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EDITORIAL

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On the front line of modern data-management and Open Access publishing: Two years of PhytoKeys – the fastest growing journal in plant systematics

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"*PhytoKeys has been among the first decided supporters of the open-access idea, and it has the experience, structures and wits to combine speed of publication, high quality standards and sophisticated editing techniques.*"
Werner Greuter
OPTIMA *Newsletter* No. 40

PhytoKeys was launched on the 1st of November 2010 as a novel, peer-reviewed, open-access outlet for plant biodiversity research (Penev et al. 2010a). The journal quickly gained the support of the international botanical community and since its launch continues to grow in reputation and volume.

The journal implemented several innovative technologies, such as a domain specific XML markup based on the TaxPub Schema (Catapano 2010; Penev et al. 2010b, 2011), compliant to the PubMedCentral standards, data publishing, automated export of content through web services to various aggregators, such as the Encyclopedia

of Life (EOL), the Global Biodiversity Information Facilities (GBIF), Species-ID, bibliographic indices and so on (see e.g., Kress and Penev 2011). PhytoKeys became one of the very few journals in plant systematics to be accepted for coverage and archiving in PubMedCentral. The journal was the first to implement mandatory registration of new species and nomenclature changes with the International Plant Name Index (IPNI). PhytoKeys is CrossRef-compliant and plans also to use ORCID authors' registry once it becomes fully operational, hopefully in 2013. The data publishing workflow in PhytoKeys is already integrated with the Dryad Data Repository and GBIF.

PhytoKeys was the first journal to announce the revolutionary changes instituted in the International Code of Nomenclature for algae, fungi and plants (ICN) in a paper published during the actual proceedings of the XVIII International Botanical Congress in Melbourne in July 2011, bringing the news to a world-wide audience (Miller et al. 2011). Thanks to the decisions of the Nomenclature Section of the Congress (see Knapp et al. 2011a), electronic publication of new taxa was allowed and PhytoKeys was again the first journal to demonstrate an immediate implementation of the Congress decisions, starting on the 1st of January with a series of exemplar papers (e.g., Vorontsova and Knapp 2012, Tepe et al. 2012, Thomas et al. 2012), each paper with its individual publication date. The completed journal issue was printed on paper on the 7th of January 2012, demonstrating our commitment of the multiple archiving of botanical content.

Since its launch the journal has received 130 submissions in total. Out of this number, 90 articles (1,456 pages) were published in volumes 1–18. Twenty-one manuscripts have been archived by the system because they were rejected during the review process, withdrawn from consideration or cancelled for other reasons. The yearly growth in numbers of published articles, issues, and number of pages in PhytoKeys has been substantial (Table 1; Fig. 1). The growth in number of published pages in the second year of PhytoKeys exceeds by 120% that of year 1. Starting with 35 articles in 2010–2011, in the second year the journal showed a substantial growth in submissions (66%) and published articles (50%). Based on the analysis of 30 randomly selected papers, the average publication time (from submission to publication) for the first two years of the existence of the journal is 78 days. The period between submission and acceptance is 63 days, and from acceptance to publication 15 days.

Altogether, four new genera, one subgenus, 90 species, and one variety have been published in the journal since its launch, or 96 new taxa in total (Table 2).

Table 1. Total number of submitted manuscripts, published articles, issues, and printed pages for the first two years of PhytoKeys.

Year	Submissions	Published articles	Issues	Pages
1 November 2010-31 October 2011	47	35	6	420
1 November 2011-31 October 2012	78	53	12	1,008
Total (until 5 December 2012)	130	90	18	1,456

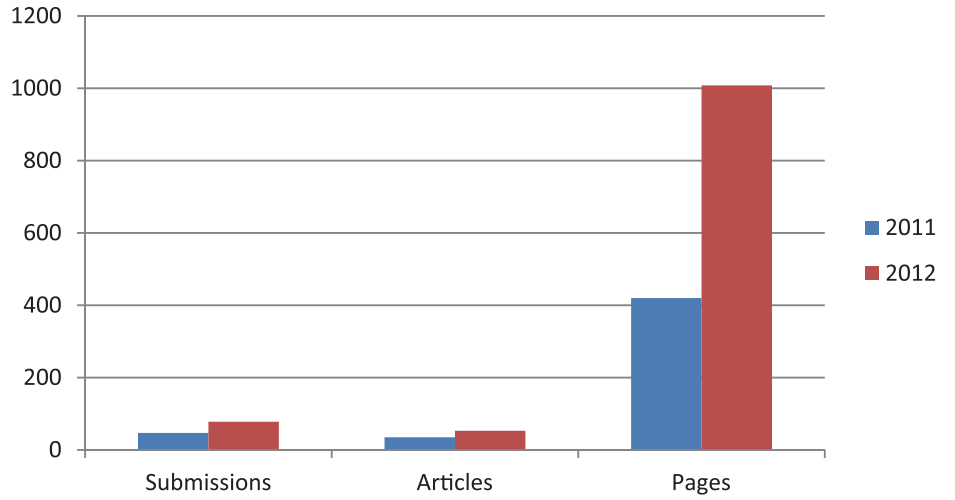

Figure 1. Total number of submitted manuscripts, published articles and pages per year in PhyltoKeys.

Table 2. New taxa published in PhytoKeys from 1st November 2009 to 6th December 2012 that have been registered in the International Plant Name Index (as per 6th December 2011, data provided by Christine Barker, IPNI).

	All ranks	Genus rank	Infrageneric rank	Specific rank	Infraspecific rank
2010	11	1	0	10	0
2011	41	2	0	38	1
2012	44	1	1	42	0
Total	**96**	**4**	**1**	**90**	**1**

The number of new combinations (55) and new names (10) published for the same period is considerable (Table 3). Thus, the number of all nomenclatural novelties published in PhytoKeys for this short period totals 161. These new taxonomic contributions encompass 42 vascular plant families, with a predominance in the families Euphorbiacea, Solanaceae and Asteraceae, with 42, 22, and 20 contributions, respectively (Fig. 2).

PhytoKeys has always been engaged with open data publishing. One of the pioneering methods for data publishing converted a conventional floristic checklist, written in a standard word processing program, into structured data in the Darwin Core Archive format (Remsen et al. 2012). A manuscript (De Egea et al. 2012) consisting of more than 4,100 taxon names, was submitted to PhytoKeys as a Microsoft Word file. After peer-review and editorial acceptance, the final revised version was converted into the Darwin Core Archive format from the original manuscript and published both as a conventional paper in PhytoKeys and as DwC-A structured data through the Global Biodiversity Information Facility (GBIF)

Table 3. Other nomenclatural novelties published in PhytoKeys for the entire period of its existence (data provided by Christine Barker, IPNI).

	New combinations			New names
	All ranks	**Specific rank**	**Infraspecific rank**	**Specific rank**
2010	1	1	0	0
2011	43	43	1	8
2012	11	5	6	2
Total	**55**	**49**	**6**	**10**

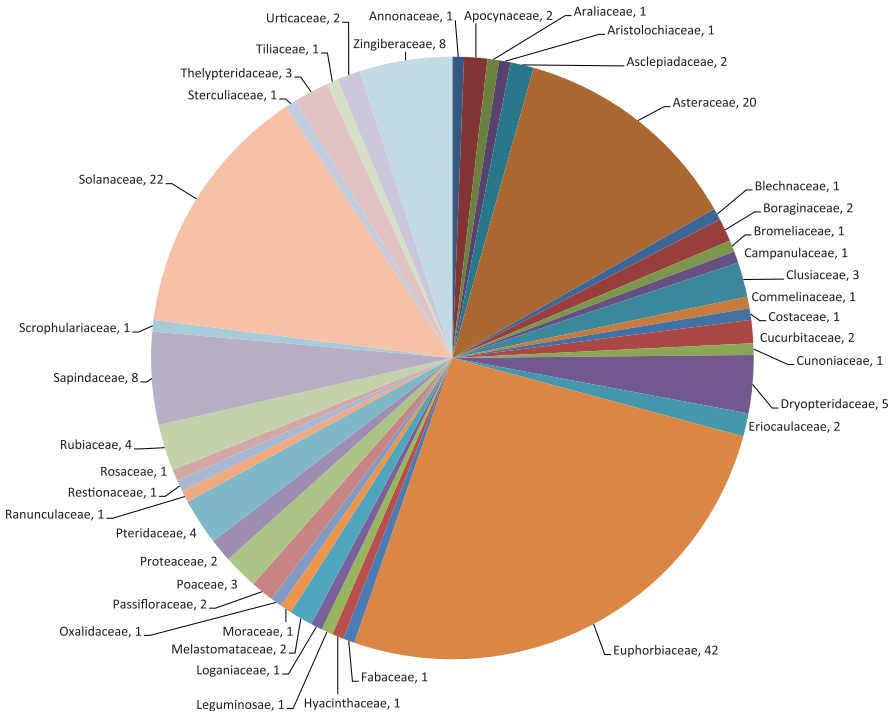

Figure 2. Taxonomic distribution by family of the published nomenclatural novelties in PhytoKeys.

Integrated Publishing Toolkit (IPT). In addition, and for the convenience of the readers and data users, the same data were also published as a supplementary Excel file in an Appendix to the checklist (doi: 10.3897/phytokeys.9.2279.app1). After publication, the data became available through the GBIF infrastructure in order to be re-used on their own or collated with other data.

The first data paper in PhytoKeys was published in May 2012 by Van Landuyt et al. (2012). It described "Florabank1" – a database comprising distributional data on the wild plants of Flanders and the Brussels Capital Region of Belgium.

Table 4. The top ten most viewed articles of PhytoKeys according to the PhytoKeys website counter accessed on the 5th of December 2012.

Article	Page views
Popovkin et al. 2011 – *Spigelia genuflexa* (Loganiaceae), a new geocarpic species from northeastern Bahia, Brazil	10,212
Miller et al. 2011 – Outcomes of the 2011 Botanical Nomenclature Section at the XVIII International Botanical Congress	8,657
Knapp et al. 2011a – Changes to publication requirements made at the XVIII International Botanical Congress in Melbourne - what does e-publication mean for you?	5,560
Telford et al. 2011 – A new Australian species of *Luffa* (Cucurbitaceae) and typification of two Australian *Cucumis* names, all based on specimens collected by Ferdinand Mueller in 1856	5,277
Kress et al. 2010 – *Larsenianthus*, a new Asian genus of Gingers (Zingiberaceae) with four species	5,155
Penev et al. 2010a – Fast, linked, and open – the future of taxonomic publishing for plants: launching the journal PhytoKeys	4,872
Vallejo-Marín 2012 - *Mimulus peregrinus* (Phrymaceae): A new British allopolyploid species	4,411
Knapp et al. 2011b - Translation into Spanish of: "Changes to publication requirements made at the XVIII International Botanical Congress in Melbourne - what does e-publication mean for you?". Translated by Carmen Ulloa Ulloa, Lourdes Rico Arce, and Renée H. Fortunato	3,878
Knapp 2010 - New species of *Solanum* (Solanaceae) from Peru and Ecuador	3,801
Tepe et al. 2012 – A new species of *Solanum* named for Jeanne Baret, an overlooked contributor to the history of botany	3,679

The top ten papers in PhytoKeys through the 5th of December 2012 have been accessed 55,502 times (Table 4). The article by Popovkin et al. (2011) on a new, genuflexing plant from Brazil took the lead as the most downloaded paper by reaching more than 10,200 views in 14 months. Among the top ten most viewed articles, the paper by Miller et al. (2011), a review article on the outcomes of the Botanical Nomenclature section at the XVIII International Botanical Congress and its Spanish version (Knapp et al. 2011b), was downloaded more than 12,500 times

In order to promote plant taxonomy, Pensoft's Public Relations office has initiated a new service aimed at facilitating our authors in promoting their research among the general public and science media. Since its launch, altogether 17 international press releases have been prepared and distributed through EurekAlert!, one of the world largest online distributors of science news, supplying information to more than 7,500 mass media and independent science journalists, and Pensoft's own channels (see Table 5 for the top ten most accessed press releases of PhytoKeys articles). At the top, with approxmately 5,000 views, is the press release of the article by Vallejo-Marín (2012) describing a new monkey flower, *Mimulus peregrinus* (Phrymaceae) discovered on the bank of a stream in Scotland created by the union of two foreign plant species. This paper described a rare example of a new species that originated in the wild in the last 150 years.

Table 5. The top ten most accessed press releases of PhytoKeys articles posted through EurekAlert!. The counter registers only downloads from EurekAlert!, mostly by science media and journalists. The actual number of readers is most likely much higher than this number.

	Title	Author/s and year of publication of the original article	Date posted	Page views since posted
1.	Rare glimpse into the origin of species: Plant overcomes infertility to give rise to a new species in Scotland	Vallejo-Marín 2012	10-Jul-2012	4,847
2.	Brave new world: Pioneering electronic publication of new plant species	Vorontsova and Knapp 2012	1-Jan-2012	3,424
3.	A new wild ginger discovered from the evergreen forest of Western Ghats of South India	Thomas et al. 2012	6-Jan-2012	3,181
4.	Jeanne Baret, botanist and first female circumnavigator, finally commemorated in name of new species	Tepe et al. 2012	3-Jan-2012	3,092
5.	Early lineage of Larkspur and Monkshood plants rediscovered in Southern Europe	Jabbour and Renner 2011	8-Dec-2011	2,767
6.	Plant DNA speaks English, identifies new species	Filipowicz et al. 2012	23-Mar-2012	2,634
7.	Early land plants: Early adopters!: The first electronically described liverwort species comes from New Zealand	von Konrat et al. 2012	4-Jan-2012	2,474
8.	Marquesas Islands in French Polynesia yield 18 new species of rare ferns and flowering plants	Tronchet and Lowry II 2011	19-Jul-2011	2,119
9.	Revolutionary changes to the Botanical Code published in 16 journals and 5 languages	Knapp et al. 2011	14-Sep-2011	1,252
10.	Botany student proves 'New England Banksia' a distinct species	Stimpson et al. 2012	28-Aug-2012	1,195

In conclusion, PhytoKeys, along with its 'brother' journals Zookeys and MycoKeys, continues to evolve its editorial workflow, constantly implementing new and improved publishing and dissemination technologies, thus always being on point for digital biodiversity science. We would like to thank all of our authors, reviewers, subject editors, readers, and journalistic followers without whose support PhytoKeys would not have become such a successful journal in just two years time! We also thank Christine Barker (IPNI) for providing information on the nomenclatural novelties published in PhytoKeys that have been registered in IPNI.

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RESEARCH ARTICLE

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Chilean *Pitavia* more closely related to Oceania and Old World Rutaceae than to Neotropical groups: evidence from two cpDNA non-coding regions, with a new subfamilial classification of the family

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Abstract

The position of the plant genus *Pitavia* within an infrafamilial phylogeny of Rutaceae (rue, or orange family) was investigated with the use of two non-coding regions from cpDNA, the *trnL-trnF* region and the *rps16* intron. The only species of the genus, *Pitavia punctata* Molina, is restricted to the temperate forests of the Coastal Cordillera of Central-Southern Chile and threatened by loss of habitat. The genus traditionally has been treated as part of tribe Zanthoxyleae (subfamily Rutoideae) where it constitutes the monogeneric tribe Pitaviinae. This tribe and genus are characterized by fruits of 1 to 4 fleshy drupelets, unlike the dehiscent fruits typical of the subfamily. Fifty-five taxa of Rutaceae, representing 53 genera (nearly one-third of those in the family) and all subfamilies, tribes, and almost all subtribes of the family were included. Parsimony and Bayesian inference were used to infer the phylogeny; six taxa of Meliaceae, Sapindaceae, and Simaroubaceae, all members of Sapindales, were also used as out-groups. Results from both analyses were congruent and showed *Pitavia* as sister to *Flindersia* and *Lunasia*, both genera with species scattered through Australia, Philippines, Moluccas, New Guinea and the Malayan region, and phylogenetically far from other Neotropical Rutaceae, such as the Galipeinae (Galipeeae, Rutoideae) and Pteleinae (Toddalieae, former Toddalioideae). Additionally, a new circumscription of the subfamilies of Rutaceae is presented and discussed. Only two subfamilies (both monophyletic) are recognized: Cneor-

oideae (including Dictyolomatoideae, Spathelioideae, Cneoraceae, and Ptaeroxylaceae) and Rutoideae (including not only traditional Rutoideae but also Aurantioideae, Flindersioideae, and Toddalioideae). As a consequence, Aurantioideae (*Citrus* and allies) is reduced to tribal rank as Aurantieae.

Keywords
Biogeography, Cneoroideae, phylogeny, Pitavia, Rutaceae, Rutoideae, *rps16*, subfamily, *trnL-trnF*

Introduction

Rutaceae is a large, predominantly tropical and subtropical family, consisting of 150–162 genera and 1500–2096 species, with three main centers of diversity: Tropical America, southern Africa, and Australia (Groppo 2010, Simpson 2010, Kubitzki et al. 2011). The family has long been economically important for edible fruits (especially *Citrus*, with many varieties of oranges, lemons, tangerines, etc.), aromatic oils (*Boronia* and *Ruta*), drugs (e.g., *Pilocarpus*, source of pilocarpine, used against glaucoma), and bitter beverages used to treat fevers (*Angostura, Galipea*). Species of *Flindersia*, *Zanthoxylum*, *Balfourodendron,* and *Euxylophora* are sources of timbers. More recently, the antimicrobial and antifungal properties of rutaceous compounds are being exploited as natural pesticides (e.g., Oliva et al. 2000), herbicides (e.g., Aliotta et al. 1996), and antimicrobials (e.g., Mandalari et al. 2007), while others are medically useful (e.g., Holmstedt et al. 1979; Moraes et al. 2003).

Given its great morphological diversity that include a variety of habits, flowers, and fruits, allied with a broad geographic distribution, Rutaceae has been traditionally divided into subfamilies, tribes, and subtribes, following the classifications of Engler (1874, 1896 and 1931, see Chase et al. 1999, and especially Groppo et al. 2008, for a detailed discussion of the these groups). Although subfamily Aurantioideae (*Citrus* and allies) has emerged as monophyletic in recent molecular analyses (e.g., Chase et al. 1999, Scott et al. 2000, Groppo et al. 2008, Bayer et al. 2009), all other subfamilies with more than one genus (Flindersioideae, Rutoideae, and Toddalioideae) and almost all tribes are not monophyletic (Groppo et al. 2008), and rearrangements of the subfamilies have been suggested or proposed (Chase et al. 1999, Scott et al. 2000; Groppo et al. 2008; Kubitzki et al. 2011). Groppo et al. (2008) demonstrated that geographic distribution of the genera could be more relevant than traditionally used characters of the fruit to an understanding of diversification within the family.

One subtribe that had not yet been sampled in molecular phylogenetic studies of the family is Pitaviinae, which comprises a single genus and species, *Pitavia punctata* Molina. (photos can be seen at http://www.florachilena.cl/Niv_tax/Angiospermas/Ordenes/Sapindales/Rutaceae/Pitavia%20punctata/Pitavia%20punctata.htm). This species is restricted to the temperate forests of the Coastal Cordillera of south-central Chile at 35°-38°S. It is the sole species of Rutaceae native to the continental area of that country (another rutaceous species, *Zanthoxylum mayu* Bertero, is restricted to Juan Fernández Island, see Reiche 1896). Both *Pitavia* and its highly fragmented forest hab-

itat are currently threatened by anthropogenic disturbances, such as clearing of forest for cultivation of wheat and unsustainable extraction of firewood (Newton et al. 2009).

Pitavia consists of small trees with simple, opposite to whorled leaves and unisexual, 4-merous, diplostemonous flowers of which the four carpels are proximally connate and joined subapically in a common style. The fruit is composed of one to four fleshy drupes, each with a solitary seed (Engler 1931, Kubitzki et al. 2011). The indehiscent fruit of *Pitavia* differs from the dehiscent, capsular or follicular fruits of all other genera in Zanthoxyleae—the tribe to which *Pitavia* belongs according to Engler (1931), who placed *Pitavia* in a subtribe of its own mainly because of these fruits and its isolated geographic distribution. Although recent molecular studies (e.g., Chase et al. 1999, Poon et al. 2007, Groppo et al. 2008) have shown that the tribe Zanthoxyleae is not monophyletic, *Pitavia* remained unsampled, and Kubitzki et al. (2011) put this genus in a *insertae sedis* position in an infrafamilial classification.

The main objective of this study is to determine the position of Chilean *Pitavia* within a the Rutaceae phylogeny and to assess whether the genus is more closely related to Australasian members of Rutaceae or to Neotropical ones (such as the tribes Galipeeae or Toddalioideae, in Engler's [1931] classification). To examine this, we chose two non-coding regions from cpDNA, the *rps16* gene intron and the *trnL-trnF* region, for a representative sampling of Rutaceae. The type II *rps16* intron was first used for phylogenetic analysis by Oxelman et al. (1997). The *trnL-trnF* region is composed of the *trn*L intron and the *trnL-trnF* intergenic spacer (Taberlet et al. 1991). Non-coding regions have higher rates of evolution than coding regions; for example, *trnL-trnF* evolved 1.93–11.72 times faster than *rbcL* in certain genera of Gramineae (Gielly and Tabberlet 1994 and references herein). Thus, fragments such as the *rps16* intron and the *trnL-trnF* region have been employed mostly at infrafamilial levels, with good resolution in groups of angiosperms, and have been commonly used in phylogenetic studies of Rutaceae (e.g., Scott et al. 2000, Samuel et al. 2001, Morton et al. 2003, Poon et al. 2007, Groppo et al. 2008, Salvo et al. 2008).

The present study includes genera from all Englerian subfamilies, tribes, and almost all subtribes of Rutaceae and accounts for a broad geographic representation of the family. The large sample of genera used here provides a basis for revising Engler's circumscription of the subfamilies of Rutaceae. Although new arrangements of subfamilies have been proposed (e.g., Kubitzki et al. 2011, Appelhans et al. 2011), a classification that comprises only monophyletic subfamilies is still needed. This new proposal will serve as a framework for other studies of the family, with the goal of recognizing only monophyletic subfamilies of Rutaceae.

Methods

Given the uncertain position of *Pitavia* within the Rutaceae phylogeny, representatives of all subfamilies and tribes and almost all subtribes of Rutaceae (sensu Engler 1931, and Swingle and Reece 1967 for tribes and subtribes of Aurantioideae) were sampled

(see Appendix 2 and Groppo et al. 2008 for details on Englerian infrafamilial classifications). This sampling is present in the combined matrix used by Groppo et al. (2008) to infer the phylogeny of infra-familial groups in Rutaceae, which comprises almost one third of the estimated number of genera in the family. Sequences from *Cneorum* and *Ptaeroxylon* are also included in the matrix, since these families have been included in Rutaceae (Chase et al. 1999; Groppo et al. 2008, APG III 2009, Appelhans et al. 2010). *Carapa, Cedrela,* and *Guarea* (Meliaceae), *Simaba* (Simaroubaceae sensu stricto, Fernando and Quinn 1995), and *Cupania* and *Allophylus* (Sapindaceae), all from families consistently included in Sapindales (Gadek et al. 1996, APG III 2009) were used as outgroups in all analyses. Thus, a total of 61 terminals (including *Pitavia*) were used (55 of Rutaceae in 53 genera, and six of Meliaceae, Sapindaceae, and Simaroubaceae). All DNA sequences are deposited in GenBank, and the accession numbers of the sequences are given in Appendix 2.

Total genomic DNA was extracted from 5 mg of dried leaf sample from a collection of *Pitavia punctata* (*Kubitzki 01-07*, Herbarium HBG) using a modified CTAB protocol (Doyle and Doyle 1987). The *rps16* intron was amplified using *rps*F> and *rps*R2< primers described in Oxelman et al. (1997). The PCR reaction volume (50 mL) contained 30.75μL of water, 3μL of 1% polyvinyl pyrrolidone (PVP), 3μL of $MgCl_2$ 50mM (Invitrogen), 5μL of *Taq*Buffer (10x, Fermentas), 5μL of dNTP 10mM (Fermentas), 0.25μL of *Taq*Polymerase (Thermo Scientific), 0.25μL of each primer (Sigma-Aldrich), and 2μL (150–200ng) of DNA sample. Thermal cycling was performed in a PTC-100 Thermal Sequencer (MJ Research Inc., Waltham, Massachusetts, USA), using initial denaturation at 95°C (2 min), followed by 33 cycles at 95°C (30s), 57°C (1min), 72°C (2min), ending with an elongation at 72°C (7min). The *trnL-trnF* region was amplified using trn-c> and trn-f< primers described in Tabberlet et al. (1991). PCR reaction volume (50 μL) contained the same proportions and substances as those used to amplify the *rps16* intron. Thermal cycling was performed using initial denaturation at 94°C (7 min), followed by 30 cycles at 94°C (1min), 56°C (1min), 72°C (1min), ending with an elongation at 72°C (7min). PCR products were purified with GFX™ PCR columns (Amersham Biociences, Piscataway, New Jersey, USA), following the manufacturer's recommendations. The sequencing reaction volume was 10μL, containing 3.25μL of water, 2μL of BigDye Terminator Ready Reaction (Invitrogen), 0.5μL (10mM) of primers, and 4.25μL of PCR product (60–150ng of DNA). The reactions were performed in an ABI-3100 automatic sequencer (Applied Biosystems-HITACHI), using 25 cycles at 96°C (10s), 50°C (15s), and 60°C (4min). Sequences were assembled and edited using the Biological Sequence Aligment Editor software (BioEdit), v.5.0.9 (Hall 1997–2011). Each fragment was carefully examined to verify concordance among the different reads. Limits of the *trnL-trnF* region and the *rps16* intron were determined by comparison with sequences deposited at GenBank. Sequences of *Pitavia* were then added to the combined matrix of Groppo et al. (2008).

Automated alignments of the sequences were made with Clustal X (Thompson et al. 1997) using default parameters. Indels were treated as missing data. As the study of Groppo et al. (2008) showed a better resolution of the clades in Rutaceae when the

rps16 and *trnL-trnF* results were concatenated, we followed the same approach here. Parsimony analyses were made using PAUP* v.4.0b10 (Swofford 2002) using heuristic search. All characters were unordered and equally weighted (Fitch parsimony, Fitch 1971). Searches were performed with the tree-bisection-reconnection (TBR) branch-swapping algorithm with "steepest descent" and "multrees" options, with 100 random-taxon addition replicates, and with 10 trees held in each replicate. Bootstrap analyses (Felsenstein 1985) were performed to compute support for clades, with 1000 pseudoreplicates (10 trees retained in each pseudoreplicate), random addition of sequences, and TBR branch-swapping.

Bayesian phylogenetic inference was performed with MrBayes v. 3.1.2 (Huelsenbeck and Ronquist 2001, Huelsenbeck et al. 2001, Ronquist and Huelsenbeck 2003) at the Computational Biology Service Unit hosted by Cornell University, USA (http://cbsuapps.tc.cornell.edu). MrModelTest v. 2.3 (Posada and Crandall 1998, 2001, Nylander 2004) was used to choose the best evolutionary model for the *rps16* and *trnL-trnF* concatenated sequences, as selected by the Akaike Information Criterion. Four independent analyses were run, each performing 10 million generations, sampling every 1000th generation and using 3 heated and 1 cold chain, with temperature 0.2 and other default settings. Tracer v 1.4.1 (Rambaut and Drummond 2007) was used to assess convergence of the runs and to discard the initial 20% of the trees as a burn-in. The remaining 30,000 trees were used to compute a 50% majority-rule consensus phylogram.

Results

The Akaike Information Criterion implemented in MrModelTest chose the GTR + G + I evolutionary model as the best fit for the *rps16* and *trnL-trnF* concatenated sequences. The burn-in value was set to 4,000 tree samplings, reflecting 2 million generations, i.e., long after the analysis was considered to have stabilized (by inspection of effective sample sizes and standard deviation of split frequencies). The aligned matrix comprised a total of 2,229 characters: 1123 invariable, 467 variable but parsimony-uninformative, and 639 parsimony-informative. At the point when the search was interrupted, parsimony analysis resulted in 10,000 most parsimonious trees with 2,535 steps, consistency index (CI) = 0.68 (0.51 excluding uninformative characters), and retention index (RI) = 0.68.

The majority-rule consensus tree with posterior probabilities (PP) that was estimated using Bayesian Inference is shown in Fig. 1. Bootstrap percentages (BP) are also shown for clades recovered in the majority-rule consensus tree of the bootstrap analysis. As commonly seen in the literature, a higher resolution was obtained with the Bayesian analysis than with the majority-rule bootstrap consensus trees based on parsimony, as can be noted in the figure: many clades that appeared in the 50% majority-rule Bayesian tree do were not recovered in the boostrap analysis. (even in clades with PP as high as 0.99). Given its better resolution and branch support values, and the generally accepted superiority of Bayesian methods in inferring reliable phylogenetic relationships we chose to discuss our results on the basis of the Bayesian tree.

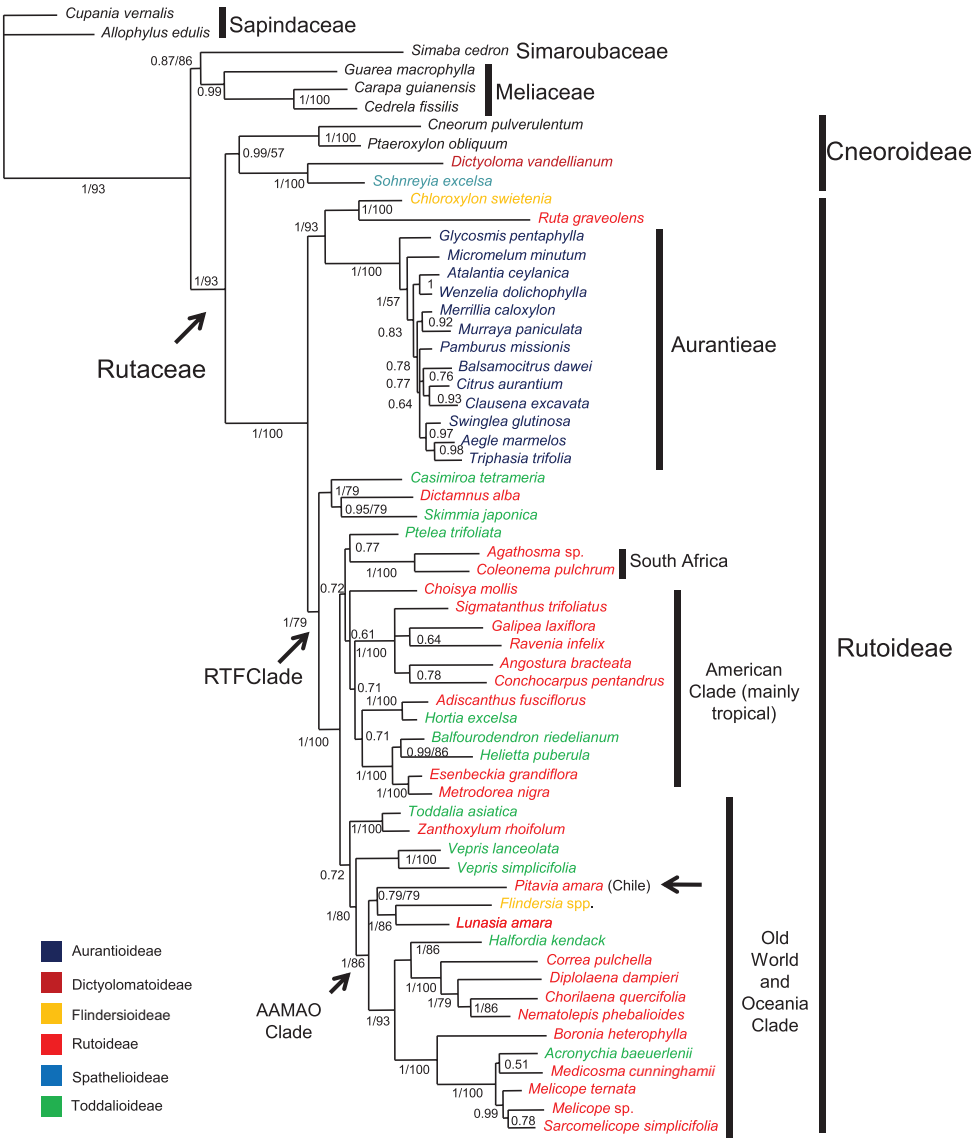

Figure 1. Majority-rule consensus tree of Rutaceae estimated using Bayesian inference on a combined *rps16* and *trnL-trnF* dataset. Posterior probabilities (PP ≥50%) are shown above branches. Bootstrap percentages (BP, only for branches in agreement with those obtained in the Bayesian analysis) follow posterior probabilities; when only one number appears supporting a clade it refers to Bayesian posterior probabilities. Taxon names are color-coded to indicate their Englerian assignment to subfamilies. A new proposal that recognizes monophyletic groups (subfamilies Cneoroideae and Rutoideae and tribe Aurantieae) is indicated by the vertical bars. The position of *Pitavia punctata*, as well as the Rutaceae, the "RTF" (from Rutoideae, Toddalioideae and *Flindersia*) and "AAMAO" ("African-Asian-Malesian-Astralasian-Oceanic") clades (see text) are indicated by arrows. Note: *Zanthoxylum* is pantropical.

Topology of the Bayesian analysis was congruent with that obtained in the study of Groppo et al. (2008) using parsimony, but with a better resolution of some clades as discussed above. Rutaceae appeared as monophyletic (PP=1, BP=93), encompassing two internal clades, one with *Cneorum, Ptaeroxylon, Sohnreyia*, and *Dictyoloma* with mixed support (strong PP=0.99 and weak BP=57) and another with the remaining Rutaceae (1/100). This clade is divided in two sister-groups: one (1/93) formed by *Chloroxylon* (Flindersioideae) plus *Ruta* (Rutoideae) and all Aurantioideae (the only monophyletic Englerian subfamily with more than one genus) and the other (1/79) with interdigitated representatives of Rutoideae (without Ruteae), Toddalioideae, and *Flindersia* (Flindersioideae), the RTF Clade. Chilean *Pitavia* appears as part of this last group, in a clade containing also *Lunasia* and *Flindersia* (1/86), which in turn is part of a larger clade (1/86) formed by representatives of Rutaceae of Old World, Australasia and Oceanic islands from Pacific (the "African-Asian-Malesian-Astralasian-Oceanic - AAMAO clade")

Discussion

Phylogenetic and biogeographic relationships of *Pitavia*

A clade comprising *Flindersia* and *Lunasia* was obtained also by Chase et al. (1999), using *rbcL* and *atpB* sequence data and by Groppo et al. (2008) *rps16* and *trnL-trnF*. The present results indicate that *Pitavia* is sister to this clade. *Flindersia* (17 species, in Australia, Moluccas, to Irian and Papua) and *Lunasia* (one species, *L. amara* Blanco, in NE Australia, New Guinea, Philippines, and the Malayan region) differ in several morphological characteristics, discussed in detail by Groppo et al. (2008). Because of its capsular fruits with winged seeds and its compound leaves, *Flindersia* was positioned by Engler (1931) in subfamily Flindersioideae, together with the genus *Chloroxylon,* whose winged seeds have to be interpreted as a convergence given the position of these two genera in the phylogeny. *Lunasia*, however, has simple leaves and features common within the Englerian subfamily Rutoideae, such as follicular fruits with elastic endocarp and unwinged seeds. Additionally, the trimerous flowers in *Lunasia*, these disposed in congested glomerules, are a unique combination of characteristics within Rutaceae. Comparing the capsular fruits and winged seeds of *Flindersia* with the follicular fruits and unwinged seeds of *Lunasia* and the indehiscent fleshy drupelets of *Pitavia* shows that indehiscent fruits and winged seeds have appeared more than once within the evolutionary history of the family (Groppo et al. 2008). In fact, in Rutaceae groups of genera with indehiscent fruits occur frequently as sisters to others with dehiscent ones (*e.g., Acronychia* and *Melicope* or *Adiscanthus* and *Hortia*, see Groppo et al. 2008). Studies of fruit development in the family have demonstrated differences in formation of dehiscent (Hartl 1957) and indehiscent fruits (Hartl 1957, Zavaleta-Mancera and Engleman 1991). Groppo et al. (2008) showed that large clades of Rutaceae correspond better with their geographic distributions than with gross fruit morphology.

The morphological resemblance of *Pitavia* to Rutaceae from Oceania and Southern Asia was implicitly suggested by Hartley (1997), when he gave the generic name *Pitaviaster* (monoespecific, from Eastern Australia) to the species *P. haplophyllus* (F.Müell.) T.G.Hartley, segregated from *Euodia* (seven species in New Guinea, North-Eastern Australia eastwards to Samoa and Niue), given its general resemblance to *Pitavia*. *Pitaviaster* and *Pitavia* share opposite to whorled, simple leaves, axillary inflorescences, rather small, 4-merous flowers, and fruit composed of 1-4 fleshy drupelets. They differ, however, especially on fruit characters: *Pitaviaster* with woody mesocarp (vs. fleshy in *Pitavia*) and cartilaginous (vs. thin, ligneous, see Kubitzki et al. 2011, p.: 342) endocarp. Even though aware of these similarities, Hartley (1997) hypothesized that *Pitavia* was nearest to *Acronychia*, given other morphological characteristics of flower and fruit. As shown in the present study, the close relationship of *Acronychia* to other genera as *Medicosma*, *Sarcomelicope,* and *Melicope*, all of them (including *Acronychia*) from Australasia, Southern Asia, Oceanic or even African/Malagasy or Indo-Himalayan (as some species of *Melicope*) regions, but relatively distant from *Pitavia*, does not corroborate a close relationship between *Acronychia* and *Pitavia*.

The association of Chilean *Pitavia* with *Flindersia* and *Lunasia* is an example of biogeographical affinity between components of the faunas and floras occurring on both sides of the Pacific Ocean especially in the Southern Hemisphere (for a reviews of this issue and examples, see Grehan 2007 and Heads 2012). *Pitavia* is restricted to temperate forests of Chile where other taxa that have Trans-Pacific distributions occur, such as species of *Nothofagus* (Fagaceae), found in Chile and eastern Argentina as well as in New Caledonia, New Guinea, Australia, Tasmania, and New Zealand (Humphries 1981), and some members of the Proteaceae (Barker et al. 2007).

Distributional patterns in Rutaceae have often been explained on basis of vicariance events (e.g., Hartley 2001a, 2001b; Ladiges and Cantrill 2007), and age estimates for disjunctions have been calibrated against the timing of plate movements suggested by geologists (Kubitzki et al. 2011). The disjunct distributions in the Southern Hemisphere have been explained in terms of vicariant events linked with the break-up of the supercontinent Gondwana over the past 160 million years (Sanmartín and Ronquist 2004). Indeed, Heads (2012, on p. 427), based mostly on the phylogeny presented by Groppo et al. (2008), presents the hypothesis in which "the high diversity of groups such as Rutaceae in Brazil, South Africa, Western Australia, New Caledonia, and the Hawaiian Islands is the direct result of phylogeny and vicariance producing allopatric, regional blocks of taxa." In this hypothesis of vicariance, events linked to the separation of land masses in the South Hemisphere would explain the link between Chilean *Pitavia* and other genera from Pacific Islands, Australasia, and portions of Asia. This view can be reinforced by the fact that fossils of Rutaceae (seeds, fruits, wood, and leaves, Gregor 1989), classified as form genera *Rutaspermum*, *Toddaliospermum*, and *Pteleaecarpum*, are dated from the Cretaceous to Palaeocene (100 mybp as the age of first 'doubtful' Rutaceae fossils and 80 mybp as first *Rutaspermum* fossils). Various species accommodated in *Rutaspermum* may represent *Zanthoxylum* (Tiffney 1980), and others may represent *Tetradium* (Hartley 2001a, 2001b). As noted by Kubitzki et al.

(2011), the oldest fossils of the family (*Tetradium, Toddalia, Zanthoxylum*) belong to the group of five genera that produce 1-btiq alkaloids and that are specialized for bird dispersal. The appearance of these genera in the Palaeocene sets a minimum age of Rutaceae, and the family may have originated earlier. Therefore, the hypothesis that a longer period of time was required to isolate *Pitavia* from related groups in the Pacific, Australasia, and Asia could appear reasonable.

Estimates of the age of Rutaceae based on molecular studies vary from 37 to 93.3 mybp (Muellner et al. 2003, Pfeil and Crisp 2008, Wilkström et al. 2001, Appelhans et al. 2012a), but many times these assumptions of age based on molecular dating conflict with a vicariance explanation for the observed distribution patterns in the family. Several authors have therefore explained some disjunct distributions in the family on terms of long-distance dispersal, e.g., the Aurantioideae's colonization of New Caledonia from other land masses (Pfeil and Crisp 2008). SanMartín and Ronquist (2004), discussing South Hemisphere distributions of groups of plants and animals, stated that there has been land connections between South America and Australia via Antarctica until about 35mybp. The same authors mention that the biogeographical patterns in the plant lineages they studied have not been significantly influenced by Gondwanan breakup. If this idea is correct, disjunction between *Pitavia* and its relatives in the Pacific Islands, Oceania, and Old World (e.g., Southern Asia), could be more recent than the Gondwana break-up, with Island conections allowing long-distance dispersion. Fleshy fruits of *Pitavia* suggest a dispersal by animals, and birds (or even bats) could act as dispersers in the past. Further molecular dating studies, in combination with further evaluation and integration of the fossil record, could help clarify the conflicting suggestions of vicariance or long-distance dispersal to explain the disjunction of *Pitavia* from its sister groups.

Despite the linking of *Flindersia*, *Lunasia*, and *Pitavia* shown in the present study, it is premature to say that *Pitavia* is indeed sister to the *Flindersia/Lunasia* clade because many genera, such as *Dinosperma, Perryodendron, Pitaviaster, Crossosperma,* and *Dutailliopsis*, have not yet been included in phylogenetic studies. However, the support (PP PP, 86% of BP) of the clade (*Pitavia*(*Flindersia,Lunasia*)) is strong enough to refute an association of *Pitavia* with the clade with *Acronychia, Melicope*, and *Sarcomelicope* (as suggested by Hartley 1997, see above) .

Chloroxylon

The placement of *Chloroxylon* (Flindersioideae) near *Ruta* is supported by the possession of diplostemonous flowers, unguiculate petals with concavities embracing the smaller antepetalous stamens, a developed urceolate disc, and more than two ovules per locule. The base chromosome number in both genera is X=10 (Stace et al. 1993), a number so far encountered elsewhere in Rutaceae only in *Boenninghausenia*, in the same subtribe (Rutinae) as *Ruta*. Thus, the base number X=10 may be a synapomorphy of this clade. *Ruta* and its allies in Rutinae, however, are characterized by an herbaceous or suffrutescent habit and unwinged seeds, and *Chloroxylon* by arborescent habit and winged seeds.

The relationship of *Ruta* and *Chloroxylon*, indicated in the present study and in Morton et al. (2003), Chase et al. (1999), and Groppo et al. (2008) is based on sequences obtained from samples of the same collection (*Chase 1291*, K). Samples from additional collections of *Chloroxylon* are needed to further test its relationship with *Ruta*.

A new classification of subfamilies in Rutaceae

Another objective of this work is to present a new proposal to replace the standard classification of subfamilies of Rutaceae , replacing that proposed by Engler (1874, 1896, 1931). In his last system of classification, Engler (1931) recognized seven subfamilies that were further divided into tribes and subtribes. As discussed by Groppo et al. (2008), Englerian subfamilies were defined mainly by degree of connation and number of carpels, fruit structure, and gland histology. Although the monogeneric subfamily Rhabdodendroideae was excluded from Rutaceae (Prance 1968, 1972, Fay et al. 1997), the remaining subfamilies, Aurantioideae, Dictyolomatoideae, Flindersioideae, Rutoideae, Spathelioideae, and Toddalioideae continued to be recognized based on characteristics of the subfamilies which were discussed in detail in Chase et al. (1999) and Groppo et al. (2008). Several studies of morphology (e.g., Hartley 1974, 1981, 1982), chromosome number (Stace et al. 1993), secondary metabolites (Da Silva et al. 1988), and more recently, molecular data (Chase et al. 1999, Poon et al. 2007, Groppo et al. 2008) have demonstrated the need for a better circumscription of the subfamilies. To further evaluate Engler's circumscriptions of the groups, the broadest sampling of Rutaceae to date, i.e., 53 genera representing all subfamilies, tribes, and almost all subtribes, was included in the study by Groppo et al. (2008) and the present one. Although Aurantioideae has emerged as a monophyletic group, all other subfamilies with more than one genus appeared as not monophyletic (see Fig. 1). The genera of Toddalioideae and Rutoideae appeared in mixed clades here and in previous studies (Chase et al. 1999, Scott et al. 2000, Poon et al. 2007, Groppo et al. 2008) and are clearly not monophyletic. The position of *Ruta* (and remaining Ruteae), far from other Rutoideae and near the Aurantioideae, has been obtained in all studies that included genera of Aurantioideae.

Given these data, realignments of the infrafamilial groups in Rutaceae have been recently made. In a survey of secondary metabolites (largely influenced by the conclusions of Waterman and Grundon 1983), Da Silva et al. (1988) proposed the rejection of Toddalioideae and its inclusion in Rutoideae (as later did Quader et al. 1991 and Thorne 1992) and several "informal tribes." Chase et al. (1999), Scott et al. (2000), and Groppo et al. (2008) suggested different circumscriptions of monophyletic subfamilies. One of the concordances among these three studies is the recognition of the *Spathelia*/*Ptaeroxylon* clade as a subfamily, named Spathelioideae (Appelhans et al. 2011) or Cneoroideae (Thorne and Reveal 2007, Kubitzki et al. 2011). Based on priority, Cneoroideae is the correct name for this group (see Appendix 1), which encompasses the Englerian subfamilies Spathelioideae and Dictyolomatoideae and

the families Ptaeroxylaceae and Cneoraceae, all recognized as Rutaceae in APG III (2009). A new tribal classification of Cneoroideae was presented by Appelhans et al. (2011, as Spathelioideae).

The remaining Rutaceae or "core Rutaceae" (Groppo et al. 2008, Kubitzki et al. 2011) are here lumped into a single subfamily, Rutoideae, sister to Cneoroideae. In this new circumscription, Rutoideae encompasses Englerian Rutoideae, Toddalioideae, Flindersioideae, and Aurantioideae–a total of 148 genera and approximately 2061 species (Table 1). Thorne (1992), Quader et al. (1991), and Appelhans et al. (2011) previously proposed the inclusion of Toddalioideae in an expanded Rutoideae, but none formally proposed the inclusion of Aurantioideae. Although continued recognition of Aurantioideae as a subfamily might be convenient to the economically important *Citrus* industry, phylogenetic studies [the present one as well as those of Chase et al. (1999), Scott et al. (2000), Groppo et al. (2008), and Appelhans et al. (2011)] show that *Ruta* is much closer to Aurantioideae than to other Rutoideae.

Restricting the name Rutoideae to *Ruta* and its allies in tribe Ruteae (excluding *Dictamnus*, see Salvo et al. 2008) to preserve Aurantioideae is one option. However, as *Cneoridium* and *Haplophyllum* (not sampled here), both Ruteae, appear to be closer to Aurantioideae than to *Ruta* (see Salvo et al. 2010), it will be necessary also to erect subfamilial names to these two groups. Besides, preservation of Aurantioideae and a narrow Rutoideae would require a different subfamilial name for one of the major clades in Rutaceae, here called "clade RTF" (Figs 1 and 2), that comprises the bulk of Englerian Rutoideae, Toddalioideae, and *Flindersia* (from Englerian Flindersioideae), a total of 114 genera and 1770 species (Table 1). Appelhans et al. (2011) used the name Toddalioideae (from 1869) for this large clade, unaware that Diosmideae (based on *Diosma*) and Zanthoxyloideae (both from 1832), have priority over Toddalioideae. Yet, the correct choice of a formal name for clade RTF is further complicated by as yet unpublished results of molecular studies by the

Table 1. A summary of the new circumscription of subfamilies in Rutaceae proposed in this study. Approximate number of genera and species and distribution taken from Kubitzki et al. (2011) and Appelhans et al. (2011, for Cneoroideae). RTF = clade comprising Rutoideae, Toddalioideae, and *Flindersia.*

Subfamily	Circumscription	Approximate number of genera/ (species)	Distribution
Cneoroideae	Englerian Dictyolomatoideae and Spathelioideae (Engler 1931), plus Cneoraceae, Ptaeroxylaceae (see Appelhans et al. 2011 and 2012a for further details)	8 (35)	Pantropical, extending to subtropical regions in Europe
Rutoideae	Englerian Aurantioideae, Flindersioideae, Rutoideae, and Toddalioideae (Engler 1931)	114 (1770) in clade RTF; 26 (206) in Aurantieae; 7 (84) in Ruteae (including *Cneoridium* and *Haplophyllum*), plus 1 (1) in *Chloroxylon*. Total: 148 (2061)	Pan-tropical, some in temperate or desert areas worldwide
Total		156 (2096)	

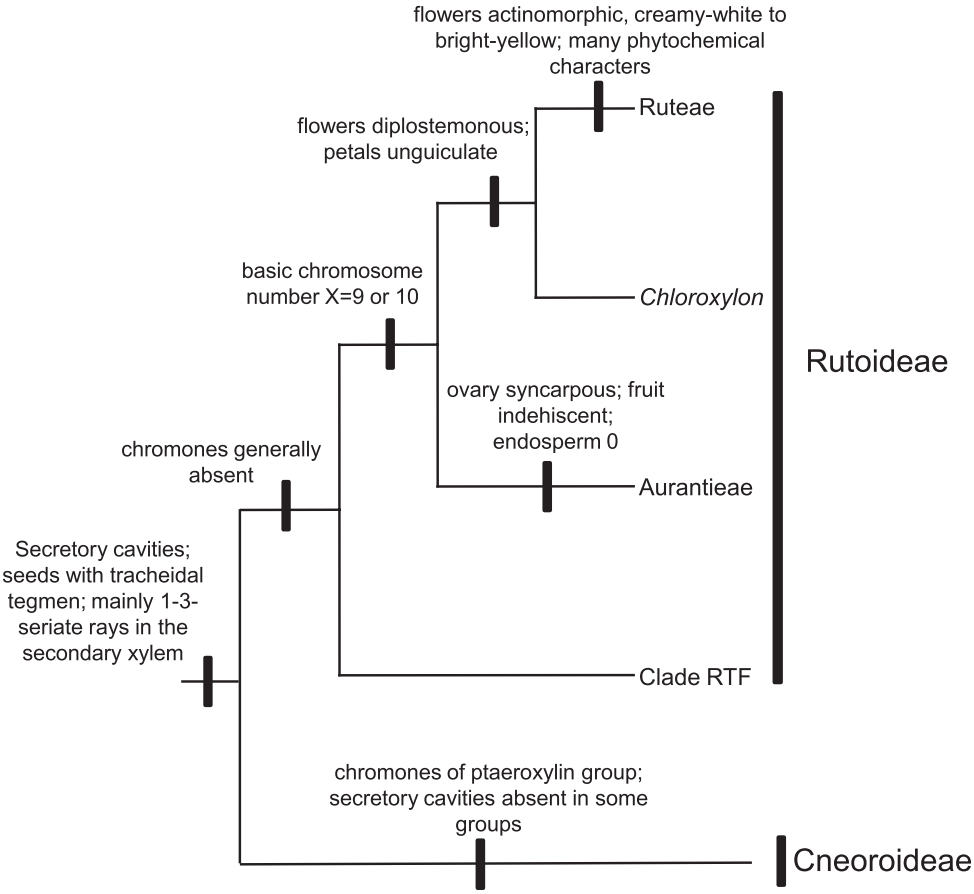

Figure 2. A summary of the phylogenetic relationships of proposed subfamilies in Rutaceae, with some non-molecular characteristics plotted onto a simplified cladogram based on the Bayesian tree. *Chloroxylon* is doubtfully attached to Aurantieae. *Haplophyllum* and *Cneoridium* (both from Englerian Ruteae but closer to Aurantieae that to remaining Ruteae, see Salvo et al. 2010) are missing. *Amyris* (from Englerian Toddalioideae), also close to Aurantieae (unpublished results) is also missing. The RTF clade corresponds to the bulk of Englerian Rutoideae, plus Toddalioideae and *Flindersia.* For discussion of characteristics see Waterman and Grundon (1983), Stace et al. (1993), Groppo et al. (2008), and Appelhans et al. (2011, 2012b).

first author, in which *Amyris*, placed by Engler (1931) in Toddalioideae, appears to be more closely related to Aurantioideae. Were *Amyris* and the Aurantioideae to be recognized as a subfamily, its correct name would be Amyridoideae (published in 1824) rather than Aurantioideae (from 1836). Alternatively, it can be treated within the Rutoideae as the monophyletic tribe Aurantieae, the name proposed by Bentham and Hooker (1862) and the group recognized by Engler (1896, 1931) as the only tribe in the Aurantioideae.

Formal recognition of the expanded Rutoideae and the Cneoroideae at the family level (i.e., respectively as Rutaceae *sensu stricto* and Cneoraceae) is at odds with shared

morphological characters. One synapomorphy uniting these two clades, despite its absence in some Cneoroideae (due to a secondary loss, Appelhans et al. 2011), is the presence of secretory cavities containing aromatic ethereal oils in almost all organs (Groppo et al. 2008, Groppo 2010), a feature unique to Rutaceae within the Sapindales. Another putative synapomorphy encountered commonly in the expanded Rutoideae (see Corner 1976 and Johri et al. 1992) and in Cneoroideae (though absent in some, again due to a secondary loss, Appelhans et al. 2011) is the presence of a tracheidal tegmen in the seeds. Additionally, Appelhans et al. (2012b) discussed some wood anatomical characters shared by Spathelioideae (here Cneoroideae) and remaining Rutaceae, as the mainly 1-3-seriate rays in the secondary xylem. Figure 1 presents our chosen classification of the Rutaceae superimposed on that of Engler (1931), and Figure 2 summarizes some characteristics and putative synapomorphies of the major internal groups in the family. A summary of the circumscriptions of the two subfamilies recognized in this study is given at the end of the text.

The classification scheme presented here, with only two monophyletic subfamilies, Cneoroideae and Rutoideae, is a framework for further studies of the family. The next step is the re-circumscription of groups below the subfamilial level, i.e., the tribes and subtribes, as Appelhans et al. (2011) has done for Spathelioideae (here Cneoroideae) and Salvo et al. (2008) for Rutinae. Another challenge is to search for morphological synapomorphies of groups within Rutoideae (especially the "RTF clade") and to include additional sampling in phylogenetic studies, such as other sequences from monospecific *Chloroxylon*, which appeared, somewhat doubtfully at this point, close to *Ruta* and to Aurantioideae in some studies. Ongoing studies of Neotropical Rutaceae, especially Galipeeae (Rutoideae), conducted by the authors are also expected to change our view of the traditional groups in the family and contribute to the understanding of the phylogeny of the large and widespread Rutaceae.

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Appendix 1

Summary of the subfamilies recognized in the present circumscription of Rutaceae. Source of dates of publication is Reveal, J. "Suprafamilial Names of Extant Vascular Plants," available at http://www.plantsystematics.org/reveal/pbio/fam/hightaxa7.html (for a complete list of synonyms see Thorne and Reveal 2007).

Rutaceae A.Juss., Gen Pl.: 296. 4 Ago 1789. (type: *Ruta* L.) *nomen conservandum*

Subfamily Cneoroideae Webb, London J. Bot. 1: 257. 1 Mai 1842. (Cneoreae). (type: *Cneorum* L.) [Circumscription: Englerian Dictyolomatoideae and Spathelioideae (Engler 1931) and Cneoraceae and Pteroxylaceae (see Appelhans et al. 2011 for a list of genera and tribal delimitation)]

Synomyms:

Cneoraceae Vest, Anleit. Stud. Bot.: 267. 1818. (type: *Cneorum* L.)

Dictyolomatoideae ("Dictyolomoideae") Engl. in Engl. and Prantl, Nat. Pflanzenfam. III, 4: 111. Mar 1896. (type: *Dictyoloma* A. Juss.).

Ptaeroxylaceae J.-F.Leroy, J. Agric. Trop. Bot. Appl. 7: 456. 1960. (type: *Ptaeroxylon* Radlk.).

Spathelioideae Engl. in Engl. and Prantl, Nat. Pflanzenfam. III, 4: 111. Mar 1896. (type: *Spathelia* L.).

Subfamily Rutoideae Arn., Encycl. Brit., ed. 7, 5: 104. 9 Mar 1832 (Ruteae). (type: *Ruta* L.) [Circumscription: Englerian Aurantioideae, Flindersioideae, Rutoideae, and Toddalioideae, see Engler (1931)]

Synomyms:

Aurantioideae Eaton, Bot. Dict., ed. 4: 39. Apr-Mai 1836 (Aurantiaceae). [(type: *Aurantium* L. (=*Citrus* L.)]. Recognized here as tribe Aurantieae Rchb., Fl. Germ, Excurs. 292). 840. 1832.

(note: see Mabberley (1998) for reasons why Aurantioideae instead of the earlier name Citroideae is to be used).

Flindersiaceae C.T.White ex Airy Shaw, Kew Bull. 18: 257. 8 Dec 1964. (type: *Flindersia* R. Br.).

Flindersioideae Luerss., Handb. Syst. Bot. 2: 681. Jun 1881 ("Flindersieae"). (type: *Flindersia* R. Br.).

Toddalioideae K.Koch, Dendrologie 1: 564. 1869 ("Toddalieae"). (type: *Toddalia* A.Juss.).

Appendix 2

Voucher information and Genbank accession numbers for taxa used in this study. Missing sequences are marked by "—." Arrangement of terminals in Rutaceae follows the new subfamilial delimitation proposed here. For classification of terminals in Engler (1931) and Swingle and Reece (1967, for "Aurantioideae") see Groppo et al. (2008).

Genbank accessions: *trnL-trnF, rps16*.

Rutaceae

Subfamily Cneoroideae

Cneorum pulverulentum Vent. — EU853787, EU853733. *Dictyoloma vandellianum* A. Juss. — EU853793, EU853739. *Ptaeroxylon obliquum* (Thunb.) Radlk. — EU853812, EU853762. *Sohnreyia excelsa* Krause — EU853820, EU853770.

Subfamily Rutoideae

Acronychia baeuerlenii T. G. Hartley — EU853774, EU853719. *Adiscanthus fusciflorus* Ducke — EU853775, EU853721. *Aegle marmelos* (L.) Corrêa ex Roxb. — AY295294, AY295268. *Afraegle paniculata* (Schum. and Thonn.) Engl. — AY295295, AY295269. *Agathosma* sp. — EU853776, EU853722. *Angostura bracteata* (Engl.) Kallunki — EU853778, EU853724. *Atalantia ceylanica* (Arn.) Oliv. — AY295288, AY295262. *Balfourodendron riedelianum* (Engl.) Engl. — EU853779, EU853725. *Balsamocitrus dawei* Stapf — AY295278, AY295252. *Boronia heterophylla* F. Muell. — EU853780, EU853726. *Casimiroa tetrameria* Millsp. — EU853782, EU853728. *Chloroxylon swietenia* DC. — AY295276, AY295250. *Choisya mollis* Standl. — EU853784, EU853730. *Chorilaena quercifolia* Endl. — EU853785, EU853731. *Citrus aurantium* L. — EU853786, EU853732. *Clausena excavata* Burm. f. — AY295284, AY295258. *Coleonema pulchrum* Hook. — EU853788, EU853734. *Conchocarpus pentandrus* (A.St.-Hil.) Kallunki and Pirani — EU853735, EU853735. *Correa pulchella* Mackay ex Sweet — EU853790, EU853736. *Dictamnus albus* L. — EU853792, EU853738. *Diplolaena dampieri* Desf. — EU853794, EU853740. *Esenbeckia grandiflora* Mart. — EU853795, EU853741. *Flindersia australis* R. Br. — AF038628 (intron) AF026009 (spacer), —,— spacer. *Flindersia collina* F. M. Bailey — —, EU853742. *Galipea laxiflora* Engl. — EU853796, EU853743. *Halfordia kendack* (Montrouz.) Guillaumin — EU853798, EU853745. *Hortia excelsa* Ducke — EU853801, EU853748. *Glycosmis pentaphylla* (Retz.) Corrêa — AY295279, AY295253. *Helietta puberula* R. E. Fries — EU853799, EU853746. *Lunasia amara* Blanco — EU853805, EU853753. *Medicosma cunninghamii* (Hook.) Hook. f. — EU853806, EU853754. *Melicope ternata* J. R. Forst. and G. Forst. — EU853808, EU853756. *Melicope* sp. — EU853807, EU853755. *Metrodorea nigra* A. St.-Hil. — EU853809, EU853757. *Micromelum minutum* (G. Forst.) Wight and Arn. — AF025520, AF320266. *Murraya paniculata* (L.) Jack — EU853810, EU853758. *Nematolepis phebalioides*

Turcz. — AF025522 (spacer), EU853759. *Pitavia amara* Blanco — KC261635, KC261636. *Ravenia infelix* Vell. — EU853814, EU853764. *Ruta graveolens* L. — EU853815, EU853765. *Pamburus missionis* (Wight) Swingle — AY295300, AY295274. *Ptelea trifoliata* L. — EU853813, EU853763. *Sarcomelicope simplicifolia* (Endl.) T. G. Hartley — EU853816, EU853766. *Sigmatanthus trifoliatus* Huber ex Emmerich — EU853817, EU853767. *Skimmia japonica* Thunb. — EU853819, EU853769. *Swinglea glutinosa* (Blanco) Merr. — AY295285, AY295259. *Toddalia asiatica* (L.) Lam. — EU853821, AF320278. *Triphasia trifolia* (Burm. f.) P. Wilson — EU853822, AY295271. *Vepris lanceolata* (Lam.) G. Don — EU853823, EU853771. *Vepris simplicifolia* (Engl.) W. Mziray — EU853824, EU853772. *Wenzelia dolichophylla* (Lauterb. and K. Schum.) Tanaka — AY295286, AY295260. *Zanthoxylum rhoifolium* Lam. — EU853773, EU853720.

Meliaceae

Carapa guianensis Aubl. — EU853781, EU853727. *Cedrela fissilis* Vell. — EU853783, EU853729. *Guarea macrophylla* Vahl — EU853797, EU853744.

Sapindaceae

Allophylus edulis (A. St.-Hil.) Niederl. — EU853777, EU85853723. *Cupania vernalis* Cambess. — EU853791, EU853737.

Simaroubaceae

Simaba cedron Planch. — EU853818, EU853768.

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RESEARCH ARTICLE

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Five new species of *Rhodamnia* (Myrtaceae, Myrteae) from New Guinea

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Abstract

Five new species of *Rhodamnia* are proposed for New Guinea, including *R. asekiensis, R. daymanensis*, *R. makumak*, *R. taratot*, and *R. waigeoensis*. *Rhodamnia sharpeana*, known previously only in Australia, is reported for the first time for Papua New Guinea. Detailed species descriptions and associated taxonomic data are provided for all species. A key is provided for species of *Rhodamnia* with stellate trichomes. Given the overall paucity of collections, all species are tentatively assigned as Data Deficient following IUCN conservation recommendations.

Keywords

Australia, conservation, Myrtaceae, New Guinea, new species, *Rhodamnia*, systematics

Introduction

Rhodamnia Jack is recognized easily among the baccate genera of Myrtaceae in Malesia and Melanesia by its 4-merous flowers (apart from a 5-merous species in New Caledonia), uniloclular ovaries, parietal placentation, and sclerotic seed coats (Scott 1979; Snow 2007).

Based on the author's current taxonomic perpectives and including those newly proposed here, *Rhodamnia* includes 42 species. The genus occurs from Myanmar, Thailand and China through Malesia and Australia, and east through Melanesia to the Solomon Islands (Scott 1979; Kress et al. 2003). The Australian species recently were treated (Snow 2007) and another new species was described from New Guinea (Snow and Takeuchi 2009). However, *Rhodamnia* remains imperfectly known in New Guinea because of low collecting densities from that island, and because some species are known from only one or a few collections.

The five species newly proposed here were recognized during curatorial duties associated with floristic inventories in Papua New Guinea by Bishop Museum. The purpose of this paper is to describe the new species of *Rhodamnia*, summarize their diagnostic character traits, and to provide a distribution map and conservation threat assessments. It also discusses the first New Guinean occurrences of *Rhodamnia sharpeana*, previously known only from Australia (Snow 2007).

Materials and methods

Measurements are based primarily on dried herbarium specimens, although dimensions for flowers and fruits were supplemented by rehydrating material in boiling water. Terminology follows that used in recent treatments for the genus (Snow 2007; Snow and Takeuchi 2009), the Systematics Association (1962) for two-dimensional shapes, and Thiers (2012) for acronyms. An exception is the present use of the term colleters in lieu of stipules in light of recent studies (da Silva et al. 2012). Descriptions for color are standardized where possible to Beentje (2010) or reported in accordance with data provided on specimen labels. As used here, the leaf apex refers to the distal 25% of the laminar surface, whereas the tip refers to the distal 10% (Snow et al. 2003). Conservation threat assessments follow IUCN (2010). Takeuchi (2000) discussed the inconsistency of vernacular names in Papua New Guinea and provided an example from Myristicaceae in which a common name was applied widely across most of the family. "However, the vernacular name is reported here if it was indicated on the specimen label.

Data resources

The data underpinning the new species described in this paper are deposited at GBIF, the Global Biodiversity Information Facility, http://ipt.pensoft.net/ipt/resource.do?r=snow_1_rhodamnia_new_guinea.

Rhodamnia asekiensis **N. Snow, sp. nov.**
urn:lsid:ipni.org:names:77123882-1
http://species-id.net/wiki/Rhodamnia_asekiensis
Figures 1, 2

Resembling Rhodamnia latifolia *but with distinctly larger leaves that have an acute to acuminate apex and differing by the larger fruits*.

Type. PAPUA NEW GUINEA. Morobe Province, Aseki, Menyama Subdistrict, 7°21'S, 146°10'E, 20 May 1968, H. Streimann & A. Kairo NGF 39049 (holotype: BISH [sheet no. 30914]!; isotypes: A!, CANB!, K!, L!, LAE n.v., NSW n.v., US!)

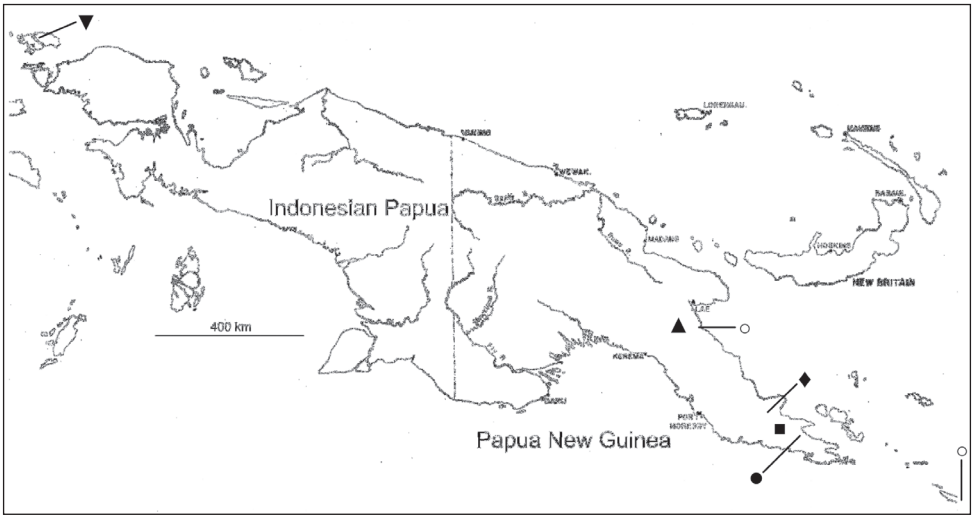

Figure 1. Island of New Guinea, showing localities of new species. Triangle (▲) = *R. asekiensis*; Square (■) = *R. daymanensis*; Diamond (♦) = *R. makumak* (at bottom of line); Closed circle (●) = *R. toratot* (at top of line); Inverted triangle (▼) = *R. waigeoensis* (upper left, at bottom of line); Open circles (○) = *R. sharpeana* (left end of line [upper] and bottom of line [lower, on truncated eastern half of Tagula Island]).

Description. Trees of unknown height; crown dense. Bark of main bole light grey, vertically fissured. Indumentum (branchlets, flowers, fruit) short-sericeous, sparsely to moderately dense, color more or less saffron (Beentje 2010). Branchlets terete, wingless, dark brown (dried); epidermis smooth, oil glands absent. Leaves opposite, evenly distributed along branchlets, strongly discolorous; venation perfect basal or slightly suprabasal acrodromous, secondary and tertiary veins visible above and below, the more prominent secondaries ca. 20–25 per side abaxially, the secondaries near base of blade splitting as they approach lateral primary vein and contrasting with those towards apex of blade that are mostly unbranched; intramarginal vein less pronounced than secondaries, parallel to leaf margins, 0.8–1.1 mm from margin at midpoint of blade. Colleters absent. Petioles 11–13 mm long, round to slightly sulcate above. Leaf blades 10.5–16.0 cm long, 3.5–4.5 cm wide, narrowly ovate (to elliptic), base cuneate, apex acuminate, tip acute; adaxial surface matte, glabrescent at base, midvein slightly and narrowly raised proximally but becoming flush distally; abaxial surface densely short and strongly-appressed sericeous between the secondary and tertiary veins, midvein projecting throughout, oil glands not visible. Inflorescence terminal or lateral, flowers solitary (=monads) or in 3-flowered cymes ("botryoids" of some authors), pedicels of monads up to 10 mm long. Bracteoles not seen, apparently caducous in fruit. Flowers unknown. Hypanthium (based on fruit) evidently not ribbed, hairy. Calyx lobes (in mature fruit) 2.5–3.0 mm long, more or less glabrous adaxially, moderately sericeous abaxially, persisent and erect in fruit. Ovary (from mature fruit) and locule 1, placentas 2, linear; ovules disposed in regular rows. Berries subcylindrical, somewhat pyriform or tapering at the base, 8.5–14.0 mm long, 8–11 mm wide, sparsely sericeous, dull dark

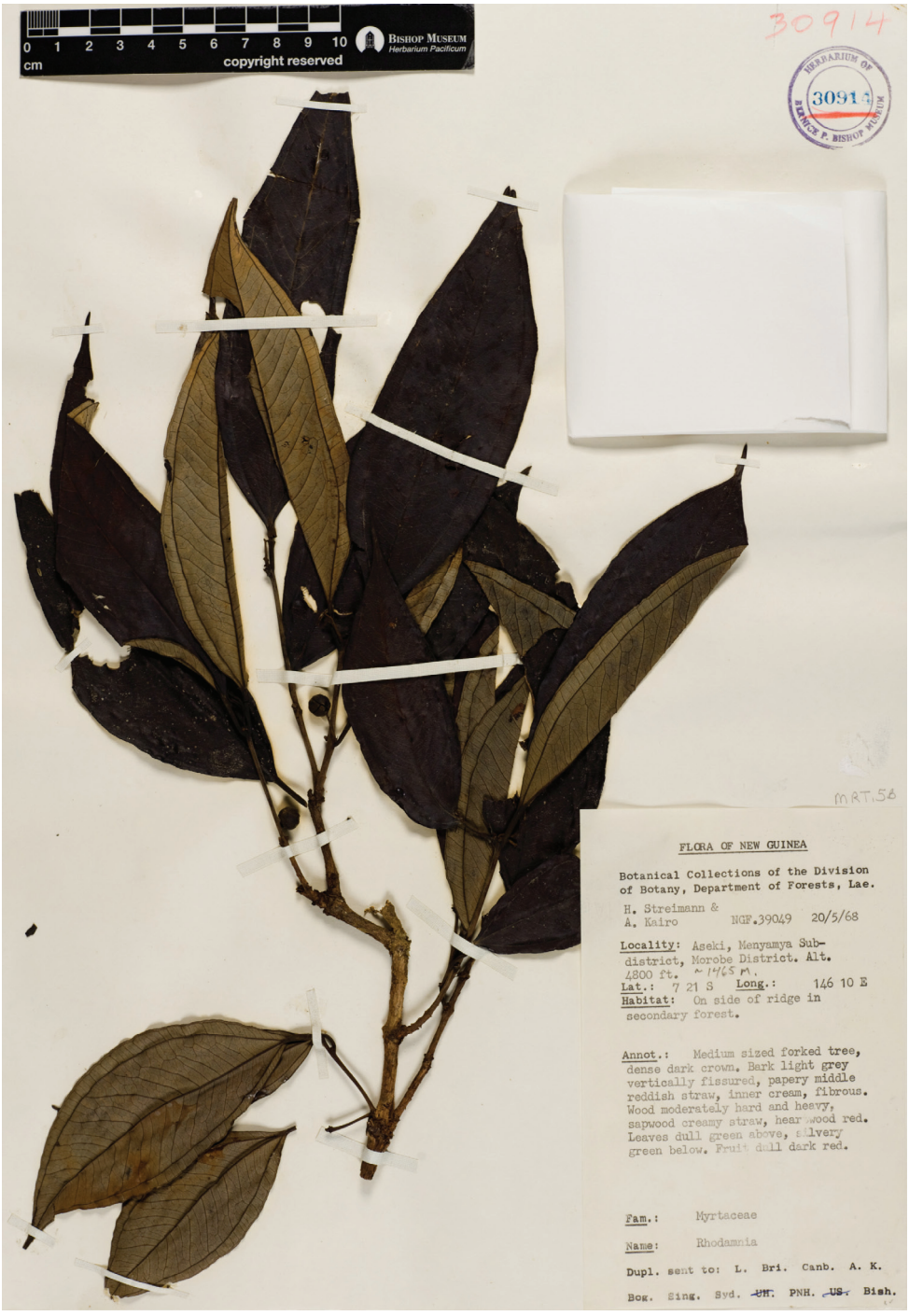

Figure 2. *Rhodamnia asekiensis* N. Snow. Photo of the holotype at BISH (*H. Streimann and A. Kairo NGF 39049*).

red (fresh) or blackish (dried). Seeds 4–10 per fruit, 4.5–5.2 mm long, 2.8–5.0 mm wide, rounded on outer portion adjacent to fruit wall but highly angular and irregularly elsewhere, light brown, seed coat highly sclerotized. Embryos not seen.

Phenology. Flowering unknown; fruiting confirmed only for May.

Distribution. Known only from Morobe Province, Papua New Guinea, on the side of a ridge in a secondary forest; ca. 1465 m.

Conservation status. Data Deficient; but the subsequent lack of collections of this species over the past 45 years locally and regionally suggest that Threatened might more accurately reflect is true status.

Comments. *Rhodamnia asekiensis* is included among the "pearly" group of species (Snow 2007) by virtue of its nacreous abaxial laminar indumentum. The 10–16 cm long leaves with the acute to acuminate apices distinguish it from *Rhodamnia latifolia*, in which Scott (1979) earlier had placed the type specimen.

***Rhodamnia daymanensis* N. Snow, sp. nov.**
urn:lsid:ipni.org:names:77123883-1
http://species-id.net/wiki/Rhodamnia_daymanensis
Figures 1, 3

Resembling Rhodamnia lancifolia *but differing by its more deeply sulcate petiole, broader leaves, and shorter yellowish indumentum on the abaxial laminar surface.*

Type. PAPUA NEW GUINEA. Milne Bay District, north slopes of Mt. Dayman, Maneau Range, 2250 m, ca. 9°47'S, 149°18'E, 2 Jun 1953, L. J. Brass 22718 (holotype: A!; isotype: L!)

Description. Trees 15–18 m. Indumentum (branchlets, inflorescence axis, flowers) densely appressed sericeous or sericeous-villous (trichomes yellowish). Branchlets terete to compressed, brown (dried), epidermis smooth, becoming flakey or scaly, sericeous-villous. Leaves opposite, evenly distributed along branchlets, strongly discolorous, internodes 1–3 cm long; venation perfect basal acrodromous, secondary and tertiary veins visible above and below; intramarginal vein closely paralleling leaf margin, 0.5–0.7 mm from margin at midpoint of blade. Colleters absent. Petioles 5–9 mm long, slightly sulcate throughout. Leaf blades 3.8–7.0 cm long, (1.1–)1.5–3.0(–3.5) cm wide, elliptic (rarely broadly elliptic), base cuneate, apex narrowly acuminate, tip acute and somewhat falcate; adaxial surface matte, sericeous but becoming glabrescent, midvein slightly sulcate in proximal half but more or less flush distally; abaxial surface densely sericeous between the secondary and tertiary veins, midvein projecting throughout, oil glands (if present) entirely obscured by indumentum. Inflorescence axillary, flowers solitary (=monads) or in 3-flowered cymes (=botryoids), solitary to paired or fascicled in axils, pedicels of monads up to 1–5 mm long, rigid and ascending. Bracteoles 1.5–3.0 mm long, less than 0.5 mm wide at base, linear, mostly erect or ascending, mostly persistent in flower. Hypanthium 2.5–3.3 mm long, ca. 2.5 mm wide at base of calyx lobes, cupulate, densely hairy. Calyx

Figure 3. *Rhodamnia daymanensis* N. Snow. Photo of the holotype at A (*L. J. Brass 22718*).

lobes 2.7–3.0 mm long, broadly obtuse, glabrescent adaxially, densely sericeous abaxially. Petals 5.5–7.0 mm long, 3.0–3.5 mm wide, ovate to narrowly ovate, whitish, mostly glabrous adaxially, densely sericeous abaxially, oil glands common. Stamens 65–75, multiseriate; staminal disk short-hairy; filaments 2–3 mm long; anther sacs 0.3–0.5 mm long, globose to subcylindrical, sub-basifixed or basifixed, crowned by a single large apical gland. Style ca. 4.5 mm long, glabrous; stigma narrow to slightly capitate, prominently papillose. Ovary and locule 1, placentas 2, linear, ovules disposed in regular rows.

Phenology. Flowering in June; fruiting interval unknown.

Distribution. Papua New Guinea, Milne Bay Province, north slopes of Mt. Dayman in the Maneau Range; mossy forest of ridge crests over metamorphic rocks (see Davies 1980; Daczko et al. 2009) at ca. 2250 meters.

Conservation status. Data Deficient. The collection label indicates the species was common (at least locally) at the time of its collection in 1953. However, the absence of additional collections over the past sixty years suggests that Threatened might more accurately reflect its true status.

Comments. *Rhodamnia daymanensis* appears to be part of the "pearly" group (Snow 2007) by virtue of its abaxial indumentum. Scott (1979) included this specimen in *Rhodamnia blairiana* var. *propinqua* (C.T. White) A.J. Scott.

Among the species of *Rhodamnia* in New Guinea occurring at elevations above 2000 meters with a similar abaxial indumentum, *R. daymanensis* mostly closely resembles *R. lancifolia*. The type collection of *R. lancifolia* (2425 m) is approximately 25 km west of the type locality of *R. daymanensis* (2250 m) in similar habitats. However, *R. lancifolia* differs by its more narrowly elliptic leaves, a less pronounced petiolar sulcus, slightly impressed adaxial laminar midvein (vs. more deeply impressed in *R. daymanensis* in the proximal half), and the more yellowish (and longer, on average) abaxial laminar indumentum. The adaxial leaf surface of *R. lancifolia*, for which there are many collections, is nearly black when dried, which contrasts with the fucosus (dark greyish brown, Beentje 2010) dried color of *R. daymanensis*. The flowers (presumably hypanthium and abaxial surfaces of calyx lobes and petals) of *R. lancifolia* have a brownish-pinkish indumentum (Stevens & Veldkamp LAE 55582; isotype [L!]), whereas the floral indumentum of *R. daymanensis* is mostly distinctly yellowish.

***Rhodamnia makumak* N. Snow, sp. nov.**
urn:lsid:ipni.org:names:77123884-1
http://species-id.net/wiki/Rhodamnia_makumak
Figures 1, 4

Resembling other species of Rhodamnia *having stellate trichomes but differing by its sessile to subsessile flowers and narrowly elliptic leaves with occasionally falcate apices.*

Type. PAPUA NEW GUINEA. Milne Bay Province: E. of Mt. Suckling in valley of the upper Maiyu R[iver] c. 15 km WNW of Biniguni airstrip, ca. 9°40'S, 149°10'E, ca.

Figure 4. *Rhodamnia makumak* N. Snow. Drawing of isotype at A (*R. Pullen 8433*). Clockwise from top: branchlet (bar = 1 cm); stellate trichome (bar = 0.1 mm); inflorescences (bar = 1 mm); style (bar = 1 mm); dehisced anther (bar = 0.3 mm).

350 m, 7 Jul 1972, R. Pullen 8433 (holotype: A! [no accession numer]; isotypes: BO n.v., BRI!, CANB!, L!, LAE n.v., K!, TNS n.v.).

Description. Trees to 25 m. Buttresses present but low of stature; fluting or twisting absent. Bark of main trunk reticulate-flaky, brownish. Indumentum, where present (branchlets, petioles, abaxial leaf surface, distal portion of adaxial leaf mid-

vein, peduncles, bracteoles, hypanthium, calyx lobes, adaxial petal surfaces), densely tomentose and velvety in texture, consisting of stellate, ferrugineous trichomes. Branchlets terete to compressed. Leaves opposite, more or less evenly distributed along branchlets, discolorous; venation perfect or imperfect suprabasal acrodromous, secondary and tertiary veins faint but visible adaxially, intramarginal vein faintly visible from adaxially, tracing irregularly between tips of secondary veins and ca 0.5 mm from blade margin. Colleters absent. Petioles 4.5–6.5 mm long, rounded in transverse section. Leaf blades 4.5–7.5 cm long, 1.4–2.2 cm wide, narrowly elliptic, base cuneate, margin flat, apex acuminate and sometimes falcate, tip (uppermost 10% of blade) acute; adaxial surface matte, midvein slightly sulcate more or less throughout to sometimes flush distally, tomentose proximally; abaxial surface orangish-velvety by virtue of indumentum, midvein projecting throughout. Inflorescence terminal and lateral, solitary or paired to mostly a fasciculate cluster of monads, the monads sessile or on pedicels up to 3 mm long. Bracteoles 1.8–2.3 mm long, 0.4–0.6 mm wide, linear, rigid, ascending to erect, the apex not reaching base of calyx lobes, persisting. Hypanthium campanulate; anthopodium (if present) up to 1 mm long; metaxyphylls absent. Calyx lobes 4, 2.2–2.7 mm long, 2 (of the 4 lobes) more or less rectangular (length-width ratio 3:2), slightly longer than the 2 shorter, broadly ovate (3:2) lobes; adaxial surface densely tomentose or somewhat less so basally and near margins, abaxial surface densely tomentose throughout. Petals (material sparse) 2–2.5 mm long, 2–2.3 mm wide, elliptic to ovate, tomentose above and below. Stamens ca. 30–40, filaments 2–3 mm long; anther sacs ca. 0.5 mm long, globose, sub-basifixed. Style 3.5–4 mm long, hairy below; stigma narrow to slightly capitate. Fruit not seen.

Phenology. Flowering confirmed only for early July but likely also in late June; fruiting unknown but probably June to July and possibly longer.

Distribution. Papua New Guinea, Milne Bay Province; known only from rainforest on a plateau of ca. 350 meters elevation.

Conservation status. Data Deficient.

Etymology. From the local vernacular name "makumak" as a noun in the nominative.

Vernacular name. *Makumak* in the local Daga language.

Comments. *Rhodamnia makumak* is part of a group of species characterized by a hypothesized synapomorphy of stellate trichomes (Snow 2007). Scott (1979) treated the type collection as *R. blairiana* var. *blairiana*, which as presently understood occurs only in Australia (Snow 2007). Dr. Gordon Guymer (BRI), who worked previously on *Rhodamnia*, likewise recognized the affinity of the type collection to *R. blairiana*, judging from his specimen annotations.

Rhodamnia makumak is said to be a large tree with low buttresses (dimensions of buttresses lacking on label). The best diagnostic characters include the stellate, ferrugineous indumentum on leaves and hypanthium, which imparts a densely velvety appearance; the sessile to subsessile axillary clusters of flowers; and narrowly elliptic leaves bearing an acuminate and sometimes falcate apex. A provisional key to species with stellate trichomes follows.

Key to species of *Rhodamnia* with stellate trichomes

1 Leaves elliptic to broadly elliptic, 11–18 cm long, apex abruptly cuspidate-caudate ..... ***R. kamialiensis* N. Snow & W. N. Takeuchi**
– Leaves narrowly elliptic or narrowly ovate to ovate or elliptic, 4–12 cm long, apex acute to acuminate **2**
2 Flowers pedicellate, pedicels mostly > 5 mm long; leaf apex acute ..... ***P. propinqua* C.T. White**
– Flowers sessile or nearly so; leaf apex acute to acuminate **3**
3 Flowers sessile or pedicels to 3 mm; leaf apex acuminate and sometimes falcate ..... ***R. makumak***
– Flowers pedicillate, pedicels 3.5–6 mm long; leaf apex acute to acuminate, rarely mucronate, never falcate **4**
4 Seeds with a thin but pronounced equatorial ridge; plants of Australia, 650–1300 m ..... ***R. blairiana* F. Muell**
– Seeds lacking an equatorial ridge; plants of Australia and Papua New Guinea, sea level to ca. 500 m ..... ***R. sharpeana* N. Snow**

***Rhodamnia toratot* N. Snow, sp. nov.**
urn:lsid:ipni.org:names:77123885-1
http://species-id.net/wiki/Rhodamnia_toratot
Figures 1, 5

Superficially resembling species with stellate and typically ferrugineous trichomes but differing by its highly crispate trichomes.

Type. PAPUA NEW GUINEA. Milne Bay District, Nowata, c. 6 miles W. of Rabaraba, 09°59'S, 149°43'E, ca. 520 m, 5 Jul 1969, R. Pullen 7709 (holotype: K!; isotypes: A! [barcode 00307479], BISH!, BO n.v., BRI!, CANB n.v. [00217141.1 and 00217141.2], G!, L n.v., LAE n.v.).

Description. Trees to ca. 5.5 m. Bark of main bole unknown. Indumentum (branchlets, leaves, flowers, fruit) mostly densely tomentose-lanate, the trichomes highly crisped, ferrugineous, and generally somewhat appressed (see also description of abaxial leaf surface below). Branchlets terete to slightly compressed, reddish-brown (dried); epidermis smooth but finely and evenly striate throughout becoming somewhat fissured with age; oil glands sparse to common (obscured by indumentum on younger branchlets). Leaves opposite, evenly distributed along branchlets, somewhat discolorous; venation perfect basal to slightly suprabasal perfect or imperfect acrodromous, secondary and higher order veins abaxially prominent, the secondaries varying greatly in prominence (and thus hard to estimate numerically) but mostly spaced (2–)3–7 mm along the midvein; intramarginal vein less pronounced than the secondary veins, paralleling leaf margin closely, mostly ca. 0.5–1.0 mm from margin at

Figure 5. *Rhodamnia toratot* N. Snow. Drawing of isotype at BISH (*R. Pullen 7709*). Clockwise from top center: branchlet; detail of branchlet indumentum; bracteole; abaxial leaf surface; seed. Scale bars = 1 mm, except branchlet bar = 1 cm.

midpoint of blade. Colleters absent. Petioles 9.0–13.5 mm long, terete, densely lanate-tomentose. Leaf blades 6.5–12.0 cm long, 3.1–5.2 cm wide, elliptic to ovate, base cuneate to nearly rounded, apex acute to acuminate, tip acute to acuminate; adaxial surface matte, initially lanate but becoming glabrescent, midvein slightly impressed throughout; abaxial surface lanate along midvein and secondary veins when younger, increasingly glabrous with age, densely/minutely hoary between veins, midvein raised prominently throughout. Inflorescence lateral in current season's growth, flowers solitary to mostly densely fascicled, sessile to subsessile with pedicels up to 5 mm long, the pedicels lax, sometimes bending. Bracteoles ca. 2.0–2.5 mm long, ca. 0.5 mm wide at base, linear, persisting in flower and frequently in fruit. Hypanthium cupulate. Calyx lobes 2.5–3.5 mm long, ovate, apex obtuse, densely hairy abaxially but adaxially less so

(especially proximally) with age, persisent and erect in fruit. Petals (material scanty), ca. 4.0–4.5 mm long, up to 3.5 mm wide, broadly obovate, more or less glabrous adaxially, densely lanate abaxially. Staminal disk ca. 4.5 mm in diameter; staminal ring narrow, shortly villous-lanate (trichomes whitish-yellow). Stamens numerous (estimated 75–105); anthers sacs (material scanty) cylindrical, ca. 1.0 mm long, bearing a single apical gland; filament length unknown. Styles not seen, but persisting bases densely lanate in fruit. Ovary with 1 locule; placentas 2; placentation parietal; ovules numerous. Fruit subglobose, 7.5–8.5 mm long (probably immature) x 8.0–9.5 mm wide, greenish when young but becoming brownish on account of dense indumentum. Seeds somewhat compressed, ca. 1–2 mm thick.

Phenology. Flowering unknown; fruiting in July.

Distribution. Milne Bay Province in Papua New Guinea; in secondary (regrowth) forest with *Dodonaea* Adans. (Sapindaceae) and *Castanopsis* (D. Don) Spach (Fagaceae).

Conservation status. Data Deficient; possibly Threatened for same reasons cited above for *R. asekiensis*.

Etymology. The specific epithet is derived from *toratot* as a noun in the nominative.

Vernancular name. Locally known as *toratot* in the Nowata language.

Comments. The tomentose to lanate indumentum on the branchlets and inflorescences (Fig. 5) of *Rhodamnia toratot* suggests its inclusion in the "villous" group of species (Snow 2007), but the minute trichomes between the tertiary and higher-order venation on the abaxial leaf surface suggest possible inclusion in the "hoary" group (Snow 2007).

Scott (1979) had assigned the type gathering of *R. toratot* to *R. blairiana* var. *propinqua*. However, the two taxa are easily distinguished based on trichome density and appearance. The abaxial laminar indumentum of *R. toratot* is characterized by the highly contorted form of the individual trichomes, which are more sparsely distributed than the densely stellate trichomes present on the type specimen of of *R. blairiana* var. *propinqua*.

***Rhodamnia waigeoensis* N. Snow, sp. nov.**
urn:lsid:ipni.org:names:77123886-1
http://species-id.net/wiki/Rhodamnia_waigeoensis
Figures 1, 6

Closely resembling but differing from Rhodamnia novoguineensis *by its thicker and more rigid pedicels, thickly coriaceous leaves, basal acrodromous venation, densely yellowish abaxial laminar indumentum, and solitary flowers*.

Type. INDONESIA. Waigeo Island, Go Isthmus, path from Poean Bay to Fofak Bay, 17 Feb 1955, P. van Royen 5556 (holotype: A! [bar code no. 00307477]; isotypes: CANB!, K!, L n.v.).

Description. Trees 5–7 m; girth to 15 cm. Branchlets terete to slightly compressed, the epidermis later becoming fissured; indumentum densely sericeous,

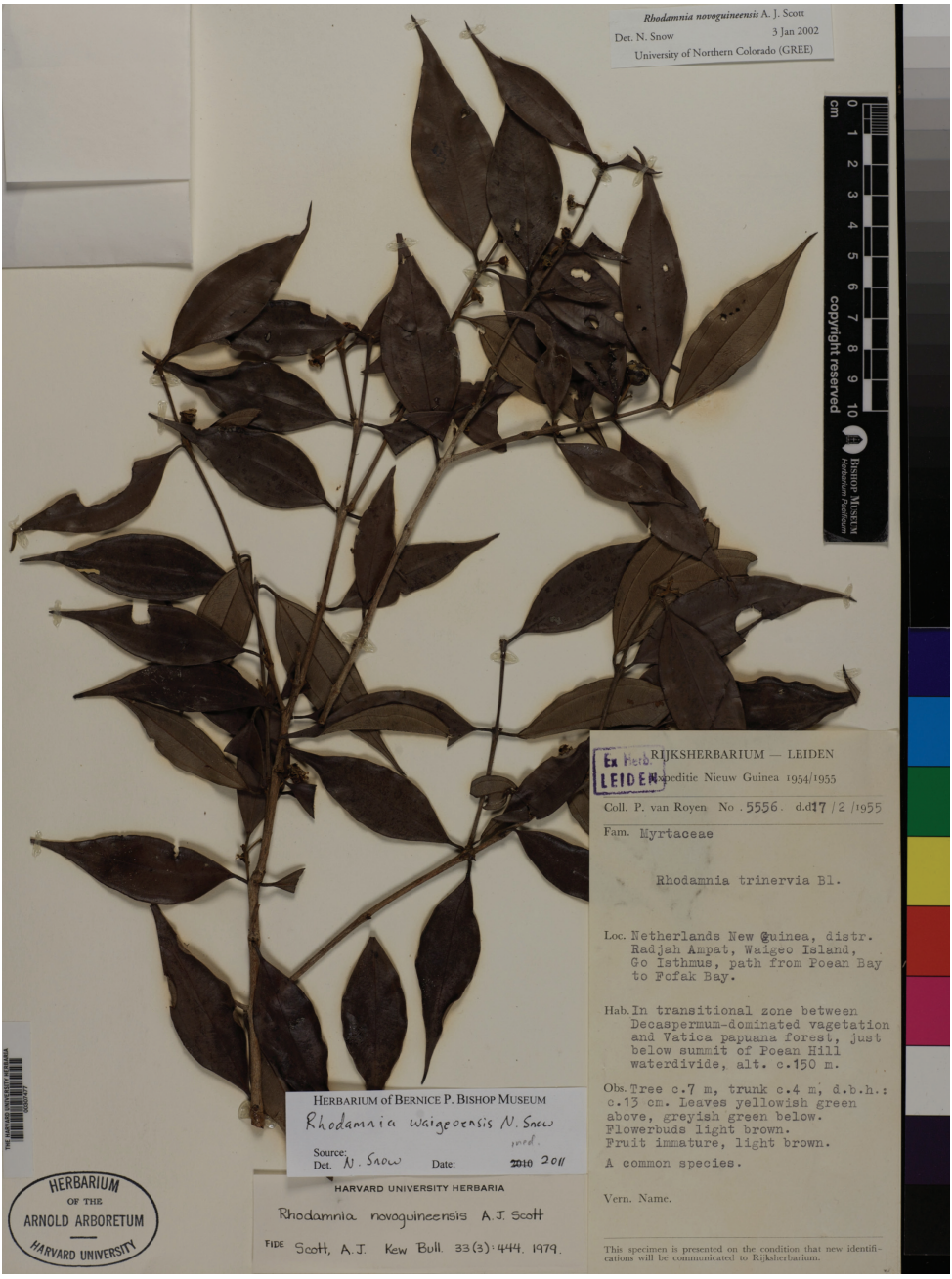

Figure 6. *Rhodamnia waigeoensis* N. Snow. Photo of the the holotype at A (*P. van Royen 5556*)

mostly yellowish or somewhat ferrugineous but becoming more whitish with age. Leaves opposite, evenly distributed along branchlets, discolorous, glossy above and below, the nacreous sheen below imparted by the dense, tightly appressed greenish-white indumentum. Colleters absent. Petioles 5–6.5 mm long, somewhat flat-

tened above, densely sericeous (or somewhat tomentose with age), the indumentum yellowish but aging whitish. Leaf blades (3.5–)6.0–10.0 cm long, (1.8–)2.5–3.7 cm wide, narrowly ovate to ovate, surface flat or slightly wavy; base cuneate, apex acuminate and occasionally somewhat falcate, tip acute; venation perfect basal acrodromous; secondary veins numerous but thin, ca. 0.8–2.0 mm apart; marginal nerve prominent, mostly 0.7–0.9 mm from mid-leaf margins; margins flat; adaxial surface sparsely sericeous, midvein flush throughout, oil glands invisible; abaxial surface densely sericeous with greenish-whitish indumentum but this mostly not obscuring venation, midvein raised throughout, oil glands invisible. Inflorescence (limited material) a 3-flowered cyme, terminal, solitary (one per leaf subtending leaf); peduncle ca. 5 mm, stiff, terete in transsection, densely yellowish-orangish sericeous; pedicel to ca. 3 mm long, indumentum as per peduncle. Bracteoles 2, narrowly triangular and stiffly erect, ca. 2 mm long, ca. 0.5 mm wide, sericeous, sometimes persisting into fruit. Hypanthium cupulate, densely sericeous, oil glands absent, texture smooth. Calyx lobes 4, 2.3–3.5 mm long, broadly ovate, sericeous above, densely sericeous below, more or less reflexed in fruit. Petals 4, 5.5–7.0 mm long, width uncertain (material scanty), apparently obovate to broadly obovate, white (based on specimen label), sparsely sericeous above, densely sericeous below. Staminal disk 2.5–3.5 mm wide, densely short-hairy. Ovary apex densely short-hairy. Stamen number uncertain but almost certainly greater than 20, filaments and anthers red (from specimen label); anthers subcylindrical (material scanty), ca. 0.5 mm. Stigma not seen. Locule 1, placentation parietal, placentas 2, ovules numerous. Fruit (reportedly immature) globose-subglobse, up to 8 mm long and 9.5 mm wide, light green when immature, densely sericeous but indumentum thinning with maturity. Seeds irregularly angular, up to 4 mm long (small sample), up to 9 per fruit, crowded; seed coat hard. Embryos not seen.

Phenology. Flowering February; fruiting in January and February.

Distribution. Waigeo Island, Indonesia; from ca. 10–150 m elevation in xerophytic, Myrtaceae-dominated vegetation at lower elevations behind and upslope of the village of Waifoi, and from transitional forests dominated by *Decaspermum* J.R. Forst. & G. Forst. (Myrtaceae) or *Vatica rassak* Blume (=*V. papuana* Schum. & Hollr. [synonym]) (Dipterocarpaceae) at the higher elevation (ca. 150 m).

Conservation status. Data Deficient given the lack of recent information or collections. *Rhodamnia waigeoensis* is presently known only from two collections. The specimen on the type label indicates that the species was common locally at the time of its collection nearly sixty years ago. A vegetation type similar to that of the type gathering occurs on the island of Rauki, where the species also may occur. While the reported ethnobotanical use of *R. waigeoensis* for cigarette making may lend the species some protection, it also may have encouraged overexploitation.

Vernacular name. *Kikir* (in the Malayan language).

Ethnobotany. The herbarium label indicates that the leaves are used for making cigarettes.

Comments. *Rhodamnia waigeoensis* belongs in the "pearly"group of species given its nacreous indumentum (Snow 2007). Scott (1979) included the type gathering of *R. waigeoensis* in *R. novoguineensis* A.J. Scott and the paratype gathering in *R. pachyloba* A.J. Scott.

Rhodamnia waigeoensis differs from *R. novoguineensis* by its thickly coriaceous leaves (vs. thinly coriaceous in *R. novoguineensis*), consistently basal acrodromous leaf venation (vs. even or uneven suprabasal acrodromous in *R. novoguineensis*), dense abaxial laminar indumentum with yellowish trichomes (vs. relatively sparse and whitish in *R. novoguineensis*), solitary flowers (vs. triads or few-flowered racemes in *R. novoguineensis*), thicker (0.5–0.7 mm wide) and rigid pedicels (vs. ca. 0.3 mm thick and flaccid in *R. novoguineensis*).

Waigeo Island is part of the Raja Ampat Islands of Indonesian New Guinea. The region harbors unusual vegetation assemblages (van Royen 1960), has high rates of endemism (Supriatna 1999), and was the subject of relatively recent rapid-assessment surveys (Takeuchi 2003a). Van Royen (1960: 54–56) summarized the vegetation on portions of Waigeo Island using six broad categories. One of these, xerophytic vegetation, is described as having three variants, one being dominated by Myrtaceae.

The label of the type specimen refers directly to the xerophytic vegetation located behind the small village of Waifoi on the east bank of Majalibit Bay. Takeuchi (2003a,b) reported that the Waigeo ultrabasic vegetation resembles the pioneer communities on the ultrabasics at the Kamilai Wildlife Management Area (KWMA) in the Bowutu Mountains (Morobe Province, Papua New Gueina). Communities at KWMA can be topographically unstable due to landslides, but in general appearance and composition are similar to those on Waigeo. However, Takeuchi (2003b) believes the vegetation on the Waigeo ultrabasics is primarily caused by fire succession.

A xerophytic vegetation similar to that occuring on the hills upslope of Waifoi, the village near the type collection, was encountered elsewhere by van Royen (1960: 39, 41) in the Kambelay Hills and the Go Isthmus of Waigeo Island. This general type of xerophytic vegetation is said to recur on Rauki Island, which lies northwest of Kabaré Bay, where it occurs at the higher elevations (probably less than ca. 40 m, but reported by van Royen [p. 45] as 25 m) along the southern end of the island (van Royen 1960: 44) at ca. 0°52'S, 130°56'E (coordinates based on Google Earth™ [accessed 2 June 2009]). (Rauki Island has been known previously as Rawak, Rawah or Lawak [van Royen 1960: 43]). The substrates underlying the xerophytic vegetation of Rauki include ultrabasic outcrops among the more prevalent limestone (van Royen 1960: 45).

Van Royen (1960: 32) described the soils underlying the xerophytic vegetation on Waigeo as "sandy brown clays with much limestone". The relatively open vegetation on the slopes was indicated as being spare of trees but conspicuous in its presence of shrubby Myrtaceae. Noted specifically for Myrtaceae (van Royen 1960: 32, 55, 59) were *Baeckia frutescens* L., *Myrtella beccarii* F. Muell. and *Decaspermum rubrum* (Blume) Baill. (as *D. fruticosum* J. R. Forst. & G. Forst. var. *rubrum*, a nomenclatural change that was apparently never validly published [Scott 1985; Govaerts et al.

2008]), and "*Rhodamnia trinervia* Reinw. ex Blume". However, the collection number (5556) that van Royen (1960: 59) cited for *R. trinervia* represents the holotype of *R. waigeoensis*, and *R. trinervia* is now considered to be a synonym of *R. rubescens* (Benth.) Miq. (e.g., TPL 2012).

Specimen examined. West Papua (Papua Barat; as Radjah Ampat on label), Waigeo Island, Waifoi on E bank of Majalibit [= Mayalibit] Bay, 18 Jan 1955, P. van Royen 5227 (L).

Updated distribution for *Rhodamnia sharpeana*

Snow (2007) previously described *R. sharpeana* from Queensland, Australia, where it occurs in rainforests between 50–500 m, ranging from the vicinity of Isabella Falls north throughout much of Cape York Peninsula. The specimen cited below from Kamiali Wildlife Management Area (KWMA) in Papua New Guinea extends the range north by ca. 650 km from the collections on Cape York Peninsula, whereas the specimen from Tagala (Tagula) Island extends its range eastwards approximately 1000 km from the collections in North Kennedy District, Queensland (Snow 2007). The specimen from Kamiali also increases the known altitudinal range by ca. 160 meters and represents a first report of the species occurring over ultrabasic substrates (Takeuchi 2003; Snow and Takeuchi 2009).

Phenology. Flowering September through December; fruiting presumably October through at least February (Snow 2007).

Distribution. Northeastern Australia to east-central and southeastern Papua New Guinea; rainforests (including ultrabasics at Kamiali in Papua New Guinea) to margins of anthropogenically derived grassland (*Brass 28176*); near sea level to 500 m.

Conservation status. Least Concern (IUCN, 2010) based on its known distribution and abundance.

Comments. The known range of *R. sharpeana* is now considerably wider than previously understood (Snow 2007). In Papua New Guinea it occurs on floodplains and along streambanks in Kamiali Wildlife Management Area (KWMA), and in anthropogenically derived grasslands on Tagula Island in the Louisiade Archipelago (Fig. 1). Takeuchi (2003b) suggested that the effect of ultramafic substrates on plant distributions is reduced with increasing levels of humidity. The presence of *R. sharpeana* in high rainfall environments at KWMA may not be surprising, given our newer understanding of its wider geographical distribution.

Specimens examined. Papua New Guinea. Morobe Province, Kamiali Wildlife Management Area; alluvial floodplain along Saia (Sela) River, 7°21.5'S, 147°08'E, ca. 25 m, 25 May 2000, W. Takeuchi 14405 (K!); near mouth of Saia River at mount of Hessen Bay, alluvial flatland forest, sea level, 7°21.7'S, 147°08.3'E, common riverbank shrub, 4–5 m height but forest occurrences much taller; leaves dry-textured, adaxially dark dull green, petals white, W. Takeuchi & A. Towati 14841 (K!); ridge to Blue Mt, 7°17'29"S, 147°05'12"E, ca. 762 m, 28 Feb 2005, W. Takeuchi & D. Ama 18977

(BISH (736568! and 736569!), LAE [n.v.]). Milne Bay Province, Sudest [= Tagula or Tagala] Island, (inland from) Rambuso, 300 m, 20 Sep 1956, L. J. Brass 28176 (BISH 733105!; A n.v., K n.v., L n.v., US n.v.).

Discussion

Sixteen new species of *Rhodamnia*, including the five newly proposed here, have been described since Scott's (1979) generic revision (Guymer and Jessup 1986; Guymer 1998; Snow and Guymer 1999; Snow et al. 2001; Snow 2007; Snow and Takeuchi 2009). Apart from the new species and those that Scott (1979 and see above) treated in other taxa, the species of *Rhodamnia* that I recognize for New Guinea differ from Scott (1979) in only two ways. First, I follow White (1951) and recognize *R. propinqua* as distinct from the Australian *R. blairiana*. Second, I maintained the Australian species *R. spongiosa* (F.M. Bailey) Domin as distinct from the New Guinea species *R. glauca* Blume (Snow 2007).

Additional studies still are clearly needed in *Rhodamnia*. The phylogeny of the genus has never been established, and the hypothesized informal groups of *Rhodamnia* (Snow 2007) need testing. All new collections from New Guinea and Malesia deserve close scrutiny. Scott (1979) adopted a broad taxonomic concept of *R. cinerea* Jack and probably was correct to synonymize many names therein given its wide geographical distribution. However, I have seen newer collections from Malesia that may merit taxonomic recognition, so a thorough review of the Malesian species, including *R. cinerea*, is now warranted given the many recent collections across that region.

Efforts also should be made to recollect all species of *Rhodamnia* in New Guinea given the paucity of specimens for many species and the present inability to assign conservation threat assessments with high levels of confidence. Two suggestions for collecting in remote, biodiverse areas are worthy of repeating. First, as Takeuchi (2000) expressed for New Guinea generally, survey botanists should collect uncritically while doing inventories, since taxonomic novelties and range extensions often are discovered only many years later in the herbarium by taxonomic specialists (Bebber et al. 2010; Snow et al. 2012), and because specimens that appear to be known species may in fact be taxonomic or geographical novelties. Second, workers are encouraged to include observations of local relative abundance for each specimen, given the value that such information can provide for later conservation threat assessments (Snow 2011: 687-688), however tentative they may be.

Acknowledgments

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Brass 22718 and van Royen 5556. Krista Anandakuttan provided the illustrations of *R. makumak* and *R. toratot* while in residency at the Bishop Museum. Drs. Michael Kiehn (W) and William A. Weber (COLO) translated passages from German. Support for curatorial work of New Guinea specimens was supported in part by the National Science Foundation (DEB 1057453) to Dr. Shelley James (BISH), whom I thank for forwarding digital images. Casey Currier also assisted with the preparation of some digital figures. Dr. Kanchi Gandhi (A) checked the derivation of Latin epithets; and Dr. Peter Wilson (NSW) and Bryan Simon (BRI) contributed to and confirmed some observations of *R. toratot* and *R. makumak*. I thank Dr. Wayne Takeuchi and an anonymous reviewer for their suggestions. This paper represents Contribution no. 2012-015 to the Pacific Biological Survey.

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Three new species of *Pilea* (Urticaceae) from limestone karst in China

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Abstract

Three hitherto undescribed species of *Pilea* (Urticaceae) from limestone karst in China are described and illustrated. Affinities of the species are discussed and Global Species Conservation Assessments presented. The new species are *Pilea cavernicola* A.K. Monro, C.J. Chen & Y.G. Wei, **sp. nov.** (Vulnerable) which most closely resembles *P. scripta* (Buch.-Ham. ex D.Don) Wedd. and *P. gracilis* Handel-Mazzetti, *Pilea shizongensis* A.K. Monro, C.J. Chen & Y.G. Wei, **sp. nov.** (Endangered) which is most similar to *Pilea aquarum* Dunn and *Pilea guizhouensis* A.K. Monro, C.J. Chen & Y.G. Wei, **sp. nov.** (Vulnerable) which resembles *Pilea boniana* Gagnep. and *P. rubriflora* C. Wright most closely.

Keywords

Urticaceae, Pilea, China, Guizhou, Yunnan, limestone karst, caves

Introduction

Pilea Lindley (1821: tab. 4) is the largest genus in the Urticaceae comprising ca 715 species (Monro, 2004) worldwide distributed throughout the tropics, subtropics and temperate regions (with the exception of Australia, New Zealand and Europe). South-east Asia is the centre of morphological and phylogenetic diversity for *Pilea* whilst the Greater Antilles and Andean countries are the centres of species diversity (Monro,

2006). *Pilea* is easily distinguished from other Urticaceae by the combination of opposite leaves and a single, ligulate, intrapetiolar stipule in each leaf axil and pistillate flowers with a 3-5 parted asymmetrical perigonium. The majority of species are succulent herbs, epiphytes or small shrubs growing in heavy shade at altitudes between 1000 and 3000 m above sea-level. Within China 81 species are recognised (Chen and Monro 2003, Chen and Monro 2007) and of these 32 are endemic.

As part of ongoing research into the diversity of cave-dwelling Urticaceae the authors undertook four field trips to SW China in 2009 and 2010. Collecting was focused on the karst area in Guangxi, Guizhou and Yunnan and caves, stone forests (karst cockpit formations), gorges and natural forest were sampled. During the course of these collecting trips seven collections (not all in caves) corresponded to unknown species of *Pilea*, three of which are described here. Their affinities are discussed and position within Weddell's (1869) and Chen's (1982) subdivision of the genus indicated, which although not phylogenetic, is based on the most comprehensive world-wide treatment of the genus.

Collecting in Karst is difficult as areas away from roads are sparsely populated and the terrain is steeply dissected and difficult to travel across. A consequence of this is that there are relatively few collections from such areas and undescribed species are frequently represented by very little material. Describing species based on a single or only two collections is problematic as there is no estimate of variation within the species and so the risk of over recognising species is greater. This is compounded in Floras such as China's where there has been a tradition of describing species from single collections resulting in a situation whereby the most closely related species may also be known from a single collection. Despite the above we have decided to describe one of the species in this manuscript based on a single collection as we feel that, given China's fast changing landscape and the fragility of many of the localities, to describe the species now affords the best hope for their conservation.

Methods

Herbarium specimens were compared with collections at IBK, BM and K and with scanned images of the collections at PE (http://pe.ibcas.ac.cn/herbinfor/vhtypequery.aspx) and HK (http://www.hkherbarium.net/Herbarium/tcc_pop.aspx) using the Flora of China. A morphological species concept developed during the course of previous taxonomic research on Pilea (Monro 2001 and 2006) was employed to delimit and compare taxa. Material was examined under a Wild M3C binocular microscope and Planapo lens at X64 to X400 magnifications.

In the case of cave habitats, photosynthetically active radiation (PAR) was recorded. Observations of PAR were made at several points in the caves associated with living plants and expressed as micro moles per m2 per second (mmol/m2/sec) using a Skye instruments 180° panorama light meter for each point. Where available these observations are included in the Distribution section of the species descriptions.

Conservation assessments were undertaken using IUCN (2001) criteria B & D. Species distributions were plotted on Google Earth and the nature of the vegetation cover, urbanisation and road proximity surrounding sites, combined with observations in the field, were used as indicators of plausible future threats.

Taxonomic treatment

***Pilea cavernicola* A.K. Monro, C.J. Chen & Y.G. Wei, sp. nov.**
urn:lsid:ipni.org:names:77123888-1
http://species-id.net/wiki/Pilea_cavernicola
Figs 1 A–E, 2 A–C, 3 A–B

Diagnosis. Most similar to *Pilea scripta* from which it can be distinguished by the shorter stems, ovate rather than elliptic or oblong leaves, stipules with auriculate bases rather than deltate ones, the staminate tepals not ribbed and the sub-compressed elliptic rather than ovoid achenes with smooth non verrucose surfaces.

Type. CHINA. Guangxi: Fengshan County, Paoli Town, Yangzi cave, 490 m, 024°23'22.2"N, 107°03'59.1"E (DMS), 9 May 2010, *A. K. Monro & Y.G. Wei 6669* (holotype: IBK; isotypes: BM001001214, MO, PE).

Description. Herb to 50 cm, terrestrial. Stems erect, drying brown, maroon to green when fresh, glabrous or pubescent at the nodes and towards the base, where pubescent the hairs 1.0 mm, erect, crooked, cystoliths fusiform, the internodes 23–300 × 1.5–2.5 mm, angulate to square in cross-section, striate. Stipules 2.5–4.0 mm, auriculate-ovate, drying brown. Leaves petiolate, distichous; petioles at each node subequal or unequal by ratio 1:1.1–2.8, 12–33 mm, pubescent or glabrous, where pubescent the hairs 1.0-1.25 mm, erect, weakly curved or crooked; laminae at each node equal or subequal, 26–90 × 12–46 mm, ovate, subchartaceous; 3-nerved, the lateral nerves visible for 2/3 or more of the lamina length, secondary nerves 7–11 pairs, borne 60–75° to the midrib, weakly curved; upper surface drying dark brown, green or bronze when fresh, glabrous, cystoliths densely scattered, less than 0.125 mm, elliptic and punctiform, midrib and secondary nerves sunken; lower surface drying brown to dark brown, pale green or flushed bronze-purplish when fresh, pubescent, the hairs 0.75–1.0 mm, appressed, weakly curved, eglandular; base symmetrical, cuneate or weakly decurrent; margin serrate, the basal 1/8–1/4 entire; apex symmetrical, cuspidate. Inflorescences 4–8 per stem, unisexual, staminate and pistillate inflorescences synchronous, born on separate stems; bracts 0.75 mm; bracteoles 0.5 mm. Staminate inflorescences 2 per axil, 17–22 mm, bearing 45–90 flowers in a loose cyme; peduncle 1/4 or less inflorescence length, 0.75 mm in diameter, glabrous, occasionally with cystoliths present; pedicels 0.50–1.5 mm, glabrous. Staminate flowers 1.5 × 1.5 mm immediately prior to anthesis, green-brown; tepals 4, 1.75 mm, valvate, fused for their basal 1/3, elliptic, glabrous, the subapical appendage less than 0.25 mm, corniculate, glabrous; stamens 4. Pistillate inflorescences 1 or 2 per axil, 8–13 mm, bearing 150–300 flowers in a loose

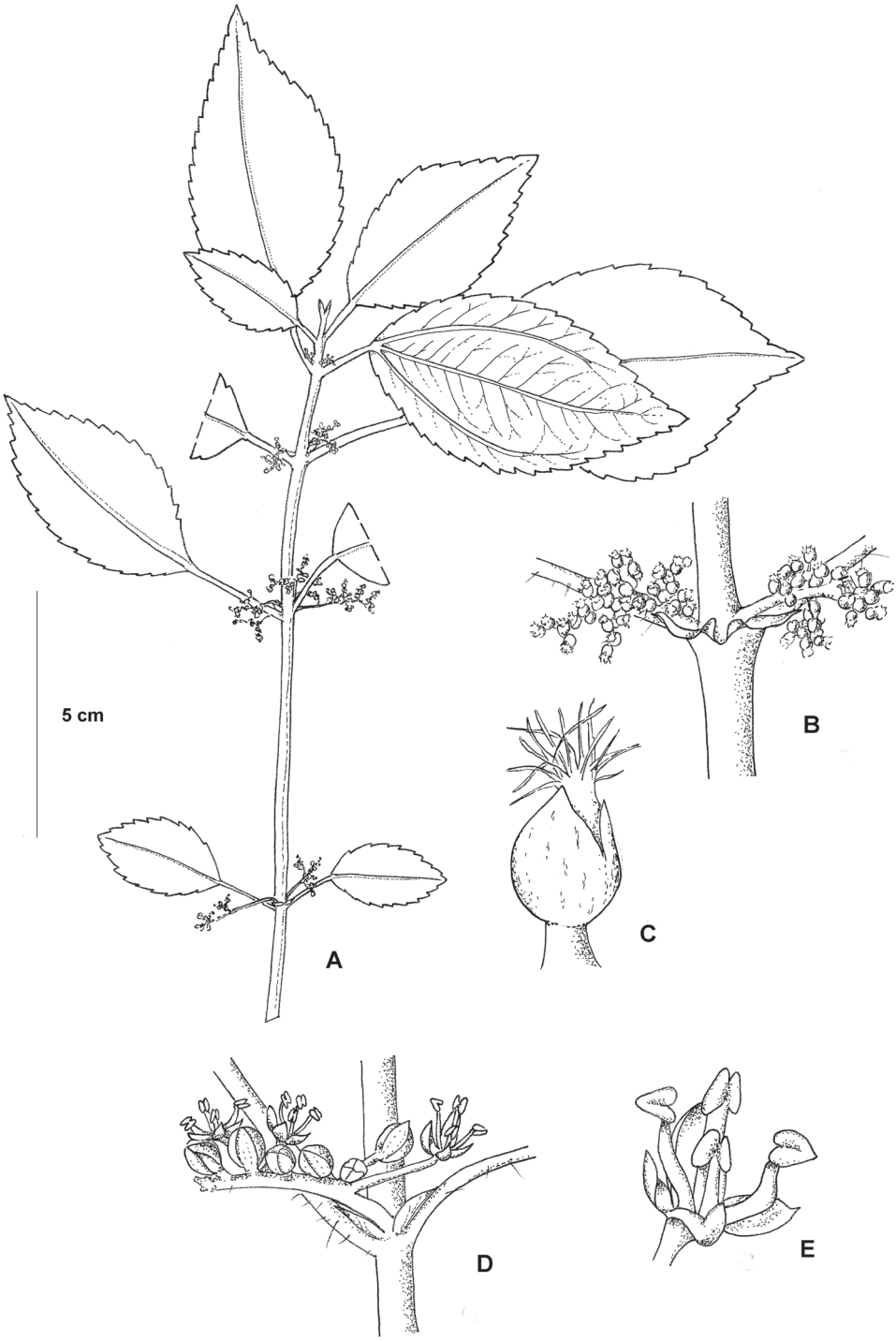

Figure 1. *Pilea cavernicola*. **A** Habit **B** Close up of a pistillate inflorescence **C** Close up of a pistillate flower **D** Close up of staminate inflorescence **E** Close up of staminate flower. Based on *Monro & Wei 6669*.

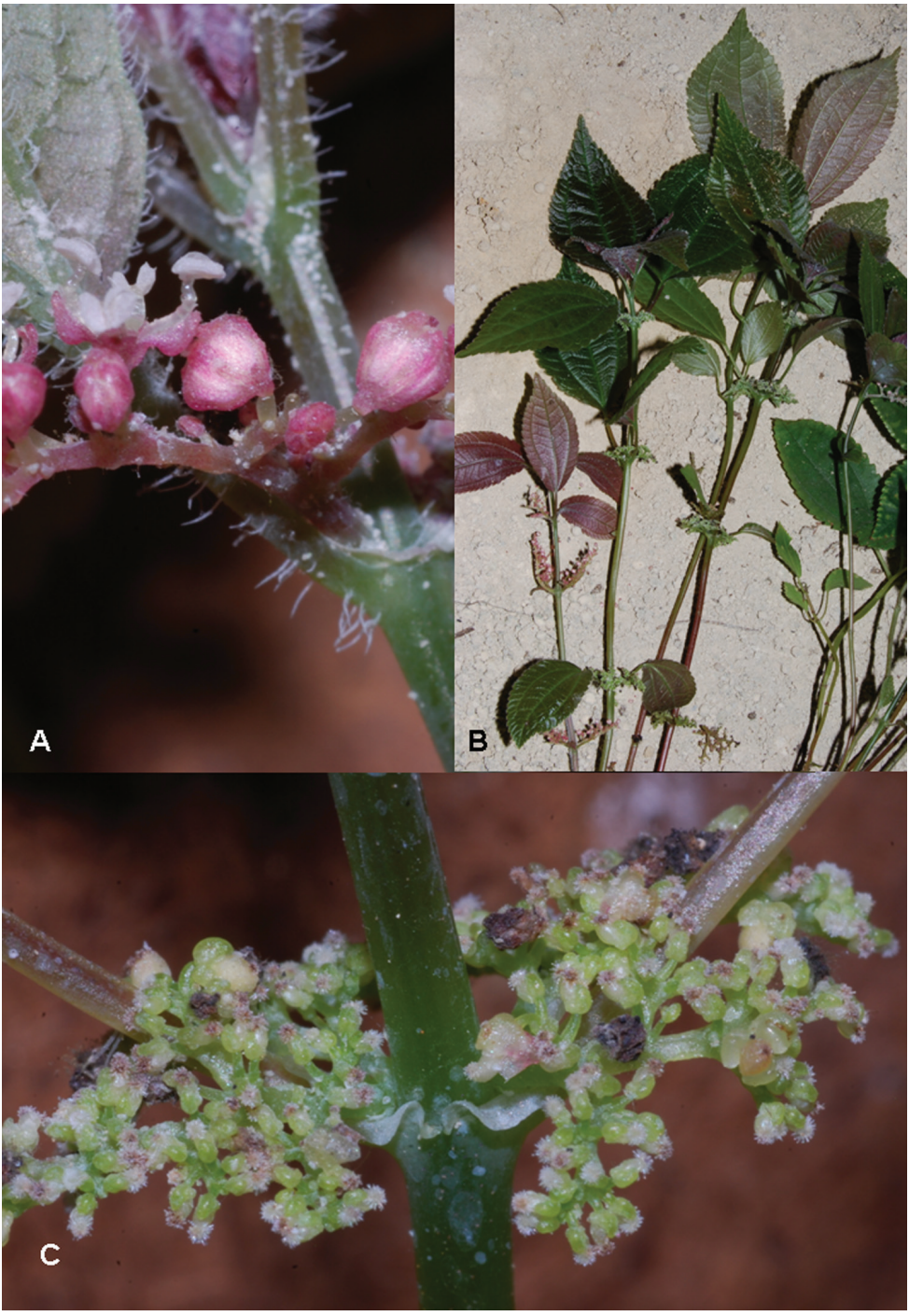

Figure 2. *Pilea cavernicola*. **A** Staminate flowers **B** Habit showing cave floor substrate in the background **C** pistillate inflorescence and flowers. Images of *Monro & Wei 6669.*

Figure 3. Habitats of species described in this manuscript. **A, B** *Pilea cavernicola,* Yangzi cave, Fengshan County. Locality for *Monro & Wei 6669* **A** Interior of cave **B** Exterior view of the cave **C** Habitat of *Pilea shizongensis,* Feng Huang Gu gorge, Shizong County. Locality for *Monro & Wei 6727* **D, E** Habitat of *Pilea guizhouensis,* petaloid travertine wall of Malinghe Gorge **E** close-up of petaloid travertine formation, Locality for *Monro & Wei 6715*.

cyme; peduncle 1/4 to 1/3 inflorescence length, 0.75 mm in diameter, densely covered in cystoliths, cystoliths punctiform, glabrous; pedicels 0.25–0.75 mm, glabrous. Pistillate flowers 0.50–0.75 mm, tepals 3, unequal, glabrous, adaxial tepal 0.50–0.75 mm, oblong or ovate, the dorsal tepal appendage 0.50–0.75 mm, oblong, markedly thickened almost hood-like; the lateral tepals 0.375–0.50 mm, asymmetrically ovate. Infructescences 8–13 mm; peduncle 1/4 to 1/3 infructescence length; achenes 0.75× 0.675 mm, sub compressed, asymmetrically ellipsoid, the abaxial margin very narrowly thickened.

Distribution. North West Guangxi Province, ca 500–1000 m, caves in limestone karst, growing at any point from the back to the entrance of the cave, PAR 0.02-1.39 mmol/m2/sec (ca 0.04-2.78 % full daylight).

Etymology. The species name refers to the cave-dwelling habit of this species.

Paratypes. CHINA: Guangxi Province: Fengshan County, Paoli Town, Sidui Village, Xibi cave, 740 m, 024°24'38.5"N, 107°04'53.5"E (DMS), 8 May 2010, *A. K. Monro & Y.G. Wei 6654* (IBK, BM001001215, PE, MO).

Discussion. Comparison of the holotype and paratype material with type specimens from the herbaria listed in the methods section recovered *Pilea scripta* (Buch.-Ham. ex D.Don) Wedd. and *P. gracilis* Handel-Mazzetti as most similar to *Pilea cavernicola*. *Pilea scripta* can be distinguished from *P. cavernicola* based on stem height, leaf shape, stipule shape, staminate tepal morphology and achene morphology as summarised in Table 1. *Pilea gracilis* can be distinguished from *P. cavernicola* based on leaf shape, stipule morphology, staminate and pistillate inflorescence morphology and achene morphology as summarised in Table 2.

Table 1.

Characters	*Pilea cavernicola*	*Pilea scripta*
Stem height	to 50 cm	to 1.5 m
Leaf shape	ovate	elliptic or oblong-lanceolate
Stipule morphology	ovate with conspicuous auriculate base	triangular with deltate base
Staminate tepal morphology	not conspicuously ribbed	conspicuously ribbed
Achene morphology	sub compressed asymmetrical ellipsoid, the surface smooth	compressed asymmetrical ovoid, the surface verrucose

Table 2.

Characters	*Pilea cavernicola*	*Pilea gracilis*
Leaf shape	ovate, apex cuspidate	elliptic or elliptic-lanceolate, apex acuminate or caudate-acuminate
Stipule morphology	ovate with conspicuous auriculate base, 2.5–4.0 mm	triangular with deltate base, ca 1 mm
Staminate inflorescence	17–22 mm	20–50 mm
Pistillate inflorescence	8–13 mm	20–50 mm
Achene morphology	the surface smooth	the surface verrucose or verrucose-spinulose

Pilea cavernicola falls within Weddell's (1869) Dentatae-Gerontogeae subdivision and Chen's (1982) Urticella Section of the genus.

Conservation status. Using IUCN criteria (IUCN 2001) *Pilea cavernicola* is considered Vulnerable (VU). *Pilea cavernicola* is known from only two localities (IUCN criteria D2, number of locations <5). At these localities the populations of this species comprises ca 100-200 mature individuals (IUCN criteria D1, number of mature individuals <1000). Using the IUCN methodology our Global Conservation Assessment for *P. cavernicola* is Vulnerable (VU) based on criteria D1 and D2: population size and number of locations combined with a plausible future threat that could drive this taxon to Endangered in a very short time. Plausible threats include the location of both caves at the edge of agricultural land, the use of the entrance of one of the cave localities (Yangzi cave) to cultivate medicinal plants (*Corydalis* sp.), requiring the terracing and tilling of the substrate. In addition mining is growing rapidly in the whole region and any localities close to roads are vulnerable to exploitation.

Pilea shizongensis **A.K. Monro, C.J. Chen & Y.G. Wei, sp. nov.**
urn:lsid:ipni.org:names:77123889-1
http://species-id.net/wiki/Pilea_shizongensis
Figs 3 C, 4 A–C, 5 A–D

Diagnosis. Most similar to *Pilea aquarum* from which it can be distinguished by the shorter stem, serrate rather than dentate leaves, shorter stipules and glabrous pistillate tepals.

Type. CHINA. Yunnan: Shizong County, Feng Huang Gu gorge, 1200 m, 024°37'54.0"N, 104°14'43.9"E (DMS), 14 May 2010, *A. K. Monro & Y. G. Wei 6727* (holotype: IBK; isotypes: BM001001216, MO, PE).

Description. Herb to 20 cm, epipetric and terrestrial. Stems procumbent and erect, drying dark brown, maroon to dark green when fresh, pubescent, more densely so towards the shoot tips, the hairs 0.5 mm, erect or weakly appressed, curved or crooked, orange-brown peltate glandular, cystoliths absent, the internodes 4–38 × 1.5–2.0 mm, angulate in cross-section, striate. Stipules 2.5–3.0 mm, auriculate-cordiform, drying brown. Leaves petiolate, distichous; petioles at each node unequal by ratio 1:3–4.4, 3–20 mm, pubescent, the hairs 0.25-0.375 mm, erect, strongly curved to curved; laminae at each node equal or subequal, 11–35 × 7–17 mm, ovate to broad ovate, chartaceous; 3-nerved, the lateral nerves visible for less than 2/3 of the lamina length, secondary nerves 4–6 pairs, borne 45–60° to the midrib, straight or weakly curved; upper surface drying brown or dark brown, dark green with maroon nerves and green flushed maroon when fresh, sparsely pubescent, the hairs 0.50–0.675 mm, appressed, straight or weakly curved, cystoliths absent, midrib raised; lower surface drying grey-brown when fresh, nerves densely pubescent, the hairs 0.375 mm, weakly appressed, curved, orange-brown peltate glandular, midrib and lateral nerves raised, cystoliths fusiform, randomly scattered; base symmetrical, cuneate or obtuse; margin serrate, the basal 1/4 entire; apex symmetrical, subcus-

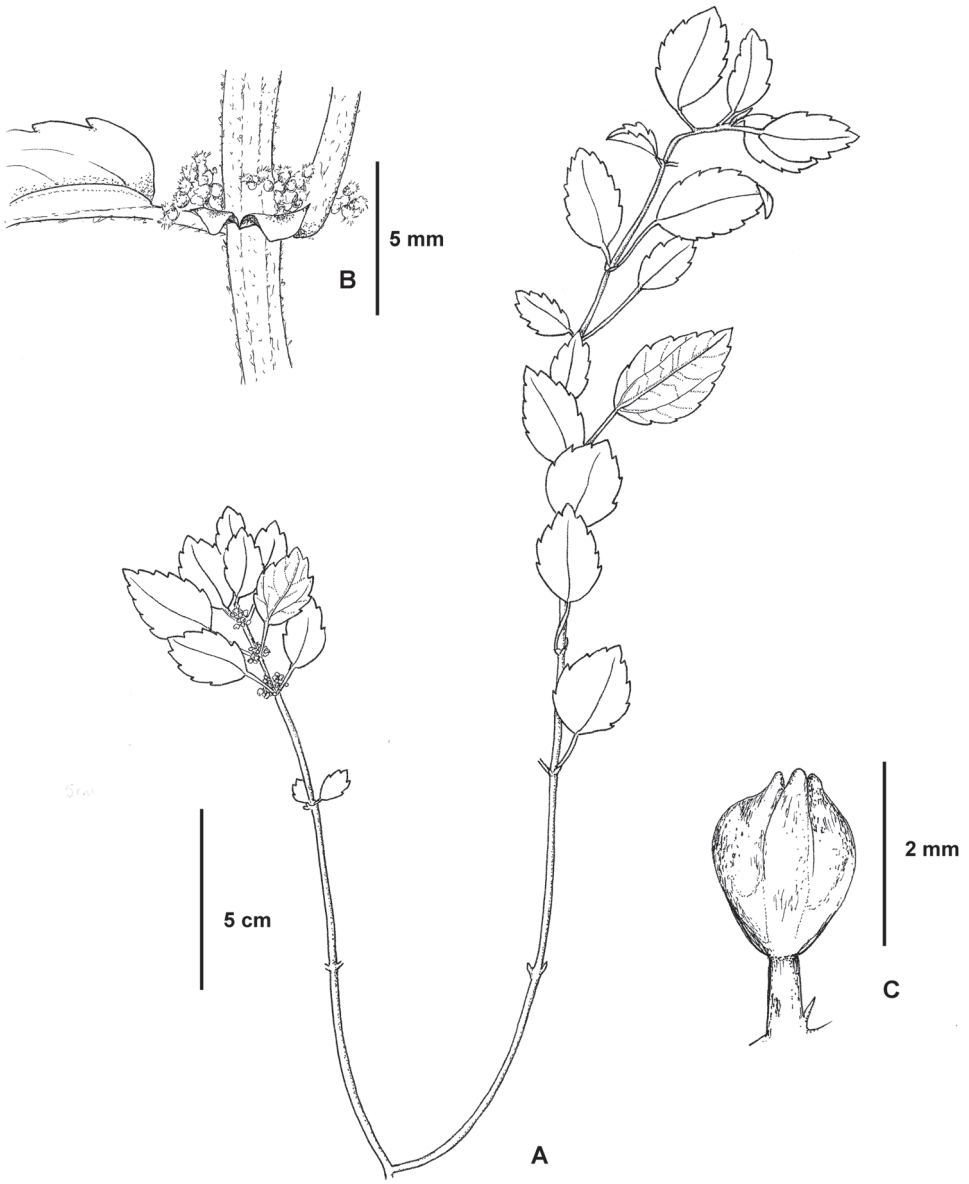

Figure 4. *Pilea shizongensis.* **A** Habit **B** Close up of pistillate inflorescence **C** Close up of a staminate flower. Based on *Monro & Wei 6727*.

pidate or cuneate. Inflorescences 4–10 per stem, unisexual, staminate and pistillate inflorescences synchronous, born on separate stems; bracts 0.375 mm; bracteoles 0.3–0.5 mm. Staminate inflorescences solitary, 17.5–25 mm, bearing 7–16 flowers in a loose cyme; peduncle 1/4 or less inflorescence length, 0.5 mm in diameter, pubescent, cystoliths absent; pedicels 0.8–1.0 mm, glabrous. Staminate flowers

Figure 5. *Pilea shizongensis.* **A** Habit **B** Shoot tip **C** Close up of a staminate flowers **D** Close up of pistillate inflorescence and flowers. Based on *Monro & Wei 6727*.

1.5–2.0 × 1.5–1.8 mm immediately prior to anthesis, deep pink; tepals 4, imbricate, 1.75 mm, fused for their basal 1/4, ovate or elliptic, glabrous, the subapical appendage 0.375 mm, corniculate, glabrous; stamens 4. Pistillate inflorescences solitary, 2.0–2.5 mm, bearing 17–30 flowers in a compact cyme; peduncle 1/2 to 2/3 inflorescence length, 0.375 mm in diameter, glabrous, cystoliths absent; pedicels 0.25–0.375 mm, sparsely pubescent. Pistillate flowers 0.375–0.50 mm, tepals 3, unequal, glabrous, adaxial tepal 0.5 mm, oblong, the dorsal tepal appendage 0.375 mm, oblong, markedly thickened; the lateral tepals 0.25–0.375 mm, asymmetrically ovate. Infructescences not seen.

Distribution. Yunnan Province, Feng Huang Gu gorge, ca 1200 m, in limestone karst, growing on the floor of the gorge in deep shade.

Etymology. The species name refers to county of the locality of the only known collection of this species, Shizong.

Discussion. Comparison of the holotype material with type specimens from the herbaria listed in the methods section recovered *Pilea aquarum* Dunn as most similar to *Pilea shizongensis*. It can be distinguished from *P. shizongensis* based on pubescence, leaf margin morphology and pistillate tepal and flower morphology as summarised in Table 3.

Pilea shizongensis falls within Weddell's (1869) Dentatae-Gerontogeae subdivision and Chen's (1982) Urticella Section of the genus.

There is some confusion over the delimitation of *Pilea aquarum* and this is relevant to the delimitation of *P. shizongensis*. It would appear that the relatively rare character trait of pubescent pistillate tepals has been overlooked by several authors and that *Pilea aquarum sensu strictu* encompass a relatively narrow range of morphological variation which would exclude the subspecies *P. aquarum* subsp. *brevicornuta* and *P. aquarum* subsp. *acutidentata*.

Conservation status. Using IUCN criteria (IUCN 2001) *Pilea shizongensis* is considered Endangered (E). *Pilea shizongensis* is known from a single locality (IUCN criteria D2, number of locations <5). At these localities the populations of this species comprises ca 100-200 mature individuals (IUCN criteria D1, number of mature individuals <250). Using the IUCN methodology our Global Conservation Assessment for *P. shizongensis* is Endangered (E) based on criteria D1 and D2: population size and number of locations combined with a plausible future threat that could drive this taxon to Endangered in a very short time. Plausible threats include the location of the only known population within a tourist site and close to the only path used by visitors to access the gorge bottom. Any expansion of the path, fire or dumping of refuse by visitors could destroy this population.

Table 3.

Character	*Pilea shizongensis*	*Pilea aquarum* subsp. *aquarum*
Stem height	10–20 cm	30–40 cm
Leaf margin	serrate	dentate
Pistillate tepal pubescence	glabrous	pubescent

Pilea guizhouensis **A.K. Monro, C.J. Chen & Y.G. Wei, sp. nov.**
urn:lsid:ipni.org:names:77123890-1
http://species-id.net/wiki/Pilea_guizhouensis
Figs 3 D, E, 6 A–C, 7 A–C

Diagnosis. Most similar to *Pilea boniana* from which it can be distinguished by the shorter inflorescence length, staminate flowers composed of four rather than five and valvate rather than imbricate tepals, and smaller achene size.

Type. China. Guizhou: Xingyi County, Xingyi City, Malinghe Gorge, 950 m, 025°08'32.9"N, 104°57'11.7"E (DMS), 12 May 2010, *A. K. Monro & Y.G. Wei 6715* (holotype: IBK; isotypes: BM001001220, MO, PE).

Description. Herb or subshrub to 50 cm, epipetric or terrestrial. Stems erect, drying brown to dark brown, green and maroon at the nodes when fresh, glabrous, brown peltate glandular on young stems and flowering nodes, cystoliths elliptic or absent, the internodes 18–200 × 1.5–2.0 mm, irregularly circular and grooved in cross-section, striate. Stipules 2.0–2.5 mm, deltate, drying red-brown. Leaves petiolate, distichous; petioles at each node unequal by ratio 1:1.8-8.5, 1.5–37 mm, glabrous; laminae at each node subequal or unequal by ratio 1: 1.9–5.4, laminae 12–130 × 5–26 mm, ovate, lanceolate, asymmetrically elliptic, oblanceolate or obovate, chartaceous; 3–nerved, the lateral nerves visible for >7/8 or more of the lamina length, secondary nerves 8-14 pairs, borne 60–75° to the midrib, weakly curved; upper surface drying dark brown, dark green when fresh, glabrous, cystoliths 0.250–0.375 mm, 'V' shaped, midrib raised; lower surface drying brown to dark brown, pale green when fresh, glabrous, eglandular; base symmetrical or asymmetrical, cuneate or obtuse; margin discretely serrulate or serrate, the basal 1/8–1/4 entire; apex symmetrical, attenuate to acuminate. Inflorescences ca 3 per stem, unisexual, staminate and pistillate inflorescences synchronous, born on separate stems; bracts 0.75–1.0 mm; bracteoles 0.50–0.675 mm. Staminate inflorescences 15–20 mm, bearing ca 60 flowers in a loose cyme; peduncle ≤1/4 inflorescence length, 0.5 mm in diameter, glabrous; pedicels 1.0–1.5 mm, glabrous. Staminate flowers 1.5 × 1.5 mm immediately prior to anthesis, pale green; tepals 4, 1.75 mm, valvate, broad elliptic or obovate, fused for their basal 1/2, glabrous, the subapical appendage ≤0.25 mm, ridge-like, glabrous; stamens 4. Pistillate inflorescences solitary, 2.0–3.5 mm, bearing 19-42 flowers in a compact cyme; peduncle 1/4 to 1/3 inflorescence length, 0.375 mm in diameter, glabrous, cystoliths absent; pedicels 0.375–0.50 mm, glabrous. Pistillate flowers 0.50–0.75 mm, tepals 3, unequal, adaxial tepal 0.5 mm, oblong to keel-shaped, the tepal appendage 0.375–0.50 mm, appearing inflated; the lateral tepals 0.375 mm, asymmetrically ovate; staminodes not visible. Infructescences 4.0–4.5 mm; achenes 0.675 × 0.375 mm, compressed, asymmetrically ovoid, the margin narrowly thickened.

Paratypes. CHINA: Guizhou: Libo County, Yaolu Town, Huangcaoping, 650 m, 025°28'25"N, 108°04'15"E (DMS, both altitude and coordinates taken from Google Earth based on label data), April 24 2005, *S. Qing & D. Londong 34* (BM001001221, PE).

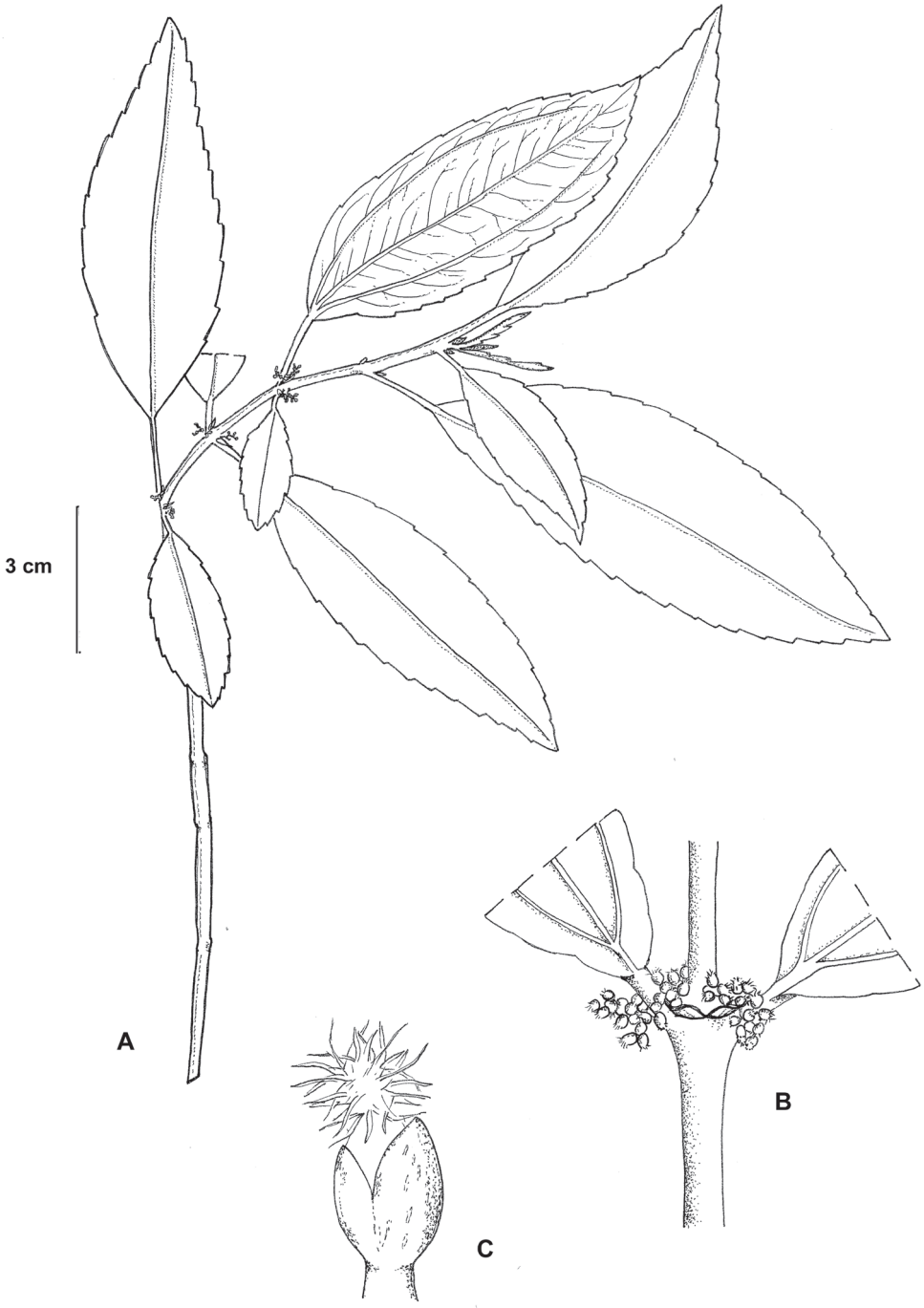

Figure 6. *Pilea guizhouensis.* **A** Habitat **B** close-up of pistillate inflorescence **C** close-up of a pistillate flower. Based on *Monro & Wei 6715*.

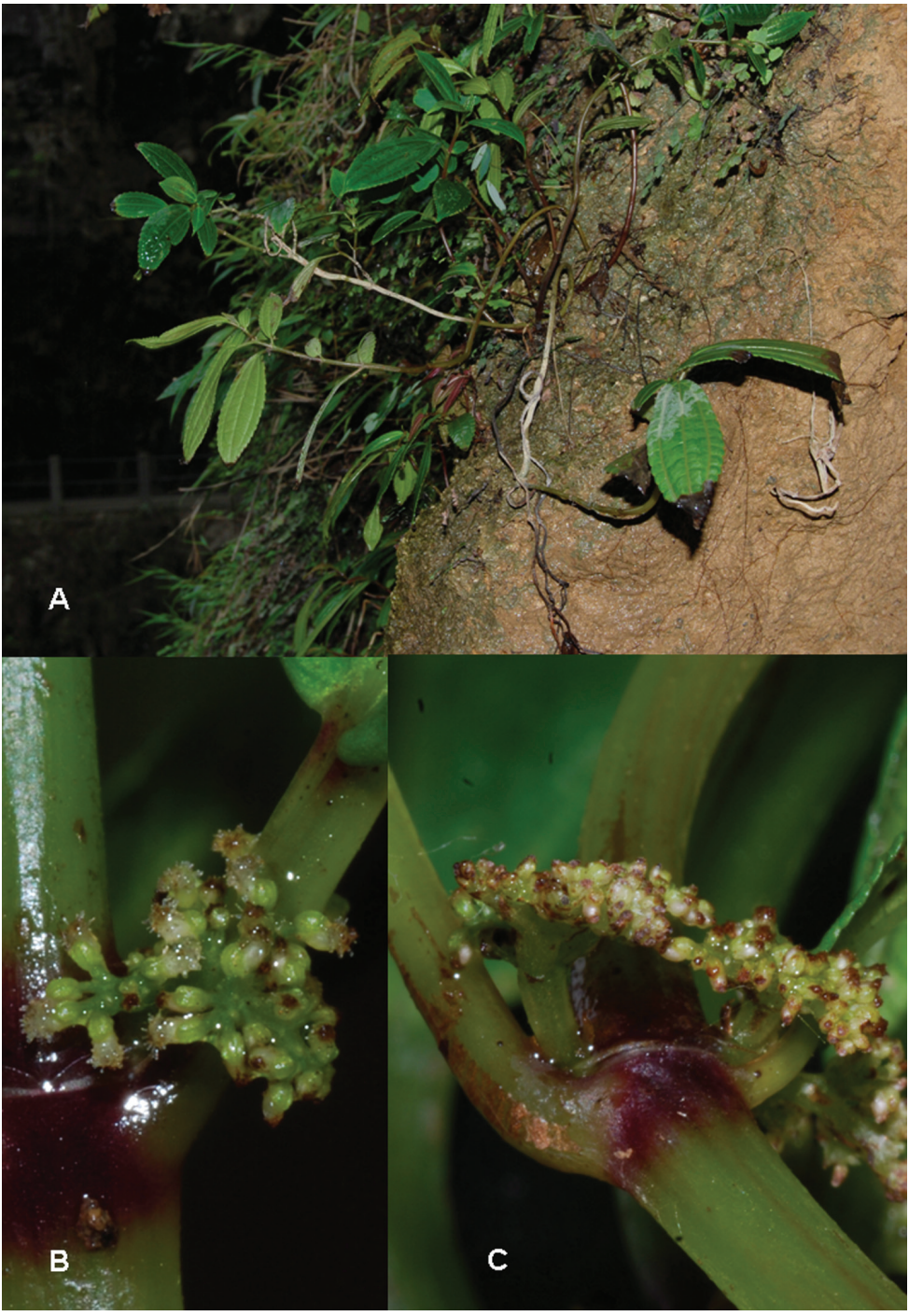

Figure 7. *Pilea guizhouensis.* **A** Habitat **B** close-up of pistillate inflorescence **C** close-up of a pistillate infructescence. Based on *Monro & Wei 6715*.

Distribution. Guizhou Province, Xingi County and Libo County, 650–950 m, in limestone Karst. The two localities are separated by ca 310km and represent semi-natural or naturally disturbed sites within an agricultural landscape.

Etymology. The species name refers to Province from which both collections of this species are known.

Discussion. Comparison of the holotype and paratype material with type specimens from the herbaria listed in the methods section recovered *Pilea boniana* Gagnep. and *P. rubriflora* C. Wright as most similar to *Pilea guizhouensis*. *Pilea guizhouensis* can be distinguished from *Pilea boniana* based on stipule, staminate, pistillate inflores and achene length and staminate tepal number as summarised in Table 4. *Pilea guizhouensis* can be distinguished from *P. rubriflora* based on internode, stipule and, staminate and pistillate flower morphology as summarised in Table 5.

Pilea *guizhouensis* falls within Weddell's (1869) Heterophyllae-Gerontogeae subdivision and Chen's (1982) Urticella Section of the genus.

Conservation status. Using IUCN criteria (IUCN 2001) *Pilea guizhouensis* is considered Vulnerable (VU). *Pilea guizhouensis* is known from two localities (IUCN criteria D2, number of locations <5). These two localities are ca 320 km apart and assuming that this species occurs within the 650-950 elevation range then the Extent of Occurrence between these localities is calculated to be 12,800 km2 (IUCN criteria B1, <20,000km2). Using the IUCN methodology our Global Conservation Assessment for *P. guizhouensis* is Vulnerable **(VU)** based on criteria B1 with a plausible future threat that could drive this taxon to Near Threatened in a very short time. Plausible threats include the presence of a tourist trail running through the Malinghe Gorge which may be expanded, re-routed or rebuilt resulting in damage to the populations. In addition the second locality is located close to an agricultural area and is therefore vulnerable to conversion from forest to farmland.

Table 4.

Character	*Pilea guizhouensis*	*Pilea boniana*
Stipules	2.0–2.5 mm	ca 1.0 mm
Staminate inflorescence	15–20 mm	60–160 mm
Pistillate inflorescence	2.0–3.5 mm	60–160 mm
Staminate flower tepals	4, valvate	5, imbricate
Achene	0.675 mm	ca 2.0 mm

Table 5.

Character	*Pilea guizhouensis*	*Pilea rubriflora*
Internodes	1.5–2.0 mm diameter	2–3 mm in dianeter
Stipules	2.0–2.5 mm, not ribbed	ca 7 mm, longitudinally ribbed
Staminate pedicels	1.0–1.5 mm	2–3 mm
Pistillate flower tepals	3	4

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RESEARCH ARTICLE

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Ridleyandra iminii (Gesneriaceae), a new species from Peninsular Malaysia

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Abstract

A new endemic species of *Ridleyandra* (Gesneriaceae), *R. iminii* Siti-Munirah from Peninsular Malaysia is described and illustrated. Among *Ridleyandra* species, it is the only one with a dark red flower.

Keywords

Gesneriaceae, *Ridleyandra*, Peninsular Malaysia, new species

Introduction

During a botanical collecting trip in 2008 to Gunung Benom, Pahang, Peninsular Malaysia, a new species of *Ridleyandra* was discovered: here described as *Ridleyandra iminii* Siti-Munirah. In Peninsular Malaysia, currently 12 species of *Ridleyandra* are known (Weber 1998; Kiew 2009). This is the first *Ridleyandra* species with deep red flowers to be described. Although in vegetative characters it resembles *R. morganii* (Franch.) A.Weber, it is completely different in the colour and patterning of the flower. The inside of the purple corolla tube of *R. morganii* has white lines on the lower surface of the throat, and the lobes are concolorous with the outside of the tube. In contrast, the corolla lobes and throat of *R. iminii* are red and contrast with the white outer surface of the tube, and the throat lacks contrasting lines. Weber has drawn attention on the coloration of *Ridleyandra* species. Flowers of other *Ridleyandra* species are yellow, white, blue or violet so the deep red throat is remarkable.

Taxonomy

Ridleyandra iminii **Siti-Munirah, sp. nov.**
urn:lsid:ipni.org:names:77123887-1
http://species-id.net/wiki/Ridleyandra_iminii
Figure 1

Diagnosis. *Ridleyandra iminii* is most similar to *R. morganii* (Franch.) A.Weber in its dentate leaves with blunt teeth more than 5 mm long, but it differs in its shorter peduncles (not 7–10 cm long), the deep red colouration of the corolla (not deep purple with white lines in the throat) and longer capsules (5-6 cm long, not 4.5–5 cm long).

Type. Peninsular Malaysia. Pahang, Gunung Benom, Krau Game Reserve. 8 January 2008 (fl & fr), Siti-Munirah FRI 55387 (holotype: KEP!).

Description. Perennial herb, **stem** unbranched, woody, to 25 cm long, glabrous except for dense dark uniseriate, multicellular hairs, ca 0.5 mm long, on upper portion of petioles, on the lower surface of midrib and on peduncles. **Leaves** opposite, clustered in a rosette at the top of the stem; petioles 1–4 cm long; lamina lanceolate-oblong, 9–18.5 × 3–5.5 cm, glossy above, slightly paler beneath, base attenuate, margin undulate, very coarsely serrate, teeth to nearly 1 cm long, broad and blunt, apex acute; midrib and veins impressed above, prominent beneath, lateral veins (10–)12(–16) pairs. **Inflorescence** single-flowered, peduncle slender, pale green, 5–8 cm long; bract pair lanceolate, 2–3 × 1–2 mm; pedicels 2.5–3 cm; *sepals* light green, divided to base, lanceolate, 5–7 × ca. 1 mm, apex acute; *corolla* trumpet-shaped; tube white outside, dark red within, ca. 4 cm long, ca. 5 mm wide at base dilating to 10–15 mm wide at the mouth, outside finely pubescent, throat and lobes dark red, nectar guides raised and slightly darker, inner surface of throat finely velvety; lobes 5, upper two lobes reflexed, ca. 5 x 10 mm and lower three lobes extending beyond the upper, ca. 5 × 12 mm; *stamens* with filaments 2–2.5 cm long, anthers white, ca. 1 × 1 mm, connective small and horn-like, staminode vestigial; *ovary* and style ca. 3 cm long, stigma broadly triangular, white. **Capsules** curved downwards, glabrous, 5–6 cm long, ca. 3 mm thick, sepals not persisting.

Distribution: *Ridleyandra iminii* is known only from the type locality, Peninsular Malaysia. Pahang: Gunung Benom, Krau Game Reserve, 3°45'N, 102°19'E.

Ecology. In upper hill dipterocarp forest on wet, sandy, moist soil on a shaded, steep slope and river bank at ca. 700 m altitude.

Etymology. The species is named after Mr. Imin Kamin, research assistant and plant collector in the Kepong Herbarium (KEP), Forest Research Institute Malaysia, with whom I first collected the plant. **Conservation status**. Rare (RA). The Malaysian Rare category has the following definition: the taxon is not exposed to any known direct or plausible potential threat and does not qualify under the five IUCN criteria and it occurs in ≤ 2 sites or has an EOO (extent of occurrence) ≤ 100 km2 or AOO (area

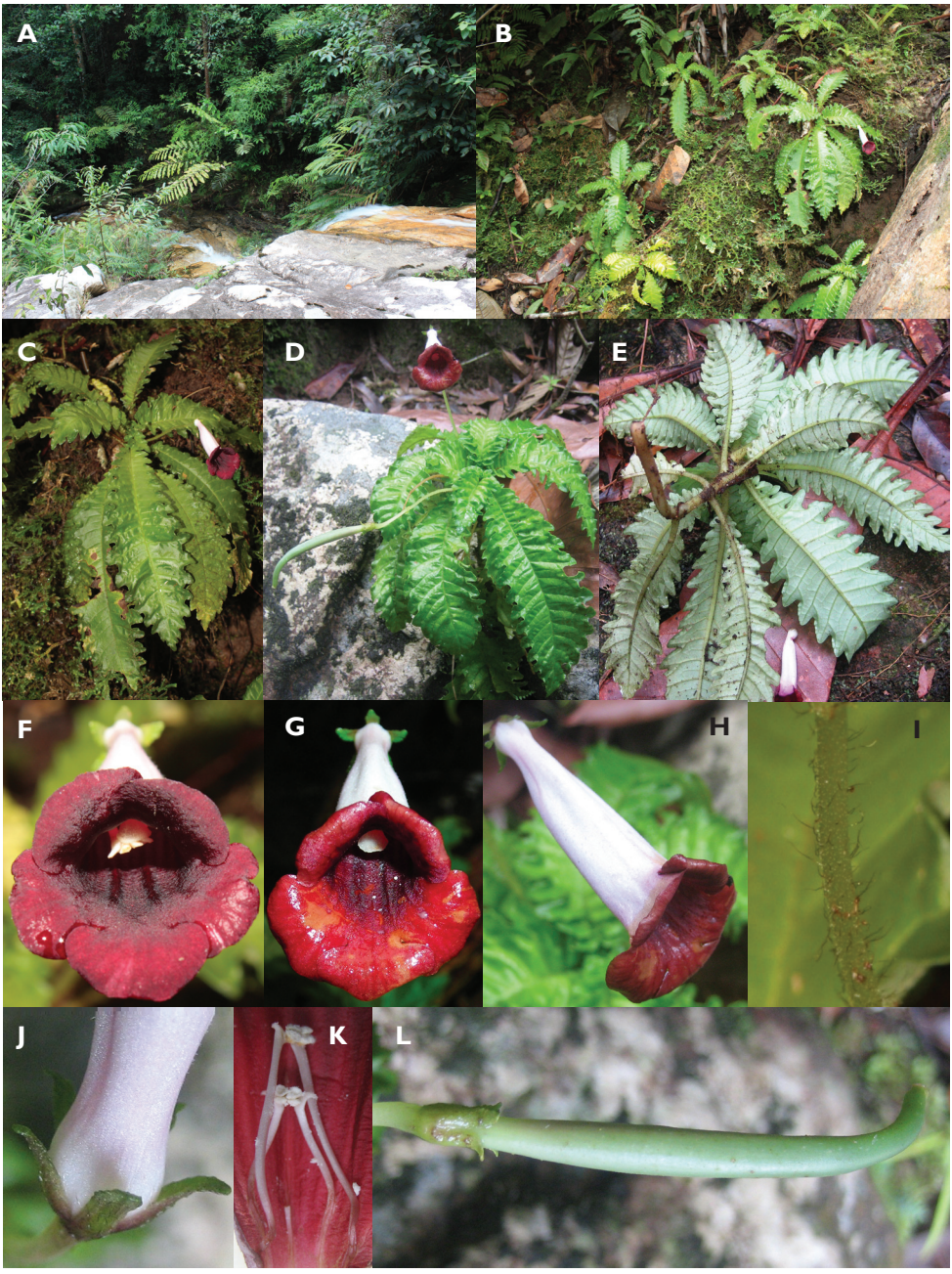

Figure 1. *Ridleyandra iminii*. **A, B** habitat **C–E** habit **F** flower with mature stamens **G** flower with mature stigma **H** side view of flower **I** peduncle hairs **J** sepals **K** stamens and staminode **L** fruit. (Photos: **A–C, F** by K. Imin, **D–E, G–L** by M.Y. Siti-Munirah).

of occupancy) ≤ 10 km2 (Chua 2012). In the case of this species, although it occurs in a Totally Protected Area (an area that is legally protected), it still vulnerable because it lies beside the main tourist trail and its population numbers about 200 individuals.

Specimens examined. Peninsular Malaysia. Pahang: Benom, Krau Game Reserve, 15 November 2009 (fl), A.R. Ummul-Nazrah FRI 70717 (KEP).

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