, form of leaf base, leaf venation, leaf indumentum, shape of sepal, and shape of corona scale. However, the *Hoya verticillata* specimens could not be consistently allocated into a discrete group based on lamina texture, color of flower and hair. Lamina texture was found to be slightly discontinuous in its range of variability. This variation appeared to be related to growing conditions in different habitats (Hill, 1988). Colour of flowers has been reported to be highly variable in this species (Kiew, 1995). In our study, we found that the colour of corolla varied from white, creamy white, yellowish white, greenish white, pinkish white to white with brown, pink and violet at apices. Hair is frequently found on the stem, corolla (adaxial surface), calyx (abaxial surface) and pedicel. Young stems and new branches varied from glabrous to pubescent, or earlier pubescent then becoming glabrous when getting old, but some plants are consistently glabrous. Hair on pedicel also varied from glabrous to densely pubescent. In contrast, in some populations hairiness varied from glabrous to densely pubescent, while the others were only glabrous or pubescent. Hair on the corolla varied from minutely pubescent (almost glabrous to the naked eye) to densely pubescent (obvious to the naked eye). All the above characters (lamina texture, color of flower and hair) possess sufficient variability for us to conclude that they are not good discriminant characters for distinguishing taxa of this complex.

Regarding their habitats and distributions, the nine recognized groups of the complex occur in different floristic regions and habitats throughout the country. It was found that Group I, II and IV occur in rather humid forests with medium to low light conditions, while the other Groups usually grow in dry habitat to some extent. These differences are possibly related in part to the degree of succulence and size of leaves that allow plants to withstand

different light conditions (Forster and Liddle, 1991). Naturally, the members of the complex occur in a wide range of habitats and geographic features in Thailand. Anyway, the habitat and distribution of the nine Groups overlap to such a degree that they are not good characters to use to distinguish taxa in the complex.

The previous treatments of the genus *Hoya* and the *Hoya verticillata* complex, were based primarily on discrete characters of floral structures (Rintz, 1978; Hooker, 1983; Forster and Liddle, 1991 and Kiew, 1995). In this study, we used floral characters in defining the species, while vegetative characters and their geographical distribution are used to characterize the varieties. Hence, we considered that the nine groups in the *H. verticillata* complex can be treated as either species or varieties. Group I and Group II of the *H. verticillata* complex were already treated at species level, due to their discontinuity in floral and vegetative characters.

Group I corresponds to the previous described species, *Hoya rigida* Kerr (Kerr, 1939). The result from this study shows good diagnostic characters to recognize this species based on leaf shape, venation, sepal shape and ratio of corolla tube length to sepal length. We agree with Kerr (1939) in separating this species from *H. verticillata*; Veldkamp *et al.* (1995) had already a suspicion about including this species in *H. verticillata* s.l.

Group II is somewhat similar to *H. verticillata* (Vahl) G. Don var. *citrina* (Ridl.) Veldkamp, except for its retention of minute hairs, scattered over the abaxial surface. Furthermore the corpusculum of anthers are oblanceolate-oblong. Rintz (1978) describes leaves and flowers of *H. verticillata* var. *citrina* and his illustrations show that lower surfaces of leaves have distinctly dense hairs and triangular-oblong corpusculum. The result from this study indicated that Group II is clearly distinguishable from the *H. verticillata s.l.* Importantly, since it has some diagnostic characters (leaf broad ovate with cordate base; prominent, 3-5 nerves, extending from base to apex, hairs minute, scattered on the abaxial surface; corpusculum oblanceolate-oblong), which did not match any previous described taxa, we consider it should be treated as a new species. In addition, the fragrance of flowers in Group II tends to differ from the other groups. We consider this preliminary evidence suggests a chemical difference that may be used to recognize Group II. At present, we tentatively treat Group II as a cryptic and undescribed species within the *Hoya verticillata* species complex.

Group III and Group IV have conspicuously discrete vegetative characters. Thus, we would define them at the varietal level. Group III is similar to *H.*

verticillata var. *citrina.* They share some common characters: possession of ovate leaves, the basal main veins extending to apex and the other veins being conspicuous, but there are still some differences. Group III has elliptic coronal scales and occurs in lowlands of northern Thailand, while *H. verticillata* var. *citrina* has ovate-lanceolate coronal scales and occurs in Malaysia, being common on limestone hills.

Group IV is an intermediate form between *H. verticillata* var. *citrina* and *H. verticillata* var. *verticillata.* It shares its venation pattern with the var. *citrina*, while leaf shape is elliptic-oblong with cuneate base; this character is similar to the var. *verticillata*.

It is evident that Group III and Group IV do not correspond to the previously described varieties. So we think that these two groups can be treated as undescribed varieties of *H. verticillata* complex. However, these two taxa are rather rare in occurrence, each being found only at one site.

Group V-IX have some discontinuity in flower and leaf characters. They cannot be clearly distinguished as distinct species, neither as varieties. Plants of Group VIII and IX correspond to the previous infraspecific taxon, *H. verticillata* var. *verticillata.* This is characterized by possession of elliptic leaf shape, cuneate base, obscure veins and the lowest basal pair of main veins extending about halfway to apex, while the other groups do not best fit to this taxon. They have broad ovate or elliptic to oblong leaf shape, obtuse to rounded at base and varied in corona lobe shape. However, they are more comparable to var. *verticillata* than the other two previously described varieties, i.e. *H. verticillata* var. *citrina* and var. *hendersonii* which have ovate leaves, cordate base, 3 prominent nerves extending from base to apex and the other veins are also conspicuous (Table 2). So we have treated Groups V-IX as being variable forms of *H. verticillata* var. *verticillata.*

In conclusion, the above reported possibly new cryptic species and maybe undescribed varieties of the *Hoya verticillata* complex in Thailand need to be researched further to reach more definitive taxonomic conclusions. Such study, however, is not part of this paper.

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References

Forster, P.I. and Liddle, D.J. 1991. Variation in *Hoya australis* R. Br. Ex Triall (Asclepiadaceae). *Austrobaileya* **3**: 502–521.

Hooker, J.D. 1883. *Flora of British India* **4**: 52–63.

Kerr, A. F. G. 1939. Contributions to the Flora of Siam. Additamentum II. *Kew Bulletin* 463.

Kerr, A.F.G. 1951. *Flora Siamensis Enumerratio* **3**: 35–42.

Kiew, R.1995.A new *Begonia* (Begoniaceae), *Hoya* (Asclepiadaceae) and *Sonerlia* (Melastoataceae) from Fraser's Hill, Peninsular Malaysia. *Sandakania* **6**: 63–71.

Hill, K.D.1988. A revision of Hoya (Asclepiadaceae) in Australia. *Telopea* **3(2)**: 241–255.

Ridley, H.N. 1923. *A Flora of Malay Peninsula* **2**: 393–402.

Rintz, R.E. 1978. The Peninsular Malaysian Species of *Hoya* (Asclepiadaceae). *Malay. Nat. J.* **30**: 467–522.

Thaithong, O. 1995. The Genus *Hoya* in Thailand. pp.83–94 . In: R. Kiew (ed.), *The Taxonomy and Phytochemistry of the Asclepiadaceae in Tropical Asia*. Universiti Pertanian, Malaysia.

Veldkamp, J.F., Vandonkelaar, R. and Kloppenburg, R.D. 1995. The Identity of *Sperlingia* Vahl (Asclepiadaceae). *Blumea* **40**: 425–428.

Table 2. Comparisons of habitat and qualitative characters of nine groups with three varieti*es* i*n* the *Hoya verticillata* complex.

Characters	*var.* citrina (Rintz ,1978; Kiew, 1995)	*var.* hendersonii (Kiew, 1995)	*var.* parasitica (Rintz, 1978; Kiew, 1995)	*Group I*	Group II	Group III	Group IV	Group V-IX
Habitat	lowland; common on limestone	highland; montane forest	lowland; common in stand forest especially on island	lowland; evergreen forest	lowland; evergreen forest	lowland; mixed deciduous forest	lowland; evergreen forest	lowland; mixed deciduous, dry dipterocarp to beach forest
Lamina								
shape	ovate	narrowly ovate-oblong	elliptic	ovate	ovate	ovate	elliptic-oblong	ovate or elliptic to oblong
base	cordate	Cordate	cuneate	cordate	cordate	subcordate	cuneate	cuneate to obtuse or subcordate
indumentum on abaxial surface	densely papillate	unknown	densely papillate	glabrous	scattered papillate	densely papillate	densely papillate	densely papillate
Leaf venation								
nerves	conspicuous	conspicuous	obscure	conspicuous	conspicuous	conspicuous	conspicuous	obscure
extension of the lowest vein pair	to apex	to apex	about half way to apex	to apex	to apex	to apex	To apex	about half way to apex or slightly longer
Sepal								
shape/sepal length	ovate/shorter than corolla tube	ovate/shorter than corolla tube	ovate/shorter than corolla tube	lanceolate/distinctly longer than corolla tube	ovate/shorter than corolla tube	ovate/shorter than corolla tube	ovate/shorter than corolla tube	ovate/shorter than corolla tube
Coronal scale								
shape (top view)	ovate	Elliptic	ovate	ovate	ovate-lanceolate	elliptic	ovate-lanceolate	elliptic or ovate to ovate-lanceolate
Anther								
corpusculum shape(width: length ratio)	triangular-oblong (<1:3)	unknown	triangular–oblong (<1:3)	triangular–oblong (<1:3)	oblanceolate-oblong (>1:3)	triangular – oblong (<1:3)	triangular – oblong (<1:3)	triangular – oblong (<1:3)

Note: Lowland: lower than 1000 m altitude; Highland: above 1000 m altitude.