

Systematic Notes on the genus *Hedychium* (Zingiberaceae) in Myanmar

Nobuyuki Tanaka^{1,*}, Tetsuo Ohi-Toma², Mu Mu Aung³ and Jin Murata²

¹Department of Botany, National Museum of Nature and Science,
Amakubo 4–1–1, Tsukuba, Ibaraki 305–0005, Japan

²Botanical Gardens, the University of Tokyo,
Hakusan 3–7–1, Bunkyo-ku, Tokyo 112–0001, Japan

³Forest Research Institute, Forest Department,
Ministry of Natural Resources and Environmental Conservation, Yezin, Myanmar

*E-mail: nobuyuki_tanaka@kahaku.go.jp

(Received 2 February 2016; accepted 23 March 2016)

Abstract The genus *Hedychium* (Zingiberaceae) occurring in Myanmar was studied on the basis of the field explorations and specimen examinations in several large herbaria of the world housing the Myanmar specimens. As the results, four species of *H. densiflorum* Wall., *H. flavescens* Carley ex Roscoe, *H. gardnerianum* Sheppard ex Ker Gawl. and *H. griffithianum* Wall. were newly recorded from Myanmar. Two undescribed taxa were also discovered as the result of field explorations. Molecular phylogenetic relationship based on nucleotide sequences of nuclear ribosomal ITS region supported that one is a putative natural hybrid and the other is closely related to *H. villosum* Wall. *Hedychium* × *natmataungense* Nob. Tanaka and *H. villosum* var. *kachinense* Nob. Tanaka are described and illustrated as new to science. The key to all taxa of *Hedychium* presently recorded in Myanmar is also provided.

Key words : *Hedychium*, Myanmar, new record, new species, Zingiberaceae.

The genus *Hedychium* J.Koenig., commonly called “ginger lily”, produces one of the most beautiful and aromatic flowers in the family Zingiberaceae (Sanoj *et al.*, 2013). This genus comprises approximately 100 species, about the half of them being distributed in the continental SE Asian region, and the remaining half in Malaysia, China, the Himalayas, and Madagascar (Sirirugsa and Larsen, 1995; eMonocot, 2016). In Myanmar, sixteen species of the genus *Hedychium*; i.e. *H. bordelonianum* W.J.Kress & K.J.Williams, *H. coccineum* Buch.-Ham. ex Sm., *H. coronarium* Koenig, *H. elatum* R.Br., *H. ellipticum* Buch.-Ham., *H. flavum* Roxb., *H. forrestii* Diels, *H. gomezianum* Wall., *H. gracile* Roxb., *H. marginatum* C.B.Clarke, *H. spicatum* Sm., *H. stenopetalum* Lodd., *H. tenuiflorum* Wall. ex Voigt, *H. thyrsoforme* Sm., *H. venustum* Wight,

and *H. villosum* Wall. have been recorded from Myanmar (Kress *et al.*, 2003; Srivastava *et al.*, 2012).

Recent significant efforts at field explorations in Myanmar have accumulated a good collection of *Hedychium*, and have resulted in the new records of several species for the flora of Myanmar and discovery of the undescribed taxa from Natma Taung (Mt. Victoria), Chin Hills, west central Myanmar, and from the Hukaung Valley Tiger Reserve, Kachin State, north Myanmar. With the addition of molecular phylogenetic relationship of available plants from Myanmar and adjacent regions, these are described and illustrated as *H. × natmataungense* Nob. Tanaka and *H. villosum* Wall. var. *kachinense* Nob. Tanaka.

Materials and Methods

Plant materials and morphological studies

Field explorations to Sagain Region, Mandalay Region, and Chin State of Myanmar were carried out, and collected the herbarium specimens with alcohol materials and identified based on the morphological characters. The morphology of the new species was analyzed using herbarium specimens and alcohol specimens collected from Myanmar. Detailed morphological measurements were made under a dissecting microscope and using digital calipers. Voucher specimens are deposited in MBK, RAF, TI and TNS. Additionally the specimens of the genus *Hedychium* previously collected from Myanmar housed in BM, CAL, E, K, MBK and TI were examined.

DNA sequencing and phylogenetic analysis

Total genomic DNA of 16 available samples of *Hedychium* and two of *Zingiber* (outgroup) from the field or cultivations (Appendix 1) was extracted from a fresh leaf tissue by the HEPES-CTAB method in Ohi-Toma *et al.* (2010). In addition, DNA samples of four *Hedychium* species from the Royal Botanic Gardens, Kew, DNA Bank (<http://www.kew.org/data/dnaBank/>) were utilized. The ITS region was amplified by standard PCR using primers pairs of ITS5 and ITS4 (White *et al.*, 1990) and *ExTaq* (TaKaRa Bio). After purifying by GeneClean III Kit (MP-Biomedical), PCR products were reacted by Big-Dye terminator v3.1 Cycle Sequencing Kit (Applied Biosystems) with each primer of ITS5, ITS4, ITS2 and ITS3 (White *et al.*, 1990). Then, DNA sequencing was performed using ABI PRISM 377 DNA sequencer. The PCR product showing overlapping double peaks at several sites on the obtained electrophelograms were cloned using TOPO TA Cloning Kit (Invitrogen). At least 24 clones per sample were picked and sequenced. In the comparison of obtained clone sequences, nucleotides that were not detected by direct sequencing were regarded as PCR errors, and chimeric sequences among dif-

ferent sequences were regarded as artificial PCR recombinants.

For the molecular phylogenetic analysis, in addition to determined sequences in this study, 28 representative ITS sequences of *Hedychium* and six sequences of its related genera that were deposited in GenBank by Wood *et al.* (2000) and Kress *et al.* (2002), were used (refer to these accession numbers in Appendix 1). Multiple sequences were manually aligned, and gaps were treated as missing. The maximum parsimony analysis with PAUP* version 4.0b10 (Swofford, 2002) was conducted using a heuristic search with a simple addition sequence, TBR branch swapping, Multrees, and no upper limit of MaxTrees. The strict consensus tree of the most parsimonious trees was generated and character changes were reconstructed on the tree with ACCTRAN character optimization using PAUP*. Bootstrap analysis was performed using 1,000 replicates and the same tree search procedure, except 100 upper limit of MaxTrees.

Results and Discussion

As the result of this study, *H. densiflorum* Wall., *H. flavescens* Carey ex Roscoe, *H. gardnerianum* Sheppard ex KerGawl. and *H. griffithianum* Wall. were newly added to the flora of Myanmar. Two new taxa were also discovered as the result of field expeditions.

In the molecular phylogenetic analysis based on nucleotide sequences of the ITS region, 585 most parsimonious trees (tree length = 199, CI = 0.7889, RC = 0.7293) were obtained and their strict consensus tree is shown in Fig. 1. The tree showed several clades in the *Hedychium*, although their bootstrap supports were not strong. Some plants contained two or three different ITS types within an individual, and most of them were belonged to the same clade. However, within a single individual, *H. natmataungense* contained three different ITS types belonging to two different clades; one (#1) is the same sequence as *H. ellipticum*, *H. glabrum*, and *H. yunnanense*, second (#2) is as one of *H. coc-*

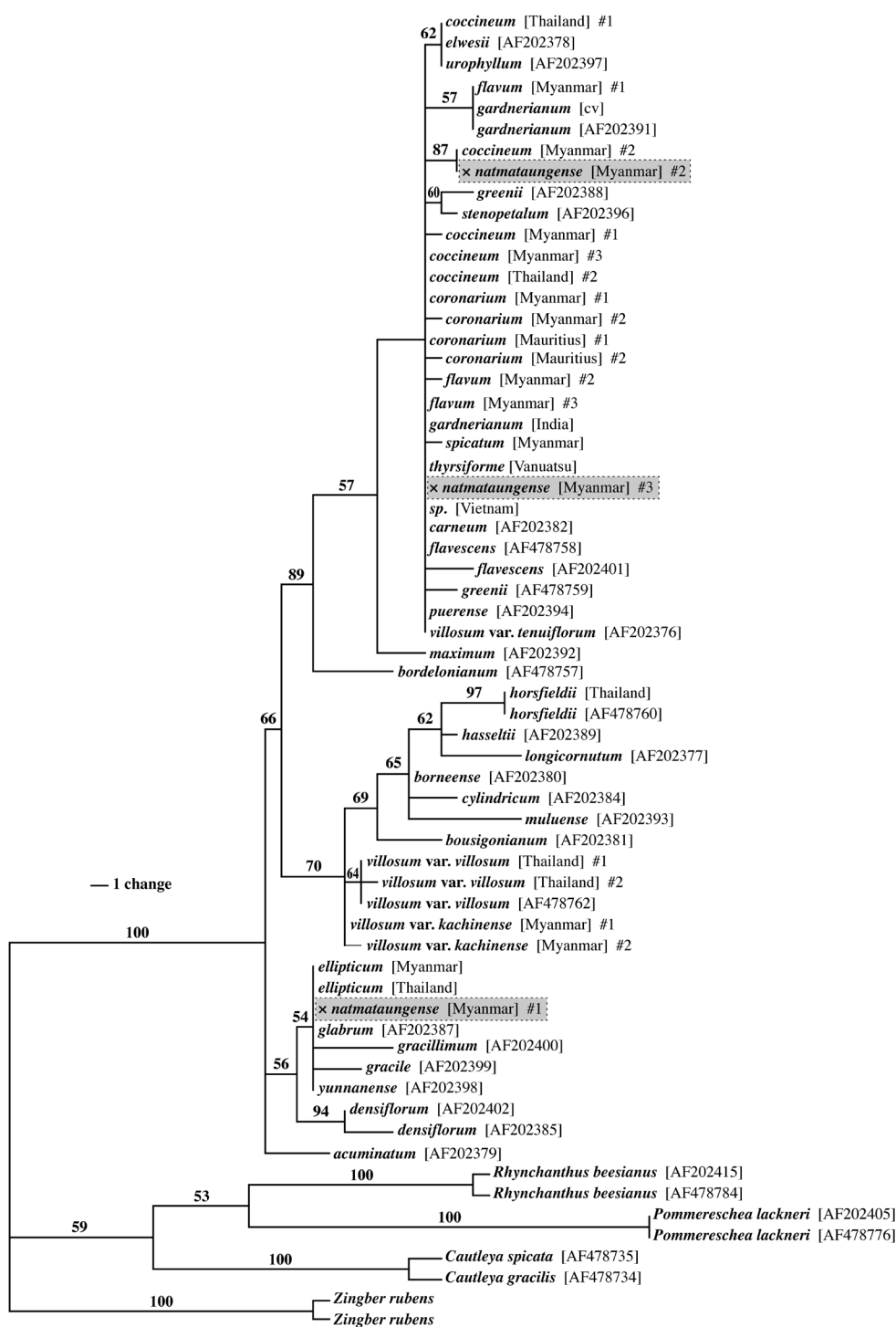


Fig. 1. Strict consensus tree of 585 most parsimonious trees, base on nucleotide sequences of the ITS region (tree length = 199, CI = 0.7889, RC = 0.7293). Numbers on branches are bootstrap values (over 50%). Source information of samples analyzed in this study or accession number of samples from GenBank is given in parentheses next to the taxon name. For samples containing two or three different ITS types within an individual, #1, #2, or #3 is given in each sequence.

cineum in Myanmar, and third (#3) is as several species including *H. coccineum* in Myanmar.

Furthermore, *H. ellipticum* (ITS type #1) and *H. coccineum* (ITS type #2 and #3) were also observed and collected around the habitat of *H. natmataungense* in the Natma Taung National Park. Thus, it is suggested that the species is originated by hybridization between at least *H. ellipticum* and *H. coccineum*. Considering the morphological similarity and the growth situation in same range, *H. natmataungense* might be a putative natural hybrid between *H. ellipticum* and *H. coccineum*. *Hedychium natmataungense* is more similar to *H. ellipticum* in the shape of inflorescence. The color of flowers in *H. natmataungense* (orange yellow) is intermediate between that of *H. ellipticum* (light yellowish) and *H. coccineum* (red). On the other hand, the taxon from Kachin State, north Myanmar, is closely related to *H. villosum* based on the phylogenetic analysis and morphological similarity, and it is described and illustrated as a new variety.

The species diversity of *Hedychium* in Myanmar appears to be the second highest to date among the neighboring countries in continental SE Asia. Since field expeditions to Myanmar have not as yet been sufficient, many more species of *Hedychium* are likely to exist. Including four species newly recorded in this study, a total of 22 taxa were recorded from Myanmar. A key to these taxa is provided below.

Newly recorded taxa of Hedychium from Myanmar

1. ***Hedychium flavescens*** Carey ex Roscoe, Monandr. Pl. Scitam.: t. 50 (1824); Wu & Larsen in Fl. China 24: 372 (2000).

Specimen examined. MYANMAR: **Sagain Region**. Grassland, Naga Hills, 5,000 ft. alt., 9 Sept. 1935, *N.L. Bor* 6482 (K).

Distribution. China, India, Myanmar, and Nepal.

Note. This species is hereby newly recorded from Myanmar as the result of identifying a single specimen housed in K. Although Wongsuwan

& Picheansoonthon (2011, 2012) treated *H. flavescens* as a variety of *H. coronarium*, we tend to retain it as an independent species because of the availability of only our collections to date not sufficiently understanding the range of variation. Our views are in agreement with Wu and Larsen (2000) and Sabu and Pradeep (2005).

2. ***Hedychium densiflorum*** Wall. [Numer. List: n. 6552 (1832)] in Hooker's J. Bot. Kew Gard. Misc. 5: 368 (1853); Wu & Larsen in Fl. China 24: 373 (2000).

Specimens examined. MYANMAR: Without detail locality, *L.S. Toppin* 3424 (E). **Kachin State**. North, upper Burma, 1914, *F. Kingdon-Ward* 1550 (E); Myitkyina, Laugyang-Pyetpah, 5400 ft., 25 May 1925, *Sutuz* 9990 (E). **Chin State**. Esakan, Mt. Victoria, 6500 ft. alt., 14 Feb. 1956, *Kingdon-Ward* 22611 (BM); Madupi, Natma Taung National Park, 22 July 2013, *Mu Aung et al.* 92649 (MBK).

Distribution. Bhutan, China, India, Myanmar and Nepal.

Note. This species has not been recorded from Myanmar previously. The three specimens collected from northern Myanmar at E were found to be this species. Additionally this specimen has also collected by the recent field exploration to northern region of Natma Taung (Mt. Victoria) National Park, western central Myanmar. Furthermore the herbarium work in BM revealed that Kingdon-Ward had already collected this species in 1956 in the same locality, Natma Taung.

3. ***Hedychium griffithianum*** Wall. in Hooker's J. Bot. Kew Gard. Misc. 5: 369 (1853); Baker in Hook.f., Fl. Brit. Ind. 6: 229 (1892).

Specimens examined. MYANMAR: **Shan State**. Taungyi, 1893, *Abdul Khalil s.n.* (CAL).

Distribution. India and Myanmar.

Note. *Hedychium griffithianum* had not previously been recorded from Myanmar, and the specimen examination in CAL revealed that it was also distributed in Myanmar. This species is known to date by only in Myanmar from this sin-

gle collection, which marks the eastern limit of the distribution range of this species.

4. ***Hedychium gardnerianum*** Sheppard ex Ker Gawl. in Bot. Reg. 9: t. 774 (1824); Kumar, Zingiberaceae of Sikkim: 52 (2001).

Specimens examined. MYANMAR: **Kachin State.** Nam Tamai Valley, 4000 ft., 17 August 1938, *R. Kaulback* 68 (BM); Sumka Uma, 2000 ft., 27 July 1939, *R. Kaulback* 294 (BM); north triangle, 4000 ft., 4 July 1953, *Kingdon-Ward* 21151 (BM).

Distribution. Bhutan, India, Myanmar, and Nepal.

Note. *Hedychium gardnerianum* is a Himalayan species. It was recorded from north Myanmar as the result of this study. This is the eastern limit of the distribution of this species.

Description of new taxa

1. ***Hedychium villosum*** Wall. var. ***kachinense*** Nob. Tanaka, var. nov. Fig. 2 A–K.

Hedychium villosum var. *kachinense* is considered to be a variation in *H. villosum*, and it is quite well distinguishable from it in having glabrous green bracts and calyx, and white corolla tube and filament.

Type: MYANMAR. Kachin State: Shyinbuiyan, Hukaung Valley Tiger Reserve, *J. Murata et al.* 20050597 (holotype-MBK, isotypes-RAF, TNS spirit).

Perennial rhizomatous herb, epiphytic on rocks, up to ca. 1.5 m in height. Rhizomes slender 1.5 cm in diameter, monopodial branching, creamy yellow internally, strongly aromatic. Leafy shoots composed of 8–10 leaves, erect, subsessile, petiole 0.5 cm long; ligule 0.8–1 cm long, 0.5 cm wide, margin membranous, glabrous, apex obtuse, reddish tinged basally; leaf blade 12.5–20 cm long, 4–4.5 cm wide, elliptic-oblongate, dark green and glabrous above, reddish tinged towards base and glabrous below, smooth, greyish pale green on lower surface, margin entire. Inflorescence 8–12 cm long, composed of 25 to 40 bracts, all bracts fertile, elliptic to cylindrical, 25 to 40-flowered. Bracts 1.5–2 cm

long, 0.9–1 cm wide, oblong, boat-shaped, green, almost glabrous, sparsely pubescent outside at base, glabrous inside, margin translucent, apex obtuse, pubescent, one bract containing 2 flowers. Bracteoles 1.3–1.5 cm long, 0.4–0.5 cm wide, white with red tinge, glabrous, membranous, translucent, non-tubular, margin entire. Flower 5.5–6 cm long, white, fragrant, opening from the morning to the noon. Calyx 1.5–1.7 cm long, 0.5 mm wide, lower half closely appressed to corolla tube, the apex roughly toothed, hairy. Floral tube 3.5–3.7 cm long, 0.1 cm wide at mouth, glabrous; dorsal corolla lobes 1.5–1.6 cm long, 0.2 cm wide, linear, lateral corolla lobes 1.6–1.7 cm long, 0.3 cm wide. Lateral staminodes 1.3–1.4 cm long, 0.2–0.3 cm wide, linear-lanceolate, white, apex bifid. Labellum 1.3–1.5 cm long, 1.4 cm wide, white, orbicular, gradually clawed at base, deeply divided, sinus 0.6–0.7 cm deep, margin wavy; lobes obtuse at apex. Stamens 7–7.5 cm long; filament 2.8–3 cm long, anthers parallel with the filament axis; connective creamy white, anther 3.5 mm long, 2 mm wide, sagittate, yellow at openings, glabrous, non-crested. Ovary 0.3 cm long, 0.2 cm wide, white, villous externally, trilocular, ovules many, placentation axile; style filiform, white, glabrous, broadens towards stigma; stigma ca. 0.8 mm wide, green, cup-shaped, margin ciliate, ca. 1.5 mm exerted from the anthers. Epigynous glands two, 3 mm long, oblong-lanceolate. Fruits unknown.

Distribution. N. Myanmar. Thus far known only from the type locality.

Etymology. The specific epithet, “*kachinense*”, derived from the type locality, Kachin State, northern Myanmar.

Note. Usually epiphytic on rocks along streams in the evergreen tropical forest, ca. 250 m alt. This species is morphologically closely related to *H. villosum*. Molecular phylogenetic analysis also supported its close relationship to *H. villosum* (Fig. 1). The plant from Myanmar is apparently not differentiated to the species rank from *H. villosum* based on its morphological differences in the diagnostic charac-

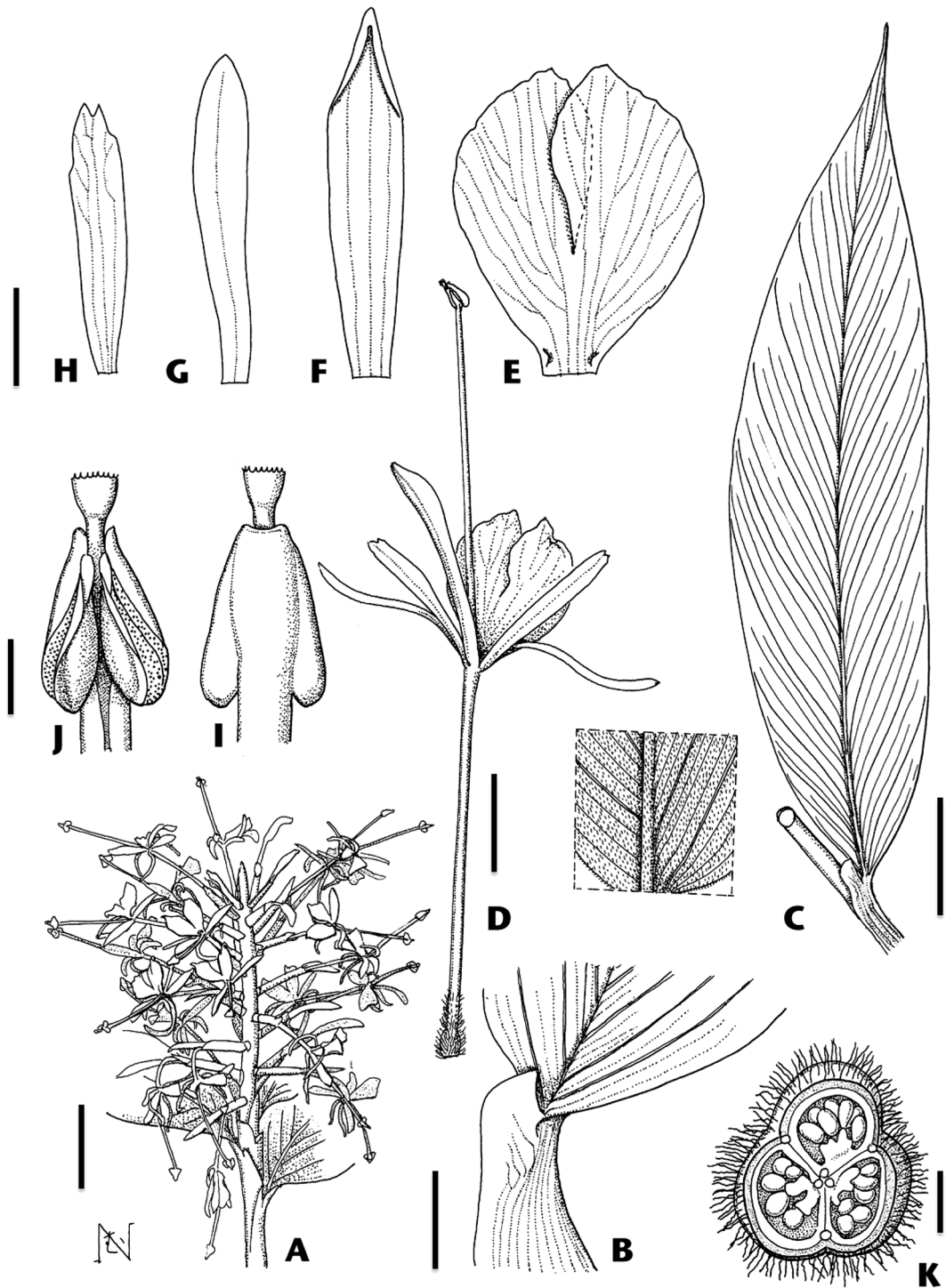


Fig. 2. *Hedychium villosum* Wall. var. *kachinense* Nob.Tanaka. A, inflorescence. B, leaf base and ligule. C, leaf blade. D, single flower. E, labellum. F, lateral corolla lobe. G, dorsal corolla lobe. H, lateral staminodes. I, rear view of anther. J, front view of anther. K, cross section of ovary. Scale bar : 3 cm for A and C. 1 cm for B and D. 0.5 cm for E, F, G, and H, and 1 mm for I, J and K.

ter. Therefore this study came to a conclusion that the plant in northern Myanmar would be separated as another infraspecific taxon under *H. villosum*. Baker (1892) treated *H. tenuiflorum* Wall. ex Voigt as a variety of *H. villosum*. Sanoj *et al.* (2013) made it clear the difference between *H. villosum* and its varieties, var. *villosum*, and var. *tenuiflorum*, however, the characters in the Myanmar plant does not match any of both infraspecific taxa in having glabrous green bracts and white corolla tube and filament. Var. *tenuiflorum* is distributed in northeastern India, Bangladesh, southern China, Thailand, Vietnam, and Malaysia from 600 to 1800 m (Wu and Larsen 2000). In the molecular phylogenetic analysis, the ITS sequence identified as *H. tenuiflorum* by Wood *et al.* (2000) was utilized, and it belongs to the different clade from *H. villosum* (Fig. 1). Although this voucher specimen (*T. Wood* 7, FLAS) is not seen in this study, it might be an error in identification.

2. *Hedychium* × *natmataungense* Nob. Tanaka, *nothospec. nov.* Fig. 3 A–H.

This taxon is presumed to be a natural hybrid between *H. coccineum* and *H. ellipticum*. Morphologically it is closely similar to *H. ellipticum*, but is distinguishable by the longer inflorescence, non-imbricated bracts, and yellow to orange yellow flowers.

Type: MYANMAR. Chin State: Natma Taung (Mt. Victoria) National Park, ca. 900–1200 m alt., *N. Tanaka et al.* 10-59 (holotype-MBK, isotypes-RAF, TNS spirit).

Terrestrial perennial rhizomatous herb, up to ca. 1.5 m in height. Rhizomes 3 cm wide, monopodial branching, creamy white internally, strongly aromatic. Leaves 14–17, sessile; ligule 0.7–1 cm long, 1–1.3 cm wide, margin membranous, translucent, apex obtuse, reddish tinged basally, hairy externally, glabrous internally; leaf blade 28–45 cm long, 4.5–10 cm wide, lanceolate-oblong, dark green and glabrous above, pubescent on midvein below; margin entire. Inflorescence 13–15 cm long, elliptic, densely flowered. Bracts 3.2–3.5 cm long,

0.9–1 cm wide, spatulate, boat-shaped, green, apex slightly pubescent externally, coriaceous, imbricating, margin translucent, apex obtuse, cinnabar 1–2-flowered. Bracteoles 1.2–1.5 cm long, 0.5–0.7 cm wide, glabrous on both surfaces, membranous, translucent, non-tubular, margin entire. Flower 11–12 cm long, orange yellow, fragrant. Calyx 3.5–3.7 cm long, 7 mm wide, lower half closely appressed to corolla tube, orange. Corolla tube 5–6 cm long, 2.5 mm wide at mouth, glabrous; lobes 4.5 cm, 0.2 cm long, linear, white. Lateral staminodes lanceolate, orange yellow, apex rounded. Labellum 2.8–3.2 cm long, 0.8–0.9 cm wide, orange yellow, gradually clawed at base, sinus 0.8 cm deep; lobes obtuse at apex. Stamens 11 cm long; filament 10.5 cm long, anther sagittate, 1–1.5 cm long, curved, orange; connective orange red, glabrous, non-crested, tip truncate-slightly notched. Ovary 0.4–0.5 cm long, ca. 0.3 mm wide, oblong, glabrous, white, trilocular, ovules many, placentation axile; style filiform, white, glabrous, broadens towards stigma; stigma 1.2–1.5 mm wide, dull green, cup-shaped, margin ciliate, 1–1.2 mm exserted from the anthers. Epigynous glands two, 0.3 cm long, oblong-lanceolate. Capsules globose, 1.5–1.6 cm long, 1.2–1.3 cm wide, green when young, red at maturity; seeds numerous, aril red.

Etymology. The specific epithet, “*natmataungense*”, is derived from a type locality, Natma Taung, a local name of Mt. Victoria in Myanmar language.

Distribution. W. Myanmar. Thus far known only from Mt. Victoria.

Notes. This taxon is thought to be a natural hybrid. Its putative parents might be *H. coccineum* and *H. ellipticum* based on the morphological characters (especially inflorescence shape) and the molecular phylogenetic relationship (Fig. 1). *Hedychium coccineum* and *H. ellipticum* are growing at the altitude of 500–1500 m, and its growing ranges overlap that of *H. × natmataungense* in Natma Taung.

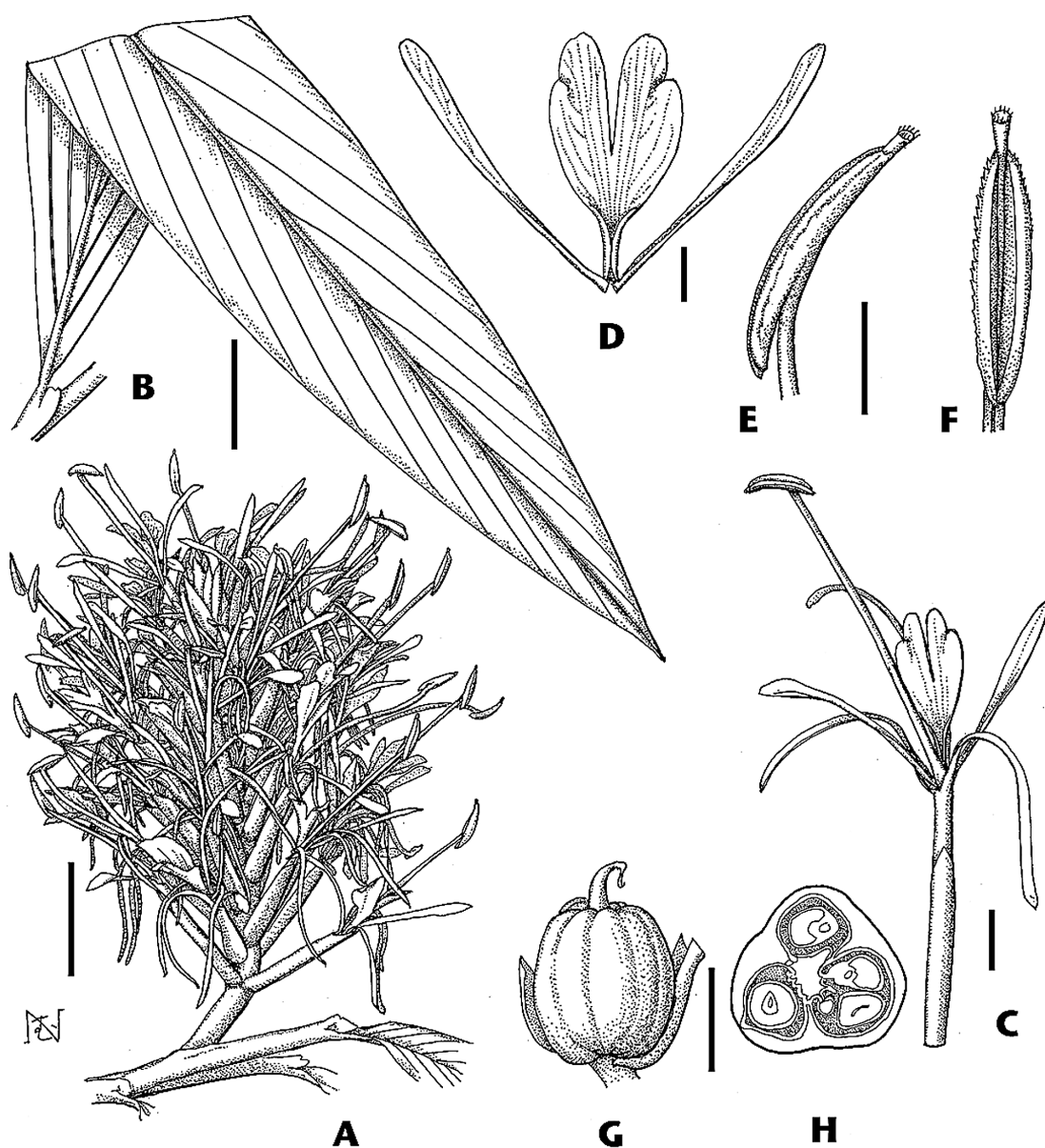


Fig. 3. *Hedychium* $\times$ *natmataungense* Nob.Tanaka. A, inflorescence. B, leaf. C, single flower. D, labellum and lateral staminodes. E, front view of anther. F, lateral view of anther. G, fruit. H, cross section of ovary. Scale bar : 3 cm for A and B. 1 cm for C, G, H, and 0.5 cm for D and E.

Key to the genus *Hedychium* thus far recorded in Myanmar

- 1a. Only apical bracts fertile, bracts imbricate, covering rachis2
- 1b. All bracts fertile, not imbricate, rachis well visible6
- 2a. Flowers white3
- 2b. Flowers yellow4
- 3a. Stamen shorter than labellum *H. coronarium*

3b. Stamen longer than labellum	<i>H. ellipticum</i>
4a. Labellum pale yellow with a dark yellow patch basally	<i>H. flavescens</i>
4b. Labellum only yellow	5
5a. Labellum longer than its width	<i>H. marginatum</i>
5b. Labellum wider than its length	<i>H. flavum</i>
6a. Usually epiphytic on tree or rock	7
6b. Usually terrestrial on ground	11
7a. Bract subtending 1 flower	8
7b. Bract subtending more than 2 flower	9
8a. Flowers red, labellum 3-lobed	<i>H. bordelonianum</i>
8b. Flowers white, labellum deeply divided	<i>H. gomezianum</i>
9a. Bract and bracteole brownish, villose	10
9b. Bracts and bracteole green, glabrous	<i>H. villosum</i> var. <i>kachinense</i>
10a. Inflorescence 17–25 cm long	<i>H. villosum</i> var. <i>villosum</i>
10b. Inflorescence 8–12 cm long	<i>H. villosum</i> var. <i>tenuiflorum</i>
11a. Bract subtending 1 flower	12
11b. Bract subtending more than 2 flowers	14
12a. Flowers orange	<i>H. densiflorum</i>
12b. Flowers white to pale yellow	13
13a. Bracts green, filament pink	<i>H. gracile</i>
13b. Bracts brownish, filament white	<i>H. venustum</i>
14a. Flowers red	<i>H. coccineum</i>
14b. Flowers white or yellow	15
15a. Stamen shorter than labellum	<i>H. spicatum</i>
15b. Stamen longer than labellum	16
16a. Labellum suborbicular to orbicular	17
16b. Labellum elliptic to oblong	18
17a. Inflorescence more than 35 cm long	<i>H. stenopetalum</i>
17b. Inflorescence less than 30 cm long	<i>H. forrestii</i>
18a. Flowers yellow	19
18b. Flowers white	20
19a. Filament red	<i>H. gardnerianum</i>
19b. Filament orange	<i>H</i> × <i>natmataungense</i>
20a. Leaf blade glandular in lines above	<i>H. griffithianum</i>
20b. Leaf blade not glandular in lines	21
21a. Filament pink, labellum red tinged	<i>H. elatum</i>
21b. Filament white, labellum white	<i>H. thyrsiforme</i>

Acknowledgments

The first author is thankful to curators, Natural History Museum of London (BM), Royal Botanic Gardens, Kew (K), and Edinburgh (E), National Central Herbarium, Botanical Survey of India, Kolkata (CAL), Makino Botanical Garden (MBK), for giving him access their collections

and providing facilities. Thanks are due to the Forest Department, Ministry of Natural Resources and Environmental Conservation, Republic of the Union of Myanmar, for their permission of our field expeditions. We also thank Prof. Dr. Robert Kaul of University of Nebraska-Lincoln for the linguistic review and M.

Nakajima for preparing the illustrations. This research was partly supported by JSPS KAK-ENHI Grant Nos. 17255004 to J. Murata, 23770101 and 15K07207 to N. Tanaka.

References

- Baker, J. G. 1892. *Zingiber*. In: Hooker, J. D. (ed.), Flora of British India vol. 6., pp. 243–249. L. Reeve and Co., London.
- eMonocot. 2016. eMonocot: An online resource for monocot plants, version 1.0.2. Available from: <http://e-monocot.org/> (accessed 19 January 2016)
- Kress, W. J., Prince, J. M. and Williams, K. J. 2002. The phylogeny and a new classification of the gingers (Zingiberaceae): evidence from molecular data. *American Journal of Botany* 89: 1682–1696.
- Kress, J., DeFilipps, R. A., Farr, E. and Kyi, Y. Y. 2003. A checklist of the trees, shrubs, herbs and climbers of Myanmar. *Contributions from the United States National Herbarium* 45: 1–590.
- Ohi-Toma, T., Wu, S., Yadav, S. R., Murata, H. and Murata, J. 2010. Molecular phylogeny of *Typhonium* sensu lato and its allied genera in the tribe Aroideae (Araceae) based on sequences of six chloroplast regions. *Systematic Botany* 35: 244–251.
- Sabu, M. and Pradeep, A. K. 2005. The spectacular *Hedychium* of North India. *Folia Malaysiana* 6: 5–16.
- Sanoj, E., Sabu, M. and Pradeep, A. K. 2013. Circumscription and lectotypification of *Hedychium villosum* and its variety *H. villosum* var. *tenuiflorum* (Zingiberaceae). *PhytoKeys* 25: 75–85.
- Sirirugsa, P. and Larsen, K. 1995. The genus *Hedychium* (Zingiberaceae) in Thailand. *Nordic Journal of Botany* 15: 301–304.
- Srivastava, S. C., Kumar, A. and Vinayranjan 2012. *Hedychium tenuiflorum* (Wall. ex Baker) K. Schum. *Folia Malaysiana* 13: 51–52.
- Swofford, D. L. 2002. PAUP*: Phylogenetic analysis using parsimony (and other methods), version 4.0 Beta. Sinauer, Sunderland, Massachusetts.
- White, T. J., Bruns, T., Lee, S. and Taylor, J. W. 1990. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: Innis, M. A., Gelfand, D. H., Sninsky, J. J. and White, T. J. (eds.), *PCR Protocols: A Guide to Methods and Applications*, pp. 315–322. Academic Press, Inc., New York.
- Wongsuwan, P. and Pichansoonthon, C. 2011. Taxonomic revision of the genus *Hedychium* J.König (Zingiberaceae) in Thailand (part 1). *Journal of the Royal Institute of Thailand* 3: 126–149.
- Wongsuwan, P. and Pichansoonthon, C. 2012. Taxonomic revision of the genus *Hedychium* J.König (Zingiberaceae) in Thailand (part 2). *Journal of the Royal Institute of Thailand* 4: 250–267.
- Wood, T., Whitten, W. M. and Williams, N. H. 2000. Phylogeny of *Hedychium* and related genera (Zingiberaceae) based on ITS sequence data. *Edinburgh Journal of Botany* 57: 261–270.
- Wu, T. L. and Larsen, K. 2000. Zingiberaceae. In: Wu, Z. Y. and Raven, P. H. (eds.), *Flora of China* vol. 24, pp. 322–377. Science Press, Beijing and Missouri Botanical Garden Press, St. Louis.

Appendix 1. List of samples used in the molecular phylogenetic analysis: species, source, voucher information, and DDBJ/GenBank accession number of ITS sequence. DNA samples from The Royal Botanic Gardens, Kew, DNA Bank are indicated with an asterisk (*).

Hedychium coccineum, Myanmar, *Funakoshi et al.* 085388 (MBK), AB968050, AB968051, AB968052; Thailand, *S. Saensouk & P. Saensouk* 157 (KKU)*, AB968053, AB968054. *Hedychium coronarium*, Myanmar, *Tanaka* 20040291 (MBK), AB968055, AB968056; Mauritius, *M. W. Chase* 18078 (K)*, AB968057, AB968058. *Hedychium ellipticum*, Myanmar, *Tanaka* 20020259 (MBK), AB968059; Thailand, *S. Saensouk & P. Saensouk* 158 (KKU)*, AB968060. *Hedychium flavum*, India (cult. in Makino Botanical Garden), *Tanaka* 20040593 (MBK), AB968061, AB968062, AB968063. *Hedychium gardnerianum*, India (cultivated in Koishikawa Botanical Gardens), *Ohi-Toma* (TI), AB968065. *Hedychium gardnerianum* cv, cultivated in Koishikawa Botanical Gardens, *Ohi-Toma* (TI), AB968064. *Hedychium horsfieldii*, Thailand, 20010249 (MBK), AB968066. *Hedychium villosum* var. *kachinense*, Myanmar, *Murata et al.* 20050597 (MBK), AB968067, AB968068. *Hedychium × natmataungense*, Myanmar, *Tanaka* 10-59 (MBK), AB968069, AB968070, AB968071. *Hedychium* sp., Vietnam, *Murata* 20110232 (MBK), AB968072. *Hedychium spicatum*, Myanmar, *Kuroiwa et al.* 022420 (MBK), AB968073. *Hedychium thyrsoforme*, Vanuatu (cult. in Makino Botanical Garden), *Tanaka* 20040492 (MBK), AB968074. *Hedychium villosum* var. *villosum*, Thailand, *S. Saensouk & P. Saensouk* 161 (K)*, AB968075, AB968076. *Zingiber rubens*, Myanmar, *Tanaka et al.* 023296 (MBK), AB968077; Myanmar, *Hayami* 20050442 (MBK), AB968078.