



Article

Characterization of *Hubera* (Annonaceae), a new genus segregated from *Polyalthia* and allied to *Miliusa*

TANAWAT CHAOWASKU¹, DAVID M. JOHNSON², RAYMOND W.J.M. VAN DER HAM¹
& LARS W. CHATROU³

¹Naturalis Biodiversity Center (section NHN), Leiden University, Einsteinweg 2, 2333 CC Leiden, the Netherlands;
email: cyathostemma@yahoo.com

²Department of Botany-Microbiology, Ohio Wesleyan University, Delaware, Ohio 43015 USA

³Wageningen University, Biosystematics Group, Droevendaalsesteeg 1, 6708 PB Wageningen, the Netherlands

Abstract

On the basis of molecular phylogenetics, pollen morphology and macromorphology, a new genus of the tribe Miliuseae, *Hubera*, segregated from *Polyalthia* and allied to *Miliusa*, is established and described. It is characterized by the combination of reticulate tertiary venation of the leaves, axillary inflorescences, a single ovule per ovary and therefore single-seeded monocarps, seeds with a flat to slightly raised raphe, spiniform(-flattened peg) ruminations of the endosperm, and pollen with a finely and densely granular infratectum. Twenty-seven species are accordingly transferred to this new genus.

Key words: Malmeoideae, molecular systematics, Old World floristics, Paleotropics, palynology

Introduction

The large magnoliid angiosperm family Annonaceae is prominent in lowland forests across the tropics (Gentry 1988, Slik *et al.* 2003). Circumscription of genera within the family was initially founded on characters emphasizing the diversity of floral morphologies represented in the family, which recapitulates many trends found with angiosperm evolution at large (Johnson & Murray 1995, Endress & Doyle 2009, Endress 2011): apocarpy/syncarpy, polypetaly/sympetaly, bisexual/unisexual flowers, reductions in stamen and carpel number, and changes in ovule number.

At the same time that molecular and other analyses have shown the homoplasious evolution of similar perianth specializations (e.g. Mols *et al.* 2004b, Saunders 2010), it is nevertheless true that such specializations still have value as morphological markers of particular clades within the family, usually at the generic level. However, reliance on perianth modifications for classification in Annonaceae has also resulted in genera defined by lack of such specializations, i.e. they are defined on the basis of symplesiomorphic perianth features (Johnson & Murray 1999). This situation is best exemplified in the family by the Paleotropical genus *Polyalthia* Blume (1830: 68), which has been defined by similarity of petals in its two perianth whorls and little else; it is thus not surprising that several analyses (e.g. Mols *et al.* 2004a, b, Richardson *et al.* 2004, Xue *et al.* 2011) have shown the genus to be polyphyletic. Even before the advent of molecular analyses, species had been removed from the genus on morphological grounds. For example, the new genus *Greenwayodendron* Verdcourt (1969: 89) was established to accommodate two African species now known to be closer to a suite of African genera (Couvreur *et al.* 2009), Johnson (1989) removed two species to the genus *Disepalum* Hooker (1860: 156), following the pollen morphology studied by Walker (1971) and *Maasia* Mols, Keßler & Rogstad in Mols *et al.* (2008: 493) was recognized following Rogstad's (1989) systematic studies, although monophyly of the last genus had been demonstrated in phylogenetic

analyses by Mols *et al.* (2004a). Phylogenetic analyses have led to removal of additional species to *Marsypopetalum* Scheffer (1870: 342; Xue *et al.* 2011), *Fenerivia* Diels (1925: 355; Saunders *et al.* 2011), and *Monoon* Miquel (1865: 15; Xue *et al.* 2012). On the other hand, *Haplostichanthus* Mueller (1891: 180) has been found to be congeneric with *Polyalthia sensu stricto* (i.e. a clade consisting of the type species of *Polyalthia*; Xue *et al.* 2012).

Molecular phylogenetics has played a crucial role in elucidating evolutionary relationships of Annonaceae and provided a new foundation for classification of genera within the family (e.g. Mols *et al.* 2004a, b, Richardson *et al.* 2004, Pirie *et al.* 2006, Couvreur *et al.* 2008, 2009, Zhou *et al.* 2009, 2010, Chatrou *et al.* 2012). Following Chatrou *et al.* (2012), Annonaceae now includes four subfamilies: Anaxagoreoideae, Ambavioideae, Annonoideae (also known as long-branch clade, LBC) and Malmeoideae (also known as short-branch clade, SBC). Previous analyses (e.g. Mols *et al.* 2004a, b, Richardson *et al.* 2004, Xue *et al.* 2011) have suggested that one group of species within subfamily Malmeoideae, tribe Miliuseae *sensu* Chatrou *et al.* (2012), currently residing in *Polyalthia*, represents the sister group to the Asian genus *Miliusa* Leschenault ex Candolle (1832: 213). This group of *Polyalthia* species, characterized by reticulate tertiary veins of the leaves, axillary inflorescences, uniovulate carpels, seeds with a flat to slightly raised raphe, and spiniform(-flattened peg) endosperm ruminations, is widespread in the Paleotropics, including East Africa and Madagascar, southern and southeastern Asia, Malesia, and the southwestern Pacific. The purpose of the present study was to investigate additional *Polyalthia* species possibly belonging to this sister clade of *Miliusa*. We proposed to examine these species with an expanded molecular dataset compared to previous analyses (e.g. Saunders *et al.* 2011) and then evaluate the systematic value of pollen and macromorphological characters with this result to determine whether or not such a grouping might be characterized using these traits. In Chaowasku *et al.* (2008), three species of this *Polyalthia* clade sister to *Miliusa* were described as having pollen with a finely and densely granular infratectum. It is worth investigating if all other species in this clade also possess the same type of pollen infratectum and thus if this character could be a potential synapomorphy of this clade. Additionally, in order to distinguish this clade from the other two unrelated but morphologically similar clades, *Monoon* and *Polyalthia s.s.*, the macromorphology and pollen morphology of these two clades will be compared. As no obvious macromorphological similarities have been found between *Miliusa* and this group of *Polyalthia* species, a survey and comparison of vegetative, floral, fruit/seed, and pollen characters will be made as well.

Materials and Methods

Materials

Voucher specimens for macromorphological observations, pollen morphological and molecular phylogenetic studies, including GenBank accession numbers, are indicated in Table 1.

Methods

Molecular phylogenetics

All 56 accessions sampled (Table 1) belong to Malmeoideae; 54 accessions comprise the ingroup: Monocarpeae and Miliuseae. Besides accessions of (former) *Polyalthia* species, accessions of representatives of nearly all other genera in the Miliuseae were included; the genera *Oncodostigma* Diels (1912b: 143) and *Phoenicanthus* Alston in Trimen (1931: 6) were not included because available material was not suitable for DNA extraction. However, they are unlikely to be nested in a clade sister to *Miliusa* because they do not possess all morphological characters diagnostic for this clade, e.g. there are ≥ 2 ovules (1 in *Miliusa*'s sister clade) per ovary in *Oncodostigma* and *Phoenicanthus*. The outgroups are species of *Bocageopsis* Fries (1931: 143) and *Oxandra*

Richard (1841: 45), both from Malmeeae. Seven plastid markers (*rbcL* exon, *trnL* intron, *trnL-F* spacer, *matK* exon, *ndhF* exon, *psbA-trnH* spacer, *ycf1* exon) were amplified. In total, 7044 characters, including 10 separately coded indels were included in the analyses. Indel coding follows Simmons & Ochoterena (2000). For a 15-nucleotide stretch in the *psbA-trnH* marker, the reverse complement was present in roughly half the accessions sequenced, and we converted this into the reverse complement in line with Pirie *et al.* (2006).

DNA extractions were performed using a CTAB method (Doyle & Doyle 1987) modified following Bakker *et al.* (1998). A standard PCR protocol was used throughout, with the addition of 50 µg of bovine serum albumin (BSA) in 50 µl PCR reactions. The PCR program used comprises 35 cycles of 94 °C: 30 sec., 53 °C–65 °C: 1 min. (annealing temperatures depending on each primer pair), 72 °C: 2 min., with the initial denaturation for 4 min. at 94 °C and the final extension for 7 min. at 72 °C. The primer sequences of the seven plastid regions were taken from the literature or newly designed (see Table 2). All PCR products were cleaned by the MinElute® PCR Purification Kit (Qiagen), and then sequenced using the Dye ET terminator sequencing kit (Amersham Pharmacia Biotech), running on the ABI Prism 3700 (Greenomics, Wageningen).

Sequences were edited using the program Staden version 1.7.0 (<http://staden.sourceforge.net/>) and subsequently manually aligned. Some sequences were obtained from previous studies (Mols *et al.* 2004a, b, Pirie *et al.* 2006, Su *et al.* 2008). Maximum parsimony analyses were performed in TNT version 1.1 (Goloboff *et al.* 2008). All characters were equally weighted and unordered. Multiple most parsimonious trees were generated by a heuristic search of the combined data, with 6000 replicates of random sequence additions, saving 10 trees per replicate, and using tree bisection and reconnection (TBR) branch swapping. Clade support was measured by symmetric resampling (SR), which is not affected by a distortion (resulting in incorrectly estimated percentages) as with some bootstrap and jackknife methods (Goloboff *et al.* 2003). A default change probability was used. Four hundred thousand replicates were run, each with two replicates of random sequence additions, saving one tree per replicate. Groups with SR of $\geq 85\%$, 70–84 %, and $\leq 69\%$ were considered strongly, moderately, and weakly supported, respectively.

Bayesian analyses was performed in MrBayes version 3.1.2 (Ronquist & Huelsenbeck 2003). Eight MCMC chains (two independent runs) were simultaneously run for 2×10^7 generations. The data matrix was divided into seven partitions (*trnL* intron and *trnL-F* spacer were included in the same partition), including a set of binary indel coding. The most appropriate model of sequence evolution for each partition was selected by AIC scores, using FindModel (<http://www.hiv.lanl.gov/content/sequence/findmodel/findmodel.html>). The default prior settings were used except for the ratepr (=variable) and brlenspr [=unconstrained:exp(100)]. The latter prior setting was used to prevent the MCMC chains from being trapped in the areas of parameter space with unrealistically high values for the tree length parameter, resulting in a false convergence or a failure to reach convergence after hundreds of millions of generations (Marshall 2010). The temperature parameter was set to 0.15. Trees and all parameter values were sampled every 1000th generation. Convergence of the runs was checked by the values for effective sample sizes (ESS) using Tracer version 1.5 (Rambaut & Drummond 2009). The posterior probability tree was generated from the two runs combined, with 10% of the first trees removed as the burn-in. Groups with posterior probabilities (PP) of ≥ 0.96 , 0.91–0.95, and ≤ 0.90 were considered strongly, moderately, and weakly supported, respectively.

Pollen morphology

Pollen data of 18 *Polyalthia* species expected or known to be members of a clade sister to *Miliusa* are available, including 11 out of the 16 species included in the phylogenetic analysis. Thirteen species were investigated with light microscopy (LM), scanning electron microscopy (SEM) and/or transmission electron microscopy (TEM) (Tables 1, 3). Pollen data (SEM or TEM) for five other species (Table 3) were taken from the literature (Le Thomas 1980, 1988, Schatz & Le Thomas 1990). Pollen data (SEM and/or TEM) for *Monoon* and *Polyalthia s.s.* were available for comparisons (Table 1). The pollen material for SEM was not acetolysed, following Chaowasku *et al.* (2008) and Couvreur *et al.* (2009). The material for TEM was prepared following Van der Ham (1990). Subdivision of the exine into tectum, infratectum and basal layer (Le Thomas 1980) was used. Further pollen terminology follows Punt *et al.* (2007).

TABLE 1. Voucher specimens for macromorphological observations, pollen morphological (with applied techniques), and molecular phylogenetic studies (with GenBank accession numbers). Symbols: #, macromorphologically observed for this study; *, type specimens; {...}, pollen samples taken, with applied techniques indicated; ---, sequences not available for this study.

Taxon - Voucher, location (herb.)	Molecular phylogenetic study (GenBank accession numbers)					
	<i>rbcL</i>	<i>trnLF</i>	<i>matK</i>	<i>ndhF</i>	<i>psbA-trnH</i>	<i>ycf1</i>
<i>Alphonsea elliptica</i>						
- Van Balgooy 5141, Bogor Bot. Gard. (L)	AY318966	AY319078	AY519907	JQ690401	JQ690402	JQ690403
<i>Bocageopsis canescens</i>						
- Maas et al. 9243, Brazil (U)	JQ690407	JQ690408	JQ690409	JQ690410	JQ690411	JQ690412
<i>Desmopsis microcarpa</i>						
- Chatrou et al. 85, Costa Rica (U)	AY319059	AY319173	AY518804	JX544758	AY841461	JX544771
<i>Hubera</i> sp. 1						
- Polak 1211A, New Guinea (L)#	---	JX544843	---	JX544854	JX544864	JX544873
<i>Hubera</i> sp. 2						
- Darbyshire 981, New Guinea (L)# {LM, SEM, TEM}	---	JX544844	JX544855	JX544865	JX544874	JX544884
<i>Hubera</i> sp. 3						
- Conn et al. 45, New Guinea (L)#						
- Takeuchi & Ama 15543, New Guinea (L)#	---	JX544845	---	JX544856	JX544866	JX544875
- Takeuchi & Ama 16263, New Guinea (L)#						
- Takeuchi & Ama 16284, New Guinea (L)#						
<i>Hubera</i> sp. 4						
- Treesucon 2009-4, Vietnam (L)#	---	JX544846	---	JX544857	JX544867	JX544876
<i>Hubera</i> sp. 5						
- Schatz & Modeste 2886, Madagascar (WAG)#	---	JX544848	---	JX544858	JX544868	JX544878
<i>Hubera</i> sp. 6						
- Katik NGF 46922, New Guinea (L)# {LM, SEM, TEM}						
<i>Hubera</i> sp. 7						
- Takeuchi 10122, New Guinea (L)# {LM, SEM, TEM}						
- Takeuchi & Regalado 10210, New Guinea (L)#						
<i>Hubera</i> sp. 8						
- Pullen 1858, New Guinea (L)# {LM, SEM, TEM}						
<i>Hubera</i> sp. 9						
- Kairo NGF 24405, New Guinea (L)#						
<i>Marsypopetalum littorale</i>						
- Rastini 153, Bogor Bot. Gard. (L)	AY319026	AY319140	AY518835	JX544804	JX544813	JX544827
<i>Meiogyne virgata</i>						
- Keßler PK 2751, Borneo (L)	AY318982	AY319094	AY518798	JX544756	JX544769	JX544784
<i>Miliusa mollis</i>						
- Keßler PK 3207, Thailand (L)	---	AY319102	AY518851	JQ690503	JQ690504	JQ690505

.....continued on the next page

TABLE 1. (Continued)

Taxon - Voucher, location (herb.)	Molecular phylogenetic study (GenBank accession numbers)					
	<i>rbcL</i>	<i>trnLF</i>	<i>matK</i>	<i>ndhF</i>	<i>psbA-trnH</i>	<i>ycf1</i>
<i>Miliusa thorelii</i>						
- Keßler PK 3184, Thailand (L)	---	AY319104	AY518846	JQ690519	JQ690520	JQ690521
<i>Miliusa velutina</i>						
- Pholsena & Koonkhunthod 2842, Thailand (L)	AY318993	AY319105	AY518847	JQ690536	JQ690537	JQ690538
<i>Mitrephora alba</i>						
- Chalermglin 440304-1, Thailand (TISTR, Bangkok)	AY318994	AY319106	AY518855	JQ889983	JQ889978	JQ889973
<i>Monocarpia maingayi</i>						
- Kaewruang 1, Thailand (L)	JQ690395	JQ690396	JQ690397	JQ690398	JQ690399	JQ690400
<i>Monoon coffeoides</i>						
- Ratnayake 1/03, Sri Lanka (HKU)	EU522288	EU522178	EU522233	---	EU522123	---
<i>Monoon fuscum</i>						
- Keßler PK 3222, Thailand (L)	AY318973	AY319085	AY518787	JX544767	JX544779	JX544792
- Kostermans 774, Thailand (L) {TEM}						
- Maxwell 87-536, Thailand (L) [#]						
<i>Monoon paradoxum</i>						
- Ambriansyah & Arifin B 1520, Borneo (L) {SEM, TEM}						
<i>Monoon viride</i>						
- Chalermglin 440214-3, Thailand (L)	AY319040	AY319154	AY518784	JX544768	JX544780	JX544793
- Phengkklai et al. 4244, Thailand (L) {TEM}						
<i>Neo-uvaria telopea</i>						
- Chaowasku 77, Thailand (L)	JX544751	JX544755	JX544766	JX544778	JX544783	JX544791
<i>Orophea kerrii</i>						
- Chalermglin 440416-1, Thailand (L)	AY319008	AY319121	AY518818	JQ690419	JQ690420	JQ690421
<i>Oxandra venezuelana</i>						
- Chatrou et al. 120, Costa Rica (U)	AY841645	AY841723	JQ690413	JQ690414	AY841495	JQ690415
<i>Phaeanthus splendens</i>						
- Keßler B 1564, Borneo (L)	JX544754	AY319126	AY518864	JX544765	JX544777	JX544790
<i>Platymitra macrocarpa</i>						
- Okada 3457, Bogor Bot. Gard. (L)	AY319013	AY319127	AY518812	JQ690422	JQ690423	JQ690424
<i>Polyalthia amoena</i>						
- Smith 6423, Fiji (BISH) [#]						
<i>Polyalthia angustissima</i>						
- Maxwell 82-168, Singapore Bot. Gard. (L) [#]	---	JX544795	---	JX544807	JX544831	---
<i>Polyalthia bullata</i>						
- Chaowasku 34, Thailand (L) [#]	---	JX544800	JX544809	JX544818	JX544825	JX544839
<i>Polyalthia capillata</i>						
- Smith 4581, Fiji (BISH) [#]						

.....continued on the next page

TABLE 1. (Continued)

Taxon - Voucher, location (herb.)	Molecular phylogenetic study (GenBank accession numbers)					
	<i>rbcL</i>	<i>trnLF</i>	<i>matK</i>	<i>ndhF</i>	<i>psbA-trnH</i>	<i>ycf1</i>
<i>Polyalthia cauliflora</i>						
- Keßler PK 3114, Singapore Bot. Gard. (L)	AY319015	AY319129	AY518823	JX544837	---	---
- S 24388, Borneo (L) {SEM, TEM}						
<i>Polyalthia celebica</i>						
- Mols 9, Bogor Bot. Gard. (IV-C-97) (L) [#] {TEM}	AY319016	AY319130	AY518827	JX544808	JX544838	---
<i>Polyalthia cerasoides</i>						
- Chalermglin 440214-4, Thailand (L) [#]	AY319017	AY319131	AY518854	JQ889985	JQ889980	JQ889975
- Larsen et al. 33731, Thailand (L) {LM, SEM, TEM}						
- Maxwell 90-744, Thailand (L) [#]						
- Vajravelu 36762, India (L) [#] {LM, SEM}						
<i>Polyalthia decora</i>						
- Phillipson 2971, Madagascar (WAG) [#]	---	JX544849	---	JX544859	JX544869	JX544879
<i>Polyalthia flagellaris</i>						
- S 57495, Borneo (L) {TEM}						
<i>Polyalthia forbesii</i>						
- Forbes 836, New Guinea [B (photograph)] ^{#*}						
- Kostermans 2787, New Guinea (L) [#] {LM, SEM, TEM}						
<i>Polyalthia gracilis</i>						
- Versteeg 1408, New Guinea [B (photograph)] ^{#*}						
<i>Polyalthia henrici</i>						
- Dorr & Koenders 3033, Madagascar (WAG) [#]	---	JX544850	---	JX544860	JX544870	JX544880
- Dorr 3039, Madagascar (WAG) [#] {LM, SEM, TEM}						
<i>Polyalthia hirta</i>						
- Zippelius s.n., New Guinea [B (photograph)] ^{#*}						
<i>Polyalthia jenkinsii</i>						
- Chaowasku 60, Thailand (L) [#]	---	JX544803	---	JX544812	JX544821	JX544842
- Gardner & Sidisunthorn ST 0974, Thailand (L) [#]						
- Geesink et al. 7761, Thailand (L) [#] {LM, SEM, TEM}						
<i>Polyalthia johnsonii</i>						
- Ford AF 3625, Australia (CNS)	---	JX544801	JX544810	JX544819	JX544826	JX544840
- Forster PIF 24658, Australia (L) [#]						

.....continued on the next page

TABLE 1. (Continued)

Taxon - Voucher, location (herb.)	Molecular phylogenetic study (GenBank accession numbers)					
	<i>rbcL</i>	<i>trnLF</i>	<i>matK</i>	<i>ndhF</i>	<i>psbA-trnH</i>	<i>ycf1</i>
<i>Polyalthia korinti</i>						
- Kostermans 24580, Sri Lanka (L) [#] {LM, SEM, TEM}						
- Kostermans 24916, Sri Lanka (L) [#]						
- Kostermans 25503, Sri Lanka (L) [#]						
- Kostermans 27618, Sri Lanka (L) [#]						
- Ratnayake 2/03, Sri Lanka (HKU)	---	EU522179	---	JX544847	EU522124	JX544877
<i>Polyalthia leptopoda</i>						
- Ledermann 6585, New Guinea [B (photograph)] ^{#*}						
<i>Polyalthia longirostris</i>						
- Brass 24039, New Guinea (L) [#]						
- Takeuchi & Ama 15656, New Guinea (L)	AY318979	AY319091	AY518826	---	---	---
- Van Royen & Sleumer 7093, New Guinea (L) [#] {TEM}						
<i>Polyalthia loriformis</i>						
- Gillespie 3639, Fiji (BISH) ^{#*}						
- Greenwood 1125, Fiji (BISH) [#]						
- Parham 7182, Fiji (BISH) [#]						
- Smith 601, Fiji (BISH) [#]						
<i>Polyalthia mossambicensis</i>						
- Torre & Correia 17062, Mozambique (P) [#]						
<i>Polyalthia nitidissima</i>						
- Ford AF 4967, Australia (L)	---	JQ889988	JQ889989	JQ889986	JQ889981	JQ889976
- Forster PIF 28246, Australia (L) [#] {SEM, TEM}						
- Gray 1959, Australia (L) [#]						
<i>Polyalthia parviflora</i>						
- Chaowasku 24, Thailand (L) [#] {TEM}	---	JX544799	---	JX544836	---	---
<i>Polyalthia pendula</i>						
- Rabevohitra 2386, Madagascar (WAG) [#] {LM, SEM, TEM}	---	AY319144	AY518852	JQ889987	JQ889982	JQ889977
<i>Polyalthia perrieri</i>						
- Capuron 20.977-SF, Madagascar (K) [#] {LM, SEM, TEM}	---	JX544851	---	JX544861	JX544871	JX544881
<i>Polyalthia rumphii</i>						
- Slik 2821, Borneo (L) [#]	---	JX544802	---	JX544811	JX544820	JX544841
<i>Polyalthia stenopetala</i>						
- Johnson & Chalermglin 2040, Thailand (OWU) [#]	JX544796	JX544823	---	JX544832	---	---
- KEP/FRI 13402, Peninsular Malaysia (L) {TEM}						

.....continued on the next page

TABLE 1. (Continued)

Taxon - Voucher, location (herb.)	Molecular phylogenetic study (GenBank accession numbers)					
	<i>rbcL</i>	<i>trnLF</i>	<i>matK</i>	<i>ndhF</i>	<i>psbA-trnH</i>	<i>ycf1</i>
<i>Polyalthia stuhlmannii</i>						
- Luke & Robertson 1424, Kenya (K) [#]	---	AY319149	AY518853	JX544852	JX544862	JX544882
<i>Polyalthia subcordata</i>						
- Gravendeel et al. 678, Java (L) {TEM}						
<i>Polyalthia suberosa</i>						
- Chatrou 480, Utrecht Univ. Bot. Gard. (U)	AY238956	AY231289 AY238949	AY238965	AY841417	AY841502	JX544817
- Maxwell 93-1463, Thailand (L) [#] {TEM}						
<i>Polyalthia tanganyikensis</i>						
- Couvreur 66, Tanzania (WAG) [#] {LM, SEM, TEM}	---	JX544853	---	JX544863	JX544872	JX544883
<i>Polyalthia trichoneura</i>						
- Von Römer s.n., New Guinea [B (photograph)] ^{**}						
<i>Polyalthia vitiensis</i>						
- Smith 647, Fiji (BISH) [#]						
- Smith 8203, Fiji (L) [#]						
<i>Polyalthia</i> sp. 1						
- Punnadee 1, Thailand (L) [#] {TEM}	---	JX544797	---	JX544833	---	---
<i>Polyalthia</i> sp. 2						
- Chaowasku 50, Thailand (L) [#] {TEM}	---	JX544798	---	JX544834	---	---
<i>Polyalthia</i> sp. 3						
- Keßler PK 3228, Thailand (L) [#]	AY319020	AY319134	AY518832	JX544835	---	---
<i>Popowia hirta</i>						
- Keßler B 1628, Borneo (L)	AY319042	AY319156	AY518860	JX544806	JX544816	JX544830
<i>Pseuduvaria fragrans</i>						
- Chaowasku 27, Thailand (L)	EU522341	EU522231	EU522286	JX544815	EU522176	JX544829
<i>Sageraea lanceolata</i>						
- Ridsdale DV-M2-1692, Borneo (L)	AY319050	AY319164	AY518799	JX544762	JX544774	JX544787
<i>Sapranthus viridiflorus</i>						
- Chatrou et al. 55, Costa Rica (U)	AY319051	AY319165	AY743493	AY841422	AY841515	JX544760
<i>Stelechocarpus burahol</i>						
- Mols 13, Bogor Bot. Gard. (L)	AY319053	AY319167	AY518803	JX544763	JX544775	JX544788
<i>Stelechocarpus cauliflorus</i>						
- Unknown s.n., Bogor Bot. Gard. (XV-A-196) (L)	AY319054	AY319168	AY518800	JX544764	JX544776	JX544789
<i>Stenanona costaricensis</i>						
- Chatrou et al. 67, Costa Rica (U)	AY319069	AY319183	AY518801	JX544759	AY841516	JX544772
<i>Tridimeris</i> sp.						
- Maas 8646, Missouri Bot. Gard. (U)	JX544750	JX544753	JX544761	JX544773	JX544782	JX544786
<i>Trivalvaria</i> sp.						
- Chaowasku 35, Thailand (L)	JX544794	JX544805	JX544814	JX544822	JX544824	JX544828
Undescribed genus						
- Chaowasku 108, Thailand (L)	JX544749	JX544752	JX544757	JX544770	JX544781	JX544785

TABLE 2. Primers used for DNA amplification in this study.

Markers	Primers	Sequences (5'→3')	References
<i>rbcL</i>	1F	ATGTCACCACAAACAGAAAC	Olmstead <i>et al.</i> (1992)
	724R	TCGCATGTACCTGCAGTAGC	Fay <i>et al.</i> (1997)
	636F	GCGTTGGAGAGATCGTTTCT	Fay <i>et al.</i> (1997)
	1460R	TCCTTTTAGTAAAAGATTGGGCCGAG	Olmstead <i>et al.</i> (1992)
<i>trnLF</i>	C	CGAAATCGGTAGACGCTACG	Taberlet <i>et al.</i> (1991)
	D	GGGGATAGAGGGACTTGAAC	Taberlet <i>et al.</i> (1991)
	E	GGTCAAGTCCCTCTATCCC	Taberlet <i>et al.</i> (1991)
	F	ATTTGAACTGGTGACACGAG	Taberlet <i>et al.</i> (1991)
<i>matK</i>	390F	CGATCTATTCAATATTTTC	Cuénoud <i>et al.</i> (2002)
	Mint-F	TCCTTTGGAAGTGTCTTGAGC	Pirie <i>et al.</i> (2005)
	Mint-R	GATCCTGTGCGGTTGAGACC	Pirie <i>et al.</i> (2005)
	1326R	TCTAGCACACGAAAGTCGAAGT	Cuénoud <i>et al.</i> (2002)
<i>ndhF</i>	1F	ATGGAACAKACATATSAAATATGC	Olmstead & Sweere (1994)
	54F	GCTCGTCGTATGTGGGCTTTTC	Present study
	660R	GTGCAGATTTAGCAACTGCACC	Present study
	481F	CGTTTGTAACGAATCGTGTAGGGG	Present study
	1089R	CCACCCATAAGAACCATGTTCTG	Present study
	972F	GTCTCAATTGGGTTATATGATG	Olmstead & Sweere (1994)
	1087F	GTCAGAACATGGTTCCTATGGG	Present study
	1650R	CGAAGGGAATTCCTATGGACCC	Present study
	1550F	CTCTGACAATAAAGACACTTCC	Present study
	2110R	CCCCCTAYATATTTGATACCTTCTCC	Olmstead & Sweere (1994)
	<i>psbA-trnH</i>	F	CGAAGCTCCATCTACAAATGG
R		ACTGCCTTGATCCACTTGGC	Hamilton (1999)
<i>ycf1</i>	72F	GTGGACACTAGGAATATTGGATGC	Present study
	1674R	CCGCGGAATCAACAAGAAGATC	Present study
	914F	GGATGGGAATGAATGAAGAAATGC	Present study
	2323R	CCGTATCAATATGCTTGTCTC	Present study

TABLE 3. Pollen morphological observations of species in clade A. -, data not available.

Taxon	Size (µm; LM)	Ornamentation (SEM)	Infratectum (TEM)	Germination zone(s) (TEM)
<i>Polyalthia cerasoides</i>	42	verrucate(-rugulate)	finely, densely granular	1?
<i>Polyalthia decora</i> ¹	-	verrucate-rugulate	-	-
<i>Polyalthia forbesii</i>	29	fossulate-perforate	finely, densely granular	2
<i>Polyalthia henrici</i>	31	rugulate	finely, densely granular	2
<i>Polyalthia jenkinsii</i>	33	(weakly) coarsely rugulate to fossulate	finely, densely granular	2
<i>Polyalthia keraudreniae</i> ¹	-	± fossulate-perforate	-	-
<i>Polyalthia korinti</i>	33	(verrucate-)rugulate	finely, densely granular	?
<i>Polyalthia multistamina</i> ¹	-	fossulate-perforate	-	-
<i>Polyalthia nitidissima</i>	-	verrucate-rugulate, with two ± psilate exine areas opposite each other	finely, densely granular	?
<i>Polyalthia pendula</i>	43	verrucate	finely, densely granular	2
<i>Polyalthia perrieri</i>	30	verrucate(-rugulate)	finely, densely granular	2
<i>Polyalthia sambiranensis</i> ¹	-	verrucate-rugulate	-	-
<i>Polyalthia stuhlmannii</i> ²	-	-	finely, densely granular	1?
<i>Polyalthia tanganyigensis</i>	32	verrucate(-rugulate)	finely, densely granular	1?
<i>Hubera</i> sp. 2	43	weakly coarsely rugulate to fossulate	finely, densely granular	2
<i>Hubera</i> sp. 6	46	± fossulate-perforate	finely, densely granular	?
<i>Hubera</i> sp. 7	43	± fossulate-perforate	finely, densely granular	2
<i>Hubera</i> sp. 8	43	± fossulate-perforate	finely, densely granular	1?

¹From Schatz & Le Thomas (1990)²From Le Thomas (1980, 1988)

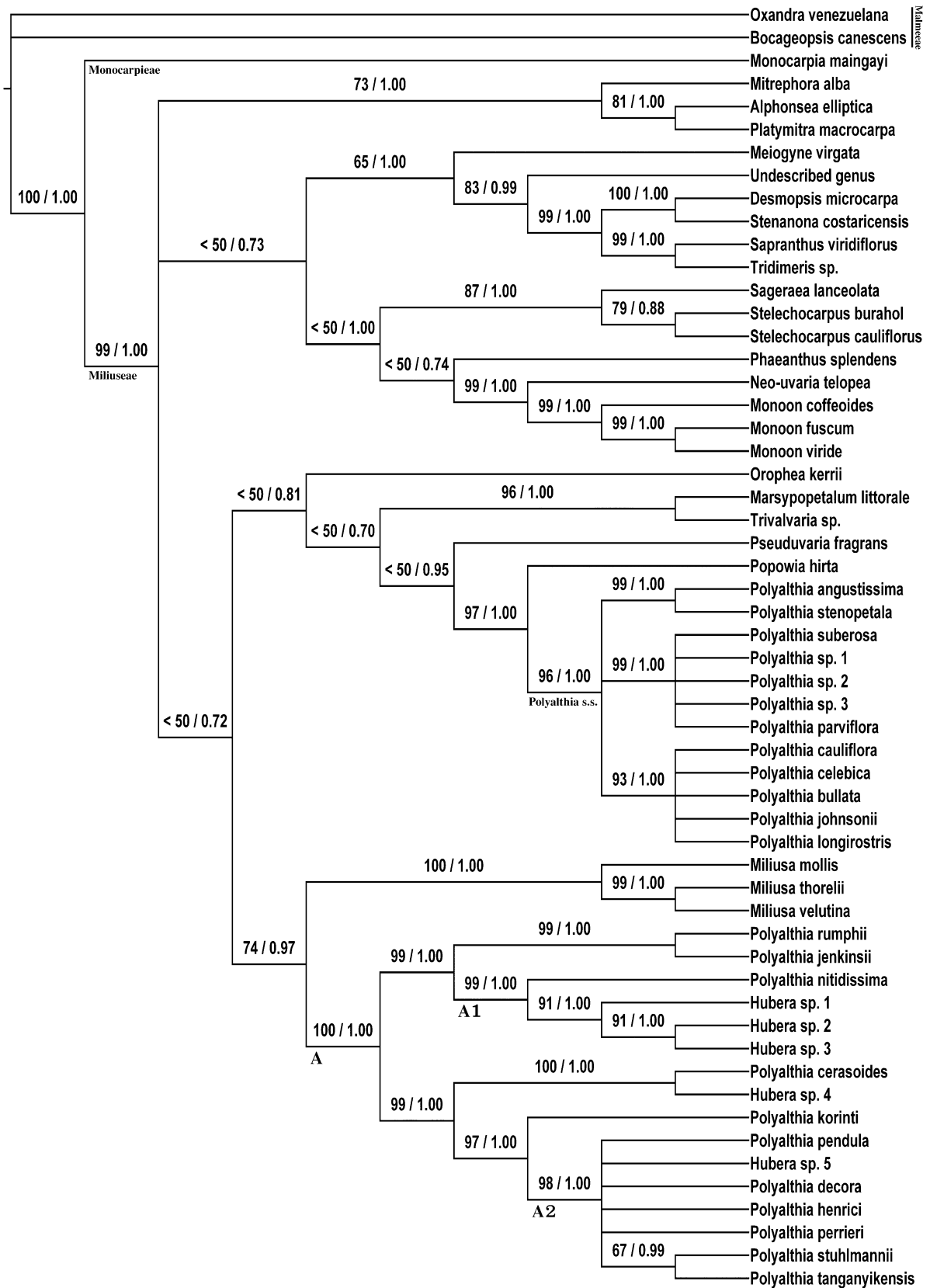


FIGURE 1. Bayesian posterior probability tree, with support indicated above branches: Bayesian posterior probabilities right of slash, maximum parsimony's symmetric resampling values left of slash.

Results

Molecular phylogenetics

Due to poor quality of extracted DNA or unavailability of leaf material, we could not produce seven markers for all accessions (see Table 1). The maximum parsimony analysis of combined datasets resulted in > 30000 most parsimonious trees of 1587 steps (results not shown). The consistency and retention indices were 0.77 and 0.76, respectively. For Bayesian analysis, the substitution model was GTR + G for all partitions except for *trnLF* (= *trnL* intron + *trnL-F* spacer) and *psbA-trnH*, which had the HKY + G model. Twenty thousand and two trees were sampled from 2×10^7 generations of two independent runs. For burn-in, 2000 trees were discarded, resulting in 18002 trees left for calculation of the posterior probability tree (Fig. 1). All effective sample size (ESS) values after discarding the burn-in were larger than 1400, indicating convergence of the runs.

A clade comprising 11 species currently known as *Polyalthia* and five most likely undescribed species is maximally supported (clade A; SR 100%; PP 1.00; see Figs. 2A–C, G for representatives). It is sister to the genus *Miliusa* with moderate to strong support (SR 74%; PP 0.97).

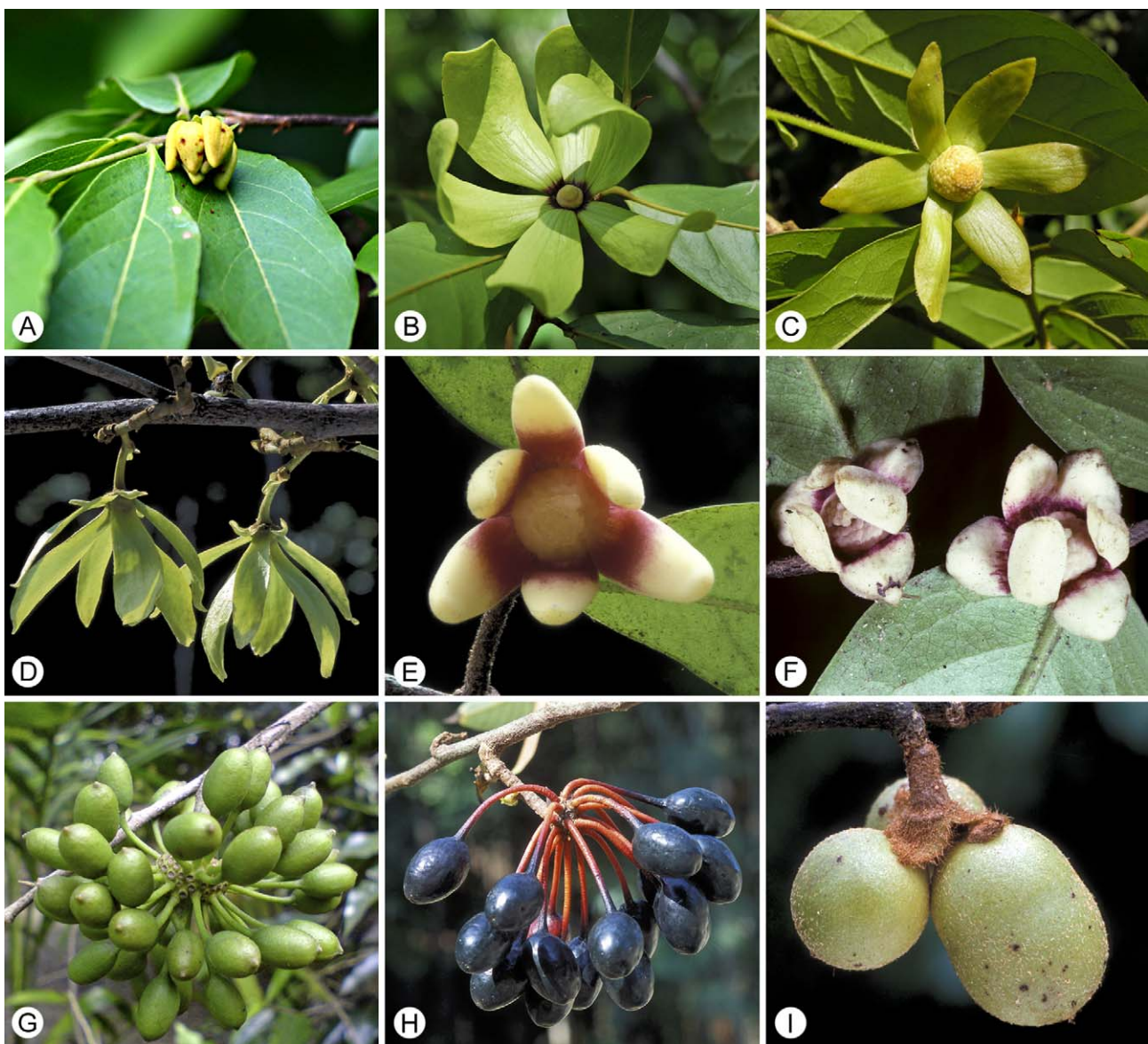


FIGURE 2. Flowers/fruits of representative species of clade A, *Monoon*, and *Polyalthia sensu stricto*. A–C, G. Clade A. A. *Polyalthia cerasoides*. B, G. *Polyalthia jenkinsii*. C. *Hubera* sp. 4. D, H. *Monoon*. *Monoon* sp. E, F, I. *Polyalthia sensu stricto*. E, I. *Polyalthia parviflora*. F. *Polyalthia submontana*. Photographs: A, Mr. Outlander from siamensis.org; B, G, K. Aongyong; C, U. Treesucon; D, E, H, I, S. Gardner; F, L. Jessup.

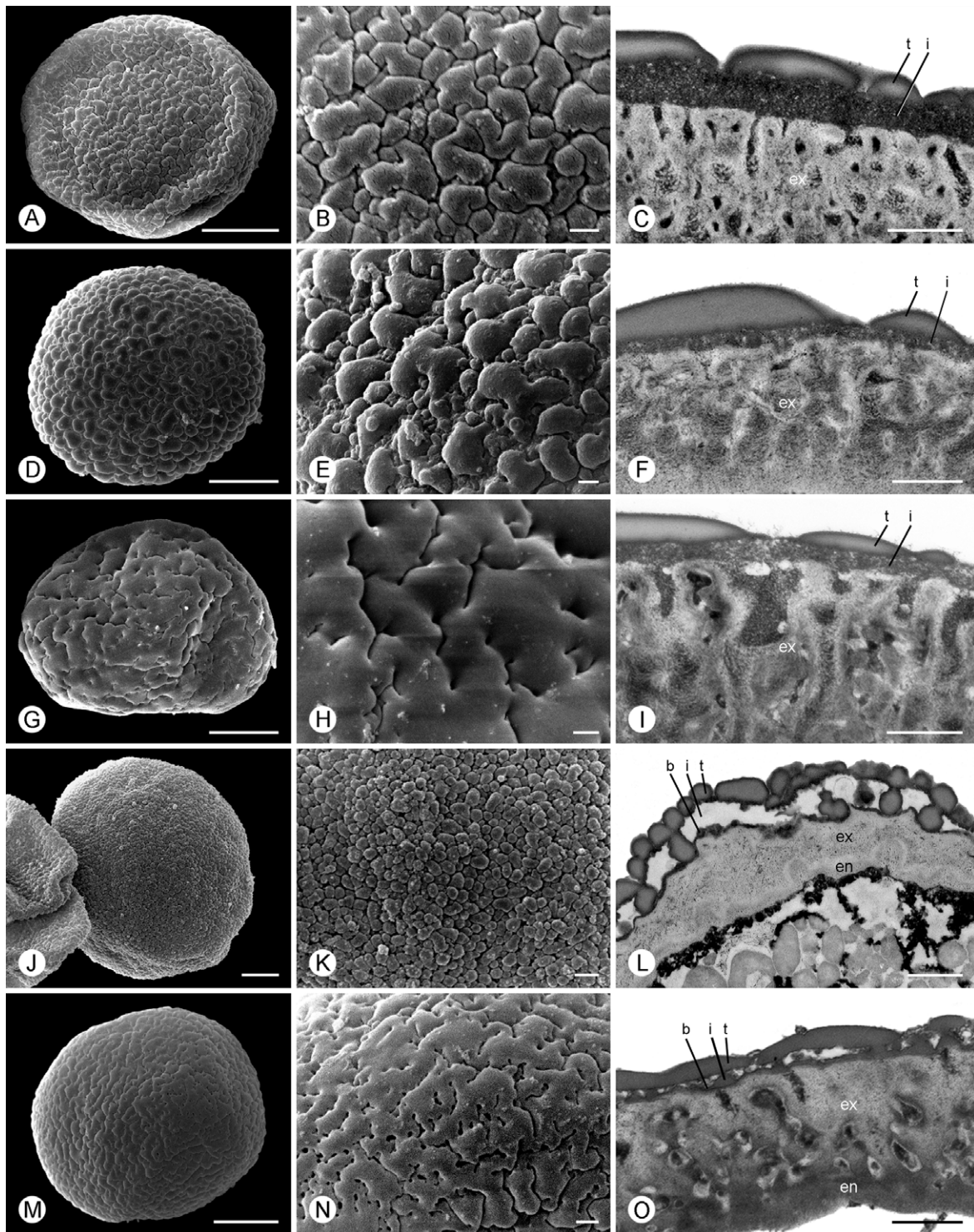


FIGURE 3. Pollen of representative species of clade A, *Monoon*, and *Polyalthia sensu stricto*.; SEM (columns 1 and 2) and TEM (column 3). A–I. Clade A. A–C. *Polyalthia cerasoides* (A, B, *Vajravelu 36762*; C, *Larsen et al. 33731*). A. Pollen grain. B. Detail showing verrucate(-rugulate) ornamentation. C. Detail of pollen wall with finely and densely granular infratectum and tubular exintine. D–F. *Polyalthia pendula* (*Rabevohitra 2386*). D. Pollen grain. E. Detail showing verrucate ornamentation. F. Detail of pollen wall with finely and densely granular infratectum and tubular exintine. G–I. *Hubera* sp. 2 (*Darbyshire 981*). G. Pollen grain. H. Detail showing weakly coarsely rugulate to fossulate ornamentation. I. Detail of pollen wall with finely and densely granular infratectum and tubular exintine. J–L. *Monoon*. *Monoon paradoxum* (*Ambriansyah & Arifin B 1520*). J. Pollen grain. K. Detail showing scabrate ornamentation. L. Detail of pollen wall showing (coarsely granular to) \pm columellate infratectum and homogeneous exintine. M–O. *Polyalthia sensu stricto*. *Polyalthia cauliflora* (*S 24388*). M. Pollen grain. N. Detail showing rugulate to fossulate(-perforate) ornamentation. O. Detail of pollen wall showing coarsely granular (to \pm columellate) infratectum and tubular exintine. Scale bars: 10 μ m (D, G, M), 5 μ m (A, J), 1 μ m (B, C, E, F, H, I, K, L, N, O). Abbreviations: b, basal layer; en, endintine; ex, exintine; i, infratectum; t, tectum.

Pollen morphology (Table 3; Figs. 3A–O)

LM: Pollen grains apolar, (sub)spheroidal, inaperturate monads, longest axis 29–46 μm .

SEM (Figs. 3A, B, D, E, G, H): Exine ornamentation verrucate to rugulate to fossulate(-perforate).

Two opposite, \pm psilate exine areas (exine “plates” *sensu* Waha & Hesse 1988), surrounded by verrucate-rugulate ornamentation, were observed in the pollen of *Polyalthia nitidissima* (Dunal 1817: 109) Bentham (1863: 51) (pollen not shown).

TEM (Figs. 3C, F, I): Exine inaperturate, tectate. Infratectum finely and densely granular, 0.3–1.8 as thick as tectum. Basal layer mostly indistinct [distinct and \pm lamellate in *Polyalthia perrieri* Cavaco & Keraudren (1957: 75) and *P. tanganyikensis* Vollesen (1980a: 56)]. Intine consisting of a thick tubular exintine and a thin homogeneous endintine, which is sometimes indistinguishable from the tubular exintine, without(?) or with one(?) or two germination zone(s).

The infratectum of species belonging to *Monoon* and *Polyalthia s.s.* thus far investigated using TEM (Table 1) is \pm columellate or coarsely granular (Figs. 3L, O).

Macromorphology

All species of clade A share the following characters [contrasted with characters of *Monoon* (see Figs. 2D, H for representatives) and *Polyalthia s.s.* (see Figs. 2E, F, I for representatives) in square brackets]: reticulate [usually percurrent in *Monoon*] tertiary venation of the leaves, axillary [often terminal in *Polyalthia s.s.*] inflorescences, six petals of \pm equal size (Figs. 2A–C) [sometimes outer petals considerably reduced in *Polyalthia s.s.*], a single ovule/seed per ovary/monocarp (Fig. 2G) [usually two or more uniseriate ovules per ovary and thus often multi-seeded monocarps (Fig. 2I) in *Polyalthia s.s.*], seeds with a flat to slightly raised [distinctly grooved in *Monoon* (Fig. 4c); generally slightly grooved in *Polyalthia s.s.* (Fig. 4b)] raphe (Fig. 4a) and spiniform(-flattened peg) [four-parted lamelliform in *Monoon*] ruminations of the endosperm. Table 4 summarizes important diagnostic characters of clade A, *Monoon* and *Polyalthia s.s.*, and figure 2 shows the similarities and differences in flower and fruit morphology of these three clades.

TABLE 4. Comparisons of important pollen and morphological characters of clade A, *Monoon*, and *Polyalthia sensu stricto*.

Characters	Clade A	<i>Monoon</i>	<i>Polyalthia sensu stricto</i>
<i>Tertiary venation of leaves</i>	reticulate	usually percurrent	reticulate
<i>Leaf base</i>	generally attenuate, wedge-shaped or obtuse; rarely unequal	generally wedge-shaped or obtuse; rarely unequal	generally \pm (sub)cordate; generally \pm unequal
<i>Domatia on lower leaf surface</i>	present or absent	absent	absent
<i>Position of inflorescences</i>	axillary	axillary	axillary or terminal
<i>Number of ovule(s) per ovary</i>	1	1	usually 2–6
<i>Seed raphe</i>	flat to slightly raised	distinctly grooved	generally slightly grooved
<i>Endosperm ruminations</i>	spiniform(-flattened peg)	four-parted lamelliform	spiniform(-flattened peg)
<i>Pollen infratectum</i>	finely, densely granular	\pm columellate or coarsely granular	\pm columellate or coarsely granular

Discussion

Clade A is maximally supported in both the maximum parsimony and Bayesian analyses (see Fig. 1), which was reported previously (Mols *et al.* 2004a, b, Richardson *et al.* 2004), but those analyses included only three

species. Besides being maximally supported by molecular phylogenetic analyses, their morphology is also highly uniform, i.e. all known species share 1) reticulate tertiary leaf venation, 2) a single ovule/seed per ovary/monocarp, 3) seeds with a flat to slightly raised raphe (Fig. 4a), and 4) spiniform(-flattened peg) ruminations of the endosperm.

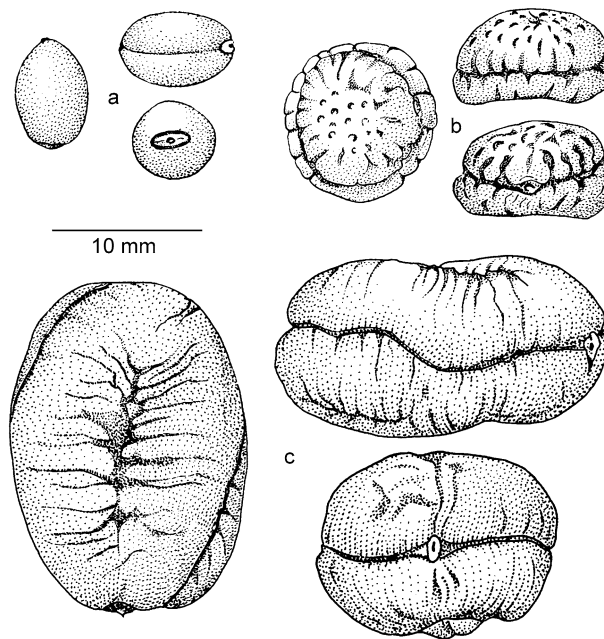


FIGURE 4. Seeds of representative species of clade A, *Monoon*, and *Polyalthia sensu stricto*. Clade A. a. *Polyalthia cerasoides*. *Monoon*. c. *Monoon fuscum*. *Polyalthia sensu stricto*. b. *Polyalthia subcordata*. All reproduced from Van Setten & Koek-Noorman (1992).

Pollen of species recovered in clade A shows a characteristic infratectum, which is one of the putative synapomorphies of the clade and can be readily distinguishable from that of *Monoon* and *Polyalthia s.s.* It is finely and densely granular (Figs. 3C, F, I), whereas it is \pm columellate or coarsely granular in *Monoon* (Fig. 3L) and *Polyalthia s.s.* (Fig. 3O). As discussed in Chaowasku *et al.* (2008), there are probably two germination zones in the pollen of clade A, although this is not always clear in the present study. Possibly, the TEM sections did not cross the germination zones.

Miliusa, the sister of clade A, possesses more or less similar pollen features of ornamentation and presence of the germination zone(s); however, its pollen infratectum differs from that of clade A in being \pm columellate or coarsely granular (Chaowasku *et al.* 2008). As clade A is not only phylogenetically unrelated to *Monoon* and *Polyalthia s.s.*, but also morphologically and palynologically distinguishable from these two clades, we propose that this clade be recognized at the generic level.

***Hubera* Chaowasku, gen. nov. Type:—*Hubera cerasoides* (Roxburgh 1795: 30) Chaowasku.**

Shrubs, treelets or medium-sized trees, evergreen or rarely deciduous (so far observed only in *H. cerasoides*). Young twigs glabrous or hairy. Leaves petiolate; elliptic(-oblong), oblong or seldom obovate, base equal or rarely unequal, attenuate, wedge-shaped, obtuse or rarely (sub)cordate, apex usually obtuse, acute(-acuminate) or (caudate-)acuminate, rarely rounded or emarginate; upper surface of midrib (slightly) sunken, flat, or (both edges) slightly raised [with one or two groove(s) in the middle]; domatia of aggregated tuft of hairs present in some species, at the axils where secondary veins meet primary veins; tertiary venation reticulate. Inflorescences usually on branches and axillary, one-flowered or seldom two-flowered, rarely cauliflorous and then > 3-flowered; pedicels often articulated above the base; bracts (and bracteoles) present

or sometimes not seen (absent?). Flowers bisexual; sepals free or rarely basally connate, triangular to ovate; petals of the outer and inner whorls equal or slightly subequal, ovate, elliptic(-ovate) or (elliptic-)tongue-shaped, erect or spreading at anthesis; in dried condition often marked by yellow powdery material. Stamens generally ≥ 40 per flower, apex of anther connective flat-topped, covering the thecae. Carpels generally ≥ 10 per flower, cylindrical or occasionally flask-shaped, peripheral ones sometimes slightly incurved; stigmas \pm globose, (ellipsoid-)obovoid, ellipsoid(-ovoid) or ellipsoid-cylindrical, generally \pm hairy; ovaries hairy, 1 ovule per ovary, sub-basal. Torus (nearly) flat or (slightly) raised with flat-topped (or with rarely rounded) apex, generally \pm hairy, often \pm enlarged in fruit. Monocarps per fruit few to many, red *in vivo*, stipitate or rarely (sub)sessile; seed-containing portion (sub)globose, ellipsoid(-cylindrical), cylindrical or rarely \pm obovoid, apex sometimes (slightly) apiculate. Seed per monocarp 1, (sub)globose, ellipsoid, cylindrical or rarely \pm obovoid; seed coat smooth; raphe flat or slightly raised; endosperm ruminations spiniform(-flattened peg).

Etymology:—Named in honour of Prof. Herbert Huber (1931-2005), who was the first to distinguish the three clades discussed in the present paper: *Hubera* (clade A), *Monoon*, and *Polyalthia s.s.* as informal groups of *Polyalthia sensu lato* based solely on morphology (Huber 1985).

Distribution:—Twenty-seven species are formally transferred here (see below); they are distributed from East Africa and Madagascar through southern and southeastern Asia to Malesia and the southwestern Pacific. It is anticipated that when the species of *Hubera* are thoroughly revised, an additional 10–20 species will be added.

Given the morphological criteria mentioned above, the following species are transferred to the new genus:

1. *Hubera amoena* (A.C.Sm.) Chaowasku, *comb. nov.*

Basionym: *Polyalthia amoena* Smith (1950: 159).

Distribution:—Fiji.

Notes:—Study of the type specimen of this species (see Table 1) was the basis for this transfer; no DNA was available for this species.

2. *Hubera capillata* (A.C.Sm.) Chaowasku, *comb. nov.*

Basionym: *Polyalthia capillata* Smith (1950: 158).

Distribution:—Fiji.

Notes:—Study of the type specimen of this species (see Table 1) was the basis for this transfer; no DNA was available for this species.

3. *Hubera ceramensis* (Boerl.) Chaowasku, *comb. nov.*

Basionym: *Polyalthia ceramensis* Boerlage (1899: 106).

Distribution:—Ceram.

Notes:—Study of a drawing and description of this species in Boerlage (1899) was the basis for this transfer; no DNA was available for this species.

4. *Hubera cerasoides* (Roxb.) Chaowasku, *comb. nov.*

Basionym: *Uvaria cerasoides* Roxburgh (1795: 30). Homotypic synonyms: *Guatteria cerasoides* (Roxb.) Dunal (1817: 127). *Unona cerasoides* (Roxb.) Baillon (1868: 272). *Polyalthia cerasoides* (Roxb.) Beddome (1869: t. 1).

Distribution:—Mainland Asia except southern Thailand and Peninsular Malaysia.

5. *Hubera decora* (Diels) Chaowasku, *comb. nov.*

Basionym: *Polyalthia decora* Diels (1925: 342).

Distribution:—Madagascar.

6. *Hubera forbesii* (F.Muell. ex Diels) Chaowasku, *comb. nov.*

Basionym: *Polyalthia forbesii* Mueller ex Diels (1912b: 131).

Distribution:—New Guinea (to Kei Islands?).

Notes:—Study of herbarium specimens including the type (see Table 1) and pollen morphology of this species (Table 3) was the basis for this transfer; no DNA was available for this species.

7. *Hubera gracilis* (Burck) Chaowasku, *comb. nov.*

Basionym: *Polyalthia gracilis* Burck (1911: 430)

Distribution:—New Guinea.

Notes:—Study of the type specimen of this species (see Table 1) was the basis for this transfer; no DNA was available for this species.

8. *Hubera henrici* (Diels) Chaowasku, *comb. nov.*

Basionym: *Polyalthia henrici* Diels (1925: 342).

Distribution:—Madagascar.

9. *Hubera hirta* (Miq.) Chaowasku, *comb. nov.*

Basionym: *Monoon hirtum* Miquel (1865: 16). Homotypic synonym: *Polyalthia hirta* (Miq.) Mueller (1877: 95).

Distribution:—New Guinea.

Notes:—Study of the type specimen of this species (see Table 1) was the basis for this transfer; no DNA was available for this species.

10. *Hubera humblotii* (Drake ex Cavaco & Keraudren) Chaowasku, *comb. nov.*

Basionym: *Polyalthia humblotii* Drake ex Cavaco & Keraudren (1957: 77).

Distribution:—Comoro Islands.

Notes:—This species was transferred to *Hubera* based on the fact that related species [e.g. *H. henrici*, *H. perrieri* (Cavaco & Keraudren) Chaowasku] with similar morphology (presence of domatia on the lower leaf surface, Schatz & Le Thomas 1990) belong to *Hubera* (Fig. 1); no DNA was available for this species.

11. *Hubera jenkinsii* (Hook.f. & Thomson) Chaowasku, *comb. nov.*

Basionym: *Gutteria jenkinsii* Hooker & Thomson (1855: 141). Homotypic synonym: *Polyalthia jenkinsii* (Hook.f. & Thomson) Hooker & Thomson (1872: 64).

Distribution:—Southeastern Asia (west of Wallace's Line).

12. *Hubera keraudreniae* (Le Thomas & G.E.Schatz) Chaowasku, *comb. nov.*

Basionym: *Polyalthia keraudreniae* Le Thomas & Schatz in Schatz & Le Thomas (1990: 124).

Distribution:—Madagascar.

Notes:—This species was transferred to *Hubera* based on the fact that a related species (*H. decora*) with similar morphology (absence of domatia on the lower leaf surface, Schatz & Le Thomas 1990), belongs to *Hubera* (Fig. 1); no DNA was available for this species.

13. *Hubera korinti* (Dunal) Chaowasku, *comb. nov.*

Basionym: *Gutteria korinti* Dunal (1817: 133). Homotypic synonym: *Polyalthia korinti* (Dunal) Thwaites (1864: 398).

Distribution:—Southern/southwestern India to Sri Lanka.

14. *Hubera leptopoda* (Diels) Chaowasku, *comb. nov.*

Basionym: *Polyalthia leptopoda* Diels (1915: 179).

Distribution:—New Guinea.

Notes:—Study of the type specimen of this species (see Table 1) was the basis for this transfer; no DNA was available for this species.

15. *Hubera loriformis* (Gillespie) Chaowasku, *comb. nov.*

Basionym: *Polyalthia loriformis* Gillespie (1931: 4).

Distribution:—Fiji.

Notes:—Study of herbarium specimens including the type of this species (see Table 1) was the basis for this transfer; no DNA was available for this species.

16. *Hubera mossambicensis* (Vollesen) Chaowasku, *comb. nov.*

Basionym: *Polyalthia mossambicensis* Vollesen (1980b: 403).

Distribution:—East Africa.

Notes:—Study of herbarium specimen of this species (see Table 1) was the basis for this transfer; no DNA was available for this species.

17. *Hubera multistamina* (G.E.Schatz & Le Thomas) Chaowasku, *comb. nov.*

Basionym: *Polyalthia multistamina* Schatz & Le Thomas (1990: 126).

Distribution:—Madagascar.

Notes:—This species was transferred to *Hubera* based on the fact that a related species (*H. decora*) with similar morphology (absence of domatia on the lower leaf surface, Schatz & Le Thomas 1990), belongs to *Hubera* (Fig. 1); no DNA was available for this species.

18. *Hubera nitidissima* (Dunal) Chaowasku, *comb. nov.*

Basionym: *Unona nitidissima* Dunal (1817: 109). Homotypic synonym: *Polyalthia nitidissima* (Dunal) Benthham (1863: 51).

Distribution:—New Guinea and northern/northeastern Australia to New Caledonia.

19. *Hubera pendula* (Capuron ex G.E.Schatz & Le Thomas) Chaowasku, *comb. nov.*

Basionym: *Polyalthia pendula* Capuron ex Schatz & Le Thomas (1990: 128).

Distribution:—Madagascar.

20. *Hubera perrieri* (Cavaco & Keraudren) Chaowasku, *comb. nov.*

Basionym: *Polyalthia perrieri* Cavaco & Keraudren (1957: 75).

Distribution:—Madagascar.

21. *Hubera rumphii* (Blume ex Hensch.) Chaowasku, *comb. nov.*

Basionym: *Guatteria rumphii* Blume ex Henschel (1833: 153). Homotypic synonym: *Polyalthia rumphii* (Blume ex Hensch.) Merrill (1923: 162).

Distribution:—Southeastern Asia (west of Wallace's Line) to Ambon (and New Guinea?).

Notes:—This and the other two morphologically similar species, *H. ceramensis* and *H. jenkinsii*, constitute a species complex (Turner 2011). To resolve this complex, detailed revisionary and phylogenetic studies are required.

22. *Hubera sambiranensis* (Capuron ex Le Thomas & G.E.Schatz) Chaowasku, *comb. nov.*

Basionym: *Polyalthia sambiranensis* Capuron ex Le Thomas & Schatz in Schatz & Le Thomas (1990: 116).

Distribution:—Madagascar.

Notes:—This species was transferred to *Hubera* based on the fact that related species (e.g. *H. henrici*, *H. perrieri*) with similar morphology (presence of domatia on the lower leaf surface, Schatz & Le Thomas 1990), belong to *Hubera* (Fig. 1); no DNA was available for this species.

23. *Hubera stuhlmannii* (Engl.) Chaowasku, *comb. nov.*

Basionym: *Unona stuhlmannii* Engler (1895: 179). Homotypic synonym: *Polyalthia stuhlmannii* (Engl.) Verdcourt (1969: 94).

Distribution:—East Africa.

24. *Hubera tanganyikensis* (Vollesen) Chaowasku, *comb. nov.*

Basionym: *Polyalthia tanganyikensis* Vollesen (1980a: 56).

Distribution:—East Africa.

25. *Hubera trichoneura* (Diels) Chaowasku, *comb. nov.*

Basionym: *Polyalthia trichoneura* Diels (1912a: 871).

Distribution:—New Guinea.

Notes:—Study of the type specimen of this species (see Table 1) was the basis for this transfer; no DNA was available for this species.

26. *Hubera verdcourtii* (Vollesen) Chaowasku, *comb. nov.*

Basionym: *Polyalthia verdcourtii* Vollesen (1980a: 56).

Distribution:—East Africa.

Notes:—This species was transferred to *Hubera* based on the fact that a related species (*H. stuhlmannii*) with similar morphology (presence of domatia on the lower leaf surface, Vollesen 1980a), belongs to *Hubera* (Fig. 1); no DNA was available for this species.

27. *Hubera vitiensis* (Seem.) Chaowasku, *comb. nov.*

Basionym: *Polyalthia vitiensis* Seemann (1865: 4).

Distribution:—Fiji.

Notes:—Study of herbarium specimens of this species (see Table 1) was the basis for this transfer; no DNA was available for this species.

Several species (e.g. *H. henrici*, *H. korinti*, *H. nitidissima*, *H. perrieri*, *H. stuhlmannii*, *H. vitiensis*) exhibit domatia on the lower leaf surface at the axils where the secondary veins meet the primary veins (Figs. 5A–D; see comparisons of lower leaf surface without domatia in Figs. 5E–H). They are characterized by a tuft of aggregated hairs visible to the naked eye. In Annonaceae, this kind of domatium has been reported to occur in *Mitrephora* Hooker & Thomson (1855: 112) (Weerasooriya & Saunders 2010), which is also a member of the Miliuseae, and *Annona* Linnaeus (1753: 536) [including *Rollinia* Saint-Hilaire (1824: 28)] (Van den Bos *et al.* 1989), a member of the subfamily Annonoideae (Chatrou *et al.* 2012).

The genus *Miliusa* was recovered as sister to *Hubera*. So far, no morphological synapomorphy linking these genera has been observed. They only share some characters considered as symplesiomorphies, such as reticulate tertiary leaf venation and pollen with verrucate to rugulate ornamentation (cerebroid *sensu* Mols *et al.* 2004b) and germination zone(s) characterized by enlargements/reductions of the intine sublayers (Chaowasku *et al.* 2008).

Among genera of Malmeoideae, *Hubera* exhibits the widest distribution, ranging from East Africa and Madagascar across southern and southeastern Asia through Malesia and the southwestern Pacific. It is the only genus of Miliuseae that occurs in Madagascar and East Africa. Phylogenetic analysis of *Hubera* (Fig. 1) shows some clear biogeographic patterns. The Afro-Madagascan species are grouped together in a strongly supported clade (clade A2), as do the species occurring in the Austro-Papuasian area, which are clustered, with strong support, in clade A1. The biogeographic scenario explaining this distribution will be the focus of another study.

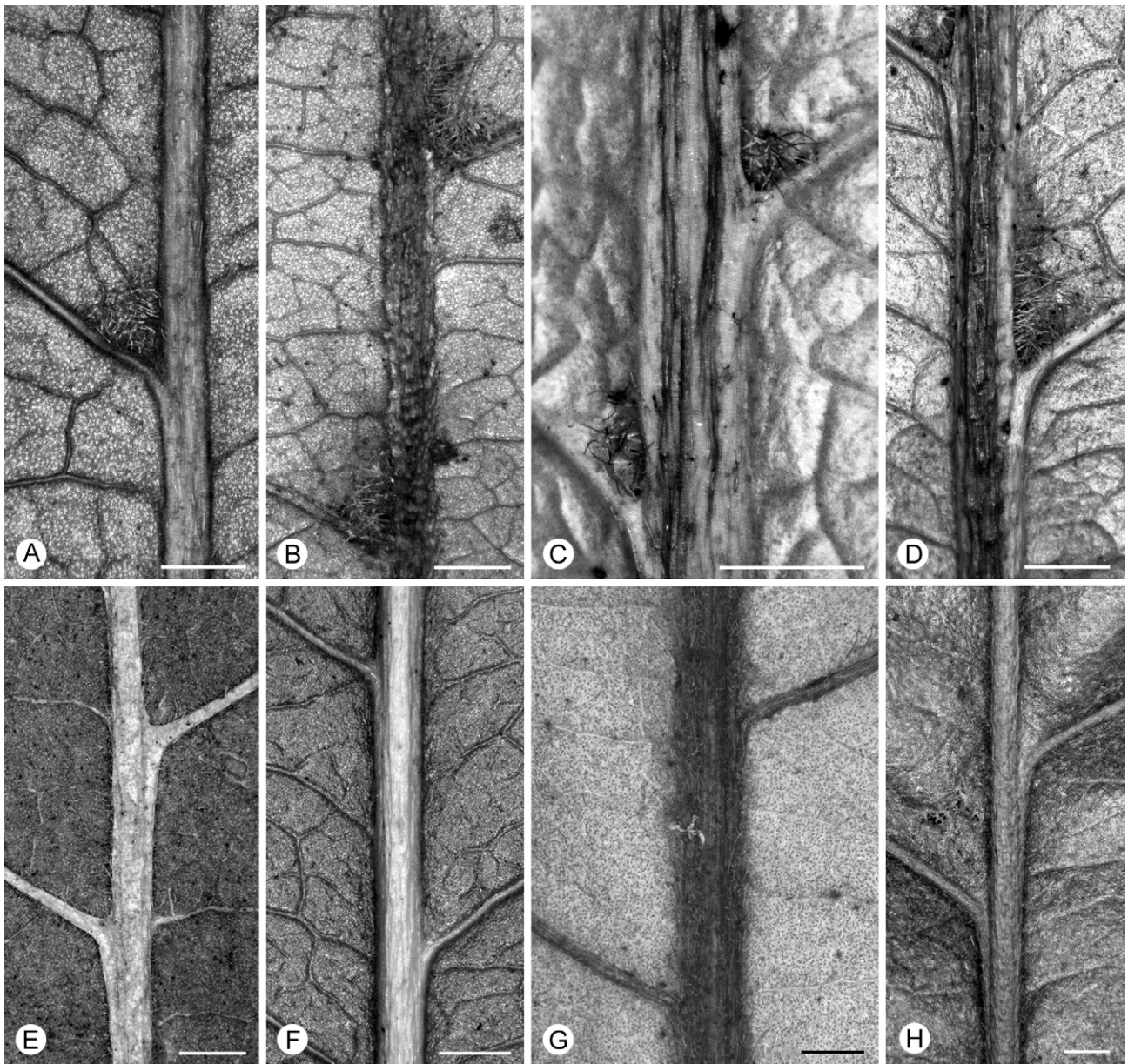


FIGURE 5. Lower leaf surface of representative species of *Hubera* with domatia (A–D) and *Hubera* (E, F), *Monoon* (G), and *Polyalthia sensu stricto* (H) without domatia. A. *Hubera nitidissima* (Forster PIF 28246). B. *Hubera vitiensis* (Smith 8203). C. *Hubera korintii* (Kostermans 24916). D. *Hubera stuhlmannii* (Luke & Robertson 1424). E. *Hubera cerasoides* (Maxwell 90-744). F. *Hubera pendula* (Rabevohitra 2386). G. *Monoon fuscum* (Maxwell 87-536). H. *Polyalthia longirostris* (Brass 24039). Scale bars: 1 mm.

Schatz & Le Thomas (1990) revised *Polyalthia* species occurring in Madagascar and distinguished five informal groups (groups A–E) based on macromorphological and pollen characters. Species of groups B and C possess monosulcate pollen and were found to form a strongly supported clade (now transferred to *Fenerivia*) recovered outside Miliuseae (Saunders *et al.* 2011), which is congruent with the phylogenetic results. Genera outside Miliuseae exhibit monosulcate pollen, whereas genera belonging to Miliuseae possess cryptoaperturate/disulcate pollen (Chaowasku *et al.* 2012). Species of groups A, D, and E have cryptoaperturate pollen, and their membership in *Hubera*, which is a member of the Miliuseae, was thus not unexpected.

It is generally difficult to distinguish *Hubera* from *Fenerivia* using only macromorphology. Both genera share some similar morphological features, e.g. axillary inflorescences, uniovulate carpels, and spiniform(-flattened peg) endosperm ruminations (Schatz & Le Thomas 1990). However, *Fenerivia* possesses a more

pronounced seed raphe that is rib-like (Saunders *et al.* 2011), whereas that of *Hubera* is flat to slightly raised (Fig. 4a). In addition, *Fenerivia* exhibits a pronounced (\pm thickened) receptacle rim (vestigial calyx flange *sensu* Saunders *et al.* 2011). This feature is considered one of the diagnostic characters of *Fenerivia*. It is absent (or rarely slightly observed) in *Hubera*. Nevertheless, the presence of domatia on the lower leaf surface should be a primary character in distinguishing Madagascan *Hubera* from *Fenerivia* because the latter does not possess this character, whereas *Hubera* species formerly known as *Polyalthia* group A of Schatz & Le Thomas (1990) do. Domatia on the lower leaf surface can also be used to quickly distinguish certain Afro-Asian species of *Hubera* from *Polyalthia s.s.* and other genera formerly known as *Polyalthia*. Another consequence of this study is elimination of *Polyalthia s.s.* from the floras of Africa and Madagascar; thus, it is strictly a genus of Australasia.

Acknowledgements

The authors would like to thank the following persons: Bertie Joan van Heuven (Naturalis Biodiversity Center, NHN) for LM and SEM; Wim Star (Naturalis Biodiversity Center, NHN) for TEM; Ben Kieft (Naturalis Biodiversity Center, NHN) for compiling the plates; Mr. Outlander from *siamensis.org*, Kithisak Aongyong, Uthai Treesucon, Simon Gardner & Pindar Sidisunthorn, and Laurie Jessup for kindly providing floral/fruit images; Yvonne C.F. Su, Richard M.K. Saunders and Andrew Ford for silica-dried leaf material; and Ria Vrieling-van Ginkel (Wageningen University) for technical assistance. Two anonymous reviewers are kindly acknowledged for providing useful comments and suggestions. The first author is grateful to the Royal Thai Government for providing opportunity and funding to study plant systematics at Leiden University.

References

- Baillon, H.E. (1868) *Histoire des plantes*, 1. Hachette & Cie, Paris, 488 pp.
- Bakker, F.T., Hellbrügge, D., Culham, A. & Gibby, M. (1998) Phylogenetic relationships within *Pelargonium* sect. *Peristera* (Geraniaceae) inferred from nrDNA and cpDNA sequence comparisons. *Plant Systematics and Evolution* 211: 273–287.
- Beddome, R.H. (1869) *The flora sylvatica for southern India*, 1. Gantz Brothers, Madras, 204 plates.
- Bentham, G. (1863) *Flora Australiensis*, 1. Reeve & Co., London, 508 pp.
- Blume, C.L. (1830) *Flora Javæ [Anonaceae]*. Frank, Brussels, 108 pp.
- Boerlage, J.G. (1899) *Icones Bogorienses*, 1 (fascicule 3). Brill, Leiden, pp. 157–208.
- Burck, W. (1911) Anonaceae [résultats de l'expédition scientifique Néerlandaise à la Nouvelle-Guinée en 1907 et 1909 sous les auspices Dr. H.A. Lorentz, first part, Botanique]. *Nova Guinea* 8: 427–433.
- Candolle, A.L.P.P. de (1832) Mémoire sur la famille des Anonacées, et en particulier sur les espèces du pays des Birmans. *Mémoires de la Société de Physique et d'Histoire Naturelle de Genève* 5: 177–221.
- Cavaco, A. & Keraudren, M. (1957) Notes systématiques et biogéographiques sur les Anonacées de Madagascar et des Comores. *Bulletin du Jardin Botanique de l'État à Bruxelles* 27: 59–93.
- Chaowasku, T., Mols, J.B. & Van der Ham, R.W.J.M. (2008) Pollen morphology of *Miliusa* and relatives (Annonaceae). *Grana* 47: 175–184.
- Chaowasku, T., Keßler, P.J.A. & Van der Ham, R.W.J.M. (2012) A taxonomic revision and pollen morphology of the genus *Dendrokingstonia* (Annonaceae). *Botanical Journal of the Linnean Society* 168: 76–90.
- Chatrou, L.W., Pirie, M.D., Erkens, R.H.J., Couvreur, T.L.P., Neubig, K.M., Abbott, J.R., Mols, J.B., Maas, J.W., Saunders, R.M.K. & Chase, M.W. (2012) A new subfamilial and tribal classification of the pantropical flowering plant family Annonaceae informed by molecular phylogenetics. *Botanical Journal of the Linnean Society* 169: 5–40.
- Couvreur, T.L.P., Richardson, J.E., Sosef, M.S.M., Erkens, R.H.J. & Chatrou, L.W. (2008) Evolution of syncarpy and other morphological characters in African Annonaceae: A posterior mapping approach. *Molecular Phylogenetics and Evolution* 47: 302–318.
- Couvreur T.L.P., Van der Ham, R.W.J.M., Mbele, Y.M., Mbago, F.M. & Johnson, D.M. (2009) Molecular and morphological characterization of a new monotypic genus of Annonaceae, *Mwasumbia*, from Tanzania. *Systematic Botany* 34: 266–276.
- Cuénoud, P., Savolainen, V., Chatrou, L.W., Powell, M., Grayer, R.J. & Chase, M.W. (2002) Molecular phylogenetics of

- Caryophyllales based on nuclear 18S rDNA and plastid *rbcL*, *atpB*, and *matK* DNA sequences. *American Journal of Botany* 89: 132–144.
- Diels, L. (1912a) Anonaceae [résultats de l'expédition scientifique Néerlandaise à la Nouvelle-Guinée en 1907 et 1909 sous les auspices Dr. H.A. Lorentz, Botanique, livraison 4]. *Nova Guinea* 8: 871–873.
- Diels, L. (1912b) Die Anonaceen von Papuasien. *Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie* 49: 113–167.
- Diels, L. (1915) Neue Anonaceen von Papuasien. *Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie* 52: 177–186.
- Diels, L. (1925) Revisio Anonacearum Madagascariensium. *Notizblatt des Botanischen Gartens und Museums zu Berlin-Dahlem* 9: 334–357.
- Doyle, J.J. & Doyle, J.L. (1987) A rapid DNA isolation procedure from small quantities of fresh leaf tissue. *Phytochemical Bulletin* 19: 11–15.
- Dunal, M.F. (1817) *Monographie de la famille des Anonacées*. Treuttel & Würtz, Paris, 144 pp.
- Endress, P.K. (2011) Evolutionary diversification of the flowers in angiosperms. *American Journal of Botany* 98: 370–396.
- Endress, P.K. & Doyle, J.A. (2009) Reconstructing the ancestral angiosperm flower and its initial specializations. *American Journal of Botany* 96: 22–66.
- Engler, A. (1895) *Die Pflanzenwelt Ost-Afrikas und der Nachbargebiete* (theil C). Reimer, Berlin, 433 pp.
- Fay, M.F., Swensen, S.M. & Chase, M.W. (1997) Taxonomic affinities of *Medusagyne oppositifolia* (Medusagynaceae). *Kew Bulletin* 52: 111–120.
- Fries, R.E. (1931) Revision der Arten einiger Anonaceen-Gattungen II. *Acta Horti Bergiani* 10: 129–341.
- Gentry, A.H. (1988) Tree species richness of upper Amazonian forests. *Proceedings of the National Academy of Sciences (USA)* 85: 156–159.
- Gillespie, J.W. (1931) New plants from Fiji-II. *Bernice P. Bishop Museum Bulletin* 83: 1–72.
- Goloboff, P.A., Farris, J.S., Källersjö, M., Oxelman, B., Ramírez, M.J. & Szumik, C.A. (2003) Improvements to resampling measures of group support. *Cladistics* 19: 324–332.
- Goloboff, P.A., Farris, J.S. & Nixon, K.C. (2008) TNT, a free program for phylogenetic analysis. *Cladistics* 24: 774–786.
- Hamilton, M.B. (1999) Four primer pairs for the amplification of chloroplast intergenic regions with intraspecific variation. *Molecular Ecology* 8: 521–523.
- Henschel, A.W.E.T. (1833) *Vita G. E. Rumphii*. Schulzium & Socios, Breslau, 215 pp.
- Hooker, J.D. (1860) Illustrations of the floras of the Malayan Archipelago and of tropical Africa. *Transactions of the Linnean Society of London* 23: 155–172.
- Hooker, J.D. & Thomson, T. (1855) *Flora Indica*, 1. Pamplin, London, 285 pp.
- Hooker, J.D. & Thomson, T. (1872) Anonaceae, pp. 45–94. In: Hooker, J.D. (ed.), *Flora of British India*, 1. Reeve & Co., London, 740 pp.
- Huber, H. (1985) Annonaceae, pp. 1–75. In: Dassanayake, M.D. & Fosberg, F.R. (eds.), *A revised handbook to the flora of Ceylon*, 5. Amerind Publishing Co., New Delhi, 476 pp.
- Johnson, D.M. (1989) Revision of *Disepalum* (Annonaceae). *Brittonia* 41: 356–378.
- Johnson, D.M. & Murray, N.A. (1995) Synopsis of the tribe Bocageae (Annonaceae), with revisions of *Cardiopetalum*, *Froesiodendron*, *Trigynaea*, *Bocagea*, and *Hornschuchia*. *Brittonia* 47: 248–319.
- Johnson, D.M. & Murray, N.A. (1999) Four new species of *Polyalthia* (Annonaceae) from Borneo and their relationship to *Polyalthia insignis*. *Contributions from the University of Michigan Herbarium* 22: 95–104.
- Le Thomas A. (1980) Ultrastructural characters of the pollen grains of African Annonaceae and their significance for the phylogeny of primitive angiosperms (first part). *Pollen et Spores* 22: 267–342.
- Le Thomas, A. (1988) Variation de la région aperturale dans le pollen des Annonacées. *Taxon* 37: 644–656.
- Linnaeus, C. (1753) *Species plantarum*, 1. Salvius, Stockholm, 560 pp.
- Marshall, D.C. (2010) Cryptic failure of partitioned Bayesian phylogenetic analyses: Lost in the land of long trees. *Systematic Biology* 59: 108–117.
- Merrill, E.D. (1923) *An enumeration of Philippine flowering plants*, 2. Bureau of Printing, Manila, 530 pp.
- Miquel, F.A.W. (1865) Anonaceae Archipelagi Indici. *Annales Musei Botanici Lugduno-Batavi* 2: 1–45.
- Mols, J.B., Gravendeel, B., Chatrou, L.W., Pirie, M.D., Bygrave, P.C., Chase, M.W. & Keßler, P.J.A. (2004a) Identifying clades in Asian Annonaceae: Monophyletic genera in the polyphyletic Miliuseae. *American Journal of Botany* 91: 590–600.
- Mols, J.B., Co, D.L.V., Gravendeel, B., Chatrou, L.W., Pirie, M.D., Van der Ham, R.W.J.M., Van Marle, E.J. & Keßler, P.J.A. (2004b) Morphological character evolution in the miliusoid clade (Annonaceae), pp. 37–75. In: Mols, J.B. (ed.), *From Miliusa to Miliuseae to Miliusoid: Identifying clades in Asian Annonaceae*. PhD thesis, Leiden University, 194 pp.
- Mols, J.B., Keßler, P.J.A., Rogstad, S.H. & Saunders, R.M.K. (2008) Reassignment of six *Polyalthia* species to the new genus *Maasia* (Annonaceae): Molecular and morphological congruence. *Systematic Botany* 33: 490–494.

- Mueller, F.J.H. (1877) Descriptive notes on Papuan plants. Appendix. Skinner, Melbourne, pp. 95–119.
- Mueller, F.J.H. (1891) Descriptions of new Australian plants, with occasional other annotations. *Victorian Naturalist* 7: 180–183.
- Olmstead, R.G., Michaels, H.J., Scott, K.M. & Palmer, J.D. (1992) Monophyly of the Asteridae and identification of their major lineages inferred from DNA-sequences of *rbcL*. *Annals of the Missouri Botanical Garden* 79: 249–265.
- Olmstead, R.G. & Sweere, J.A. (1994) Combining data in phylogenetic systematics: An empirical approach using three molecular data sets in the Solanaceae. *Systematic Biology* 43: 467–481.
- Pirie, M.D., Chatrou, L.W., Erkens, R.H.J., Maas, J.W., Van der Niet, T., Mols, J.B. & Richardson, J.E. (2005) Phylogeny reconstruction and molecular dating in four Neotropical genera of Annonaceae: The effect of taxon sampling in age estimations, pp. 149–174. In: Bakker, F.T., Chatrou, L.W., Gravendeel, B. & Pelsers, P.B. (eds.), *Plant species-level systematics: New perspectives on pattern & process*. Regnum Vegetabile 143, Gantner Verlag, Ruggell, Liechtenstein, 348 pp.
- Pirie, M.D., Chatrou, L.W., Mols, J.B., Erkens, R.H.J. & Oosterhof, J. (2006) ‘Andean-centred’ genera in the short-branch clade of Annonaceae: Testing biogeographic hypotheses using phylogeny reconstruction and molecular dating. *Journal of Biogeography* 33: 31–46.
- Punt, W., Hoen, P.P., Blackmore, S., Nilsson, S. & Le Thomas, A. (2007) Glossary of pollen and spore terminology. *Review of Palaeobotany and Palynology* 143: 1–81.
- Rambaut, A. & Drummond, A. (2009) Tracer v1.5. Available from: <<http://tree.bio.ed.ac.uk/software/tracer>>.
- Richard, A. (1841) Essai d’une flore de l’île de Cuba, 1. In: Sagra, R. de la (ed.), *Histoire physique, politique et naturelle de l’île de Cuba* [Botanique-plantes vasculaires by A. Richard]. Bertrand, Paris, 663 pp.
- Richardson, J.E., Chatrou, L.W., Mols, J.B., Erkens, R.H.J. & Pirie, M.D. (2004) Historical biogeography of two cosmopolitan families of flowering plants: Annonaceae and Rhamnaceae. *Philosophical Transactions of the Royal Society, series B: Biological Sciences* 359: 1495–1508.
- Rogstad, S.H. (1989) The biosystematics and evolution of the *Polyalthia hypoleuca* complex (Annonaceae) of Malesia I. Systematic treatment. *Journal of the Arnold Arboretum* 70: 153–246.
- Ronquist, F. & Huelsenbeck, J.P. (2003) MrBayes 3: Bayesian phylogenetic inference under mixed models. *Bioinformatics* 19: 1572–1574.
- Roxburgh, W. (1795) *Plants of the coast of Coromandel*, 1. Bulmer & Co., London, 68 pp.
- Saint-Hilaire, A. de (1824) *Flora Brasiliae meridionalis*, 1. Belin, Paris, 400 pp.
- Saunders, R.M.K. (2010) Floral evolution in the Annonaceae: Hypotheses of homeotic mutations and functional convergence. *Biological Reviews* 85: 571–591.
- Saunders, R.M.K., Su, Y.C.F. & Xue, B. (2011) Phylogenetic affinities of *Polyalthia* species (Annonaceae) with columellar-sulcate pollen: Enlarging the Madagascan endemic genus *Fenerivia*. *Taxon* 60: 1407–1416.
- Schatz, G.E. & Le Thomas, A. (1990) The genus *Polyalthia* Blume (Annonaceae) in Madagascar. *Bulletin du Muséum national d’Histoire naturelle, section B, Adansonia, série 4*, 12: 113–130.
- Scheffer, R.H.C.C. (1870) Observationes phytographicae. Pars II. *Natuurkundig Tijdschrift voor Nederlandsch-Indië* 31: 338–375.
- Seemann, B. (1865) *Flora Vitiensis: A description of the plants of the Viti or Fiji Islands with an account of their history, uses, and properties*. Reeve & Co., London, 453 pp.
- Simmons, M.P. & Ochoterena, H. (2000) Gaps as characters in sequence-based phylogenetic analyses. *Systematic Biology* 49: 369–381.
- Slik, J.W.F., Poulsen, A.D., Ashton, P.S., Cannon, C.H., Eichhorn, K.A.O., Kartawinata, K., Lanniari, I., Nagamasu, H., Nakagawa, M., Van Nieuwstadt, M.G.L., Payne, J., Saridan, A., Sidiyasa, K., Verburg, R.W., Webb, C.O. & Wilkie, P. (2003) A floristic analysis of the lowland dipterocarp forests of Borneo. *Journal of Biogeography* 30: 1517–1531.
- Smith, A.C. (1950) Studies of Pacific island plants VI. New and noteworthy flowering plants from Fiji. *Journal of the Arnold Arboretum* 31: 137–171.
- Su, Y.C.F., Smith, G.J.D. & Saunders, R.M.K. (2008) Phylogeny of the basal angiosperm genus *Pseuduvaria* (Annonaceae) inferred from five chloroplast DNA regions, with interpretation of morphological character evolution. *Molecular Phylogenetics and Evolution* 48: 188–206.
- Taberlet, P., Gielly, L., Pautou, G. & Bouvet, J. (1991) Universal primers for amplification of three non-coding regions of chloroplast DNA. *Plant Molecular Biology* 17: 1105–1109.
- Thwaites, G.H.K. (1864) *Enumeratio plantarum Zeylaniae: An enumeration of Ceylon plants* (part 5). Dulau & Co., London, pp. 321–483.
- Trimen, H. (1931) *A hand-book to the flora of Ceylon*. Part 6 [supplement by A.H.G. Alston]. Dulau & Co., London, 350 pp.
- Turner, I.M. (2011) A catalogue of the Annonaceae of Borneo. *Phytotaxa* 36: 1–120.
- Van den Bos, W.J., Koek-Noorman, J. & Berendsen, W. (1989) Studies in Annonaceae. XII. Domatia in *Annona* and *Rollinia*: Occurrence, SEM structure, and taxonomic significance. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, series C* 92: 325–330.

- Van der Ham, R.W.J.M. (1990) Nephelieae pollen (Sapindaceae): Form, function, and evolution. *Nationaal Herbarium Nederland, Leiden Botanical Series* 13: 1–255.
- Van Setten, A.K. & Koek-Noorman, J. (1992) Fruits and seeds of Annonaceae: Morphology and its significance for classification and identification. *Bibliotheca Botanica* 142: 1–101.
- Verdcourt, B. (1969) The status of the genus *Polyalthia* Blume (Annonaceae) in Africa. *Adansonia, série 2*, 9: 87–94.
- Vollesen, K. (1980a) Notes on Annonaceae from Tanzania. *Botaniska Notiser* 133: 53–62.
- Vollesen, K. (1980b) A new species of *Polyalthia* (Annonaceae) from Mozambique. *Botaniska Notiser* 133: 403–404.
- Waha M. & Hesse, M. (1988) Aperture types within *Sapranthus* and *Polyalthia* (Annonaceae). *Plant Systematics and Evolution* 161: 135–146.
- Walker, J.W. (1971) Pollen morphology, phytogeography, and phylogeny of the Annonaceae. *Contributions from the Gray Herbarium of Harvard University* 202: 3–131.
- Weerasooriya, A.D. & Saunders, R.M.K. (2010) Monograph of *Mitrephora* (Annonaceae). *Systematic Botany Monographs* 90: 1–167.
- Xue, B., Su, Y.C.F., Mols, J.B., Keßler, P.J.A. & Saunders, R.M.K. (2011) Further fragmentation of the polyphyletic genus *Polyalthia* (Annonaceae): Molecular phylogenetic support for a broader delimitation of *Marsypopetalum*. *Systematics and Biodiversity* 9: 17–26.
- Xue, B., Su, Y.C.F., Thomas, D.C. & Saunders, R.M.K. (2012) Pruning the polyphyletic genus *Polyalthia* (Annonaceae) and resurrecting the genus *Monoon*. *Taxon* 61: 1021–1039.
- Zhou, L., Su, Y.C.F. & Saunders, R.M.K. (2009) Molecular phylogenetic support for a broader delimitation of *Uvaria* (Annonaceae), inclusive of *Anomianthus*, *Cyathostemma*, *Ellipeia*, *Ellipeiopsis* and *Rauwenhoffia*. *Systematics and Biodiversity* 7: 249–258.
- Zhou, L., Su, Y.C.F., Chalermglin, P. & Saunders, R.M.K. (2010) Molecular phylogenetics of *Uvaria* (Annonaceae): Relationships with *Balonga*, *Dasoclema* and Australian species of *Melodorum*. *Botanical Journal of the Linnean Society* 163: 33–43.