

# *Chlorohiptage* (Tetrapteroids, Malpighiaceae), a distinct new genus endemic to Vietnam based on morphological and molecular data

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## Abstract

**Background and aims** – Vietnam is one of the leading diversity centres for Asian Malpighiaceae, comprising 24 accepted species and three native genera (i.e. *Aspidopterys*, *Hiptage*, and *Tristellateia*). During recent fieldwork towards completing the taxonomic revision of Malpighiaceae for the Flora of Vietnam, we have collected specimens from two populations that could not be placed in any of the three native genera of this family. We performed morphological and molecular phylogenetic studies to test the generic placement of those specimens.

**Material and methods** – We sampled 27 genera (including the Asian *Acridocarpus*, *Aspidopterys*, *Brachylophon*, *Hiptage*, *Stigmaphyllon*, and *Tristellateia*, out of a total of 75) of Malpighiaceae representing all phylogenetic clades comprising paleotropical lineages (i.e. acridocarpoids, bunchosoids, tetrapteroids, malpighioids, and stigmaphylloids), the unusual specimen recently collected in Vietnam, and the two genera of Elatinaceae as outgroups. Maximum Likelihood analysis was carried out based on a molecular matrix alignment of the internal transcribed spacer marker (ITS). Comprehensive morphological analyses were also carried out based on the collected specimens and additional herbarium specimens.

**Key results** – Our molecular phylogeny strongly supported the unusual specimen from Vietnam placed as sister to *Hiptage* in the tetrapteroid clade. Key morphological traits differing these Vietnamese specimens from *Hiptage* were identified related to the floral bud imbrication, shape, colour, posture of sepals and petals, length of stamen filaments, number of styles, and shape of mericarps, allowing the proposition of a new monospecific genus.

**Conclusions** – *Chlorohiptage vietnamensis* is proposed as a new monospecific genus closely related to *Hiptage* but differing in several key morphological traits. A complete morphological description is provided alongside photographic illustrations and notes on its conservation, distribution, ecology, etymology, and taxonomy. Additionally, an updated identification key to the genera of the tetrapteroid clade is provided.

## Keywords

Asia, *Hiptage*, Malpighiales, systematics, taxonomy, tetrapteroid

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## INTRODUCTION

Malpighiaceae (Malpighiales) have undergone unparalleled changes in its traditional classification in the last two decades due to the publication of several molecular phylogenetic studies (Cameron et al. 2001; Davis et al. 2001; Davis and Anderson 2010; Almeida et al. 2023a). Several new lineages were resolved, bringing to light taxonomic problems regarding the monophyly of its subfamilies, tribes, and genera (Cameron et al. 2001; Davis et al. 2001; Davis and Anderson 2010; Almeida et al. 2017, 2023a, 2023b; Almeida and van den Berg 2020, 2021). Subsequently, numerous authors have gradually proposed new genera and combinations to accommodate these newly identified relationships (Anderson 2006, 2011; Anderson et al. 2006; Almeida and van den Berg 2021). Although morphological characters were used to reconstruct the latest generic phylogeny for Malpighiaceae (Davis and Anderson 2010), no morphological characters were ever recovered and/or discussed for circumscribing these newly resolved relationships (Almeida and van den Berg 2021, 2022). Currently, Malpighiaceae are divided into ten phylogenetic clades without any formal rank: byrsonimoids, acridocarpoids, mcvaughoids, barnebyoids, ptilochaetoids, bunchosoids, hiraeoids, tetrapteroids, malpighioids, and stigmaphylloids (Almeida et al. 2023a).

This family comprises 75 currently accepted genera and ca 1,300 species of trees, shrubs, subshrubs, and lianas in the tropics and subtropics of both the Neo- and Paleotropics (POWO 2024). From those, 17 genera and ca 150 species occur exclusively in the Paleotropical region (Davis and Anderson 2010), with only *Acridocarpus* Guill., Perr. & A.Rich. (one species, acridocarpoid clade), *Aspidopterys* A.Juss. ex Endl. (24 species, malpighioid clade), *Brachylophon* Oliv. (two species, acridocarpoid clade), *Hiptage* Gaertn. (46 species, tetrapteroid clade), *Stigmaphyllon* A.Juss. (23 species, stigmaphylloid clade), and *Tristellateia* Thouars (one species in Asia, bunchosoid clade) naturally occurring in Asia (POWO 2024). The conspicuous floral conservatism of Neotropical Malpighiaceae (i.e. zygomorphic flowers with glandular sepals, connective oil glands, and pantocolporate pollen grains) was lost in these Old World genera due to a shift in their pollination system as an evolutionary adaptation to the absence of oil-collecting bees in the Paleotropics (Cameron et al. 2001; Davis et al. 2014; Almeida et al. 2023a, 2023c). Consequently, Old World genera frequently show actinomorphic flowers with eglandular or nectariferous sepals and pantoporate pollen grains (Cameron et al. 2001; Davis et al. 2014).

In Asia, the formerly French territory known as Indochina (i.e. formed by current Cambodia, Laos, and Vietnam) is one of the main diversity centres for Malpighiaceae comprising all four Asian genera and ca 36 species (POWO 2024). In fact, historical biogeographic studies using molecular phylogenies and molecular clock calibrations have pointed out both Indochina and

Vietnam as evolutionary hotspots for plant diversity and Malpighiaceae (Bruyn et al. 2014; Almeida and van den Berg 2022). Using molecular datasets for diverse groups of plants, vertebrates, and invertebrates, Bruyn et al. (2014) corroborated Borneo and Indochina's critical evolutionary role in lineage diversification in Southeast Asia. Additionally, Almeida and van den Berg (2022), also using a molecular dataset and historical biogeography analyses for *Hiptage*, identified Vietnam as the probable centre of origin for the most recent common ancestor of *Hiptage*.

During field collection to complete the monograph of Malpighiaceae for the Flora of Vietnam, we found some unusual Malpighiaceae specimens from two populations in limestone areas of the Cam Lo district, Quang Tri province, Central Vietnam. This region is located in the Truong Son Mountain range (Annamite Mountain), a well-known important biodiversity hotspot of Vietnam. Surprisingly, we could not place these unidentified specimens into any Old World genus of Malpighiaceae solely based on morphological traits. In order to test the phylogenetic placement of these unusual specimens at the generic level, we performed a complete morphological and taxonomic study of them allied to a molecular phylogenetic analysis sampling all Paleotropical lineages of Malpighiaceae based on sequences of the internal transcribed spacer.

## MATERIAL AND METHODS

### Molecular analyses

We sampled 61 species and 94 specimens in this study representing all five phylogenetic clades of Malpighiaceae comprising Paleotropical genera (i.e. acridocarpoids, bunchosoids, tetrapteroids, malpighioids, and stigmaphylloids), representatives of the early diverging byrsonimoids and barnebyoids, and two species of *Bergia* L. and *Elatine* L. (Elatinaceae), each, as outgroups (Supplementary file 1). We used leaf fragments from one field specimen dried in silica gel for DNA extraction. Genomic DNA was extracted using the CTAB 2× protocol, modified from Doyle and Doyle (1987). Protocols to amplify and sequence the ITS region followed Almeida et al. (2017). PCR products were purified using PEG 11% (polyethylene glycol) and were sequenced directly with the same primers used for the PCR amplification. Sequence electropherograms were produced in an automatic sequencer (ABI 3130XL Genetic Analyzer) using Big Dye Terminator 3.1 (Applied Biosystems). Additional sequences from ITS were retrieved from GenBank, edited using Geneious (Kearse et al. 2012) and aligned using Muscle (Edgar 2004), with subsequent adjustments in the preliminary matrices made manually by eye. The complete data matrices are available at Zenodo (<https://zenodo.org/doi/10.5281/zenodo.10887243>). All trees were rooted in Elatinaceae (*Bergia* + *Elatine*), the

sister group of Malpighiaceae, according to Davis and Anderson (2010). A Maximum Likelihood analysis (ML) was performed for the aligned matrix using RAxML v.8 (Stamatakis 2014) implemented in RAxMLGUI2 (Edler et al. 2021), and a mixed model (GTR+G+I) with unlinked parameters was selected using hierarchical likelihood ratio tests (HLRT) in jModelTest 2 (Darriba et al. 2012). ML analyses were performed with 10 independent replicates, and default settings and support values were estimated using parametric bootstrapping (BS) with 500 replicates. Support values are presented on branches, with bootstrap values shown above branches.

## Taxonomy

Vouchers were deposited in the herbaria of Vietnam National Museum of Nature, Vietnam (VNMN) and Southern Institute of Ecology, Vietnam (SGN). Morphological traits were observed, measured, and photographed based on both fresh and herbarium specimens and compared with descriptions of protologues, type specimens, and herbarium sheets available from the following herbaria: HN, HNU, IBK, IBSC, K, KUN, P, PE, and VNMN (acronyms according to Thiers 2024). Images of type specimens were consulted from JSTOR Global Plants (<http://plants.jstor.org>), the Chinese Virtual Herbarium (<http://www.cvh.ac.cn>), and the Kew Herbarium Catalogue (<http://apps.kew.org/herbcat/navigator.do>). Furthermore, relevant literature (e.g. Niedenzu 1928; Arènes 1944; Sirirugsa 1991; Srivastava 1992; Pham 2000; Nguyen 2003; Chen and Funston 2008) was also reviewed. The indumentum terminology follows Anderson (1981), structure shapes follow Radford et al. (1974), inflorescence terminology and morphology follow Weberling (1965, 1989), and fruit terminology follows Spjut (1994) and Anderson (1981). The conservation status was proposed following the recommendations of IUCN Red List Categories and Criteria, Version 3.1 (IUCN 2012, 2022) and GeoCAT (Bachman et al. 2011).

## RESULTS

### Phylogenetic analyses

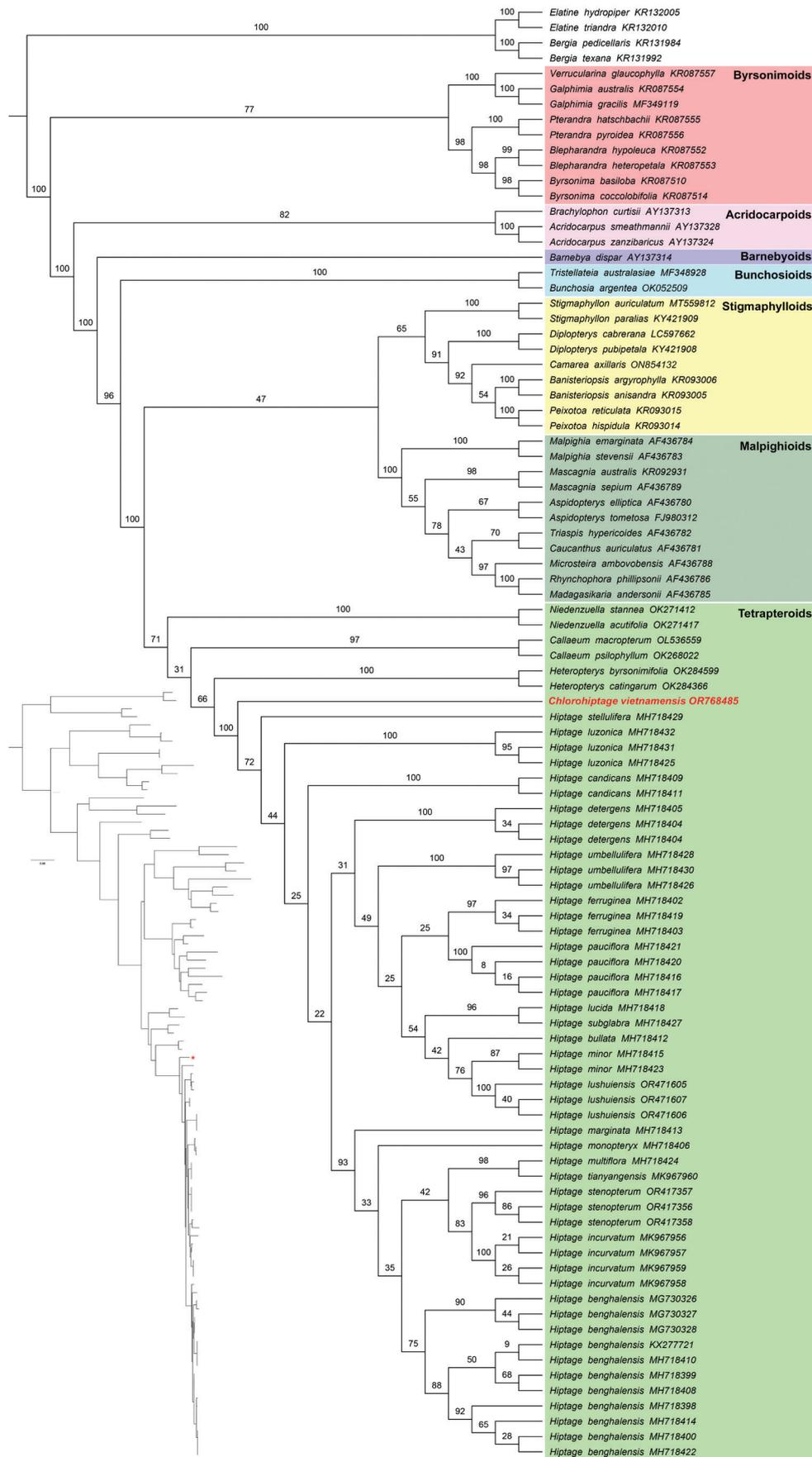
The ITS dataset represented 795 characters with the ML analysis recovering a fully resolved tree with seven well-supported (BS65) main clades (Fig. 1). The first lineage to diverge within Malpighiaceae was the byrsonimoids (BS77) comprising species of the genera *Blepharandra* Griseb., *Byrsonima* Rich. ex Kunth, *Galphimia* Cav., *Pterandra* A.Juss., and *Verrucularina* Rauschert (Fig. 1). The second lineage to diverge was the acridocarpoids (BS82) comprising the species of the genera *Acridocarpus* and *Brachylophon* (Fig. 1). The third lineage to diverge was the barnebyoids (BS100) with the species of *Barnebya* W.R.Anderson & B.Gates (Fig. 1). The fourth lineage to diverge was the bunchosoids (BS100) comprising the

species of *Bunchosia* Rich. ex Kunth and *Tristellateia* (Fig. 1). The fifth lineage to diverge was the stigmaphylloids (BS65), comprising the species of the genera *Stigmaphyllon*, *Diplopterys* A.Juss., *Camarea* A.St.-Hil., *Banisteriopsis* C.B.Rob., and *Peixotoa* A.Juss. (Fig. 1). The sixth lineage to diverge was the malpighioids (BS100), including the species of the genera *Malpighia* L., *Mascagnia* (Bertero ex DC.) Bertero, *Aspidopterys*, *Triaspis* Burch., *Caucanthus* Forssk., *Microsteira* Baker, *Rhynchophora* Arènes, and *Madagasikaria* C.Davis (Fig. 1). Finally, the seventh lineage to diverge was the tetrapteroids (BS71) comprising the species of the genera *Niedenzuella* W.R.Anderson, *Callaeum* Small, *Heteropterys* Kunth, *Hiptage* and the unusual specimen collected in Vietnam (highlighted in red in Fig. 1). This unusual specimen was recovered as sister group to *Hiptage*, which includes 19 species sampled out of 46 (Fig. 1).

## DISCUSSION

Morphologically, the specimens collected in Vietnam are characterised by having actinomorphic flowers, eglandular calyces, androecium with 10 stamens (9 longer with thinner filaments and one shorter and thicker filament), gynoecium with three free styles and much shorter than the filaments, and mericarps with 1 lateral wing unequally 3-lobed and dorsal wing absent. They share some morphological similarities with *Hiptage* and *Aspidopterys* (Fig. 2, Table 1) but are distantly related to the latter (Fig. 1). The unusual Vietnam specimen is clearly sister to *Hiptage* according to our results, being differentiated from the latter by the petals being pale-green to yellowish-green (vs white to yellow) with margins erose and velutine (vs dentate to fimbriate and glabrous), stamens 9 long + 1 short (vs 9 short + 1 long), styles 3 (vs 1–2), shorter than the filaments (vs longer than the filaments), mericarps with 1 lateral wing, 3-lobed (vs 3 free lateral wings; Fig. 2).

One could argue that this unusual Vietnamese specimen would be better placed as the first lineage to diverge in *Hiptage*. This genus is currently subdivided into three subgenera based on the presence and number of sepal glands: *H.* subg. *Archihiptage* Nied. shows 2–8-glandular calyces, *H.* subg. *Hiptage* Nied. shows 1-glandular calyces, and *H.* subg. *Metahiptage* Nied. shows eglandular calyces (Niedenzu 1928). Since the last taxonomic revision of *Hiptage* by Niedenzu (1928), several new species have been described, mainly in India (Srivastava 1992), south-eastern China (Wei 1981; Chen 1996; Yang et al. 2018; Tan et al. 2019; Dong et al. 2020), and Indochina (Arènes 1954; Balakrishnan and Srivastava 1983; Sirirugsa 1987; Zhang et al. 2023). Nonetheless, all three currently accepted subgenera of *Hiptage* were recently recovered as paraphyletic by Almeida and van den Berg (2022): *H.* subg. *Archihiptage* was recovered in two distantly related lineages (i.e. *H. stellulifera* Arènes and *H. lucida* Pierre + *H. subglabra* Arènes + *H. bullata* Craib clades); *H.* subg.



**Figure 1.** Phylogenetic tree derived from the Maximum Likelihood analysis using the ITS aligned matrix. Numbers on the branches indicate the bootstrap values of the maximum likelihood. Word in red indicates the new species/new genus.

**Table 1.** Comparison of morphological traits of *Chlorohiptage* with *Hiptage* and *Aspidopterys*. \*Morphological characters derived from the protologue (Gaertner 1791), recent descriptions (Arènes 1944, 1954; Srivastava 1992; Pham 2000; Chen and Funston 2008), and our own observation from the herbarium specimens. \*\*Morphological characters derived from the protologue (Jussieu 1840), recent descriptions (Arènes 1944, 1954; Pham 2000; Chen and Funston 2008), and our own observation from the herbarium specimens.

Morphological traits	<i>Chlorohiptage</i> gen. nov.	<i>Hiptage</i> *	<i>Aspidopterys</i> **
Stipules	Absent	Minute, glandlike or absent	Absent or caducous
Basal glands on the abaxial surface	2 or sometimes absent	2 or sometimes absent	Absent
Marginal glands on the abaxial surface	Absent	Present	Absent
Inflorescences	Thyrse	Thyrse	Corymbs
Flowers	Actinomorphic	Zygomorphic or sometimes actinomorphic	Actinomorphic
Calyx	Eglandular	Glandular to rarely eglandular	Eglandular
Sepals	Valvate	Imbricate	Valvate
Petals	Green, margin erose, clawed	White to yellow, margin fimbriate to dentate, clawed	White to pale yellow, margin entire, not clawed
Androecium	Stamens 10 with 9 longer and slender filaments and one shorter and stouter filament	Stamens 10 with 9 shorter and slender filaments and one longer and stouter filament	Stamens 10, with equal or subequal filaments
Gynoecium	Styles 3, curved, shorter than the androecium	Style 1(-2), curved, longer than the androecium	Styles 3, straight, as long as filaments
Mericaip	1-winged, 3-lobed	3-winged, without lobes	Surrounded by a disc-like lateral wing, orbicular to oblong
Lateral wings	Lanceolate	Oblong-elliptic	Orbicular

*Hiptage* was recovered in seven distantly related lineages (i.e. *H. candicans* Hook.f., *H. luzonica* Merr., *H. detergens* Craib, *H. monopteryx* Sirirugsa + *H. benghalensis* (L.) Kurz + *H. multiflora* F.N.Wei + *H. incurvatum* K.Tan & M.X.Ren, *H. umbellulifera* Arènes, *H. pauciflora* Y.H.Tan & Bin Yang, and *H. ferruginea* Y.H.Tan & Bin Yang clades); and *H.* subg. *Metahiptage* was recovered in two distantly related lineages (i.e. *H. marginata* Arènes and *H. minor* Dunn clades). Additionally, since several morphological traits important to circumscribe *Hiptage* seem to differ in this Vietnamese specimen, such as sepals valvate (vs imbricate), petals green (vs white to yellow), margins erose (vs fimbriate to dentate), stamens 9 long + 1 short (vs 9 short + 1 long), styles 3 (vs 1-2), mericaip 1-winged (vs 3; Table 1), we propose here a new genus and species endemic to this country.

## TAXONOMIC TREATMENT

***Chlorohiptage*** T.V.Do, T.A.Le & R.F.Almeida, **gen. nov.**

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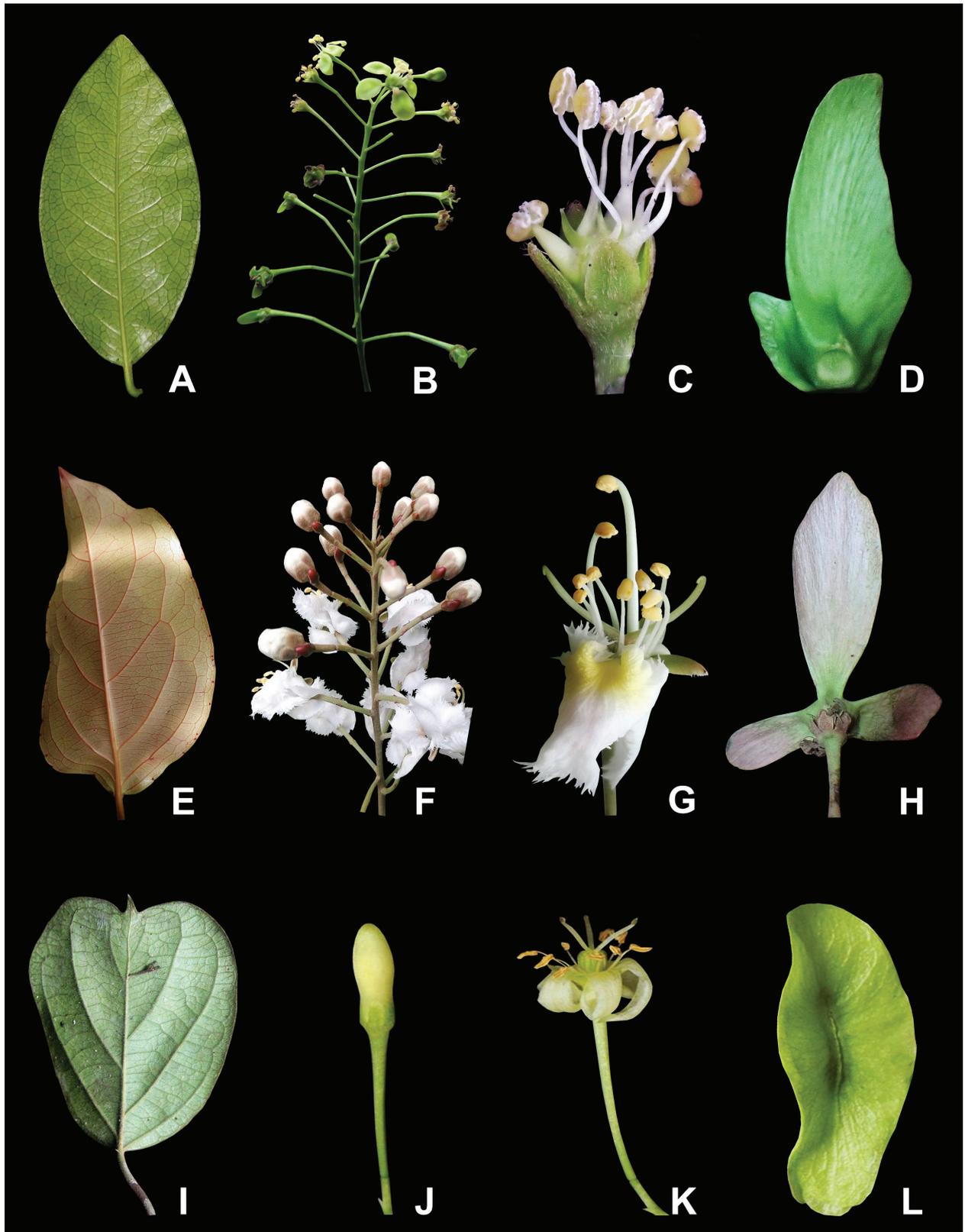
Figs 2–4

**Type species.** *Chlorohiptage vietnamensis* T.V.Do, T.A.Le & R.F.Almeida, sp. nov.

**Diagnosis.** Distinguished from *Hiptage* by its floral buds valvate (vs imbricate), petals pale-green to yellowish-green (vs white to yellow) with margins erose and velutine

(vs dentate to fimbriate and glabrous), stamens 9 long + 1 short (vs 9 short + 1 long), styles 3 (vs 1-2), shorter than filaments of the stamens (vs longer than filaments of the stamens), mericaips with 1 lateral wing, 3-lobed (vs 3 free lateral wings).

**Description.** Woody scandent shrubs; xylopodium absent; axillary buds densely sericeous; indumentum throughout the plant ranging from sparsely sericeous to glabrous; stipules absent. Leaves opposite, never reduced in the inflorescences; petioles cylindric, eglandular, sparsely sericeous; blade elliptic to ovate, base cuneate to attenuate, margin entire, apex obtuse to acute, sometime retuse, abaxially 2–4-glandular along midvein near the base. Thyrses solitary, mostly terminal; cincinni 1-flowered; bracts present; peduncles present; bracteoles present. Flowers bisexual, actinomorphic, chasmogamous; pedicels elongate; sepals not concealing petals during enlargement of bud, erect at anthesis, all sepals abaxially eglandular; petals clawed, pale-green to yellowish-green, densely velutine at margins, limb narrowly falcate to obovate, base truncate to subcordate, margin erose, apex acute, claw plane, all petals patent to deflexed at anthesis. Androecium 10, stamens all fertile; filaments connate at base, curved, 9 long and more slender stamens + 1 short and stout stamen, glabrous; connective conspicuous, apparently glandular; 9 anthers monomorphic, 1 anther larger, erect at apex, glabrous. Gynoecium with 3 carpels connate their whole length in flower, separating during fruit development, styles 3, slender, cylindric,



**Figure 2.** Comparison of morphological traits of *Chlorohiptage* T.V.Do, T.A.Le & R.F.Almeida, gen. nov. with *Hiptage* and *Aspidopterys*. A–D. *Chlorohiptage*. A. Leaves with two basal glands. B. Close up of a thyrse. C. A flower without petals showing the androecium and gynoecium structure and eglandular calyx. D. Close up of a mericarp. E–H. *Hiptage benghalensis* (L.) Kurz. E. Leaves with two basal glands and marginal glands. F. Close up of a thyrse showing glandular calyces. G. Flower showing the androecium and gynoecium structure and petal with fimbriate margins. H. Close up of mericarp. I–K *Aspidopterys tomentosa* (Blume) A.Juss. I. Leaves eglandular. J. Floral bud showing eglandular calyx. K. Flower showing the androecium and gynoecium structure and petals with margin entire. L. Shape of mericarp. Photographed and designed by Truong Van Do, Anh Tuan Le, and Rafael Felipe de Almeida.

curved, equal, convergent, shorter than stamens, apex of styles truncate, punctiform, stigma terminal, capitate. Schizocarp breaking apart into 3 winged mericarps, separating from a short torus; mericarps with dorsal wing absent; lateral wing 1, developed, 3-lobed; wings coriaceous, margin entire; nut slightly ridged; areole cylindrical. Seeds angular-globose; embryos not seen.

**Etymology.** The name *Chlorohiptage* is the combination of the Greek words “chlorós” (= green) and “hiptamai” (= to fly), referring to the unique green flowers of this *Hiptage* look-alike new genus.

**Notes.** *Chlorohiptage* is endemic to open subtropical broad-leaved evergreen forests and limestone-steeped mountains in Central Vietnam at ca 100–250 m.

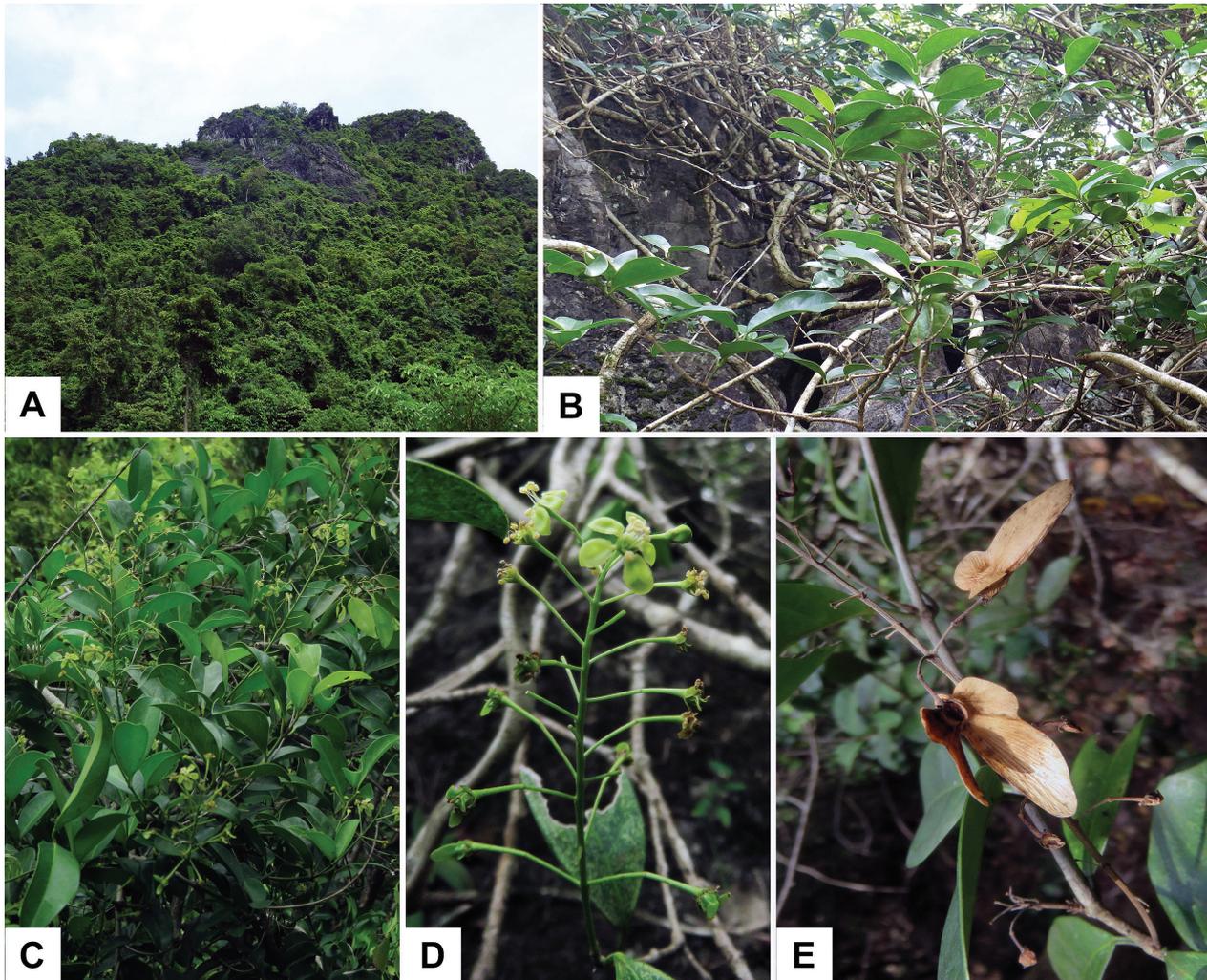
***Chlorohiptage vietnamensis*** T.V.Do, T.A.Le & R.F.Almeida, **sp. nov.**

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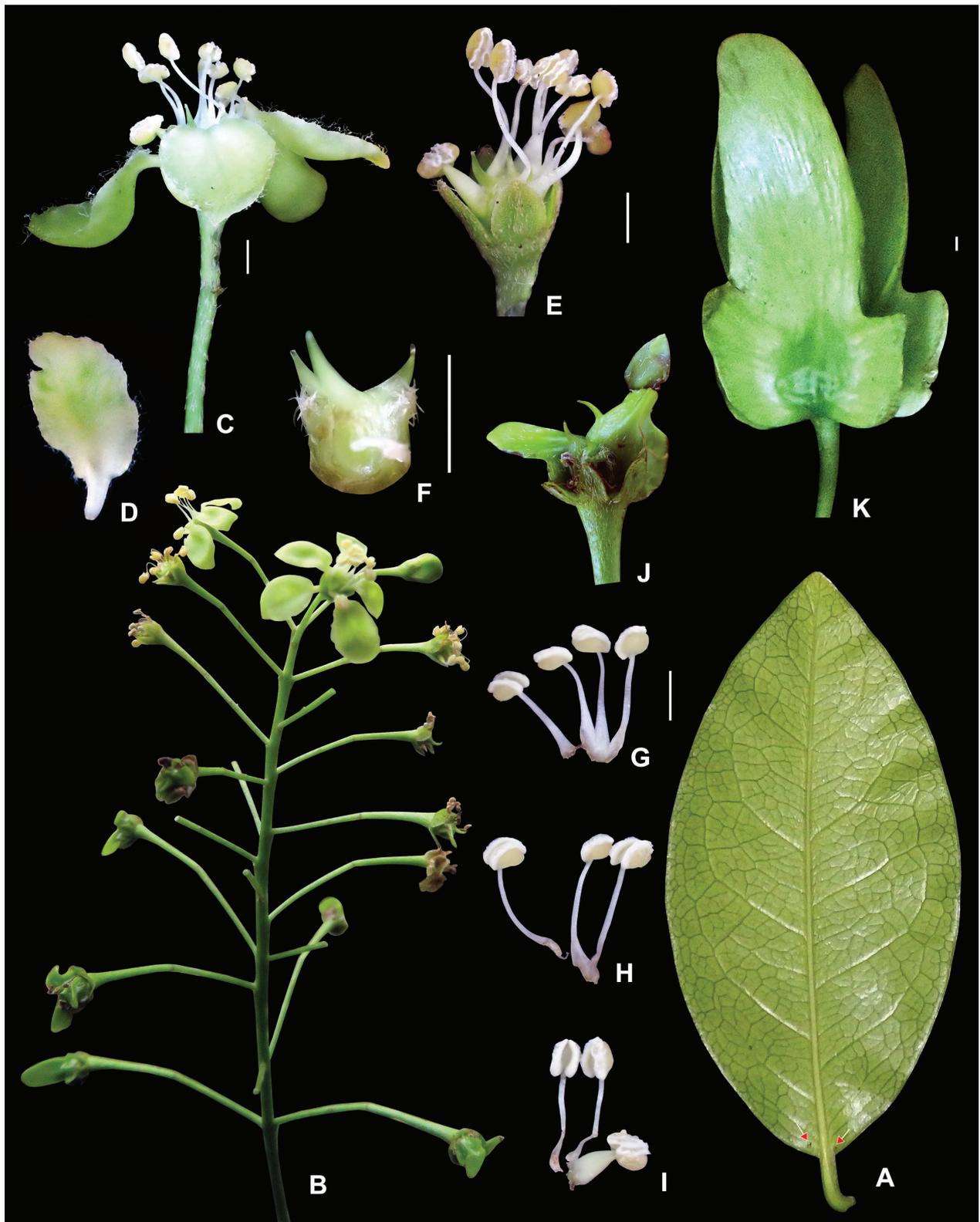
Figs 2–4

**Type.** VIETNAM – Quang Tri province • Cam Lo district, Cam Tuyen commune, Rockpile summit; 16°46'50.9"N, 106°51'07.2"E; elev. 250 m; 16 Sep. 2023; fl., fr.; *Do Van Truong and Le Tuan Anh ĐVT 1010*; holotype: VNMN; isotypes: VNMN, SGN.

**Description.** Woody climbing shrubs; young branches sericeous, older ones glabrescent, lenticels rounded, dot-like rough warts; internodes 2–2.5 cm long; axillary buds densely sericeous. Leaves simple, opposite; stipules absent; petiole 5–8 mm long, rounded, sericeous to glabrous, eglandular; leaf blades 4–7.5 × 2.5–4.5 cm, coriaceous, ovate to elliptic-lanceolate, base cuneate to attenuate, margin entire, apex obtuse to acute, sometime retuse; venation reticulate, lateral veins pinnate, 4–6 pairs, prominent on both surfaces; young leaves whitish sericeous on both surfaces; mature leaves glabrous on both surfaces, except for the midvein abaxially with sparsely sericeous; (0–)2–4-glandular abaxially along midvein near the base. Thyrses, axillary or terminal,



**Figure 3.** Photos of *Chlorohiptage vietnamensis* T.V.Do, T.A.Le & R.F.Almeida, sp. nov. from the original population in the natural habitat. A. Habitat. B. Habit. C. Branch bearing thyrses. D. Close up of a thyrses. E. Branch bearing mature mericarps. Photographed and designed by Truong Van Do and Anh Tuan Le.



**Figure 4.** Photographic plate of *Chlorohiptage vietnamensis* T.V.Do, T.A.Le & R.F.Almeida, sp. nov. **A.** Leaves with two basal glands (indicated by red arrows). **B.** Close up of a thyrse. **C.** Open flower. **D.** Shape of petals. **E.** Flower without petals showing the androecium and gynoecium structure and the eglandular calyx. **F.** Close up of a 3-styled gynoecium. **G–I.** Close up of the androecium structure. **J.** Immature mericarp. **K.** Shape of the mature mericarp. Photographed and designed by Truong Van Do, Anh Tuan Le, and Rafael Felipe de Almeida (scale bars 1 mm).

solitary, 8–18-flowered; bracts 1.2–1.5 mm long, triangular, deciduous; peduncle 6–11 cm long, sparsely sericeous; bracteoles 4–5 × 1–2 mm, lanceolate, caducous. **Flowers** with pedicels 1.3–2 cm long, sparsely sericeous; sepals 5, 2.5–3 × 1.5–2 mm, ovate to elliptic, apex obtuse, adaxially sparsely sericeous, abaxially glabrous, margin entire, eglandular; petals 5, pale green to yellowish-green, patent to deflexed at anthesis, 4–5 × 3–3.5 mm, obovate to elliptic, falcate, apex acute, margin erose and velutine, base rounded to subcordate, abaxially sparsely whitish sericeous, adaxially glabrous to sparsely whitish sericeous at base; claws 1–1.5 mm long, plane; stamens 10, slightly connate at base; 9 stamens with longer and slender filaments, 3.5–4 mm long, equal, white, curved at apex, anthers 0.9–1.0 × 0.5–0.6 mm, oblong; 1 stamen with a shorter and stouter filament, 1.5–2 mm long, white, anther elliptic, 1.1–1.2 × 0.6–0.7 mm; connectives conspicuous, whitish; pollen sacs yellow, rimose; ovary 1.2–1.5 mm diam., ovoid, sparsely tomentose; styles 3, 1.0–1.2 mm long, shorter than filaments, pale green, slightly curved upwards, glabrous; stigma terminal, capitate. **Mericarps** 3, green turning to brown when older, with parallel veins, glabrous; dorsal wing absent; lateral wing 1, 3-lobed, 2.3–3.5 × 1.3–2.0 cm, each lobe triangular to lanceolate, apex acute to rounded. **Seeds** 6–7 × 4–5 mm, yellowish-white, angular-globose, glabrous. **Embryo** not seen.

**Distribution.** *Chlorohiptage vietnamensis* is currently known only from the limestone areas in the Cam Tuyen commune, Cam Lo district, Quang Tri province, Central Vietnam, where the Truong Son Mountain range is located (Fig. 3).

**Habitat and ecology.** The new species grows in open forests and on the peak of the limestone mountain in subtropical broad-leaved evergreen forests, at elevations of ca 100–250 m, with some dominant species such as *Pistacia weinmanniifolia* J.Poiss. ex Franch., *Tetrastigma*

*quadridens* Planch., *Pterospermum truncatolobatum* Gagnep., *Bauhinia curtisii* Prain, *Jasminum subtriplinerne* Blume (Fig. 3).

**Phenology.** Flowering was observed from August to September and fruiting from September to October.

**Etymology.** The specific epithet is derived from the name of its country of origin, Vietnam.

**Preliminary IUCN conservation assessment.** *Chlorohiptage vietnamensis* shows an extent of occupancy of 4 km<sup>2</sup>, represented by two populations in the small limestone areas in Cam Tuyen commune, Cam Lo district, Quang Tri province, Central Vietnam. The forests are only protected by local communities but out of the nationally protected forest areas such as National Parks and Nature Reserves. These limestone areas have continuously declined due to over-exploitation by the stone and lime factories, threatening *C. vietnamensis* natural habitat. Therefore, we consider this new species to face a very high risk of extinction in the wild and preliminary propose it as Critically Endangered: CR B1ab(ii,iii)+2ab(ii,iii), according to the IUCN Red List Categories and Criteria (IUCN 2012, 2022).

**Additional specimens examined.** VIETNAM – Quang Tri Province • Cam Lo District, Cam Tuyen Commune, Razorback Hill; 16°47'13.3"N, 106°50'32.7"E; elev. 150 m; 25 Jun. 2023; *Do Van Truong and Le Tuan Anh* ĐVT 1008; VNMN.

**Notes.** *Chlorohiptage vietnamensis* is easily distinguished from all species of *Hiptage* by the green petals (vs white to yellow), with margins erose and velutine (vs fimbriate to dentate and glabrous), androecium comprising 9 long + 1 shorter stamen (vs 9 short + 1 longer stamen), 3 styles shorter than the androecium (vs 1 style longer than the androecium), and mericarps with 1 free, 3-lobed lateral wing (vs 3 free lateral wings). For a comparison between *Chlorohiptage*, *Hiptage*, and *Aspidopterys*, see Table 1.

**Key to the genera of the tetrapteroid clade (modified from Almeida and van den Berg 2021)**

- 1. Styles 1–2, mericarps with 3 lateral wings or many setae..... 2
- Styles 3, mericarps with 1, 2, or 4 lateral wings ..... 3
- 2. Style 1, truncate, stigma terminal, mericarps with 3 free lateral wings, Africa and Asia ..... *Hiptage*
- Styles 2, uncinata, stigma lateral, mericarps with many setae, South America (Argentina) ..... *Tricomaria*
- 3. Petals green, styles shorter than the filaments, mericarps with 1 lateral wing, 3-lobed, Asia (Vietnam)..... *Chlorohiptage*
- Petals white, lilac, yellow, orange or red, styles longer than the filaments, mericarps with 2 or 4 lateral wings, Africa or Americas.. ..... 4
- 4. Sepals deflexed, stigma terminal, Africa..... 5
- Sepals erect, stigma lateral, Americas ..... 6
- 5. Leaves with marginal glands, petiole 2-3 pairs of glands, stigma capitate..... *Flabellaria*
- Leaves with glands near margin, petiole eglandular, stigma truncate..... *Flabellariopsis*
- 6. Petals glabrous to glabrescent..... 7
- Petals densely pubescent ..... 10
- 7. Sepals exposing petals on floral buds, filaments usually glabrous ..... 8
- Sepals concealing petals on floral buds, filaments usually pubescent ..... 9
- 8. Thyrsi or corymbs, mericarps bearing 1 dominant dorsal wing ..... *Heteropterys*
- Umbels, 4–6-flowered, arranged in dichasia, mericarps bearing 4 dominant lateral wings..... *Tetrapteryx*
- 9. Leaves with glands near margin, petioles eglandular, dichasia of 4-flowered umbels, bracteoles elliptic, mericarps bearing 2 dominant lateral wings, connate at base..... *Malpighiodes*

- Leaves with marginal glands, petioles usually with 1 pair of glands, thyrsi of 1-flowered cincinni, bracteoles triangular, mericarps bearing 2–4 dominant lateral wings, free ..... *Niendenzuella*
- 10. Bracteoles leaf-like, sepals enlarged in fruits, nuts..... *Dicella*
- Bracteoles minute, sepals not enlarged in fruits, schizocarps..... 11
- 11. Dichasia of 4-flowered umbels..... 12
- Thyrsi of 1-flowered cincinni..... 14
- 12. Sepals deflexed at anthesis, anterior lateral petals deflexed at anthesis, posterior lateral petals patent at anthesis, mericarps with several lateral winglets vertically inserted between lateral wings and the dorsal wing ..... *Jubelina*
- Sepals erect to patent at anthesis, all lateral petals deflexed at anthesis, mericarps without lateral winglets or when present (i.e. *Mezia*) they are horizontally inserted between the lateral wings and the dorsal wing..... 13
- 13. Bracteoles not enclosing floral bud at pre-anthesis, connectives minute, lateral wings free at base ..... *Callaeum*
- Bracteoles enclosing floral bud at pre-anthesis, connectives enlarged, lateral wings connate at base ..... *Mezia*
- 14. Bracts, bracteoles, sepals and petals with glandular margins, mericarps with acicular (unbranched) hairs..... *Christianella*
- Bracts, bracteoles, sepals and petals with eglandular margins, mericarps with 2-branched hairs ..... 15
- 15. Stipules interpetiolar, petioles eglandular, petals fimbriate, anthers pubescent..... *Carolus*
- Stipules epipetiolar, petioles glandular, anthers glabrous ..... 16
- 16. Petioles with 2–4 pairs of glands, bracteoles eglandular, lateral petals erect, mericarps bearing 2 lateral wings dominant, usually connate at base..... *Alicia*
- Petioles with 1 pair of glands or eglandular, bracteoles glandular, lateral petals patent, mericarps bearing 2–4 lateral wings dominant, free..... *Glicophyllum*

## CONCLUSIONS

Vietnam is indeed corroborated as the possible centre of origin for the ancestor of the clade comprising *Chlorohiptage* + *Hiptage*, as previously suggested by Almeida and van den Berg (2022). Fieldwork in poorly sampled areas allied to extensive herbarium studies in Southeast Asia might still reveal new species or genera of Malpighiaceae to science, such as *Chlorohiptage vietnamensis*. In light of the discovery of this new genus, an updated identification key for the genera of the tetrapteroid clade is provided. Still, additional studies are urged to revisit the preliminary taxonomic study for this clade provided by Almeida and van den Berg (2021).

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## SUPPLEMENTARY MATERIAL

### Supplementary material 1

List of species/specimens sampled in this study with their respective GenBank accession numbers. Sequences from the studies of Davis et al. (2002), Cai et al. (2016), Almeida and van den Berg (2020, 2021, 2022), Almeida et al. (2017, 2018, 2023a, 2023b), and Zhang et al. (2023).

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