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Numerical Taxonomy of the *Hoya parasitica* (Asclepiadaceae) complex in Thailand

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ABSTRACT.– *Hoya parasitica* sensu lato is a climbing epiphyte of the family Asclepiadaceae. At present, the taxonomic status of this species in Thailand is still indeterminate due to the great variation in size, shape and color of the leaves and flowers. Therefore, this plant is referred to as the *H. parasitica* complex. A previous study on morphological and anatomical variations of the complex showed that nine forms (Form I-IX), based on leaf shape, form of leaf base, leaf venation, leaf indumentum, shape of sepal, and shape of coronal scale, could be recognized. In this present study, two techniques of numerical taxonomy were used to investigate the taxonomic status of these forms in the *Hoya parasitica* complex in Thailand. To facilitate this latter investigation, 534 specimens (OTUs) of the nine morphological forms collected from their natural habitats throughout Thailand, were analysed using cluster and canonical discriminant analyses. A total of 35 quantitative and 14 qualitative characters were employed. In cluster analysis using only quantitative characters, the complex could be separated into three groups; i.e. Form I, Form II, and Form III-IX at average taxonomic distance 1.80. The same result was obtained when both quantitative and qualitative characters were used. Likewise, canonical discriminant analysis suggested the occurrence of three groups within the complex. The important characters used for separating these three groups are sepal length, corpusculum width, and leaf width. As a result of our findings, it is proposed here that the *H. parasitica* complex in Thailand should be treated as 3 species; i.e. *H. rigida* Kerr (Form I), *Hoya* sp. nov. (Form II) and *H. parasitica* (Roxb.) Wall. ex Wight (Form III-IX).

KEY WORDS: Cluster analysis, *Hoya parasitica* complex, Thailand

INTRODUCTION

Hoya parasitica (Roxb.) Wall. ex Wight (Asclepiadaceae) is one of the most common members of the section Hoya. 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), included three varieties: *H. parasitica* (Roxb.) Wall. ex Wight var. *parasitica*, *H. parasitica* (Roxb.) Wall. ex Wight var. *citrina* (Ridl.) Rintz, and *H. parasitica* (Roxb.) Wall. ex Wight var. *hendersonii* Kiew. These varieties can be

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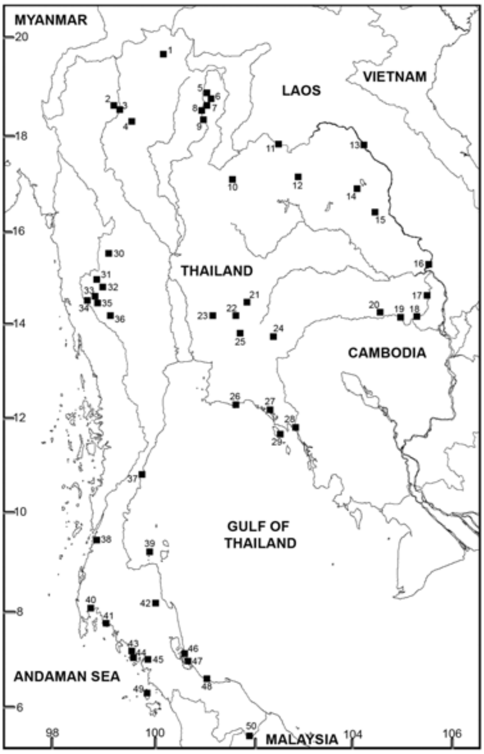

FIGURE 1. Sampling sites of *Hoya parasitica* complex in Thailand. Site numbers correspond to those in Table 1

distinguished from each other by leaf characters and habitat. *H. parasitica* var. *parasitica* is distinguished from the other two varieties by its elliptic leaf, cuneate leaf base, and 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. parasitica* sensu lato is the most common, 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. parasitica* complex” (Thaithong, 1995). However, variations within this complex did not match properly with the three formerly recognized varieties. 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. parasitica* sensu lato. *H. ridleyi* is found in peninsular Thailand (Ridley, 1923), but has also been recognized as *H. parasitica* var. *parasitica* (Rintz, 1978). Then, Veldkamp et al. (1995) suggested that *H. rigida,* a species endemic to Thailand, may be included in *H. parasitica* sensu lato. Thus, the taxonomic status of *H. parasitica* complex in Thailand remained unclear and needed to be reinvestigated.

The results of morphological studies indicated that nine forms (Form I-IX) can be recognized based on leaf shape, form of leaf base, leaf venation, leaf indumentum, shape of sepal, and shape of coronal scale (Kidyue, et al., unpublished data). Form I corresponds to the previous described species, *Hoya rigida* Kerr (Kerr, 1939). Form II is somewhat close to *H. parasitica* (Roxb.) Wall. ex Wight var. *critina* (Ridl.) Rintz, but also has minute hairs scattered over the abaxial surface, and the shape of the corpusculum is oblanceolate-oblong. It was treated as unidentified taxon in the *H. parasitica* complex. Forms III-IX have a slight discontinuity in flower and leaf characters from characters of *H. parasitica* (Roxb.) Wall. ex Wight. Thus they still should be treated as variable forms of *H. parasitica* complex.

The objectives of this study thus were: 1) to determine the importance of morphological and anatomical characters that contribute to the discrimination among them, and 2) to clarify the taxonomic status of the nine forms previously recognized based on classical classification in the *H. parasitica* complex using morphometric multivariate analyses. And finally, we (3) discuss the taxonomic treatment of these newly recognized groups as compared with the previous classification (Hooker, 1883; Ridley, 1923; Kerr, 1939; Rintz, 1978; Kiew, 1995; Veldkamp et al., 1995).

TABLE 1. Locality and collected-forms of the *Hoya parasitica* complex in Thailand. Note: [a] =Site numbers correspond to those in Figure 1; [b] =Nine forms distinguished by morphological and anatomical study.

Site no.[a]	Locality	Form[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 Rong 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	IX
26	Ban Pe, Rayong Province	VIII
27	Nam Tok Phliou 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

MATERIALS AND METHODS

Specimen Collections and Measurements

Specimens were gathered from 50 localities in their natural habitats throughout Thailand (Fig. 1 and Table 1) during 2003 to 2004. Specimens of each sample including leaves and flowers were preserved in 70% ethanol and deposited at the Professor Kasin Suvatabandhu Herbarium, Department of Botany, Faculty of Science, Chulalongkorn University (BCU).

TABLE 2. Thirty five quantitative characters with their methods of scoring used in the study of *Hoya parasitica* complex.

Abbreviation	Characters
LL	leaf length in cm
LW	leaf width in cm
DBL	distance from base to the widest point of leaf in cm
LS	leaf shape (calculated by DBL/LL)
PETL	petiole length in cm
PETW	petiole width in cm
PECL	pedicel length in mm
PECW	pedicel width in mm
SPL	sepal length in mm
SPW	sepal width in mm
DCO	diameter of corolla in mm
COL	corolla length in mm
COLL	corolla lobe length in mm
DCOT	diameter of corolla tube in mm
DBCL	distance from base to the widest point of corolla lobe in mm
COAL	corolla lobe apex length in mm
COTL	corolla tube length in mm
COLW	corolla lobe width in mm
COBW	corolla lobe base width in mm
DCN	diameter of corona in mm
DCNR	diameter of coronal receptacle in mm
DCOR	distance from corpuscle to the outer point of receptacle in mm
DCNL	distance between corona lobes in mm
CNLL	corona lobe length in mm
DBCN	distance from base to the widest point of corona lobe in mm
CNLS	corona lobe shape (calculated by DBCN/CNLL)
CNLW	corona lobe width in mm
RCRD	ratio of corona diameter and receptacle diameter
RCCD	ratio of corona diameter and corolla tube diameter
POLL	pollinium length in micron
POW	pollinium width in micron
COPL	corpusculum length in micron
UCNL	upper apex of corpusculum length in micron
LCNL	lower apex of corpusculum length in micron
COPW	corpusculum width in micron

TABLE 3. Fourteen qualitative characters with their methods of scoring used in the study of *Hoya parasitica* complex.

Abbreviation	Characters
LLS	shape: broad-ovate (1), ovate (2), elliptic (3), oblong (4) note: "broad-ovate" denotes leaf width: length ratio of 1: <1.5, "ovate" denotes leaf width: length ratio of 1:2-2.5
LLB	base: cuneate (1), obtuse (2), rounded (3), cordate (4)
LTX	texture: coriaceous (1), fleshy to succulent (2), very succulent (3) note: "very succulent" denotes leaf thickness of 2.5-3.5 mm, " fleshy to succulent" denotes leaf thickness of 1.2-1.6 mm, coriaceous denotes leaf thickness < 1.2 mm (Forster and Liddle, 1991)
LVV	venation: brochidodromous (1), acrodromous (2) note: "brochidodromous" denotes primary venation pinnate with a looped intramarginal vein, "acrodromous" with three or five principal veins arising near base (Hill,1988)
LVP	vein prominence: obscure (1), conspicuous (2) note: "conspicuous" denotes veins easily seen, "obscure" denotes unclear veins
LVE	the lowest pair of lateral veins extending: about half way to apex (1), to apex (2)
IND	indumentum: absent (1), scattered (2), dense (3)
PDH	pedicel hair: absent (1), scattered (2), dense (3)
SPS	sepal lobe shape: ovate (1), ovate-oblong (2), ovate-lanceolate (3)
PTC	petal color: creamy white (1), yellowish white (2), pinkish white (3) white with brown to violet at apex (4)
CSD	corona spreading: erect (1), slightly erect (2), flat (3)
CLS	corona lobe shape (top view): ovate (1), elliptic (2)
UCC	upper corona lobe color: white (1), pale pink (2), deep pink or red (3)
CPS	corpusculum shape: triangular (1), oblong (2)

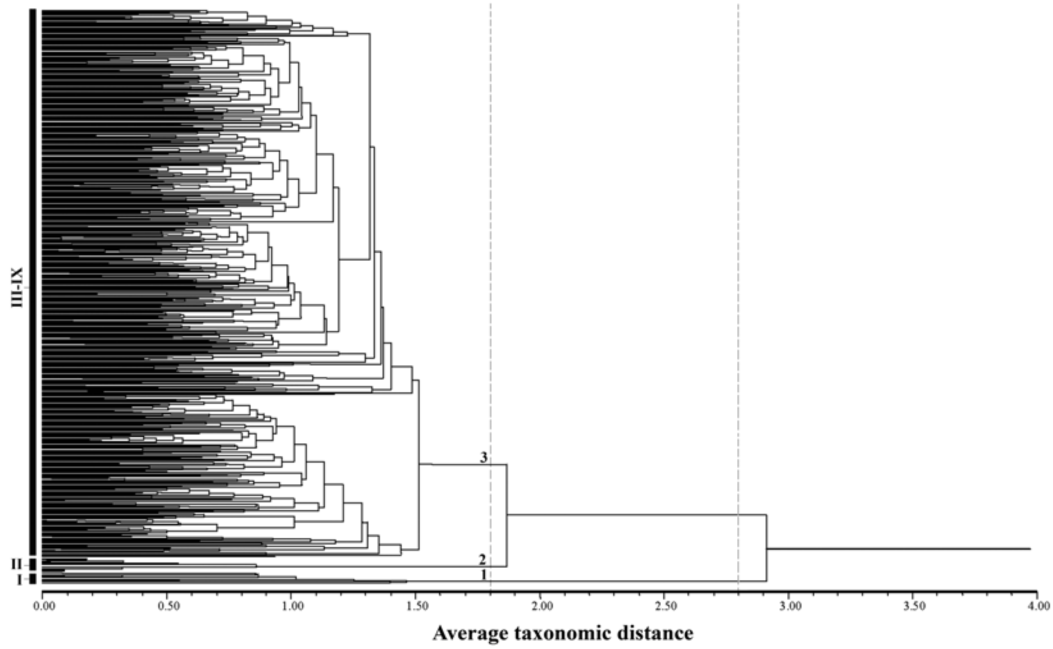

FIGURE 2. UPGMA clustering of 534 OTUs based on 35 quantitative characters of *Hoya parasitica* complex in Thailand (1-Form I, 2-Form II, 3-Form III-IX).

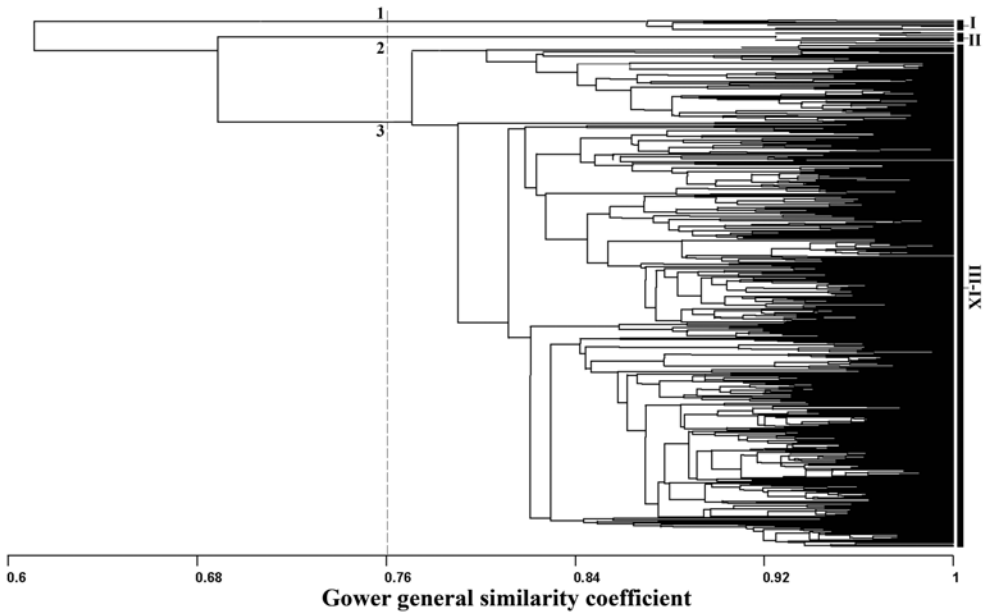

FIGURE 3. UPGMA clustering of 534 OTUs based on Gower's general similarity coefficient calculated between means of 35 quantitative and 14 qualitative characters of the *Hoya parasitica* complex in Thailand (1-Form I, 2-Form II, 3-Form III-IX).

TABLE 4. Poolled within canonical structure of 9 forms based on 35 vegetative and reproductive characters.

Character	Discriminant function							
	1	2	3	4	5	6	7	8
LW	.615	-.200	.156	-.289	-.215	-.296	-.049	.121
CNLW	.395	-.076	-.219	.196	-.007	-.161	-.110	.102
POLL	.385	-.126	-.210	.296	-.058	-.138	.067	.187
PETW	.379	-.133	-.067	-.273	-.244	-.143	.314	.002
PECL	.343	-.147	-.178	.167	.045	-.316	-.314	.036
COL	.315	.057	-.205	.256	.104	.063	-.211	-.031
DCO	.314	.135	-.202	.265	.057	.045	-.119	-.084
COAL	.311	-.087	-.210	.197	-.045	.006	-.304	.135
COLL	.276	.079	-.204	.247	.014	-.004	-.162	-.011
DCOT	.275	.061	-.194	.132	.072	.084	-.170	-.001
DBCN	.267	-.042	-.049	.171	-.066	-.225	-.150	.060
COBW	.246	.025	-.227	.154	-.033	.186	-.162	.044
COTL	.212	-.004	-.108	.143	.180	.127	-.181	-.042
SPL	.132	.608	-.053	.207	-.249	.119	-.209	.101
DBCL	.117	.203	-.110	.187	.064	-.011	.046	-.148
RCCD	-.128	.128	.280	.040	-.154	-.132	-.020	.177
RCRD	-.045	.141	.256	-.198	-.068	.197	-.119	.252
DCNR	.313	.170	-.147	.482	-.050	-.252	-.210	.027
COPL	.252	-.101	.119	.456	-.053	-.175	.205	.144
DCNL	-.126	.159	.304	.419	-.174	.108	-.154	.002
DCOR	.168	.167	-.102	.343	-.029	-.118	-.232	-.009
LCNL	.223	-.088	.050	.339	.186	.250	.142	.170
COLW	.248	.022	-.070	.339	.008	-.083	-.195	.044
COPW	.056	-.045	-.281	.373	-.500	-.251	-.014	.082
LL	.326	-.043	-.090	-.425	.050	-.433	-.214	.041
DBL	.112	-.040	-.083	-.358	.048	-.378	-.223	.239
UCNL	.145	-.060	.107	.308	-.178	-.362	.148	.061
CNLS	.183	-.181	-.062	.039	-.066	-.260	.020	-.087
PECW	.288	.005	-.124	.145	-.140	.199	-.338	-.231
DCN	.208	.238	.074	.225	-.090	-.048	-.250	.209
CNLL	.197	.135	-.007	.211	-.026	-.051	-.245	.181
LS	-.364	.027	-.001	.009	.050	-.026	-.090	.470
PETL	.170	.177	-.012	-.308	-.017	-.216	-.054	.392
POW	.310	-.063	-.314	.279	.036	-.038	.132	.367
SPW	-.013	.206	.061	.150	-.157	-.040	-.019	.249

Data Analysis

Five hundred and thirty-four specimens were used for all analyses. Thirty-five quantitative and fourteen qualitative characters of both vegetative and reproductive characters (Table 2, Table 3) were subjected to discriminant and cluster analyses. Cluster analysis, sequential, agglomerative, hierarchical and nested (SAHN) clustering (Sneath and Sokal, 1973) were performed using average taxonomic distance and the unweighted pair-group method with arithmetic averages (UPGMA) implemented in NTSYS-pc package version 2.l0m (Rohlf, 2000) to place individual specimens into groups. When mixed characters, quantitative and qualitative characters were measured altogether, the Gower similarity coefficient was calculated and clustered by the group-average method (Gower, 1971) of MVSP program (Kovach Computing Services, MSVP Plus, version 3.1). The characters used in the analysis were assumed to be as important as each others and were unweighted.

A subset of characters that maximized differences among the groups determined by morphological and anatomical forms (forms are groups of plant that were distinguished by the characteristics of leaf and flower; Kidyue et al. unpublished data) and cluster analysis was selected by stepwise discriminant analysis. To characterize mean differences among the species, canonical discriminant analysis was used to acquire insight into group differences and to estimate character weights from correlations between canonical variables and original variables. Procedure CLASSIFY in SPSS/PC for Windows, release 10.0 (Anonymous, 1999) was used to analyze a set of discriminant analysis.

RESULTS AND DISCUSSION

Cluster Analysis

The result of the first cluster analysis is shown in Figure 2. The dendrogram split the 534 specimens into either two or three groups at values 2.80 and 1.80 of phenon line, respectively. In the two-cluster grouping, specimens classified as group 1 consisted of all

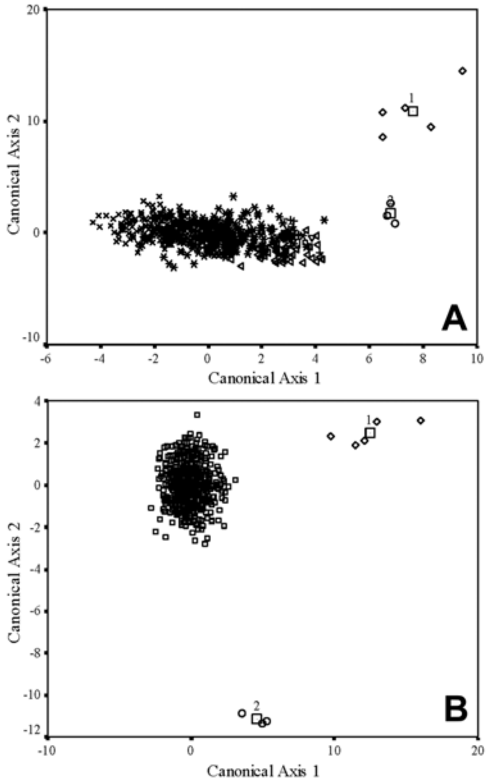

FIGURE 4. The ordination plot on the canonical axes 1 and 2. **A**) the ordination plot of 9 forms using 9 categories as priori groups; **B**) the ordination plot of 3 clustering groups using 3 categories as priori groups. (I-◊, II-○, III-□, IV-△, V-▽, VI-◁, VII-▷, VIII-×, IX- ✱).

members of Form I. Specimens classified as group 2 consisted of Forms II-IX. In the three-cluster grouping, group 1 is the same as in the two-cluster grouping, consisted of all Form I. All members of Form II were placed in group 2. Group 3 consisted of Forms III-IX.

Both the two and three-cluster groupings demonstrate a clear separation of Form I. In three-cluster groupings, the dendrogram also shows that Forms III-IX is closer to Form II than to Form I. Lastly, Forms III, IV, VI, VII, VIII and IX are shown to be very closely related groups and their previously postulated individually separate status is not supported by the findings of this study.

Similar results were obtained when both quantitative and qualitative characters were used. The dendrogram derived from the second cluster analysis is shown in Figure 3. Using the 76% similarity phenon line as a reference (Sneath & Sokal, 1973), three main groups could be distinguished in the UPGMA phenogram. The members of the three groups were the same as those of the three groups obtained from the first cluster analysis.

Canonical Discriminant Analysis

1. Stepwise analysis of nine forms (Morphological and Anatomical forms): Thirty-five characters were used in this analysis. The linear discriminant function classification results showed 84.6% correctly classified. The nature of the differences between entries was shown by the pooled within canonical structure (Table 4). Canonical variable 1 was 87.4 % correlated with the thirty-five characters and explained 46.6% of the total variance. It was highly associated with characters LW, PETW, PECL, COL, DCO, COAL, and COBW. Canonical variable 2 explained 21.1% of the total variance. This axis is mostly associated with SPL. Canonical variable 3 explained 16.7 % of the total variance. The twelve variables CNLW, POLL, COLL, DCOT, DBCN, COTL, DBCL, RCCD, RCRD, DCOR, UCNL, and CNLS were not used in the analysis according to the result of stepwise discriminant analysis (Table 4).

The ordination plot on the two canonical axes shows that the nine categories are not clearly

TABLE 5. Classification function coefficients of 3 groups obtained from cluster analysis based on 35 vegetative and reproductive characters.

Character	Categories		
	1	2	3
LW	-52.854	-12.564	-54.597
LS	442.812	492.772	554.384
PETL	29.370	7.669	2.659
PETW	306.529	205.671	316.067
PECL	-27.143	-25.872	-16.311
SPL	196.675	102.985	86.620
SPW	-7.905	58.102	55.449
DCO	231.209	122.270	120.460
COL	-270.374	-165.666	-200.234
COLL	-135.144	-90.711	-84.865
COAL	102.254	69.774	136.433
COLW	45.274	102.515	54.330
COBW	-47.353	-65.717	-14.506
DCN	102.335	104.234	58.771
DCNR	426.471	301.034	349.626
DCNL	-93.637	-46.082	-73.920
POW	21.544	14.832	19.056
COPL	2.820	14.307	4.468
COPW	24.488	3.321	24.629
(Constant)	**-268.990**	**-894.289**	**-987.442**

distinct (Fig. 4A). The 9 categories separated the 534 specimens into 2 groups in canonical axis 1. Group 1 consists of Form I and II of *Hoya parasitica* complex. Group 2, the largest group, composed of Form III-IX of *Hoya parasitica* complex. In canonical axis 2, 9 categories can be divided into 2 groups. This axis separated Form I to group 1 and the other Forms to group 2.

2. Stepwise analysis of three groups according to the result from cluster analysis: Thirty-five characters were used in this analysis. The linear discriminant function classification results showed 100% correctly classified. For this reason, the linear discriminant function (Table 5) could be used for identification of specimens of the *Hoya parasitica* complex in Thailand. The nature of the differences between entries was shown by the pooled within canonical structure (Table 6). Canonical variable 1 was 78.4% correlated with the thirty-five characters and explained 67.3% of the total variance. It was highly associated with characters SPL, DCN, DCNR, DCO, PETL, COL, LS, COLW, SPW, COLL, PETW, and PECL. Canonical variable 2 explained 32.3% of the total variance. This axis was highly associated with COPW, LW, POW, COBW, COAL, COPL, and DCNL. Canonical variable 3 explained 16.7% of the total variance. The sixteen variables DCOR, CNLL, PECW, COTL, DCOT, CNLW, LL, DBCN, DBCL, DBL, RCRD, RCCD, POLL, LCNL, UCNL, and CNLS were not used in the analysis according to the result of stepwise discriminant analysis (Table 6).

TABLE 6. Poolled within canonical structure of 3 groups obtained from cluster analysis based on 35 vegetative and reproductive characters.

Character	Discriminant function	
	1	2
SPL	.600	.238
DCN	.350	-.020
DCNR	.334	.158
DCO	.288	.132
DCOR	.269	.168
CNLL	.257	.026
PECW	.249	.125
PETL	.237	-.038
COL	.222	.108
COTL	.213	.045
DCOT	.211	.129
LS	-.198	.110
COLW	.183	.046
SPW	.179	.062
CNLW	.177	.103
LL	.165	-.099
COLL	.162	.122
DBCN	.150	.037
DBCL	.142	.065
PETW	.111	-.048
PECL	.087	.051
DBL	.060	-.047
COPW	.014	.454
LW	.176	-.250
RCRD	.092	-.207
POW	.123	.199
COBW	.158	.170
RCCD	.041	-.163
POLL	.124	.142
LCNL	.125	-.136
COAL	.110	.125
COPL	.114	-.116
DCNL	.088	-.095
UCNL	.054	-.054
CNLS	-.008	.027

The ordination plot on the two canonical axes showed that the three categories were distinct (Fig. 4B). The three categories were separated into three groups on canonical axis 1. Group 1 consisted of Form I of *Hoya parasitica* complex, while Group 2 included Form II. Group 3, the largest group, comprised Forms III-IX of the *Hoya parasitica* complex. In canonical axis 2, the three categories were divided into two groups. This axis separated Form II to group 1 and the other forms to group 2.

The overall results showed that the *Hoya parasitica* complex in Thailand has discontinuous variations. These observed variations did not obviously correspond to the taxonomic status of individual plants according to previous descriptions, and our analysis lead to the conclusion that these variations could not be the results of infraspecific variations of a single species, *Hoya parasitica* (Roxb.) Wall. ex Wight. Consequently, the complex should be segregated into species, subspecies or varieties and forma.

Form I corresponds to the previously described species, *Hoya rigida* Kerr (Kerr, 1939). The result from morphological and anatomical studies shows good diagnostic characters for recognizing this species, based on leaf shape, leaf venation, leaf indumentum, and sepal shape. This corresponds to the results obtained from numerical study. The length of sepal, and petiole, and the diameter of corona and corolla are larger than those of the others. This species will be separated from *H. parasitica* s. l. as a result of this study. A corresponding result was presented by Kerr (1939), and eliminated the suspicion (Veldkamp et al., 1995) that this species should be included in *H. parasitica* s. l. Therefore, we agree–with Kerr (1939) to separate *H. rigida* Kerr from *H. parasitica* s.l. and treat them as closely related taxa.

Form II is rather similar to *H. parasitica* (Roxb.) Wall. ex Wight var. *citrina* (Ridl.) Rintz, according to its characters. The result of morphological and anatomical study indicated that form II is clearly distinguishable from the *H. parasitica* s. l. Its diagnostic characters are the broad ovate leaf with cordate base; 3-5 prominent nerves, extending from base to apex, minute hairs scattered on the abaxial surface; and oblanceolate-oblong corpusculum. These characters do not match any previously described taxon. Therefore our conclusion is that form II should be treated as a new species of the genus *Hoya*. The results of the statistical taxonomic analysis support the separation of this form from the others. The two most important characters are the broad leaves and narrow corpusculums. Up to the present, form II has been treated as a cryptic and undescribed species (*Hoya* sp. nov.) within the *H. parasitica* complex and has been considered as a closely related taxon of *H. parasitica* (Roxb.) Wall. ex Wight var. *citrina* (Ridl.) Rintz and *H. rigida* Kerr.

Form III and form IV have conspicuously discrete vegetative characters and share common characters of the flower. Thus, they should be treated at the varietal level of this complex. Nevertheless, differences in leaf venation of a small number of specimens are still not sufficient to distinguish these two forms as distinct varieties of the species. The differences of form III and form IV from the others might be more or less an effect of gene mutation or an environmental variation.

The closely related forms, V and IX possess common characters of leaves and flowers as well as geographical distribution; however, the results of numerical taxonomy suggest that the two forms are not distinct. Therefore, they are considered to be variable forms of *H. parasitica* (Roxb.) Wall. ex Wight. Whether or not these two forms are new varieties of *H. parasitica* s.l. was not determined during this examination, and more specimens and further study will be needed to resolve this question.

Due to the small discontinuity in flower and leaf characters in forms V-IX, they do not clearly distinguish to different taxa. From morphological and anatomical study, it was found that forms V-VII did not properly fit to *H. parasitica* var. *parasitica*, due to their slight differences in leaf and flower characters.

In contrast, members of form VIII and IX fit best to the distinct taxa *H. parasitica* (Roxb.) Wall. ex Wight var. *parasitica* and *H. ridleyi* King & Gamble, respectively. However, the only difference between them is in size of leaves. This variation might occur due to the environmental difference of the two situations; littoral plant (full or partial exposure to sun-

TABLE 7. F-values, means and standard errors of 35 quantitative characters of the 3 taxa of *Hoya parasitica* complex in Thailand. Note: The characters in **bold** letter represent the important variables for separation of the three taxa

Characters	F-value	Sig.	*H. rigida* (form I)		*H.* sp.(form II)		*H. parasitica* (form III-IX)	
			Mean	±SE	Mean	±SE	Mean	±SE
LL	8.850	.000	15.850	1.419	16.000	1.127	11.549	2.721
LW	25.812	.000	7.710	0.829	11.967	1.069	5.103	1.506
DBL	.172	.842	5.170	0.952	5.233	0.448	4.987	1.269
LS	19.024	.000	0.326	0.036	0.328	0.024	0.433	0.051
PETL	24.104	.000	3.080	0.228	2.133	0.058	1.314	0.512
PETW	5.685	.004	0.550	0.053	0.530	0.029	0.444	0.080
PECL	3.782	.023	23.145	2.173	18.317	1.458	18.975	3.350
PECW	14.479	.000	1.177	0.086	0.939	0.105	0.952	0.089
SPL	164.251	.000	5.109	0.316	1.970	0.053	1.931	0.303
SPW	14.319	.000	2.147	0.160	1.655	0.146	1.630	0.205
DCO	38.680	.000	19.618	1.345	13.713	0.258	13.902	1.330
COL	23.278	.000	10.226	0.487	7.576	0.140	7.715	0.774
COLL	14.150	.000	6.344	0.393	4.654	0.386	4.985	0.550
DCOT	15.586	.000	7.854	1.268	5.669	0.136	6.137	0.642
DBCL	9.504	.000	2.546	0.392	1.829	0.018	1.841	0.329
COAL	8.331	.000	3.799	0.318	2.824	0.393	3.145	0.369
COTL	19.137	.000	3.882	0.127	2.909	0.240	2.730	0.378
COLW	14.595	.000	5.976	0.437	5.038	0.428	4.891	0.427
COBW	16.410	.000	5.017	0.624	3.529	0.096	3.990	0.399
DCN	52.215	.000	9.527	1.174	8.013	0.111	6.982	0.532
DCNR	52.304	.000	4.983	0.404	3.736	0.013	3.786	0.242
DCOR	40.058	.000	1.417	0.139	1.060	0.052	1.024	0.090
DCNL	5.152	.006	0.695	0.041	0.790	0.103	0.577	0.136
CNLL	29.888	.000	4.548	0.268	3.917	0.074	3.509	0.296
DBCN	17.741	.000	2.109	0.284	1.459	0.155	1.506	0.207
CNLS	4.236	.015	0.462	0.043	0.372	0.033	0.429	0.043
CNLW	14.036	.000	2.382	0.176	1.742	0.013	1.880	0.207
RCRD	12.422	.000	1.909	0.107	2.153	0.039	1.846	0.107
RCCD	9.705	.000	1.232	0.193	1.414	0.053	1.146	0.108
POLL	5.301	.005	560.394	25.024	456.881	1.369	503.223	46.250
POW	14.419	.000	219.037	21.482	156.748	0.374	183.532	16.615
COPL	8.225	.000	189.709	7.557	203.395	9.433	168.626	18.429
UCNL	3.859	.022	95.131	2.528	96.267	3.235	81.153	14.805
LCNL	6.587	.001	94.577	6.500	107.129	6.199	87.473	10.044
COPW	41.859	.000	130.794	5.859	69.810	1.402	116.920	10.566

light and dry habitat) and inland plant (partial shade and moist habitat). It is accepted that light level conditions have a pronounced effect on leaf development (Forster and Liddle, 1991). In shady habitats leaves are usually larger than in open habitat. The results of statistical analysis also show no significant difference in this character, so recognition of forms VIII and IX as separate taxa cannot be supported. This study agrees with Rintz (1978) who reduced *H. ridleyi* King & Gamble to a variety of *H. parasitica* (Roxb.) Wall. ex Wight

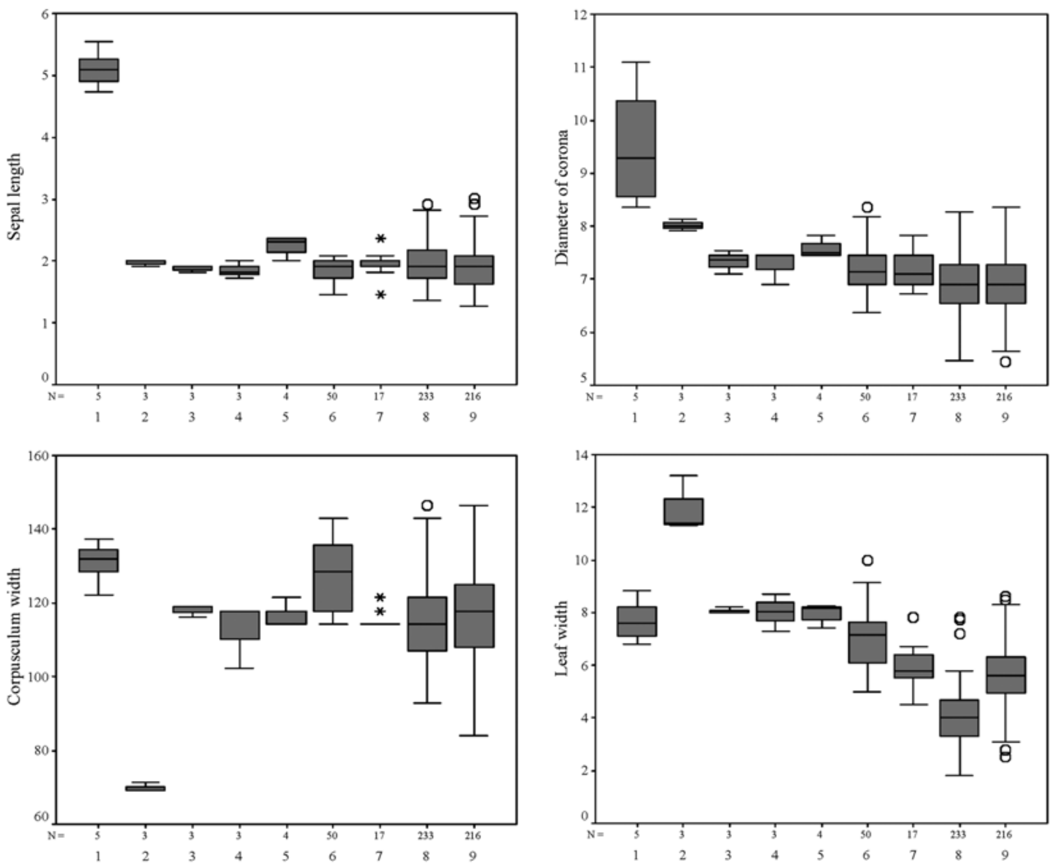

FIGURE 5. Boxplots (mean value) of the four most important characters of *Hoya parasitica* complex. (1-I, 2-II, 3-III, 4-IV, 5-V, 6-VI, 7-VII, 8-VIII, 9-IX).

var. *parasitica*. Finally, the results of statistical analysis also showed that the entire range of forms V-IX are not distinct. They should be treated as variable forms of a single species and variety *H. parasitica* (Roxb.) Wall. ex Wight var. *parasitica*.

CONCLUSION

Two techniques of numerical taxonomy were used to investigate the taxonomic status of the nine forms (delimited by morphological and anatomical data and suggested during previous study) in the *Hoya parasitica* complex in Thailand. It was concluded that the results from our numerical taxonomic study as well as the comparison of qualitative morphological and anatomical characters of leaf and flower provide justification for recognition of the segregation of the initial nine groups of the complex (Form I-Form IX). However, the results from this, our second study, demonstrate that classification of the *H. parasitica* complex in Thailand into three groups, not nine as originally proposed, based on the morphological and anatomical studies of the preliminary paper and this later numerical taxonomic study, more accurately provides good taxonomic boundaries as a basis for understanding this natural species complex. However, it should be noted that there were some continuous variations in quantitative characters of leaf and flower.

The cluster analysis demonstrated a separation of Form I and Form II. The clear-cut separation of these forms from the remainder is probably due to their extreme differences in leaf and flower characters from the others. Furthermore, there are close relationships on the dendrogram among the Forms III, IV, V, VI, VII, VIII, and IX and the taxonomic status none of them is distinct from the others. In both cluster analyses, it is evident that the *H. parasitica* complex should comprise three taxa. In the discriminant analyses, it can be concluded that when nine categories or nine forms were used as *a priori* grouping, the ordination plot (Figure 4a) did not show the clear separation of the nine forms. Finally, when the three clustering grouping from a result of the cluster analysis was used as *a priori* grouping in the discriminant analyses, the three groups were recognized (Figure 4b), i.e. group 1 (Form I), group 2 (Form II) and group III (Form III-IX). The most 8 important characters for separation of the three groups were sepal length (SPL), diameter of corona (DCN), diameter of coronal receptacle (DCNR), diameter of corolla (DCO), petiole length (PETL), corolla length (COL), corpusculum width (COPW) and leaf width (LW).

In all, the results from multivariate analyses of morphological data guide to the conclusion that the nine forms should not be infraspecific variations of a single species, *Hoya parasitica* (Roxb.) Wall. ex Wight. The *H. parasitica* complex in Thailand should consist of at least three species; i.e. *H. rigida* Kerr (Form I), *H.* sp.nov. (Form II) and *H. parasitica* (Roxb.) Wall. ex Wight (Form III-IX).

Box plots of the four most important characters are shown in Figure 5 and Table 7. It is noted that sepal length, corpusculum width and leaf width are useful quantitative characters for discrimination of the three groups. An identification key to the species of the *H. parasitica* complex in Thailand based on quantitative characters is provided below.

1. Sepals longer than the corolla tubes, more than 4.5 mm long.................... *Hoya rigida* Kerr
1. Sepals equal in length or shorter than corolla tubes, less than 2 mm long
   2. Leaf width more than 11 cm, corpusculum less than 75 μm wide......... *Hoya* sp. nov.
   2. Leaf width less than 9 cm, corpusculum more than 100 μm wide...................... .... *Hoya parasitica* Wall. ex Wight

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