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The Systematics of tribe Millettieae

(Leguminosae-Papilionoideae)

A Thesis submitted by

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to my parents

Declaration

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

Sawai Mattapha

Abstract

The tribe Millettieae belongs to the family Leguminosae. As traditionally circumscribed it comprises approximately 45 genera and over 900 species distributed pantropically and in subtropical regions. Previous phylogenetic studies revealed that many genera in the tribe are not monophyletic. The most problematic genus is the massive genera *Millettia*. Various authors have attempted to clarify generic circumscription since the genus was established in 1834. This thesis attempts to clarify the phylogenetic relationships of doubtfully placed genera of the tribe Millettieae, with the emphasis on the polyphyletic genus *Millettia* and its closed allies.

Forty-five genera placed in the Millettoid *s.l.* were sampled for phylogeny reconstruction, representing 22 genera putatively part of the Core Millettieae, 17 genera from the Basal millettoid & phaseoloid group (BMP) of the Millettoid *s.str.* Group, and six genera from the IRLC Clade. Phylogenetic relationships are reconstructed in this study using Maximum Likelihood and Bayesian analysis. Three DNA markers were used in the study, which included published and newly-generated sequence data. In total, there were 361 sequences of the ribosomal nuclear DNA (nrDNA) *ITS* region; a combined chloroplast (*matK+trnL-F*) included 306 individuals, and the total evidence analysis (*ITS+matK+trnL-F*) included 436 individuals. The Maximum Likelihood and Bayesian analyses which produced comparable phylogenies are largely congruent.

The total evidence phylogeny supported the monophyly of genera in Millettoid *s.str.* Group, namely *Antheroporum*, *Apurimacia*, *Chadsia*, *Leptoderris*, *Mundulea*, *Philenoptera*, *Piscidia*, *Platysepalum*, *Pongamiopsis*, *Pyranthus*, *Solori*, *Sylvichadsia* and *Tephrosia*, while others were not monophyletic and need to be re-evaluated, namely *Dahlstedtia*, *Deguelia*, *Derris*, *Fordia*, *Lonchocarpus*, *Millettia*, *Muelleria*, *Ptychlobium* and *Requienia*. Genera with uncertain placement that now more robustly placed are: *Antheroporum* and *Disystemon* in the Basal Millettoid and phaseoloid group (BMP), and *Deguelia*, *Fordia*, *Leptoderris*, *Platysepalum* and *Sylvichadsia* in the Core Millettieae. In case of genus *Millettia*, all sequences were distributed between Group 1 and Group 2 of the Millettoid *s.str.* Group, groups which correspond with the Canavanine Group and the Non-canavanine Group. Within these groups eleven subgroups were recognized.

The distribution of canavanine, a Non-Protein Amino Acid Accumulating (NPAAA), is explored by means of a literature review, in the light of the new phylogenetic hypothesis. The investigation found three species without canavanine in the Canavanine Group, and two species with canavanine in the Non-canavanine Group. Consequently, these groups are considered whether to retain old names or proposed possible alternative names.

In order to retain the monophyletic *Derris*, a need for a new combination and a new name for *Millettia pachycarpa* Benth. was identified. Here *Derris lithocarpa* (Benth.) Mattapha & Hawkins, *com.nov. et nom.nov.* is proposed. In relation to this, a new species of *Derris* from Thailand is newly described as *Derris constricta* Mattapha & Hawkins, *sp.nov.*

Furthermore, three new species *Millettia* are also newly described, two species from Thailand namely *M. calcicola* Mattapha & Hawkins, *sp.nov.* and *M. khaoyaiensis* Mattapha & Hawkins, *sp.nov.* and another species from Vietnam, *M. fulva* Mattapha, Forest & Hawkins, *sp.nov.* However, the generic placement for these new species might yet prove to be provisional, since generic limits remain unsatisfactory.

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Chapter 1 Introduction

1.1 An overview of the family Leguminosae

1.1.1 The Leguminosae

The family Leguminosae or Fabaceae, known as the bean or pea family, comprises approximately 727 genera and 19,325 species worldwide (Lewis *et al.*, 2005). It is the 3rd largest family of flowering plants after Orchidaceae and Asteraceae respectively. Polhill in 1981 recognized 650 and 671 genera respectively, and in 1994, estimated there were 18,000 species. This is fewer than recognized by Lewis *et al.* (2005). This large increase in the number of genera over the two decades since Polhill's treatment is largely due to the recognition, at generic rank, of several segregates of larger and previously unnatural paraphyletic genera (Lewis *et al.*, 2005).

The legume family traditionally comprised three subfamilies; Caesalpinioideae, Mimosoideae and Papilionoideae, of which the latter is the most diverse species rich. More recently a revised subfamilial classification of the Leguminosae based on a phylogeny of the chloroplast gene region *matK* recognises six robustly supported subfamilies: a recircumscribed Caesalpinioideae DC., Cercidoideae LPWG, Detarioideae Burmeist., Dialioideae LPWG, Duparquetioideae LPWG, and Papilionoideae DC (LPWG, 2017). Table 1.1 lists the subfamilies and their most important characters.

The family varies in habit, encompassing from herbs, shrubs, lianas, twiners to trees. Flowers are zygomorphic or actinomorphic. The ovary has a single superior carpel with one locule with a few exceptions. Lewis *et al.* (2005) noted some species of tribe Ingeae of the subfamily Mimosoideae have several free carpels in a flower, and some species of *Astragalus* and *Oxytropis* have bilocular carpels. The placentation is marginal with one to many ovules. The pod is variable, generally a legume, valved, dehiscent or indehiscent.

The tribal rank is important in Legume classification, and the comprehensive guide to the Legumes, *Legumes of the World*, presents descriptions of tribes, and is organized so that the genera are presented according to their tribal placement (Lewis *et al.*, 2005). This volume recognizes 36 tribes. Table 1.2 presents numbers of genera and species according to their new subfamilial classification.

Table 1.1 A comparison of the six subfamilies, based on the LPWG classification (LPWG, 2017).

Characters	Cercidoideae	Detarioideae	Duparquetioideae	Dialioideae	Caesalpinioideae	Papilionoideae
Habit	Trees, shrubs or lianas, many with tendrils, branches rarely modified into cladodes	Unarmed trees, sometimes shrubs, rarely suffruticose	Unarmed scrambling liana	Unarmed trees or shrubs, rarely suffruticose	Trees, shrubs, lianas, suffruticose or functionally herbaceous, commonly armed with prickles or spines	Mostly unarmed trees, shrubs, lianas, herbs, or twining or tendriled vines
Extrafloral nectaries	Specialised extrafloral nectaries lacking on petiole and leaf rachis, often stipular	Specialised extrafloral nectaries often present on the underside, rarely on the margins, of leaflets or on leaf rachis	Specialised extrafloral nectaries lacking on petiole and leaf rachis	Specialised extrafloral nectaries lacking on petiole and leaf rachis and on leaflet surface	Specialised extrafloral nectaries often present on the petiole and/or on the primary and secondary rachises, usually between pinnae or leaflet pairs, more rarely stipular or bracteal	Specialised extrafloral nectaries lacking on petiole and leaf rachis, occasionally stipular, stipellar or bracteal nectaries, or swollen and nectar-secreting peduncles, rarely on sepals
Stipules	Stipules in lateral position, free	Stipules in intrapetiolar position and then free, valvate and connected by chaffy hairs, or fused, either partly at base or entirely, rarely lateral and free	Stipules in lateral position, free, narrowly triangular	Stipules in lateral position, free or absent	Stipules in lateral position, free or absent	Stipules in lateral position, free or absent
Leaves	Leaves uni- or bifoliolate, pulvinate	Leaves paripinnate or bifoliolate, rarely simple or unifoliolate, pulvinate	Leaves imparipinnate, pulvinate	Leaves imparipinnate, rarely paripinnate, 1-foliolate or palmately-compound	Leaves commonly bipinnate, otherwise pinnate, and then mostly paripinnate, rarely imparipinnate, less often bifoliolate, modified into phyllodes or lacking, usually pulvinate	Leaves mostly pari- or imparipinnate to palmately compound, commonly uni- or trifoliolate, rarely bi- or tetrafoliolate, never bicomponent (rarely palmately-pinnate), either pulvinate or not

Table 1.1 Continued.

Characters	Cercidoideae	Detarioideae	Duparquetioideae	Dialioideae	Caesalpinioideae	Papilionoideae
Leaflets	Leaflet blade (when unifoliolate) entire or bilobed with a small mucro at the apex or between the lobes, exstipellate	Leaflets opposite or alternate, translucent glands sometimes present, exstipellate	Leaflets opposite, exstipellate	Leaflets alternate, rarely opposite, exstipellate	Pinnae and leaflets mostly opposite, rarely alternate; stipels rare, not to be confused with the more commonly present paraphyllidia (reduced basal leaflet pair on the pinnae)	Leaflets opposite or alternate, sometimes modified into tendrils, rarely in phyllodes, stipels present or absent
Bracteoles	Bracteoles minute or large	Bracteoles small to large, frequently petaloid, valvate, imbricate or partially fused, partially or completely enclosing the bud	Bracteoles small	Bracteoles small or absent	Bracteoles commonly absent or small	Bracteoles usually present, rarely enlarged, valvate, enveloping bud
Inflorescence	Inflorescence raceme or pseudoraceme	Inflorescence raceme or a cymose panicle	Inflorescence a terminal raceme	Highly branched, thyrsoid inflorescences, less commonly racemes with distichous anthotaxy, borne in both terminal and axillary positions, or reduced to one axillary flower	Inflorescences globose, spicate, paniculate or racemose	Inflorescence mostly racemes, pseudoracemes or panicles, less often pseudocymose, spicate or capitate, axillary or terminal, or flowers solitary

Table 1.1 Continued.

Characters	Cercidoideae	Detarioideae	Duparquetioideae	Dialioideae	Caesalpinoideae	Papilionoideae
Flowers	Flowers bisexual, rarely unisexual (plants polygamous or dioecious), slightly to strongly zygomorphic, sometimes “papilionate-like”	Flowers bisexual, actinomorphic or slightly to strongly zygomorphic (never “papilionate-like”)	Flowers bisexual, strongly zygomorphic	Flowers bisexual, rarely polygamous	Flowers usually bisexual, rarely unisexual (species dioecious or monoecious), or bisexual flowers combined with unisexual and/or sterile flowers in heteromorphic inflorescences, actinomorphic, less frequently zygomorphic or asymmetric	Flowers bisexual, usually zygomorphic (“papilionate”), rarely asymmetric, actinomorphic or nearly so
Hypanthium	Hypanthium greatly elongated to almost absent	Hypanthium elongated to almost absent	Hypanthium absent	Hypanthium rarely present, receptacle may be broad and flattened, bearing nectary-like bodies	Hypanthium lacking or cupular, rarely tubular	Hypanthium present or absent
Sepals	Sepals united in a spathaceous or 2–5-lobed calyx or free	Sepals commonly 5 or 4 (two adaxial sepals often fused), rarely absent or more (–7)	Sepals 4, unequal, the abaxial and adaxial sepals cucullate, sepaloid, the lateral sepals petaloid	Sepals (3 or 4)-5-(6), free, equal to sub-equal	Sepals (3)–5–(6), free or fused, or sepal whorl lacking	Sepals 5, united at least at the base, sometimes the calyx entire and splitting into irregular lobes or the calyx lobes dimorphic and some petaloid

Table 1.1 Continued.

Characters	Cercidoideae	Detarioideae	Duparquetioideae	Dialioideae	Caesalpinioideae	Papilionoideae
Petals	Petals free, 5, rarely 2, 6 or absent, imbricate, the adaxial petal innermost and frequently differentiated	Petals free, 0–5(–7), when present imbricate, the adaxial petal innermost, all equal or the abaxial rudimentary	Petals free, 5, dimorphic, the adaxial and the two lateral petals ovate, two abaxial petals strap-like, oblong, all 5 petals with stalked gland-like extrusions along their margins, imbricate, the adaxial petal innermost	Petals free, 5 or fewer (0, 1, 3, 4), rarely 6 (petals usually in number equivalent to the sepals), equal to sub-equal, imbricate, the adaxial petal innermost	Petals free or fused, (3)–5–(6), or petal whorl lacking, aestivation valvate or imbricate and then the adaxial petal innermost	Petals 5 and then imbricate, the adaxial petal outermost, mostly “papilionate” (standard outermost and largest, usually overlapping wings and keel) or actinomorphic with little or undifferentiated 5 petals, less often only one (standard) petal present or all petals absent
Stamens	Stamens usually 10 (sometimes fewer) in two whorls of alternate length	Stamens usually 10, sometimes 2–numerous	Stamens 4	Stamens 5 or fewer, rarely 10, usually only antesealous whorl present, uniform, rarely dimorphic	Stamens commonly diplostemonous or haplostemonous, rarely fewer (–4), frequently many (100+)	Stamens typically 10, rarely 9 or many
Stamen fusion	Filaments partly connate or free	Filaments partly connate or free	Filaments free	Filaments free	Filaments free or fused	Filaments commonly connate into a sheath or tube, or uppermost filament wholly or partly free, rarely all free

Table 1.1 Continued.

Characters	Cercidoideae	Detarioideae	Duparquetioideae	Dialioideae	Caesalpinioideae	Papilionoideae
Anthers	Anthers mostly uniform and dorsifixed, opening by a longitudinal slit or central pore in each theca	Anthers dorsifixed or basifixed	Anthers basifixed, with pointed appendages, the thecae dehisce by a short, apical, poricidal slit, the anthers post-genitally fused into a curving synandrium	Anthers basifixed, rarely dorsifixed, dehiscing via long longitudinal slits, often reduced to a short apical, poricidal slit	Anthers basifixed or dorsifixed, sometimes heteromorphic, often with a stipitate or sessile apiculate gland, dehiscing via long longitudinal slits or apical or basal poricidal slits	Anthers uniform or dimorphic, basifixed or dorsifixed, dehiscing longitudinally
Pollen	Pollen 3-colporate, 3–6-colpate, 3-porate, 3-porate, 3–4-colporoidate or inaperturate monads, rarely in tetrads	Pollen mostly 3-colporate monads with a vast array of sculptures	Pollen in monads, asymmetrical, one equatorial-encircling ectoaperture with two equatorial endoapertures	Pollen in tricolporate monads with punctate or finely reticulate, rarely striate sculpture patterns	Pollen in tricolporate monads, or commonly in tetrads, bitetrads or polyads	Pollen in monads, mostly 3-colporate, 3-colpate or 3-porate
Gynoecium	Gynoecium 1-carpellate, stipe of ovary free or adnate to abaxial wall of the hypanthium	Gynoecium 1-carpellate, stipe of ovary free or adnate to abaxial wall of the hypanthium	Gynoecium 1-carpellate, stipitate, with four ridges running along the length of the ovary	Gynoecium 1-carpellate (sometimes bicarpellate), ovary stipitate or sessile	Gynoecium 1- or more rarely polycarpellate	Gynoecium 1-carpellate, very rarely polycarpellate
Ovules	Ovary 1–many-ovulate	Ovary 1-many-ovulate	Ovary few-ovuled	Ovary frequently 2-ovulate (1-many)	Ovary 1-many-ovulate	Ovary 1-many-ovulate

Table 1.1 Continued.

Characters	Cercidoideae	Detarioideae	Duparquetioideae	Dialioideae	Caesalpinioideae	Papilionoideae
Fruits	Fruits dehiscent (often explosively with twisted valves) or indehiscent and samaroid	Fruits mostly woody and dehiscent, sometimes indehiscent, woody or thin valved, samaroid, rarely filled with pulpy mesocarp or endocarp	Fruits oblong four-angled, woody, dehiscent, valves spirally coiled	Fruits commonly indehiscent drupes or samaroid, rarely dehiscent or the drupaceous fruit with indurating endocarp into one seeded segments	Fruits thin valved, dehiscent on one or both sutures, often a lomentum, lomentaceous, craspedium or thick and woody and then indehiscent or explosively dehiscent, often curved or spirally coiled	Fruits dehiscing along one or both sutures, or an indehiscent loment, samara or drupe
Seeds	Seeds with apical crescent-shaped hilum, rarely circular, lens inconspicuous, lacking pleurograms, pseudopleurograms, wing or aril (rarely two funicular aril-like lobes adnate to the testa leaving a short crescent-shaped scar or a long scar running nearly around the seed circumference)	Seeds often overgrown, sometimes hard and then occasionally with pseudopleurograms (i.e., with a colored line that mimics the break of a pleurogram), frequently arillate	Seeds 2–5, oblong to ovoid, the testa thick	Seeds 1-2, rarely more	Seeds usually with an open or closed pleurogram, sometimes with a fleshy aril or testa, sometimes winged; hilum usually apical, lens usually inconspicuous	Seeds usually with hard testa, rarely overgrown; complex hilar valve, elongate hilum and lens, pleurogram absent

Table 1.2 Subfamilial placement follows the new LPWG treatment (LPWG, 2017), and estimated numbers of genera and species are indicated, following Legumes of the World (Lewis *et al.*, 2005).

Subfamily	Number of genera	Number of species
1. Cercidoideae	13	ca. 335
2. Detarioideae	84	ca. 760
3. Duparquetioideae	1	1
4. Dialioideae	17	ca. 85
5. Caesalpinioideae	148	ca. 4,400
		(incl. the Mimosoida clade)
6. Papilionoideae	504	ca. 14,000

1.1.2 Ecology and Distribution

The Leguminosae are found in all terrestrial habitats from equator to desert margins (Polhill, 1981). An analysis of the vegetation types in which legumes are found showed the majority of species of the family can be found in one or more of four major vegetation types, termed biomes, following Schrire *et al.* (2005a).

- **Succulent Biome** occupies the Neotropics and the Old World, including the habitats of a semi-arid, fire intolerant, succulent-rich and grass poor, dry tropical forest, ticket and bushland.
- **Grass Biome**, the second largest biome, consists of a fire-tolerant, succulent-poor and grass-rich, seasonally dry tropical forest, woodland and savannah (grass land). The main regions of distribution are the Neotropics in South America, the Old World and tropical Asia to Australia.
- **Rainforest Biome** comprises a tropical wet forest which the centre of distribution is restricted to the equatorial tropics. Many taxa of legumes are scattered widely through the Rain forest regions worldwide, but the most species are found in the temperate and grass biomes.
- **Temperate Biome**, the largest biome, includes both the Northern and Southern Hemispheres. The centre of distribution is confined to the Mediterranean, warm and cold temperate regions of both the Northern and Southern Hemispheres, linked directly through montane tropical regions.

1.1.3 Economic Botany

Many species of legumes have been economically valuable in various aspects of human daily life, such as human food, gardens and ornamentals, medicinal uses, construction and furniture, soil improvement & reforestation. Some species are considered to have multiple uses. Foods of legume products can be frequently found worldwide from local markets to supermarkets. Young shoots, flowers, fruits, seeds and tuberos are commonly cultivated to use as vegetables or fruits, for example; some species in genera *Cordeauxia* (*C. edulis* Hemsl., yebeb nut), *Leucaena*, *Neptunia*, *Parkia*, *Pithecellobium* (*P. dulce* (Roxb.) Benth.) in the subfamily Caesalpinioideae; *Tamarindus indica* L. (tamarind) in the subfamily Detarioideae; ripening fruits of *Dialium indum* L. in the subfamily Dialioideae; *Archidendron jiringa* (Jack), I. Nielsen; *Arachis hypogaea* L., *Cajanus cajan* (L.) Millsp. (pigeon pea), *Lens culinary* Medik (lentil), *Pisum sativum* L. (garden pea), *Psophocarpus tetragonolobus* (L.) DC. (winged bean), in the subfamily Papilionoideae (taken from Lewis *et al.*, 2005).

Hard woody trees of many species are used commercially as timber, for example; in the subfamily Caesalpinioideae are *Marmaroxylon racemosum* (Ducke) Killip., *Parapiptadenia* spp. and *Viguieranthus* spp.; in the subfamily Detarioideae are *Afzelia* spp., *Baikiaea plurijuga* Harms (Rhodesian teak, Zambesi redwood, umgusi), *Intsia bijuga* (Colebr.) Kuntze and *Sindora* spp.; in the subfamily Papilionoideae are *Alexa imperatricis* (R.H. Shomb.) Bail., *Dalbergia cochinchinensis* Pierre, *D. latifolia* Roxb., *D. melanoxyton* Guill. ex Perr. and *D. sissoo* Roxb.

Several species of legumes bearing elegant and spectacular flowers are widely grown as ornamentals and shade trees in parks, along streets and communities, particularly in big cities. For example, *Adenopodia* spp., *Bauhinia* spp., *Calliandra* spp., *Saraca* spp. and *Stryphnodendron adstringens* (Mart.) Coville from the subfamily Caesalpinioideae; *Barnebydendron riedelii* (Tul.) J.H. Kirkbr. (guacamyo) from the subfamily Detarioideae; *Afgekia* spp., *Butea monosperma* (Lam.) Taub., *Callerya atropurpurea* (Wall.) Schot, *Campylotropis* spp., *Cordyla* spp., *Mirbelia* spp., *Pultenaea* spp., and *Strongylodon macrobotrys* A. Gray from the subfamily Papilionoideae.

Some species play a key role as local medicines or as poisons to other animals, such as fish and insects. Several *Bauhinia* and *Phanera* species are used locally as medicines, especially

roots and hardwood. Most legumes used are taxa from the subfamily Papilionoideae e.g. *Acosmium panamense* (Benth.) Yalovlev (inner bark used as anti-malaria), *Aganope*, *Humularia* spp. (used as medicine), *Derris* & its allies and *Millettia* (commercial insecticides), *Cadia* spp. Baker and *Sylvichadsia* (used as fish poison) and *Nissolia* (used as fish poisons, and an antidote to snakebite). Besides, several legumes are used in agriculture for soil improvement, fencing, shading crops and livestock fodder (Lewis *et al.*, 2005).

Reforestation is one way to rehabilitate damaged and disturbed forests, and because legumes can grow rapidly, despite arid and tolerant habitats, they are often used in rehabilitation. However, some introduced species are likely to be invasive weeds which lead to problems in agricultural land or other habitats. Soil improvement and agronomy uses can be found in the subfamily Caesalpinioideae such as *Acacia mangium* Willd., and found in Papilionoideae such as *Stylosanthes* spp.

1.2. Delimitation and subdelimitation of tribe Millettieae

1.2.1 Historical taxonomic delimitation of tribe Millettieae

Millettia was first described by Wight and Arnott in 1834 based on two species; *M. rubiginosa* Wight & Arn. and *M. splendens* Wight & Arn. The genus gave its name to a tribe, tribe Millettieae, twenty one years later when Miquel (1855) described tribe Millettieae to include *Aganope* Miq. (3 spp.), *Brachyptera* Wight & Arn. (4 spp.), *Derris* Lour. (11 spp.), *Mundulea* DC. (monotypic), *Millettia* Wight & Arn. (11 spp.) *Otosema* Benth. (monotypic), *Pongamia* Vent. (6 spp.) and *Padbruggea* Miq. (monotypic) (table 1.3). The species placed in the new tribe by Miquel (1855) included species with racemes and with indehiscent or dehiscent legumes. Miquel's tribal concept differs from Bentham (1840) placed winged legume genera in the tribe Dalbergieae. Miquel (1855) considered that some genera placed in tribe Dalbergieae *sensu* Bentham whose definition included, in general, genera with indehiscent pods, belonged elsewhere. Therefore, several genera with dehiscent and indehiscent pods and bearing pseudoracemes and pseudopanicles were split into a new tribe, named Millettieae. Instead of following Miquel's concept, Bentham and Hooker revised tribal delimitations in *Genera Plantarum* in 1865. They transferred species with legumes that were samaras to subtribe Lonchocarpeae within tribe Dalbergieae. The genera with samaras that were transferred included *Derris*, *Hymenolobium* Benth., *Lonchocarpus*

Table 1.3 The tribal classification of genus *Millettia*, since its description in 1834 by Wight and Arnott. For each author, the higher level classification of the genus *Millettia* is noted and genera placed with *Millettia* also listed.

Authors	Tribe	Other genera in the tribe, subtribe or section
Bentham (1840)	Tribe Dalbergieae	<i>Ateleia, Brachypterum, Brownea, Brya, Butea, Callisemaea, Centrolobium, Commilobium, Corytholobium, Dalbergia, Derris, Dipterix, Discolobium, Drepanocarpus, Ecastaphyllum, Echinodiscus, Endospermum, Geoffroya, Machaerium, Millettia, Miscolobium, Moutouchia, Phellocarpus and Piscidia</i>
Miquel (1855)	Tribe Millettieae	<i>Aganope, Brachypterum, Derris, Millettia, Mundulea, Otosema, Padbruggea and Pongamia</i>
Bentham & Hooker (1865)	Tribe Galegeae	Subtribe Tephrosieae; <i>Barbieria, Chadsia, Galega, Millettia, Mundulea, Peteria, Ptychosema, Sylistra, Tephrosia and Wisteria</i>
Hutchinson (1964)	Tribe Millettieae	<i>Antheroporum, Burkillia, Chadsia, Craibia, Dewevrea, Fordia, Goodia, Millettia, Platysepalum, Poecilanthe, Schefflerodendrom, Taralea, Terua and Wisteria</i>
Geesink (1981)	Tribe Tephrosieae	<i>Afgekia, Aganope, Antheroporum, Apurimacia, Behaimia, Bergeronia, Burkiliodendron, Chadsia, Craibia, Craspedolobium, Cyclolobium, Dahlstedtia, Dalbergiella, Derris, Dewevrea, Fordia, Hesperothamnus, Kunstleria, Leptoderris, Lonchocarpus, Margaritolobium, Millettia, Subg. <i>Millettia</i>, Subg. <i>Otosema</i>, Sect. <i>Albiflorae</i>, Sect. <i>Podocarpae</i> & <i>Lonchocarpus</i> and Sect. <i>Caudaria</i>, <i>Muelleria, Mundulea, Neodunnia, Ostryocarpus, Padbruggea, Paratephrosia, Piscidia, Platycyamus, Platysepalum, Poecilanthe, Pongamia, Pongamiopsis, Ptycholobium, Requienia, Sarcodum, Schefflerodendron, Tephrosia, Whitfordiodendron, Willardia, Wisteria and Xeroderris</i></i>

Table 1.3 Continued.

Authors	Tribe	Other genera in the tribe, subtribe or section
Geesink (1984)	Tribe Millettieae	<i>Afgekia, Antheroporum, Apurimacia, Austrosteenisia, Behaimia, Bergeronia, Brachypterum, Burkilliodendron, Callerya, Caulocarpus, Chadsia, Craibia, Craspedolobium, Cyclobium, Dahlstedtia, Deguelia, Derris, Dewevrea, Disystemon, Endosamara, Hesperothamnus, Imbracalyx, Kunstleria, Leptoderris, Lonchocarpus, Lupinophyllum, Margaritobium, Millettia, Muellera, Mundulea, Neodunnia, Philenoptera, Piscidia, Platycyamus, Platysepalum, Pongamiopsis, Ptychlobium, Requiencia, Sarcodum, Schefflerodendron, Tephrosia and Wisteria</i>
Schrire (2005b)	Tribe Millettieae	<i>Afgekia, Aganope, Antheroporum, Apurimacia, Austrosteenisia, Behaimia, Bergeronia, Burkilliodendron, Callerya, Chadsia, Craibia, Craspedolobium, Dahlstedtia, Dalbergiella, Deguelia, Derris, Dewevrea, Disystemon, Endosamara, Fordia, Kunstleria, Leptoderris, Lonchocarpus, Margaritobium, Millettia, Muellera, Mundulea, Ostryocarpus, Paraderris, Paratephrosia, Philenoptera, Piscidia, Platycyamus, Platysepalum, Pongamiopsis, Ptychlobium, Pyranthus, Requiencia, Sarcodum, Schefflerodendron, Sylvichadsia, Tephrosia, Wisteria and Xeroderris</i>

Kunth, *Mullerya* (*Muellera* L.f.), *Ostryocarpus* Hook.f., *Piscidia* L., *Platymiscium* Vogel and *Pongamia*.

The genus *Millettia* and its allied genera, *Barbieria* DC., *Chadsia* Bojer, *Galega* L., *Mundulea* DC. ex Miq., *Peteria* A. Gray, *Ptychosema* Benth. ex Lindl., *Sarcodum* Lour., *Sylistra*, *Tephrosia* Pers. and *Wisteria* L., were placed in subtribe Tephrosieae within tribe Galegeae (Benth. & Hook., 1865). These genera had been placed in tribe Dalbergieae by Bentham (1840).

Later in the 19th century, the genus *Millettia* was reinstated at the tribal rank from the tribe Galegeae subtribe Tephrosieae to the tribe Millettieae by Hutchinson (1964). Furthermore, he raised the subtribe Lonchocarpeae Benth. & Hook. to tribal rank by splitting many genera from the tribe Dalbergieae, and he also raised subtribe Tephrosieae of the tribe Galegeae *sensu* Benth. & Hook. to tribal level as Tephrosieae (Benth.) Hutch. A decade later, Polhill (1981) reclassified the tribe Dalbergieae Bronn ex DC., to comprise 19 genera, distinguishing it from other dehiscent groups, so it included *Andira* A.L. Juss., *Cascaronia* Griseb., *Centrolobium* Mart. ex Benth., *Dalbergia* L.f., *Etaballia* Benth., *Fissicalyx* Benth., *Geoffroea* Jacq., *Hymenolobium* Benth., *Inocarpus* J.R. & G. Forster, *Machaerium* Pers., *Paramachaerium* Duck, *Platymiscium* Vogel, *Platypodium* Vogel, *Pterocarpus* Jacq., *Ramorinoa* Speg., *Riedeliella* Harms., *Tipuana* (Benth.) Benth., *Vatairea* Aubl. and *Vataireopsis* Ducke. Notably, *Millettia* and its allies were excluded from Polhill's Dalbergieae *s.str.*

Geesink (1981) accepted 52 genera in the tribe Millettieae, formerly Tephrosieae. Three years later, Geesink (1984) accepted only 42 genera in his Scala Millettiearum account, more narrowly circumscribing Millettieae than in his first treatment in 1981. Most genera were retained in the Scala Millettiearum. One was transferred to tribe Dalbergieae because of distinguishing from the tribe Millettieae by apparently free wings from and keels, uniseriate woodrays and present seed chamber. Finally, Geesink (1984) delimited core genera of *Callerya*, *Derris*, *Lonchocarpus* and *Millettia*. As a result of Geesink's treatment, those genera were subdivided mainly by considering inflorescence types. The genera *Austrosteenisia* Geesink and *Endosamara* were established for segregation of *Millettia* Sect. *Bracteatae* Dunn, and *Imbralyx* Geesink was established for species from *Millettia* Sect. *Albiflorae* Dunn.

1.2.2 Phylogenetic insights into the delimitation and subdivision of tribe Millettieae

Molecular evidence is now plentifully available for many plant groups, and phylogeny plays a significant role in the reclassification of many groups. A number of molecular phylogenetic studies have included genera in or allied to tribe Millettieae. Unfortunately, Millettieae includes a large number of species. Therefore the tribal and generic circumscriptions are still vague and need clarification through more comprehensive sampling (Schrire, 2005b).

Table 1.4 An overview of the studies including representatives of the Millettieae.

Authors (year)	Gene regions	Taxa sampled (total)
Doyle <i>et al.</i> (1997)	<i>rbcL</i>	10 taxa of Caesalpinioideae, 1 taxa of Mimosoideae and 60 taxa of Papilionoideae
Lavin <i>et al.</i> (1998)	Phytochrome genes (PHY)	53 genera of Papilionoideae including 20 genera with 31 species of tribe <i>Millettieae sensu</i> Geesink (1984); 1 genera with 1 species of Mimosoideae 4 genera with 4 species of Caesalpinioideae
Hu <i>et al.</i> (2000)	<i>trnK/matK</i>	57 genera of Papilionoideae including 27 species from Millettieae <i>sensu</i> Geesink (1984)
Kajita <i>et al.</i> (2001)	<i>rbcL</i>	194 genera of Leguminosae including 32 taxa from Millettieae <i>sensu</i> Geesink (1984)
Hu <i>et al.</i> (2002)	<i>ITS/5.8s</i>	- All major subgroups of the tribe Millettieae from Hu <i>et al.</i> 's study (2000) including 72 taxa from the Core Millettieae <i>sensu</i> Geesink (1984)
Hu & Chang (2003)	<i>rbcL</i>	<i>Endosamara racemosa</i> (Roxb.) Geesink and <i>Callerya vasta</i> (Kosterm.) Schot
Wojciechowski (2004)	<i>matK</i>	235 genera of Leguminosae 179 genera from Papilionoideae 28 genera from Caesalpinioideae 28 genera from Mimosoideae

Table 1.4 Continued.

Authors (year)	Gene regions	Taxa sampled (total)
Sirichamorn <i>et al.</i> (2012)	Three Chloroplast genes ; <i>trnK-matK</i> , <i>trnL-F IGS</i> & <i>PsbA-trnH IGS</i> and <i>ITS/5.8S</i>	50 species of palaeotropic <i>Derris</i> -like taxa
da Silva <i>et al.</i> (2012)	nuclear ribosomal DNA; <i>ITS/5.8S</i> and chloroplast DNA; <i>trnL-trnF</i> & <i>matK</i>	177 species of Papilionoideae, including 115 species of genus <i>Lonchocarpus</i> and 62 genera of tribes Abreae and Millettieae

A summary of the phylogenetic studies sampling species and genera of the Millettieae and its relatives is shown in table 1.4. Schrire (2005b) reviewed molecular phylogenetic studies up until 2005 for Legumes of the world, and the Legume Phylogeny Working Group (LPWG) presented a new review in 2013. The latter considered the whole family and cited 281 papers related to the phylogeny of the Indigoferoid/Millettoid old world clade. Doyle *et al.* (1997) analyzed the *rbcL* gene and suggested that the Millettieae and Phaseoleae fell into two main clades, Millettieae and the bulk of Phaseoleae. The relationships among genera in the Core Millettieae seemed difficult to circumscribe. Lavin *et al.* (1998) found monophyletic subgroups within the tribe Millettieae using the phytochrome gene (PHY). The results suggested that most genera of the tribe Millettieae belonged to the *Derris-Lonchocarpus* clade or to a *Tephrosia* clade. Genera *Deguelia* and *Afgekia* might not be members of the core-Millettieae because both genera have canavanine amino acid accumulation, and *Afgekia* has a terminal racemose inflorescence type. The PHY gene also suggested that *Austrosteenisia*, *Callerya*, *Craibia*, *Cyclobium*, *Fordia*, *Platycamus*, *Poecilanthe* and *Wisteria* were distantly related to the core-Millettieae.

The circumscription of the core-Millettieae was well supported in a study using chloroplast *trnK/matK* genes (Hu *et al.*, 2000). Hu *et al.* gave a new definition of the Core Millettieae to include 11 genera in three major clades; the *Philenoptera*, *Tephrosia* and *Derris-Lonchocarpus* clades. They suggested that *Derris* and *Lonchocarpus* are more closely related

to the core-Millettieae than Dalbergieae *sensu* Bentham. The following genera, *Callerya*, *Cyclolobium*, *Poecilanthe* and *Wisteria* are distantly related to the core-Millettieae (Figure 1.1).

In terms of the evolution of characters of Millettieae and its allies, Hu *et al.* (2000) assumed that the absence of canavanine, in the core-Millettieae members evolved from the most recent common ancestor of the Hologalegina and the Indigofereae-Millettieae-Phaseoleae clades. In Hu *et al.* (2000) study all but one of their examples of the core-Millettieae, had canavanine, such as *Millettia grandis*, *M. leptobotrya* and genus *Philenoptera*. Similarly, canavanine is also found in genera *Callerya* and *Wisteria*, and found in the sisters of the core-Millettieae and elsewhere such as genera *Galactia* and *Platycyamus* (Figure 1.2).

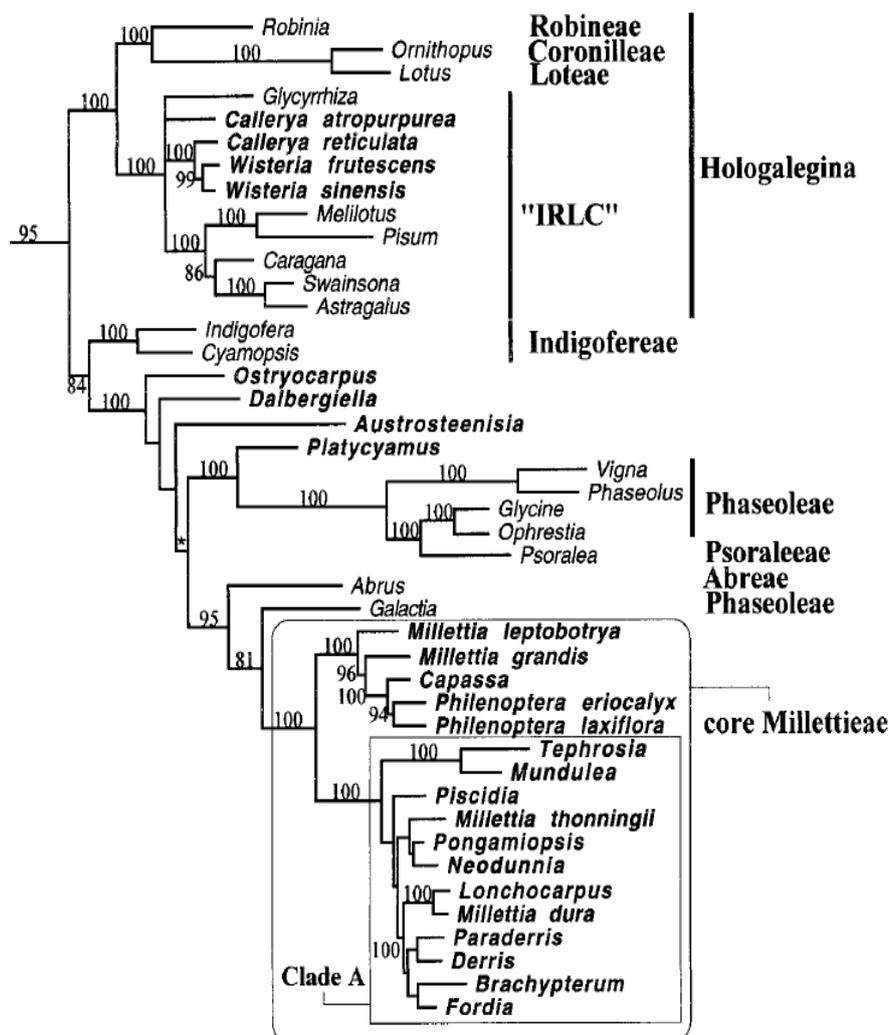
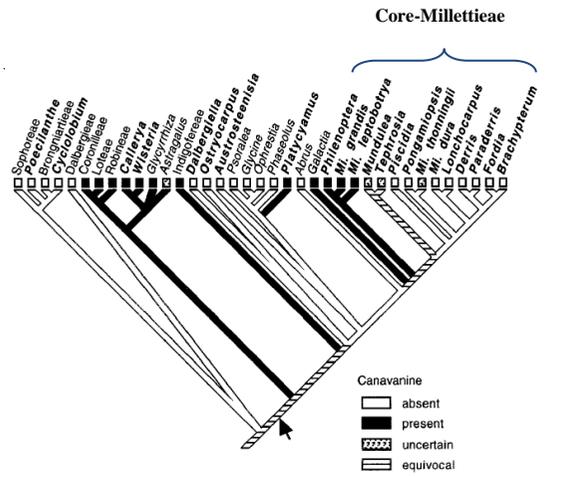
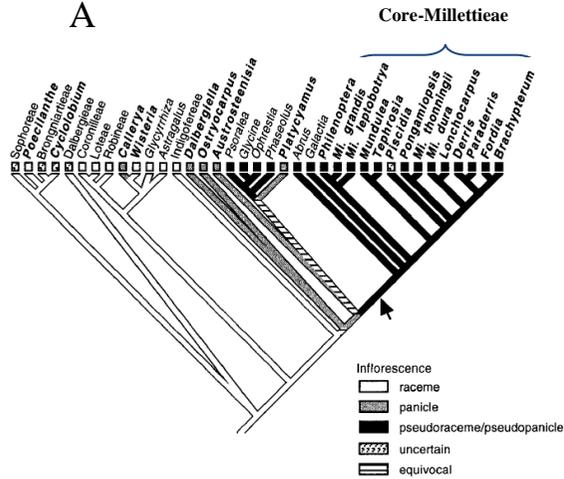


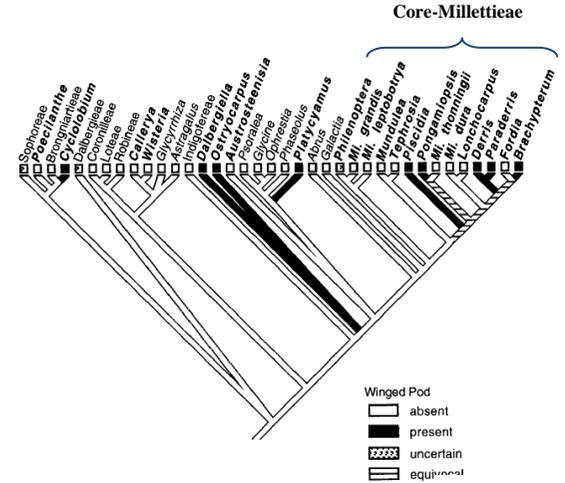
Figure 1.1 Part of the tree showing the phylogenetic relationships of Millettieae and its allies based on the *trnK/matK* data set (Hu *et al.*, 2000). The Brongniartieae and other clades are not included.



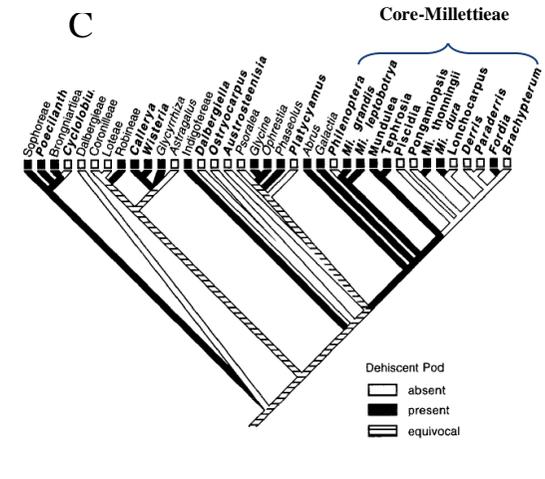
A



B



C



D

Figure 1.2 Character distribution of Millettieae and its allies. A= Canavanine, Marked arrows show, arrow shows the first possible appearance of Non-canavanine protein amino acids, B=arrow shows pseudoraceme/pseudopanicle clade, C= winged pods, D= dehiscent pods (Hu *et al.*, 2000).

The inflorescence type, winged pods and pod dehiscence are not synapomorphies for the core-Millettieae. The inflorescence type of Millettieae *sensu* Geesink (1981) is variable. Hu *et al.* (2000) suggested a paniculate inflorescence found in genera *Austrorostenia*, *Callerya*, *Dalbergiella*, *Platycyamus* and *Ostryocarpus* was derived from a pseudoraceme or pseudopaniculate inflorescence type. However, two genera *Poecilanthe* and *Wisteria* treated in the tribe Millettieae by Geesink (1981), are racemose with uncertain type of inflorescence in genus *Cyclolobium*. The rest of Core Millettieae is whether pseudoracemose or pseudopaniculate including a few genera of the tribe Phaseoleae, *Abrus* and *Galactia* nested in the Core Millettieae clade. Fruit characters were suggested to be a little weight of tribal classification because the phylogenetic study shown that winged pods have evolved in several times in legumes. The phylogenetic study of Hu *et al.* (2002) shown genera *Cyclolobium* and *Poecilanthe* were nested in tribe Brongniartieae but the first genus was winged pod. Notably, these two genera were moved out from and in the tribe Millettieae by Geesink (1981 & 1984). Pod dehiscence was also thought to have evolved in several times. Genera *Derris*, *Paraderris*, *Lonchocarpus* and their allies of the tribe Millettieae and the tribe Dalbergieae are distinctly separated in Hu *et al.* (2000). *Pongamia pinnata* (L.) Panigrahi is one of difficulty in definition of pod dehiscence when facing the tardy condition.

Kajita *et al.* (2001) conducted a phylogenetic study of family Leguminosae and its allies based on the *rbcL* gene. Within the Leguminosae, tribes Millettieae and Phaseoleae were both shown to be polyphyletic; subtribes Ophrestinae and Diocleinae were sister to the Core Millettieae. Some allied Millettieae groups, *Afgekia* Craib, *Millettia japonica* and *Wisteria* Nutt. formed a well-supported group within a Hologalegina clade. The sister group of this clade is Millettoids/Phaseoloids which has some taxa of tribe Indigofereae forming a small sister group. The Millettoid/Phaseoloid clade comprises various tribes of Dalbergieae (*Hymenolobium excelsum*), Desmodieae with a few taxa, Millettieae, and Phaseoleae which includes subtribes Cajaninae, Clitoriinae, Diocleinae, Erythrinae, Glycininae, Kennediinae, Phaseolinae and Ophrestinae dominating in the clade (Figure 1.3).

Hu *et al.* (2002) analysed the phylogeny of *Poecilanthe-Cyclolobium*, the Core Millettieae and the *Callerya* group using nuclear ribosomal *ITS/5.8s* sequences. The phylogeny revealed that *Poecilanthe* and *Cyclolobium* together were moderately supported as a Brongniartieae clade. They suggested that these two genera should not be included in the tribes Millettieae,

Dalbergieae or Robinieae. The Millettieae was confirmed as a polyphyletic group and the *Callerya* clade comprising *Afgekia*, *Callerya* and *Wisteria* was retained within the Inverted Repeat Lacking Clade (IRLC), which the clade lack a copy of the 25-kb inverted repeat in chloroplast genome.

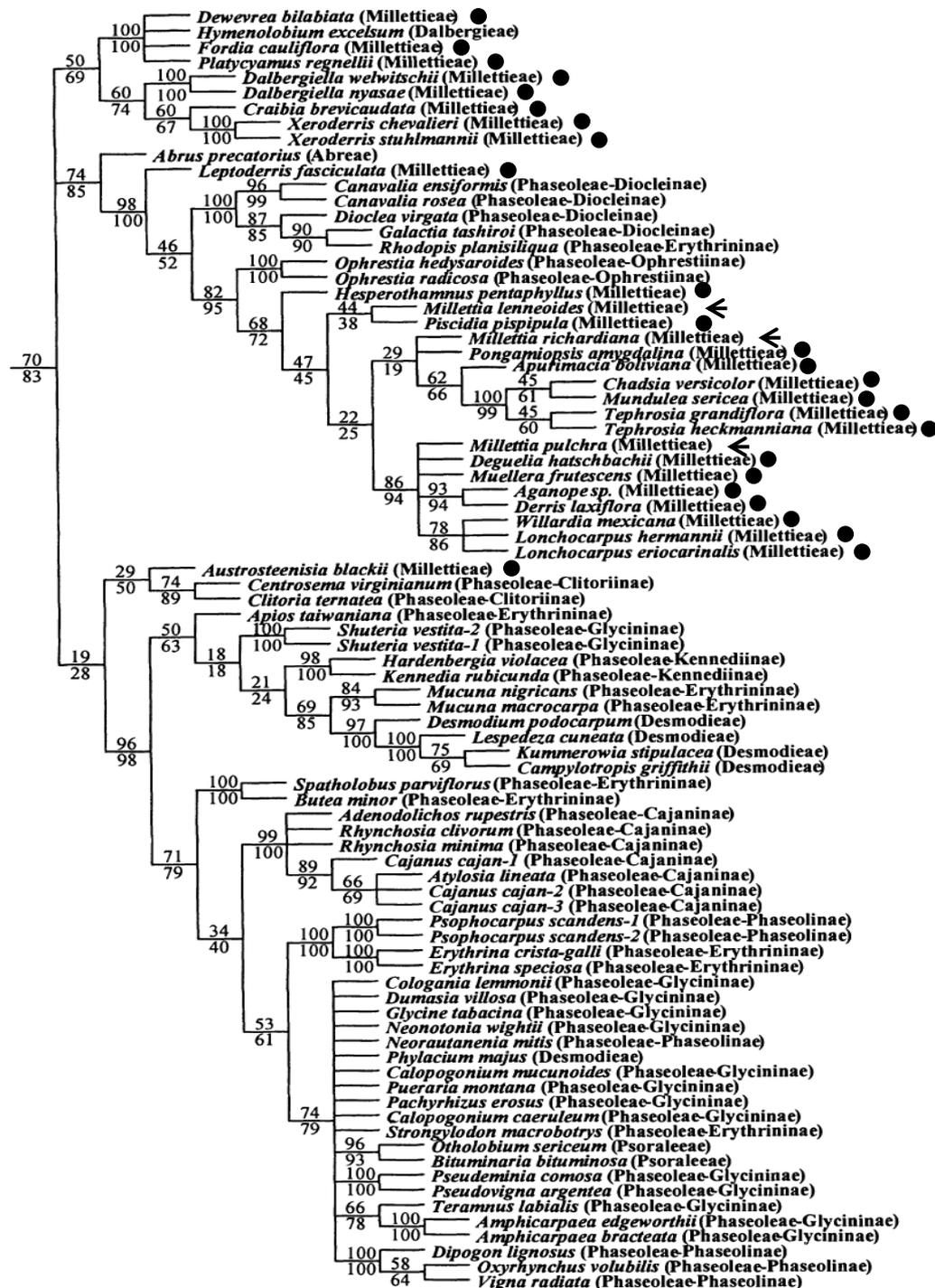


Figure 1.3 The phylogenetic relationships of Millettoid/Phaseoloid groups from Kajita *et al.* (2001). Members of tribe Millettieae are indicated with a black circle and genus *Millettia* with an arrow. Kajita *et al.* recognized Millettieae *sensu* Geesink, and genus *Millettia s.l.*

Hu & Chang (2003) studied the *Callerya* group; *Endosamara racemosa* and *Callerya vasta*, based on analysis of chloroplast *rbcL* sequences. They showed that the group was not close to other Millettieae *s.l.* and they suggested that several taxa of the genus *Callerya* should be segregated from the Core Millettieae group. Wojciechowski (2004) analyzed the phylogenetic relationships of the family Leguminosae based on the plastid *matK* gene. Tribe Indigofereae emerged as the moderately supported sister group of a Millettoid clade (Figure 1.4a) which included all genera of the tribe Millettieae, except for *Afgekia*, *Callerya*, and *Wisteria* which were placed in the IRLC within a Hologalegina clade. Also included in the Millettoids were tribes Abreae, Indigofereae, Phaseoleae, Psoraleae and Desmodieae; subtribes Desmodiinae and Lespedezinae were also included since they are nested in the tribe Phaseoleae. Genera *Xeroderris* and *Platycyamus* have weakly supported relationships in the molecular phylogeny, and there is nonmolecular evidence to support the tribe Indigofereae as a sister to the tribe Millettoid clade. Phylogenetic relationships in the Millettoid group IRLC and Astragalean clades are nested in Hologalegina clade of the Millettoids, and Vicioid clade is a sister group to Astragalean clade. Robinoid clade is also part of the Millettoids with the strong support (Figure 1.4b). The phylogenetic work of Hu *et al.*, (2000) and Wojciechowski *et al.*, (2004) using *matK*, *matK/trnK* and nuclear ribosomal *ITS* data and the studies of Käss & Wink (1995 & 1996); Doyle *et al.* (1997 & 2000); Kajita *et al.* (2001) and Hu & Chang (2003), and the *rbcL* gene have confirmed that Millettieae is polyphyletic. The genus *Millettia* and its closely related genera are a cryptic group. In 2005, Schrire summarized the molecular studies and suggested the circumscription of a revised tribe Millettieae is not possible until the genera are more comprehensively sampled (Schrire, 2005b).

In 2005, Schrire reviewed and interpreted the molecular, phytochemical and wood anatomy studies of current papers of *Millettieae s.l.* and its sister group. He based his review on previous studies of Evans *et al.* (1985), Lavin *et al.* (1998), Hu (2000), Hu *et al.* (2000), Kajita *et al.* (2001), Hu *et al.* (2002) and Hu & Chang (2003). Schrire (2005b) outlined two informal groups; a Millettoid group and core-Millettieae (Figure 1.5). There are twenty-three genera and *ca.* 131 species belonging to the first group, and 22 and *ca.* 777 species belonging to the latter. There are three groups within a Millettoid group. The subtribes Diocleinae and Phrestiinae of the tribe Phaseoleae and Abreae are sister to core-Millettieae at basal Millettoid *s.str.* group because they share a pseudoraceme inflorescence, absence of protein canavanine amino acids and chromosome number of $x=11$ (Hu, 2000). The classification of the relationships and the evolutionary history of character changes between Millettieae and Phaseoleae are still required the further studies (Schrire, 2005a). IRLC Millettoid group, designated as “IRLC clade”, is composed of genera *Afgekia*, *Antheroporum*, *Callerya*, *Endosamara* and *Wisteria*, uncertain placement of this group. Another Millettoid group, “Basal millettoid and phaseoloid group” may belong either in the Millettoids *s.str.* or Phaseoleae *s.l.*, or to a clade sister to both these groups. A subgroup of the genera *Cyclolobium* and *Poecilanthe*, previously associated with tribe Millettieae were transferred to tribe Brongniartieae (Hu *et al.*, 2002).

The core-Millettieae group has 22 genera and *ca.* 777 species, and consists of two subgroups; Canavanine, a proteinogenic amino acid found in seeds, and non-Canavanine, a non-proteinogenic amino acid found in seeds. Based on molecular and chemical evidence, *Millettia* and *Fordia p.p.* and *Philenoptera* is segregated from the Non-canavanine Group. The large Non-canavanine Group includes five major subgroups; *Derris*, *Lonchocarpus*, *Millettia*, *Piscidia* and *Tephrosia*. However, the relationships between the groups remain unclear (Schrire, 2005b).

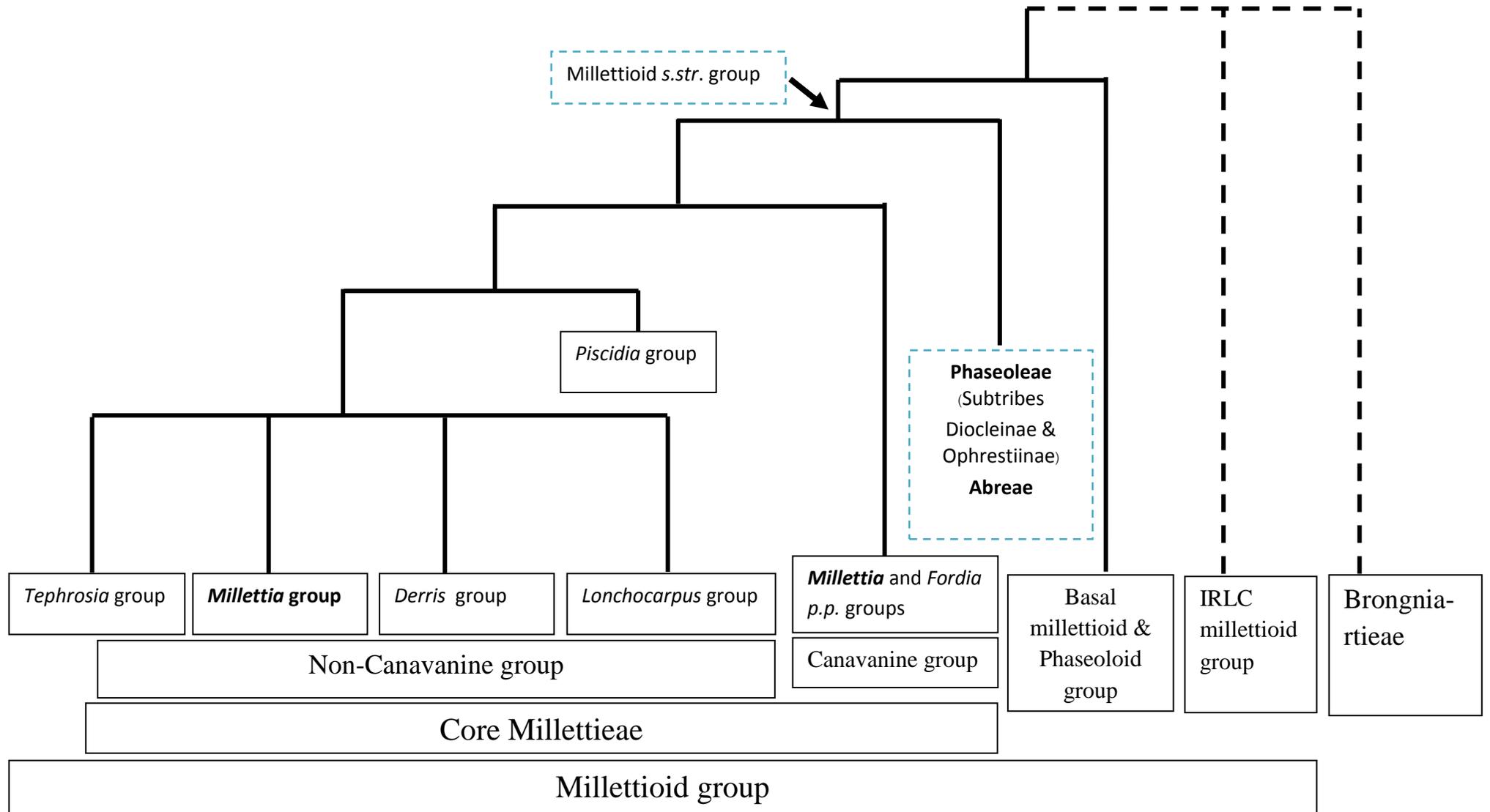


Figure 1.5 Diagram of relationships between informal groups within the traditional circumscription of tribe Millettieae, (applied from Schrire, 2005b).

There have been significant studies sampling groups within the Core Millettieae at species level, since Schrire's revision of 2005. The first, Sirichamorn *et al.* (2012) focused on the *Derris* group, and da Silva *et al.* (2012) focused on *Lonchocarpus*. Sirichamorn *et al.* (2012) shown reorganization of infrageneric classifications of the whole *Derris*-like group, comprising 6-9 samara pod genera. The analysis was based on three chloroplast and nuclear DNA sequences; *trnK-matK*, *trnL-F IGS* & *PsbA-trnH IGS* and *ITS/5.8S* respectively. Their results have shown that certain genera *Aganope*, *Brachypterum*, *Deguelia*, *Leptoderris*, *Lonchocarpus* and *Philenoptera* were distantly related to *Derris s.str.* (Figure 1.6). They suggested that the delimitation of the genus *Derris s.str.* should be re-circumscribed by excluding the genus *Brachypterum*, and the combination of genus *Paraderris* has been reduced to the genus *Derris*. Da Silva *et al.* 2012, studied phylogeny and biogeography of *Lonchocarpus s.l.* and its allies from the sequences of nuclear ribosomal DNA; *ITS1* & *ITS2* and chloroplast DNA; *trnL-trnF* & *matK* (Figure 1.7).

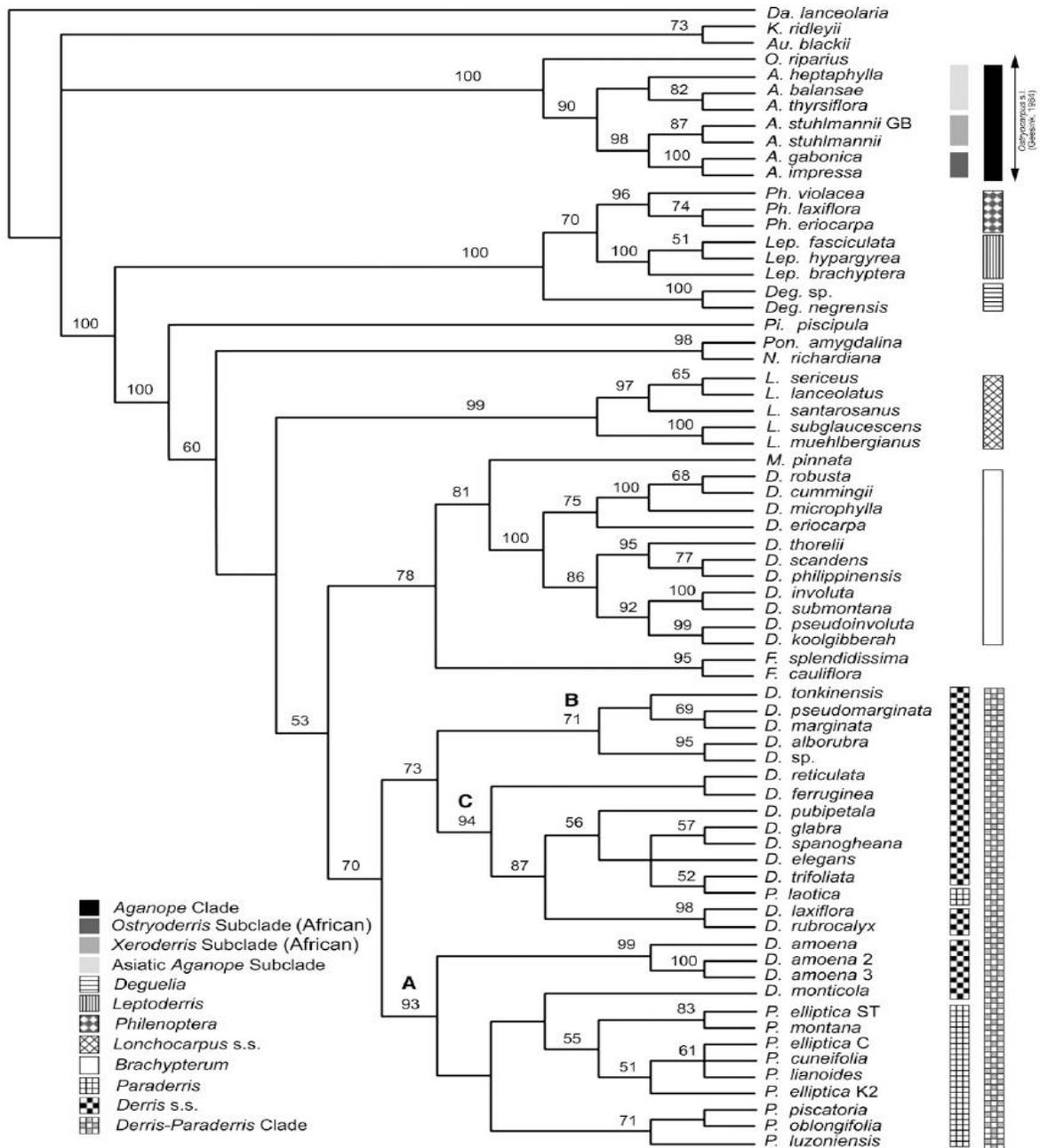


Figure 1.6 Phylogenetic relationship based on the combined data set of three chloroplast regions (Sirichamorn *et al.*, 2012).

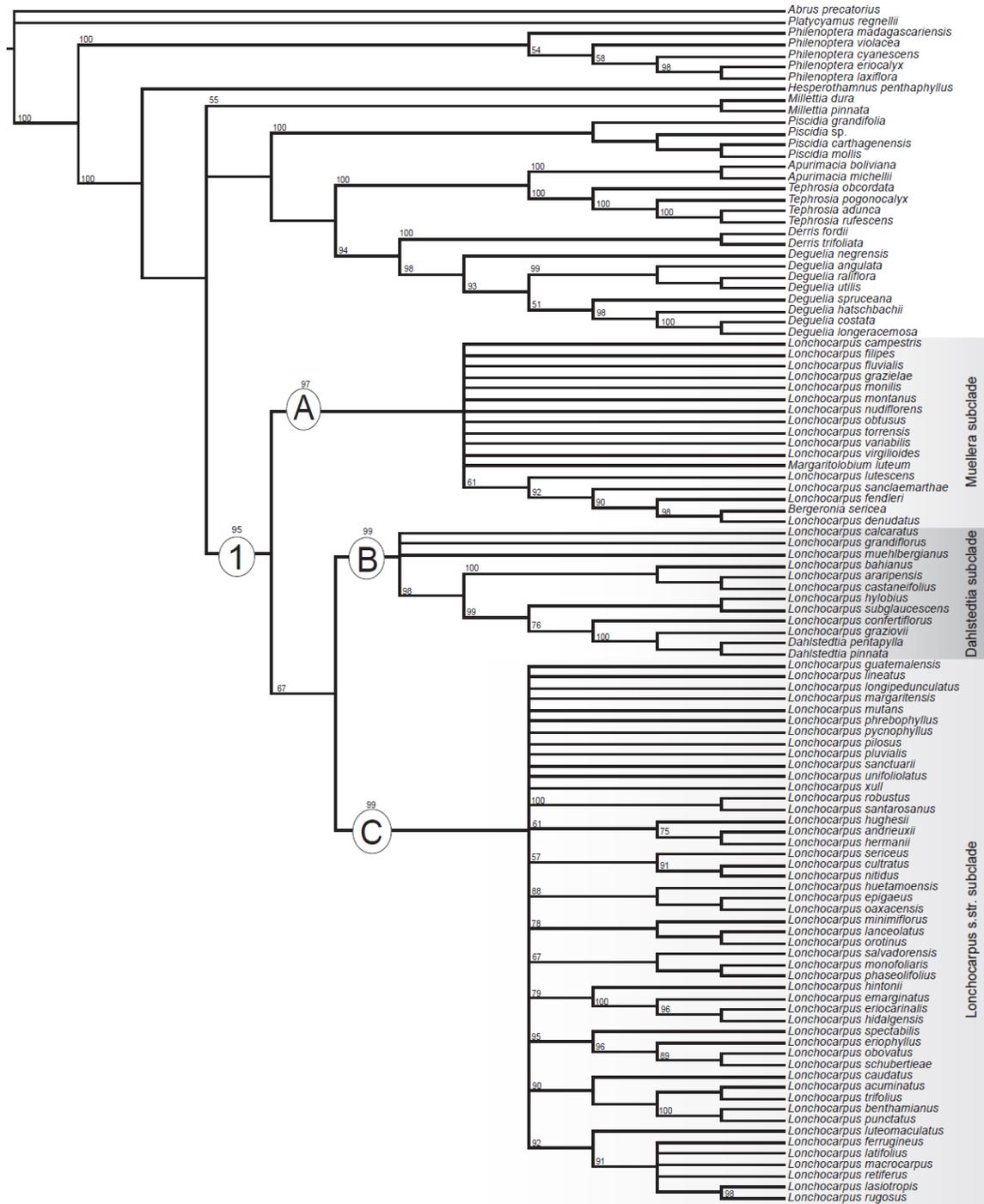


Figure 1.7 Strict consensus tree from combined plastid DNA *trnL-trnF* + *matK* and nuclear DNA (*ITS1+ITS2*) dataset (da Silva *et al.* 2012).

The genus *Lonchocarpus* was retained in the tribe Millettieae and was distinct from the closely related genera, *Deguelia*, *Derris* and *Philenoptera*. They also re-circumscribed *Dahlstedtia*, *Lonchocarpus* and *Muelleria*, using morphological traits and distribution data. Analysis of molecular dating revealed that *Lonchocarpus* and its allies originated in Central America around 6-8 Ma ago, and emigrated from Central to South America and to Africa. *Lonchocarpus s.l.* was shown to be a paraphyletic group, with small genera namely *Bergeronia*, *Dahlstedtia* and *Margaritolobium*, nested in it.

1.3 Infrageneric classification & regional treatment of the genus *Millettia s.l.*

1.3.1 Global treatments

Wight and Arnott in (1834) described the genus *Millettia* to accommodate two new species, *M. rubiginosa* Wight & Arn. (Type: Wight cat. No. 912) and *M. splendens* Wight & Arn. (Type: Wight cat. No. 998). The first species was selected as a type. By the time of Dunn's revision (1912) of the genus, 138 more species had been decided. Dunn divided the genus, including *Berrebera* Hochst. *Callerya*, *Fornasinia* Bertol, *Marquartia* Vog. and *Otosema* Benth. which are considered as synonymized genera of *Millettia*, into 16 sections, based on three characters; the presence or absence of stipellae (stipels), an auriculate or exauriculate standard petal, and the degree of indumentum on petals (Table 1.5).

The sixteen sections of the genus *Millettia sensu* Dunn has shown that eight sections belong to Asian *Millettia*, one is confined to Australian and other more seven to African. Interestingly, *Fragiliflorae*, one of the Asian *Millettia* section has the largest member with 19 species, and *Sericanthae*, one of the African *Millettia* section with 23 species. Although the Dunn's monograph was made in the large scale of species from many parts of the world, it is not well satisfactory classification of the most complicate genus because the relationships among sections and species are confused and delimited in many exceptions which seem to appear in his systematic classification by later taxonomists. One of well-known accepted concept, Geesink (1981, 1984) defined several genera in the tribe *Millettieae* (formerly *Tephrosieae s.l.*). He suggested that Dunn's section with flowers in panicles should better be transferred to

Table 1.5 Sections of the genus *Millettia* established by Dunn (1912).

Section	Stipellae	Standard	Petals	Other distinguishing characters
1. Typicae	+	E	H	Pedicels fascicled
2. Eurybotryae	+	E	(6)	Pedicels single
3. Austro-Millettia	+	A	H	Pods woody, terete
4. Bracteatae	+	E	G	Bracts exceeding flowers
5. Podocarpae	-	E	G	Ovary stipitate
6. Macrospermae	-	E	H (7)	Seeds thick, oval
7. Fragiliflorae	-	A(9)	G(8)	Pedicels slender
8. Otosema	+	A	H	Pedicels clustered
9. Albiflorae	-	A(1)	G	Petals white, glabrous
10. Efulgentes	+(2)	A	G	Petals white, glabrous
11. Compresso-Gemmae	+	A	H	Buds compressed
12. Afroscedentes	+(3)	E	H	West African climbers
13. Truncatocalyces	-	E	G	Calyx truncate
14. Sericantae	(4)	E	H	Chiefly E, African shrubs
15. Polyphyllae	+(5)	E	H	Leaflets numerous, oblong
16. Robustiflorae	+	E	H	Stamens protruded

Remarks

+ = present, - = absent; A = auriculate, E = exauriculate; H = hairy, G = glabrous

1. One is exauriculate.
2. A few exstipellate.
3. *M. barteri* Benth. and *M. calabarica* Dunn have no stipellae.
4. Some stipellate, some exstipellate.
5. *M. lenneoides* Vatke has no stipellae.
6. Two well-marked divisions having glabrous and hairy petals respectively.
7. Except *M. pachycarpa* Benth.
8. Or sometimes slightly pubescent
9. Except *M. stipulata* Dunn and *M. litoralis* Dunn, in which the standard is folded, but without callous at the base.

Padbruggea and *Whitfordiodendron*, and Sect. *Bracteatae* should be whether raised to generic rank or included in *Sarcodum* Lour.

In China, Wei (1985), categorized thirty-three Chinese *Millettia* species into 6 sections, three of which were proposed as new Chinese sections. In Wei's revision the sect. *Eurybotrya* Dunn was preserved with a newly described Chinese species but some species in this section were transferred in different new sections that to the sect. *Curvistylae* Z. Wei and other two, *M. fordii* Champ. and *M. speciosa* Dunn to the sect. *Corynecarpae* Z. Wei in the same work. In addition, the sect. *Typicae* Dunn was not only taxonomically corrected to be the sect. *Millettia*, designated *M. rubiginosa* Wight & Arn. as the type species but *M. pulchra* Kurz var. *typica* forma *laxior* Dunn was also raised as a new status varietal level.

1.3.2 African and Madagascan treatments

The number of African *Millettias* has been estimated to approximately (70-)90-100 (Schrire, 2005b). Historically, Baker (1871), in Flora of Tropical Africa treatment, recognized the genus *Millettia* with 11 species in the tribe Galegeae by wide senses of having not joined and dehiscent pods, and diadelphous stamens (Table 1.6).

Table 1.6 Important regional treatments of the genus *Millettia* in Africa and Madagascar.

Regions	Authors (year)	Number of species
Africa & Madagascar	Baker (1871)	11
West Tropical Africa	Hutchinson & Dalziel (1928)	72
East Tropical Africa	Gillett (1971) & Gillett & Brummitt (1971)	24
Madagascar	Du Puy <i>et al.</i> (2002)	8

Four decades later, Dunn (1912) revised the genus *Millettia* into 16 sectional groups, seven of which belong to African, namely *Afroscandentes*, *Compresso-gemmatae*, *Efulgentes*, *Polyphyllae*, *Robustiflorae*, *Sericantae* and *Truncatocalyxces*. The Flora of West Tropical Africa contributed by Hutchinson and Dalziel (1928) had been revealed 13 genera in the tribe Galegeae *sensu* Hutch., one of which 16 *Millettias* were discovered. In the account of the Flora of Tropical East Africa treated by Gillett *et al.* (1971) has added 6 genera in the tribe Tephrosieae; 24 *Millettia* have been accounted. *Millettia* Sect. *Truncatocalyxces* Dunn, one of

a small African section, comprised of only five species which is recognizable by its stipellae absence, truncate calyxes, glabrous corolla and flowers in axillary pseudoracemes, has been revised by Mollel & Adema (2006). Those species within the section can be found in various habitats in tropical Africa, ranging from secondary and disturbed forests to mangrove and moist forests as some useful species are extensively grown as shade and ornamental trees along roads. Recent Leguminous Madagascan Millettieae has also been revealed by Du Puy *et al.* (2002), composed of eight species in the genus *Millettia*.

1.3.3 Asian treatments

1.3.3.1 The British Indian and Burmese regions

Initially, first treatment of Indian and Burmese *Millettia* was worked by Baker (1879). He accepted 24 spp. in 2 subgenera; *Eumillettia* Baker, *Otosema* Benth. in The Flora of British India Vol. II, and also divided these subgenera by distinguishing by an auricled standard (*Otosema* with 19 spp.) and an exauriculated standard (*Eumillettia* with 5 spp.) (Table 1.7). Around two decades after the Flora of British India had completely finished by Sir Joseph Hooker, which the completion was taken almost a quarter of a century 1872-97. Prain (1903) studied in more wider areas than the previous study in Hilmalayan plants entitled "Bengal Plants" published in two volumes. He classified classically Bengal plants as 24 classes, following the very well-known Linnaen system and interpreted William Roxburg from Flora of Indica 1820-1832. Consequently, the four Bengal *Millettia* species and its relatives then were compiled in the class Monodelphia, androgynous flowered, and stamens are united in one Phalanx or bundle, and in the synopsis of the natural order Leguminosae: suborder Papilionaceae. There were 21 species recorded from Indian and Burmese regions and a few species were restricted to Myanmar.

1.3.3.2 Malesian region

Miquel 1855, in Flora van Nederalandsch Indie Vol. I, described eleven species of *Millettia s.l.* represented mainly in Malesiana. He combined Sumatran species, i.e *M. obtusa* Blume as a variety rank and others *M. subcordata* Blume and *M. brachycarpa* as a forma rank, under *M. sericea* Wight & Arn. Two lianas Malesian *Millettias*, *M. eriantha* (Benth.) Schot and *M. cinerea* Benth. Schot., later were legitimately transferred by Schot (1994), to a new genus,

Callerya. In the material for a Flora of the Malayan Peninsula, other Malayan *Millettias* were treated as new species, under tribe Galegeae *sensu* Benthams by King (1897), surprisingly although Malaysia and Indonesia are very close each other, there are almost 10 species differences when compared to Miquel (1855). In the same year of King's treatment, twenty-nine Indian *Millettia* species were also additional provided by Prain (1897). In 1911 Dunn provided the key to species of 11 Phillipine *Millettias* including three new species from islands. Later Merrill (1967) in enumeration of the flowering plants in the Phillipine islands has accepted 11 species of *Millettia s.l.* in The Flora of the Malay Peninsula treatment with illustrations by Hutchinson. Ridley (1922) placed the genus *Millettia* with other Malesian genera; *Adinobotrys*, *Fordia*, and *Padbruggea* from the tribe Galegeae *sensu* Baker to the tribe Millettieae and remained Dalbergioid group in the tribe Dalbergieae *sensu* Baker. As a result, there are six species of Malaysian *Millettia* with 2 species in each the rest genera.

Recently, Adema (2000b) revised Malesian *Millettia s.str.* for the treatment of the Flora of Malesiana recognizing a total 15 spp. Two sections were found, Sect. *Millettia* and Sect. *Fragiliflorae* Dunn, with two described new species, *M. borneensis* and *M. glabra* belonging to the latter section. Furthermore, *M. velvetina* Adema was proposed and emended in the revision. The sections *Typicae* and *Macrospermae* were united together under the sect. *Millettia*. Adema additionally suggested that the difference of the presence and absence of stipellae of these two sections were not enough to separate them. Therefore, the Malesian Sect. *Millettia* can be distinguishable from *Fragiliflorae* by button-shaped axillary buds, pulvinus peduncles, standard with two basal callosities and hairy anthers.

1.3.3.3 Indo-Chinese regions and China

The first treatment of *Millettia* in Indo-China was treated by Gagnepain (1916), a distinguished French botanist. He treated the genus *Millettia s.l.* included 43 spp. in 6 informal groups. In Thailand, Craib (1931), a well-known Irish botanist, carried out a survey on Leguminous plants which were mainly collected by A.F.G. Kerr, an English botanist. Twenty five species in the genus *Millettia* were enumerated in *Florae Siamensis Enumeratio Vol. I: Polypetalae- A list of the plants known from Siam with records of their occurrence*. This is the first account of the genus of the family Leguminosae in the country. In China, Wei (1985) recognized 6 sections with 35 spp. and 11 varieties, of which five species with four varieties were described as new in his revision. Lock and Heald (1994) published a check-list

of Legumes of Indo-china; the genus *Millettia* and related genera of the tribe Millettieae are listed, as follows; *Millettia* (51 species), *Padbruggea* (3 species), *Pongamia* and *Sardodum* (each genus with one species) and *Tephrosia* (8 species), whereas Malesian *Millettia* consists of 18 species. Lôt & Vidal (2001) revised family Leguminosae-Papilionoideae in Flore Cambodia, Laos and Vietnam, a revision of Flore Générale de L'Indo-Chine published by Gagnepain in 1916. There some Indo-Chinese *Millettias* were combined, e.g. *M. buteoides* Gagnep. and *M. latifolia* Dunn under *M. leucantha* Kurz as a varietal level; var. *buteoides* (Gagnep.) Lôt & Vidal and var. *latifolia* (Dunn) Lôt & Vidal respectively. Recently, Wei and Pedley (2010) revealed 36 species (incl. 18 endemic spp.) of the genus *Millettia* of *Millettieae s.l.* in the recent treatment of Flora of China. In China, some Chinese and Bornean *Millettia* species were changed the generic level when Hemsley (1886) described a remarkable Chinese cauliflorous tree species from Kwangtung province under a genus *Fordia*; *Fordia cauliflora* Hemsl. Dunn (1911b) named Malayan islands species under, and transferred *Millettia stipularis* Prain and *M. filipes* Dunn, to the genus *Fordia* which differs from the genus *Millettia* in structure of inflorescences, flowers and fruits, with a strong support Hemsley's generic circumscription for without perplexing with the genus *Millettia*. However, *Fordia* species were converted to the genus *Millettia* by Gagnepain (1916) in Notulae Systematicae vol. 3 but many other botanists accepted the genus *Fordia* as a certain genus, such as Merrill (1916); Ridley (1922); Craib (1927); Buijsen (1988); Wei (1989); Dasuki & Schot (1991) and Wei and Pedley (2010).

Table 1.7 Important regional treatments of the genus *Millettia* in Asia.

Regions	Authors (year)	Number of species
British Indian and Burmese		
India	Baker (1879)	24
	Prain (1897)	21
Myanmar	Kurz (1877)	19
Malesian		
Malesiana	Miquel (1855)	11
	Adema (2000b)	15
Malaysia	King (1897)	12

Table 1.7 Continued.

Regions	Authors (year)	Number of species
	Ridley (1922)	6
The Philippines	Dunn (1912)	11
	Merrill (1967)	11
Indo-Chinese		
Cambodia, Laos & Vietnam	Gagnepain (1916)	43
	Lock and Heald (1994)	28
Thailand	Craib (1931)	25
China	Wei (1985)	35
	Wei and Pedley (2010)	36

1.4 Studies of genera, other than *Millettia*, in the Millettieae

The previous section (section 1.3) reviews studies of genus *Millettia*, but in this study it is necessary to consider genus *Millettia* alongside the other genera placed in the tribe. Table 1.8 lists the genera in the tribe *sensu* Geesink and notes whether they have been the focus of recent study, whether phylogenetic or revisionary.

Table 1.8 List of the genera in the tribe Millettieae *sensu* Geesink (1984), phylogeny and taxonomic revision. Some genera are phylogenetically partial studied.

Genus	Recent studies on Taxonomy & phylogeny
<i>Afgekia</i> Craib	Lôc & Vidal (2001)
<i>Aganope</i> Miq.	Lôc & Vidal (2001); Sirichamorn <i>et al.</i> (2014)
<i>Antheroporum</i> Gagnep.	Lôc & Vidal (2001)
<i>Apurimacia</i> Harms	Macbride (1943); Lavin & Sousa (1995)
<i>Austrosteenisia</i> R.Geesink	Dixon (1997)
<i>Behaimia</i> Griseb.	Lewis (1988)
<i>Bergeronia</i> Micheli	da Silva <i>et al.</i> (2012)
<i>Burkilliodendron</i> Sastry	Adema (2000a)
<i>Callerya</i> Endl.	Schot (1994); Lôc & Vidal (2001); Li <i>et al.</i> (2014)
<i>Chadsia</i> Bojer	Du Puy <i>et al.</i> (2002)
<i>Craibia</i> Harms & Dunn	Gillett (1960); Hu <i>et al.</i> (2002)
<i>Craspedolobium</i> Harms	Lôc (1998)
<i>Dahlstedtia</i> Malme in Ark.	da Silva <i>et al.</i> (2012)
<i>Dalbergiella</i> Baker.f.	Milne-Redhead & Polhill (1971); Hu <i>et al.</i> (2000)
<i>Deguelia</i> Aubl.	Azevedo-Tozzi (1989)

Table 1.8 Continued.

Genus	Recent studies on Taxonomy & phylogeny
<i>Derris</i> Lour.	Adema (2003b); Sirichamorn <i>et al.</i> (2014)
<i>Dewevrea</i> Micheli	Hauman (1954); Kajita <i>et al.</i> (2001)
<i>Disyngstemon</i> R.Vig.	Du Puy <i>et al.</i> (2002)
<i>Endosamara</i> R.Geesink	Lôc & Vidal (2001); Hu & Chang (2003)
<i>Fordia</i> Hemsl.	Buijsen (1988); Dasuki & Schot (1991)
<i>Hesperothamnus</i> Brandegees	Rydberg (1924)
<i>Kunstleria</i> Prain	Ridder-Numan & Kornet (1994)
<i>Leptoderris</i> Dunn	Dunn (1910); Kajita <i>et al.</i> (2001)
<i>Lonchocarpus</i> Kunth	da Silva <i>et al.</i> (2012)
<i>Margaritobium</i> Harms	da Silva <i>et al.</i> (2012)
<i>Millettia</i> Wight & Arn.	Dunn (1912); Adema (2000b); Lôc & Vidal (2001)
<i>Muellera</i> L. f.	da Silva <i>et al.</i> (2012)
<i>Mundulea</i> (DC.) Benth.	Du Puy <i>et al.</i> (2002)
<i>Ostryocarpus</i> Hook.f.	Dunn (1911); Sirichamorn <i>et al.</i> (2014)
<i>Paraderris</i> (Miq.) Geesink	Adema (2003a); Sirichamorn <i>et al.</i> (2014)
<i>Paratephrosia</i> Domin	Wheeler <i>et al.</i> (1992)
<i>Philenoptera</i> Hochst. ex A. Rich.	Schrire (2000); da Silva <i>et al.</i> (2012)
<i>Piscidia</i> L.	Rudd (1969); Hu <i>et al.</i> (2000 & 2002)
<i>Platycaamus</i> Benth.	Moura <i>et al.</i> (2016); Hu <i>et al.</i> (2000)
<i>Platysepalum</i> Welw. ex Baker	Gillett (1960)
<i>Pongamiopsis</i> R.Vig.	Du Puy <i>et al.</i> (2002)
<i>Ptychobium</i> Harms	Brummitt (1980)
<i>Pyranthus</i> Du Puy & Labat	Du Puy <i>et al.</i> (2002)
<i>Requienia</i> DC.	Brummitt (1980)
<i>Sarcodum</i> Lour.	Adema (1999), Clark (2008)
<i>Schefflerodendron</i> Harms	Léonard & Latour (1950)
<i>Solori</i> Adans.	Sirichamorn <i>et al.</i> (2014)
<i>Tephrosia</i> Pers.	Du Puy <i>et al.</i> (2002); Bosman & De Haas (1983)
<i>Wisteria</i> Nutt.	Valder (1995); Li <i>et al.</i> (2014)
<i>Xeroderris</i> Roberty	Milne-Redhead & Polhill (1971); Sirichamorn <i>et al.</i> (2014)

1.5 Structure of this thesis work

This thesis includes six chapters. In this way, each chapter represents its aims in order to answer questions fittingly as follows:

1) This first chapter aims to introduce the family, tribes and genera that are the focus of this study. The main aim of this PhD work was to contribute to taxonomic understanding of the Millettieae. The approach taken is a phylogenetic one. The phylogenetic work was devised so that the status of the genera, particularly of *Millettia*, but also the other genera in the tribe could be tested. For this reason published sequence data was included, alongside newly generated sequence data so that the main groupings of *Millettia* were well-represented for the first time, and so that the majority of the genera of the Millettieae were well represented. Relationships between genera would also be recovered in this way.

2) Chapter 2 aims to describe the new phylogenetic hypothesis based on DNA sequence data. Current taxonomy is reviewed in the light of the emerging phylogenetic hypotheses. Ultimately, the possible taxonomic implications were numerous, so given time constraints I decided to focus in on two of the main findings. The first is the status of the two informal lineages comprising the Core Millettieae, and the second is the status of genus *Derris*. Chapters 3 and 4 explore the implications of the phylogeny in the case of the informal lineages and *Derris*, considering the distribution of other non-molecular characters in relation to the lineages discovered.

3) Chapter 3 aims to investigate the distribution of canavanine in the Core Millettieae, and considers the delimitation of the informal groups referred to as the Canavanine Group and the Non-canavanine Group (Schrire, 2005b; see Figure 1.5).

4) Chapter 4 aims to focus on *Derris*, a genus recently revised (see Table 1.8). In this case it is necessary to make nomenclatural changes to retain a monophyletic *Derris*, and morphological characters in the group are reviewed in the light of the new circumscription of the genus. In addition to a new combination for an existing species, a new species is described for *Derris*.

- 5) Chapter 5 aims to present three species description for new species which are also included in the phylogenetic study. These treatments are prepared for the Flora of Thailand.
- 6) Chapter 6 aims to review the work completed, making suggestions for classification and for future work.

Chapter 2 A new phylogenetic hypothesis for the Millettioids and allies to investigate the circumscription of genus *Millettia*

2.1 Introduction

Millettia s.l. as traditionally described is a genus of some 100-150 species placed in tribe Millettieae, part of the taxonomically confused “Millettoid *s.l.* clade” (Schrire, 2005b). The genus is well-known to be polyphyletic, though few species have been placed in molecular phylogenies to date (Lavin *et al.* (1998); Hu *et al.* (2000 & 2002); Kajita *et al.* (2001); Wojciechowski (2004); da Silva *et al.* (2012), and phylogenetic study is needed to identify lineages which might be referred to a monophyletic *Millettia* in the future. The genus has been divided into sections, and although the most complete treatment is more than 100 years old (Dunn, 1912), it serves as a framework for sampling the genus.

The Core Millettieae, an informally-named clade, includes twenty two other genera assigned to these two lineages (Schrire, 2005b). It might be expected of genus *Millettia* that species would be distributed in both of the main lineages of the Core Millettieae, the Canavanine Group and Non-canavanine Group. Some other genera placed within the Core Millettieae have been the focus of detailed phylogenetic study. Da Silva *et al.* (2012) studied *Lonchocarpus* and allied genera, and Sirichamorn *et al.* (2012 & 2014) made detailed phylogenetically-informed study of the genus *Derris* and *Derris*-like genera. These studies used overlapping selections of DNA markers for phylogeny reconstruction: Sirichamorn *et al.* (2012 & 2014) used three chloroplast genes, *trnK-matK*, and the *trnL-F* and *psbA-trnH* intergenic spacers, and also the nuclear ribosomal *ITS /5.8S* region; da Silva *et al.* (2012) used three of the same regions, excluding only the *psbA-trnH* intergenic spacers. Given the availability of *trnK-matK*, *trnL-F* and *ITS/5.8S* data for many members of the Millettieae, this study was devised to extend the sampling of these gene regions.

It was decided to extend the sampling widely, to include not only all the genera known to be placed in the Core Millettieae and representatives of all the sections of genus *Millettia*, but genera outwith the Millettioids *s.str.* Many sequences of the *trnK-matK*, *trnL-F* and *ITS/5.8S* regions are also available for the wider Millettoid taxa. Since several genera are doubtfully placed in either the Basal Millettoid/Phaseoloid or the Core Millettieae (specifically *Leptoderris*, *Platysepalum*, *Sylvichadsia*, *Disynstemon* and *Fordia p.p.*, according to Schrire, 2005a), only dense and representative sampling of the core Millettioids and the Basal

Millettoid/Phaseoloid group can adequately investigate the placement of these genera, several of which might yet prove to be allied to species of *Millettia*. For the purposes of this analysis the scope of the sampling was extended to the putative sister group of the Basal Millettoid/Phaseoloid clade, and includes the Millettoid Group of the Inverted Repeat Lacking Clade (IRLC) clade. Further details of the taxonomic history of *Millettia*, and of the groups sampled here are presented in Chapter 1.

The aim of the study presented here is to clarify phylogenetic relationships within the higher level informal group, the Millettoids and allies. More specifically the delimitation of the genera placed in the group will be tested, their relationships recovered and to lineages within genus *Millettia* identified and placed in the phylogeny. The phylogeny will allow revised circumscription of informal higher-level groupings in the light of phytochemistry (Chapter 3), and a re-circumscription of *Derris* in the light of existing and new morphological surveys (Chapter 4). This chapter is focused on the description of the relationships with respect to current taxonomy and existing phylogenetic hypotheses, but not in the light of additional data.

2.2 Materials and Methods

2.2.1 Taxonomic sampling

Existing published sequences were accessed from Genbank, or existing alignments were downloaded if sequences were not available in Genbank. Appendix 2.1 lists the sequences from Genbank or existing publications. New sequence data was generated from field-collected silica-dried leaf material and from leaf material sampled from herbarium specimens. Field collection was carried out in South East Asia during three field trips to Thailand. Appendix 2.2 lists the specimens collected in the field, and sequenced for this study. In Thailand any plant considered to belong to the the Millettoids and allies was sampled. The field-collected specimens sequenced here includes specimens thought to represent ten putative new species, four of which are described here. Two others are placed in genus *Callerya* and have been newly described (Sirichamorn *et al.*, 2015).

In order to achieve representative sampling of the sectional groups of genus *Millettia* and also the main clades of the Millettoids, sampling was also carried out from herbarium specimens. Appendix 2.3 lists the herbarium specimens from which sequence data included

in this study were generated. All of the herbarium material used in this study was sourced from Kew herbarium specimens (K), except for two additional specimens. One was a specimen of *Millettia rubiginosa* Wight & Arn., the type species of *Millettia*, sampled from Naturalis Biodiversity Center, Leiden (L; L.2040850). The other was an indet. Specimen of *Millettia* (accession number P02753791) from Museum Nationale D'Histoire Naturelle, Paris, France. Despite being unidentified, this specimen is cited for the Flora of CLV as *Millettia sericea* (Gagnepain (1916); Lôt & Vidal 2001). However, this specimen appeared to be identified in error, and was morphologically very similar to one of the putatively new species collected in the field.

2.2.2 Molecular methods

Total genomic DNA from leaf tissues collected in the field in Thailand (Appendix 2.2) were extracted using the DNeasy Plant mini kit (Qiagen, Hilden, Germany) following the protocol of the manufacturer. Total genomic DNA of herbarium samples (Appendix 2.3) were isolated in the Jodrell laboratory using a modified acetyl trimethyl ammonium bromide (CTAB) method (Doyle and Doyle, 1987 & 1990). To improve the purification of herbarium DNA, crude DNA was cleaned up following QIAquick PCR Purification Kit (Qiagen, Hilden, Germany) before running the PCR step. *ITS* regions, including *ITS1*, *ITS2* and 5.8s of nuclear ribosomal DNA (NrDNA) were amplified using universal primers; *ITS1*, 2, 3 & 4; 17E and 26SE (Wojciechowski *et al.*, 1993; Sun *et al.*, 1994) following the methods described in Wojciechowski *et al.* (1993). The *trnL-F* and *matK* amplification protocols followed da Silva *et al.* (2012) using their primers and protocols. PCR fragments were checked for length and yield by gel electrophoresis on a 1 or 2% gel and purified using the QIAquick PCR Purification Kit (Qiagen, Hilden, Germany). Ultimately, cleaned forward and reward PCR products were sent for sequencing using the service of Source Bioscience Sequencing, Department of Biochemistry, University of Oxford, UK.

2.2.3 Sequence handling and phylogenetic analysis

The reads from sequencing were assembled using the Seqman program (DNASTAR, Lazergene) or DNA Baser (DNA Sequence Assembler v4, 2013). Following assembly of contigs, alignment was performed using Bioedit ver. 7.2.5.0 (Hall, 1999). Three alignments were used in phylogenetic analysis. The first comprised only the *ITS* sequence data and we

refer to it here as the *ITS* phylogeny. The second comprised the *matK* and *trnL-F* data, and the resulting trees we refer to as the combined chloroplast phylogenies. Finally, data for all three regions were combined into a total evidence analysis. Gene regions were concatenated using the Winclada ver. 1.0000 (Nixon, 1999-2002); in all concatenated data all samples were included, whether they were sequenced for one, two or three regions. Two methods were used reconstruct the phylogenies from these alignments, Maximum Likelihood (ML) and Bayesian Analysis (BA). For ML analysis the alignment file was saved in to Phylip format and uploaded to the CIPRES site (<https://www.phylo.org/>) and ML analysis was performed using RAxML (Stamatakis *et al.*, 2008) using a Gamma model of rate heterogeneity. The most likely tree with branch lengths and bootstrap values was viewed and manipulated to produce tree figures in the software FigTree v1.4.0 (Morariu *et al.*, 2008; <http://tree.bio.ed.ac.uk/software/figtree/>). For Bayesian Analysis, an appropriate model of sequence evolution was chosen according to MrModeltest v.2.2 (Nylander, 2004). The model identified by the Akaike criterion was GTR+I+G for *ITS*, for *matK*, and for the *trnL-F* partition. MrBayes ver. 3.2.6 was used for Bayesian analysis. The analysis the alignment file was saved in to Nexus format and uploaded to the CIPRES site (<https://www.phylo.org/>; Miller *et al.*, 2010). The analysis used two runs of four chains for 10,000,000 iterations, sampling every 1000th generation. The “sumt” command was used to create the majority rule consensus tree in order to determine the posterior probabilities of clades. The outgroup specified for all analyses was *Airyantha schweinfurthii* (Taub.) Brummitt (tribe Sophoreae *p.p.*), though two outgroups were included in the study, *Dalbergia sisoo* Roxb. ex DC. and *D. lanceolata* Zipp. ex Span. (tribe Dalbergieae).

2.3 Results

2.3.1 Alignment statistics

Alignment statistics are presented in Table 2.1. The new sequence data that was generated was for all three regions for the field-collected material, but only for *ITS* for the herbarium material. This was because of difficulties with PCR of longer amplicons, and also because of time and financial constraints.

2.3.2 The phylogenies

Here we describe three Maximum Likelihood (*ML*) phylogenies for the *ITS*, combined chloroplast (*matK+trnL-F*) and total evidence analyses (*ITS+matK+trnL-F*). The phylogenies are large, and for ease of interpretation each phylogeny is presented as five figures. The results of the *ML* analysis of the *ITS* region are shown in Figures 2.1 to 2.5, the combined chloroplast phylogeny in Figures 2.6 to 2.10 and the total evidence phylogeny in Figures 2.11 to 2.15. All *ML* phylogenies are provided as a tree file in the electronic supplementary data (supplementary 2.1.1-2.1.3). The Bayesian Majority Rule consensus phylogenies are also provided as tree files in the electronic supplementary data (supplementary 2.2.1-2.2.3). The *ML* and *BA* analyses produced comparable phylogenies, so only the *ML* phylogenies are discussed here.

Table 2.1. Alignment statistics from *ML* analyses of individuals, combined chloroplast (*matK+trnL-F*) and total evidence (*ITS+matK+trnL-F*).

Partition	Length of the alignment (bp)	Number of variable characters which are parsimony informative	Number of sequences
<i>ITS</i>	909	492	361
<i>matK</i>	3,055	992	292
<i>trnL-F</i>	1,395	349	218
Combined chloroplast	4,450	1,332	306
Total evidence	5,340	1,824	436

2.4 Description of phylogenies and comparison to existing hypotheses of relationships

2.4.1 Higher-level relationships

Figure 2.1 shows a summary *ITS* phylogram; comparable summary phylograms for the combined chloroplast analysis and the total evidence analysis are shown in Figures 2.6 and 2.11 respectively. Inspection of these phylogenies, which collapse monophyletic groups, reveals higher-level relationships. Considering the Millettoid *s.str.* Group, this group is sister *Abrus prectatorius* all analyses (with 42%, 87% and 17% BS support for *ITS*, combined chloroplast and total evidence partitions respectively). The group comprising *Abrus* plus the Millettoid *s.str.* Group is nested in a paraphyletic Basal Millettoid and phaseoloid (BMP) grade in all analyses. Together Millettoid *s.str.* plus *Abrus* plus BMP finds 88% BS support in the *ITS* phylogeny, 100% support in the combined chloroplast phylogeny and 53% support in the total evidence phylogeny. The Inverted Repeat Lacking Clade (IRLC) is sister to *Schefflerodendron* in the *ITS* phylogeny, though this relationship finds only 30% BS support and is not recovered in the total evidence phylogeny; no data were included for either of the chloroplast regions, so *Schefflerodendron* does not appear in the combined chloroplast phylogeny. *Schefflerodendron* plus the IRLC are sister to the “BMP plus Millettoid *s.str.*” Group, with 83% BS support in the *ITS* phylogeny (Figure 2.1). In the combined chloroplast phylogeny IRLC is sister to “BMP plus Millettoid *s.str.*” with 99% BS support (Figure 2.6). This relationship is not recovered in the total evidence tree (Figure 2.11). The *Millettia s.str.* Group is recovered in analyses of all three partitions, with 80%, 93% and 31% BS support for *ITS*, combined chloroplast and total evidence analyses respectively. Comparing these findings with the summary phylogeny in Schrire’s (2005b) treatment for Legumes of the World reveals some differences, notably in the composition of the IRLC and BMP groups. The IRLC *sensu* Wojciechowski *et al.* (2000) comprises the traditional tribes Galegeae, Cicereae, Fabeae (formerly Viciae), Hedysareae, and Trifolieae, as well as some members of Millettieae. In our study we restricted sampling to the genera considered the IRLC Millettoids *sensu* Schrire (2005b): *Afgekia*, *Antheroporum*, *Callerya*, and *Wisteria*. *Endosamara* and *Sarcodum*, the other IRLC Millettoid genera were not sampled. The IRLC finds 99% in the *ITS* phylogeny and 100% BS in the other phylogenies, and the IRLC

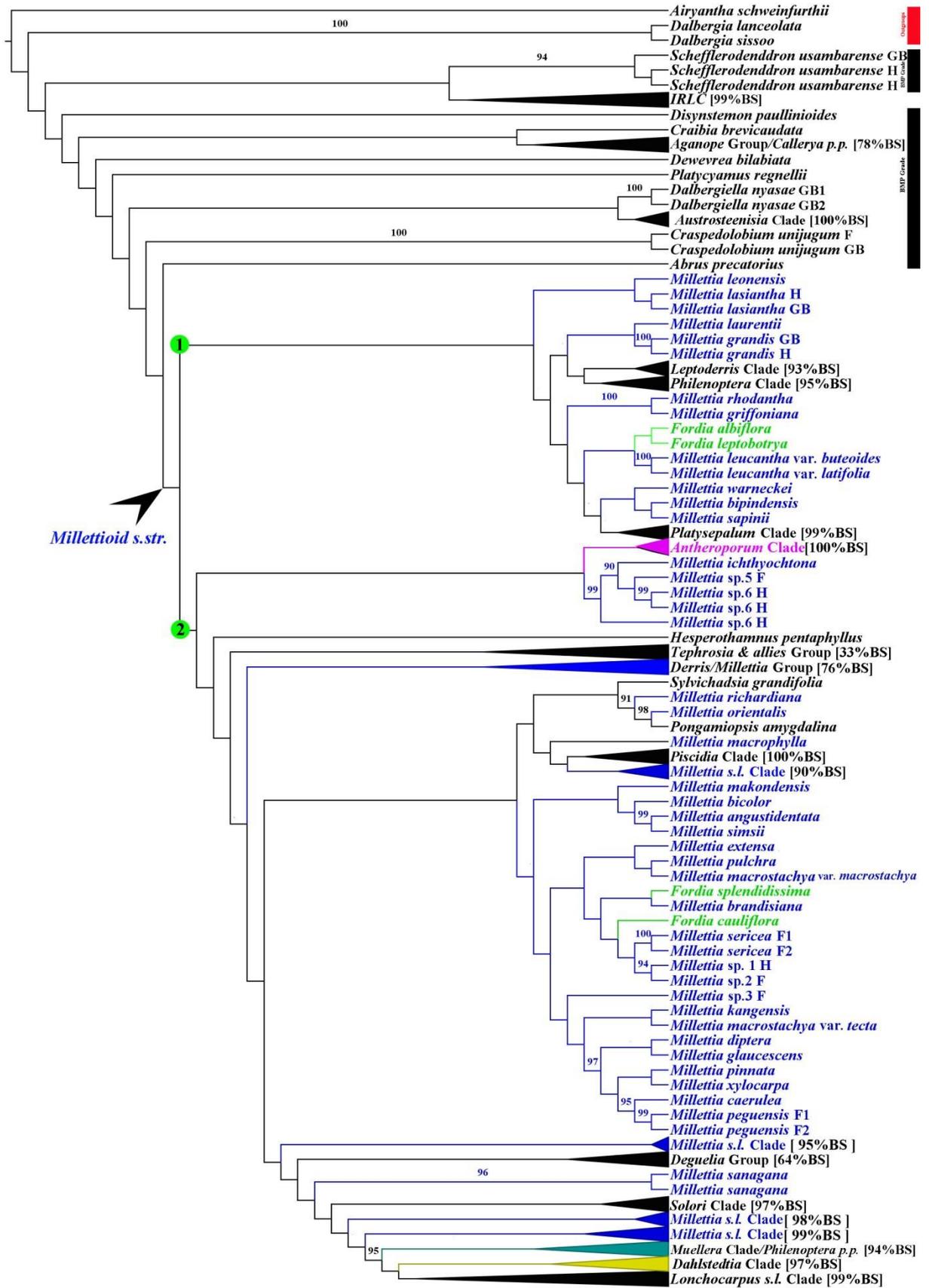


Figure 2.1 Maximum Likelihood summary phylogeny showing the relationships between the major clades recovered in the analysis of sequence data from the *ITS* region. The millettoid *s.str.* Group *sensu* Schrire and the basal Millettoid and Phaseoloid (BMP) Group *sensu* Schrire are indicated, and the IRLC is collapsed. Lineages collapsed with bootstrap support less than 90% are called “Group” here. Most *Millettia* with bootstrap support less than 90% are shown. Monophyletic genera are shown collapsed in colour, as are some clades which include predominantly species of one or few genera but are not monophyletic. All clades collapsed with bootstrap values greater than 90% and indicated in blue include only or predominantly species of *Millettia s.l.* Group 1 and 2 are indicated here for the purpose for delimiting subtrees for illustration in subsequent figures. Only bootstrap values greater than 90% are shown, either above the branches or in square brackets after the clade name for collapsed clades. Poorly supported branches, bootstrap values lower than 90%, are not shown. Letters after species names where there is more than one sequence for a species are used as follows: H= sequence generated in this study from herbarium specimen; F= sequence generated in this study from field-collected specimen; GB= sequence from Genbank; P= published sequence by da Silva *et al.* (2012), but not from Genbank. Otherwise the sources of all sequences can be seen in Appendix 2.1-2.3.

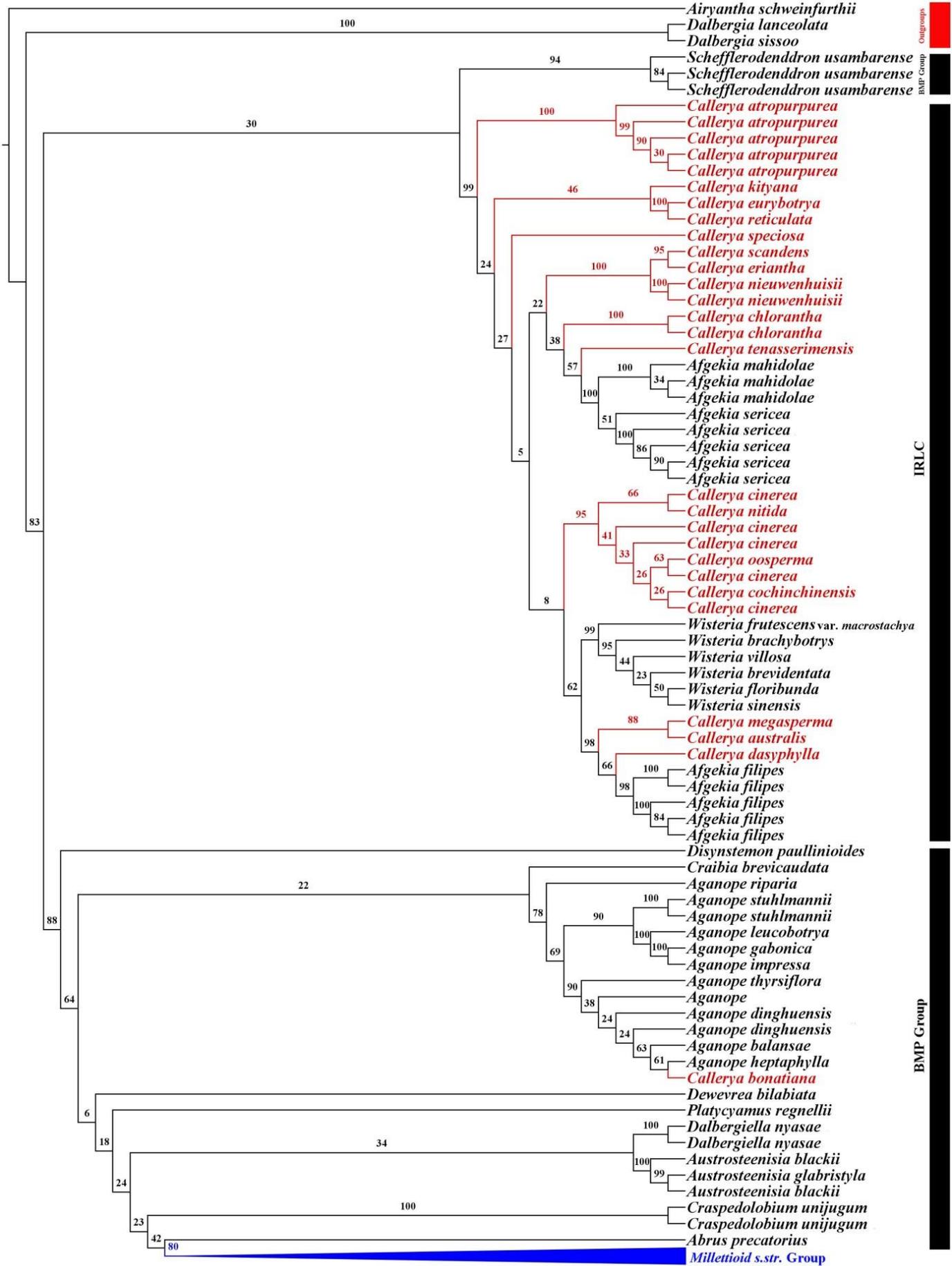


Figure 2.2 Maximum Likelihood phylogeny with the Millettoid *s.str.* Group collapsed, in order to illustrate species relationships outwith the Millettoid *s.str.* Group recovered in the analysis of sequence data from the *ITS* region. The IRLC (99% BS) is indicated with a bar. The Basal Millettoid and Phaseoloid (BMP) Group is also indicated. Only the Millettoid *s.str.* Group (shown blue) includes species of *Millettia*. Species of genus *Callerya* are indicated in red to highlight the polyphyletic nature of this genus. Numbers above branches indicate Bootstrap support values (BS). Letters after species names where there is more than one sequence for a species are used as follows: H= sequence generated in this study from herbarium specimen; F= sequence generated in this study from field-collected specimen; GB= sequence from Genbank.

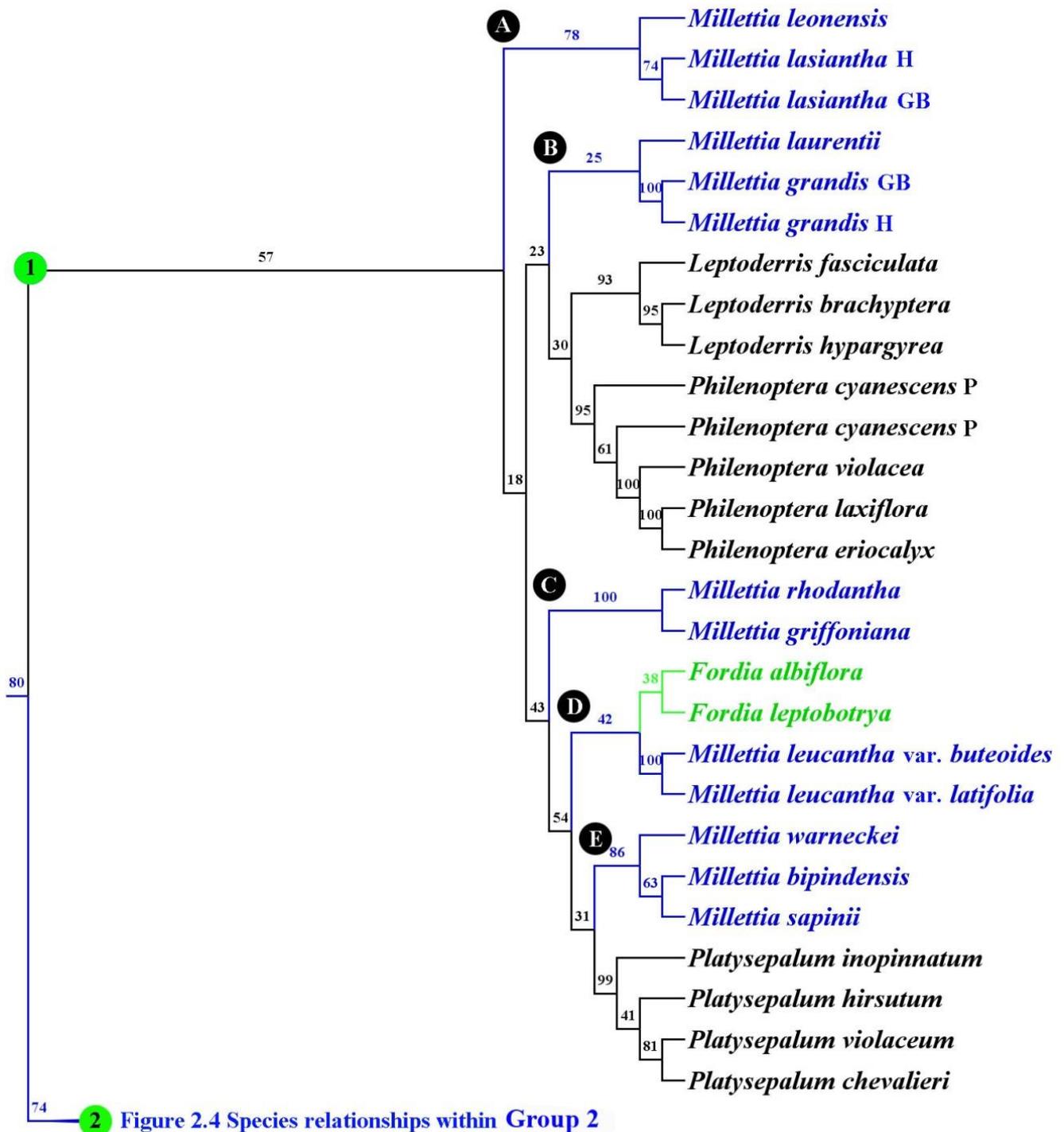


Figure 2.3 Species relationships within Group 1, recovered in the Maximum Likelihood analysis of all *ITS* data. *Millettia* subgroups are indicated A through to E as in Table 2.4. Bootstrap values are shown over the branches, and the *Millettia* species are shown in blue. Letters after species names where there is more than one sequence for a species are used as follows: H= sequence generated in this study from herbarium specimen; GB= sequence from Genbank; P= published sequence by da Silva *et al.* (2012), but not from Genbank.

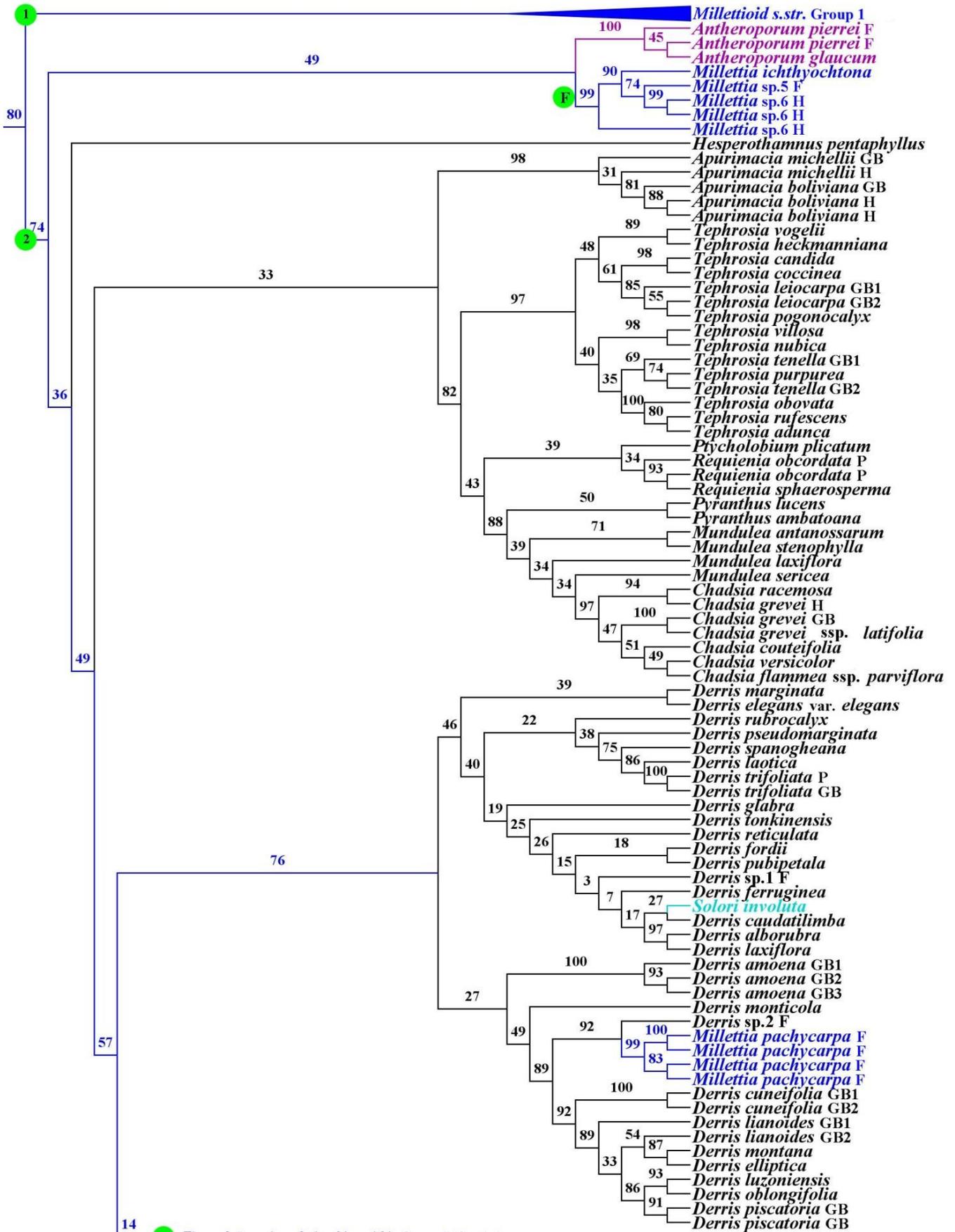


Figure 2.5 species relationships within Group 2 (Contin.)

Figure 2.4 Species relationships within Group 2, recovered in the Maximum Likelihood analysis of all *ITS* data. *Millettia* Subgroup F is indicated as in Table 2.4. Species relationships within the *Derris/Millettia* Subgroup showing *Millettia pachycarpa* sunken within the subgroup. Bootstrap values are shown over the branches, and the *Millettia* species are shown in blue. Letters after species names where there is more than one sequence for a species are used as follows: H= sequence generated in this study from herbarium specimen; F= sequence generated in this study from field-collected specimen; GB= sequence from Genbank; P= published sequence by da Silva *et al.* (2012), but not from Genbank.

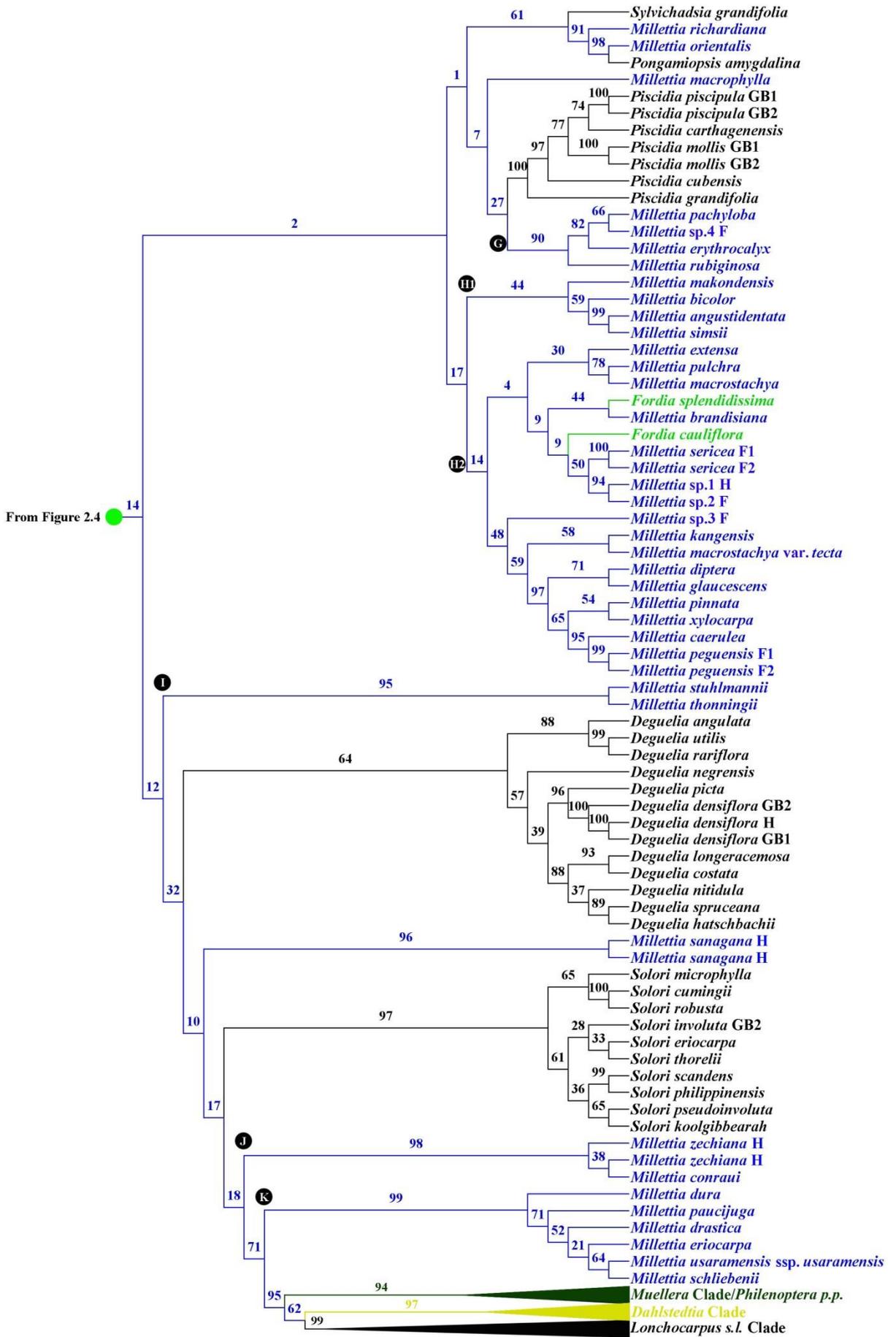


Figure 2.5 Species relationships within Group 2, recovered in the Maximum Likelihood analysis of all *ITS* data. *Millettia* subgroups or clade are indicated G through to K as in Table 2.4. Bootstrap values are shown over the branches, and the *Millettia* species are shown in blue. Letters after species names where there is more than one sequence for a species are used as follows: H= sequence generated in this study from herbarium specimen; F= sequence generated in this study from field-collected specimen; GB= sequence from Genbank.

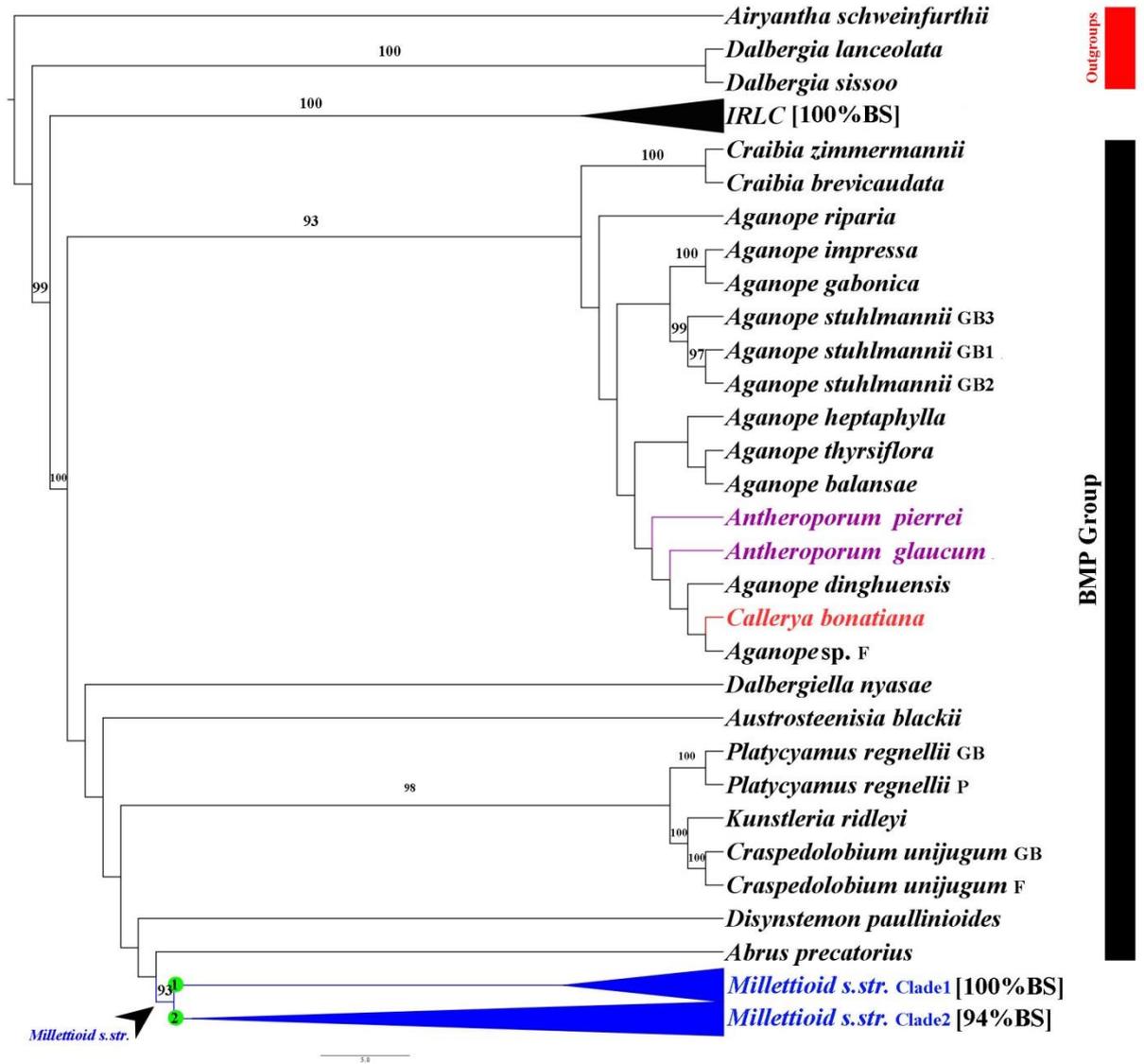


Figure 2.6. Maximum Likelihood summary phylogeny showing the relationships between the major clades recovered in the analysis of sequence data from the combined chloroplast regions (*matK* and *trnL-F*). The *Millettiod s.str.* Group *sensu* Schrire and the basal *Millettiod* and Phaseoloid (BMP) group *sensu* Schrire are indicated, and the IRLC is collapsed. Monophyletic genera are shown collapsed in black, as are some clades which include predominantly species of one or few genera but are not monophyletic. All clades collapsed and indicated in blue include only or predominantly species of *Millettia s.l.* Clades 1 and 2 are indicated here for the purpose for delimiting subtrees for illustration in subsequent figures. Only bootstrap values greater than 90% are shown, either above the branches or in square brackets after the clade name for collapsed clades. Poorly supported branches are not shown. Letters after species names where there is more than one sequence for a species are used as follows: H= sequence generated in this study from herbarium specimen; F= sequence generated in this study from field-collected specimen; GB= sequence from Genbank; P= published sequence by da Silva *et al.* (2012), but not from Genbank. Otherwise the sources of all sequences can be seen in Appendix 2.1-2.3.

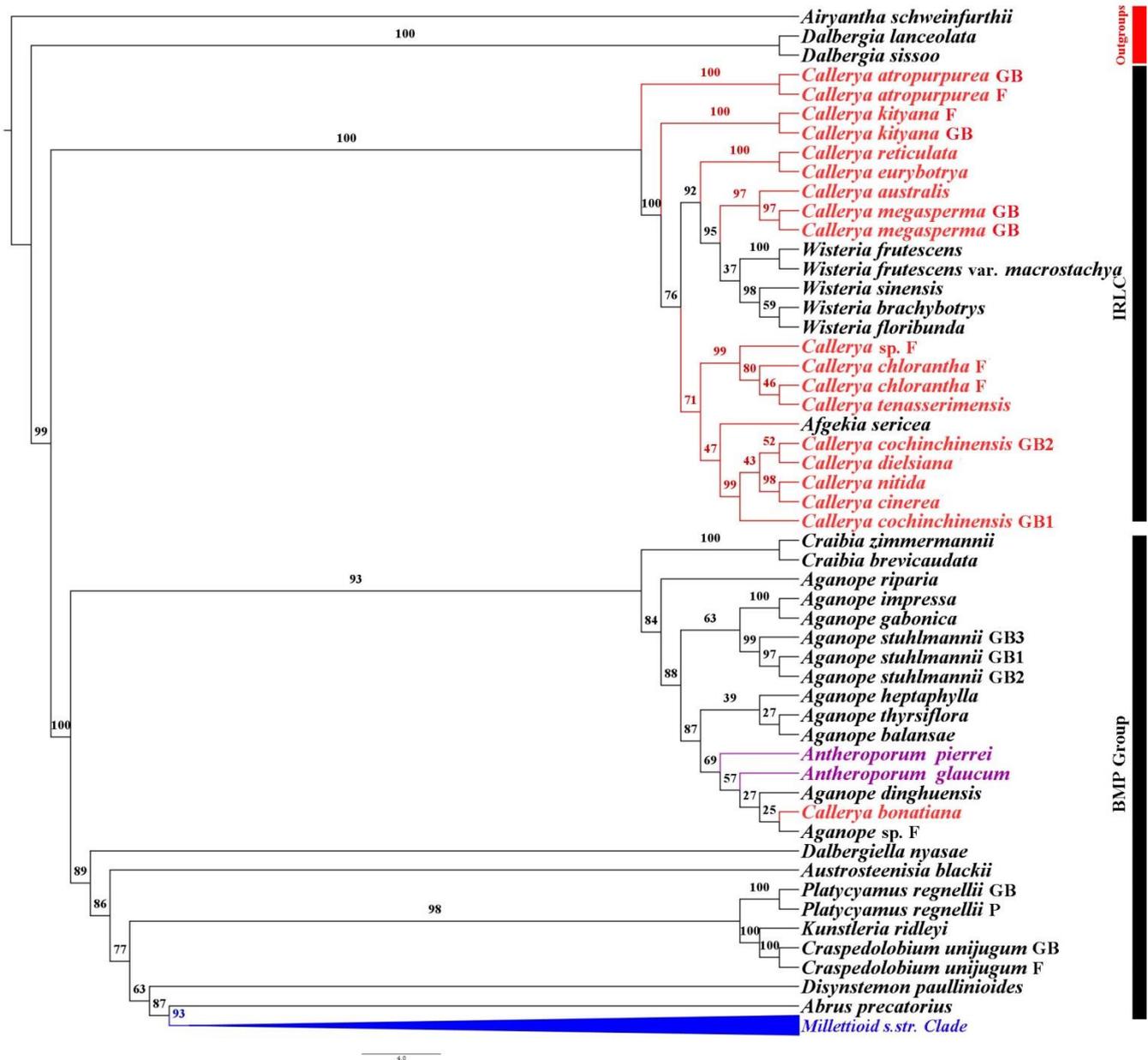


Figure 2.7. Maximum Likelihood phylogeny with the Millettioid *s.str.* clade collapsed, in order to illustrate species relationships outwith the Millettioid *s.str.* clade, recovered in the analysis of sequence data from the combined chloroplast regions (*matK* and *trnL-F*). The IRLC (100% BS) is indicated with a bar. The Basal Millettioid and Phaseoloid (BMP) Clade is also indicated. Only the Millettioid *s.str.* clade (shown blue) includes species of *Millettia*. Species of genus *Callerya* are indicated in red to highlight the polyphyletic nature of this genus. Numbers above branches indicate Bootstrap support values (BS). Letters after species names where there is more than one sequence for a species are used as follows: H= sequence generated in this study from herbarium specimen; F= sequence generated in this study from field-collected specimen; GB= sequence from Genbank; P= published sequence by da Silva *et al.* (2012), but not from Genbank.

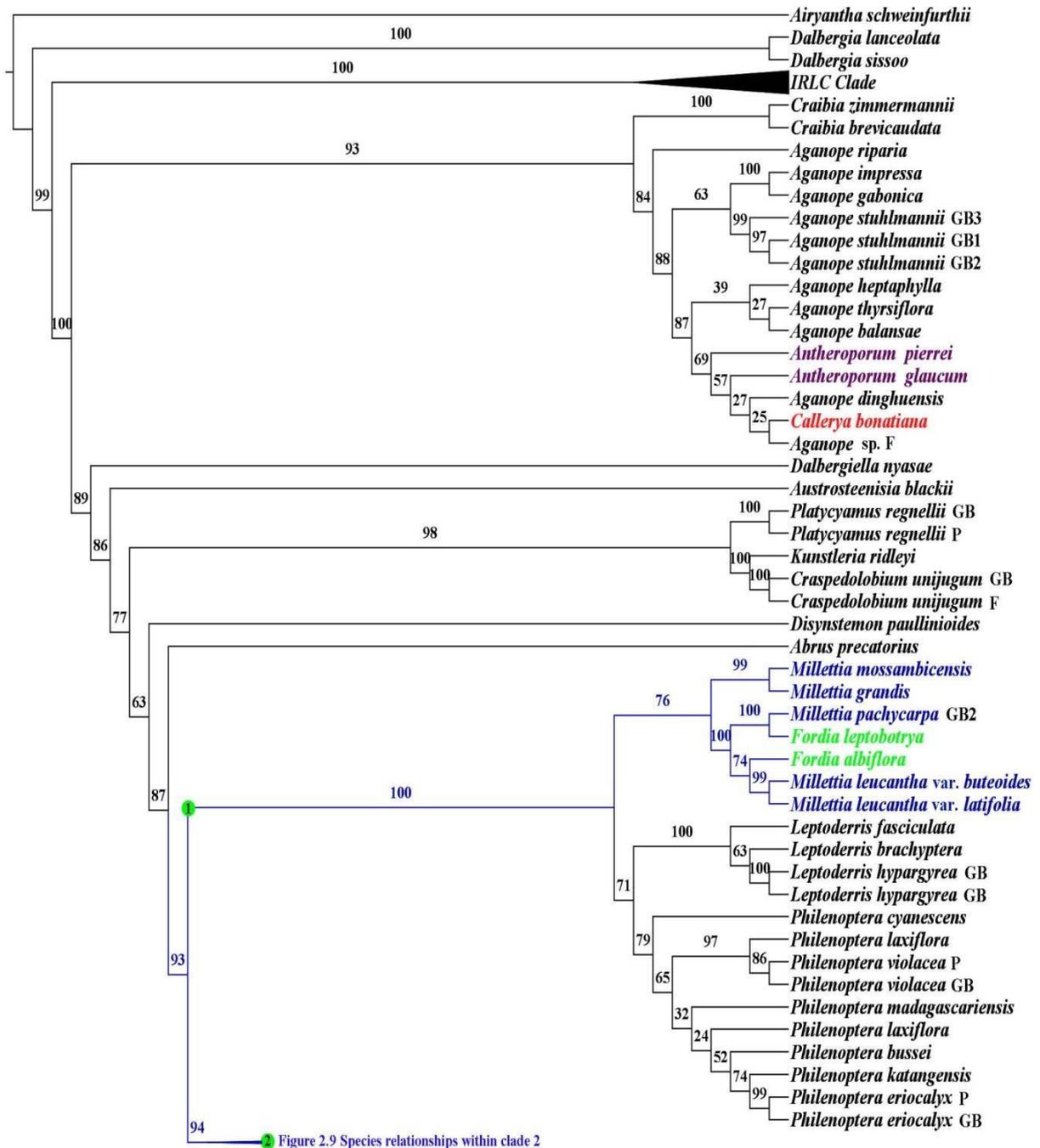
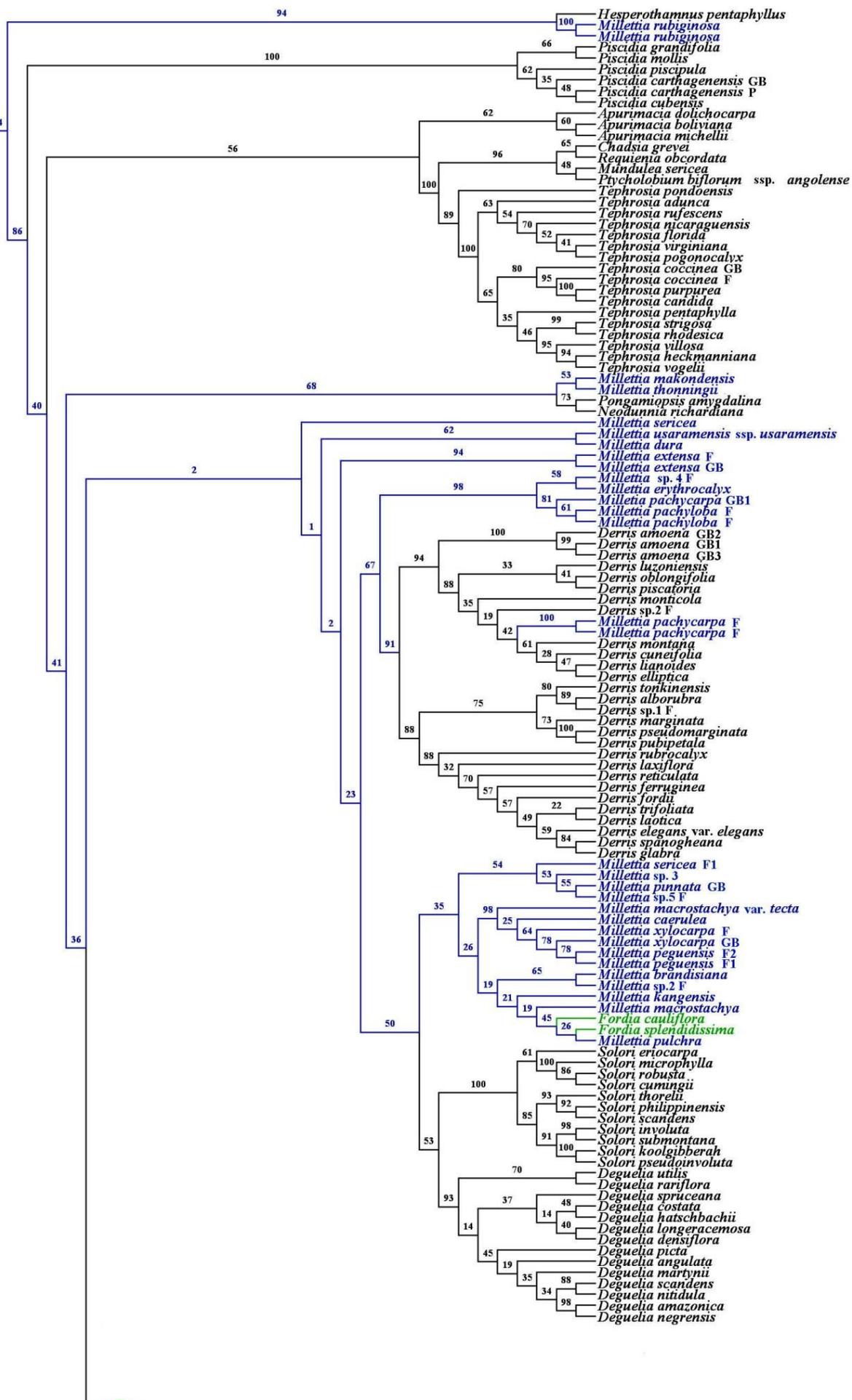


Figure 2.8 Species relationships within Clade 1, recovered in the Maximum Likelihood analysis of sequence data from the combined chloroplast regions (*matK* and *trnL-F*). Bootstrap values are shown over the branches, and the *Millettia* species are shown in blue. Letter after species names where there is more than one sequence for a species are used as follows: H= sequence generated in this study from herbarium specimen; F= sequence generated in this study from field-collected specimen; GB= sequence from Genbank; P= published sequence by da Silva *et al.* (2012), but not from Genbank.

From Figure 2.8

2



85 Figure 2.10 Species relationships within Clade 2 (Contin.)

Figure 2.9 Species relationships within clade 2, recovered in the Maximum Likelihood analysis of sequence data from the combined chloroplast regions (*matK* and *trnL-F*). Species relationships within the *Derris/Millettia* subgroup showing *Millettia pachycarpa* sunken within the subgroup. Bootstrap values are shown over the branches, and the *Millettia* species are shown in blue. Letters after species names where there is more than one sequence for a species are used as follows: H= sequence generated in this study from herbarium specimen; F= sequence generated in this study from field-collected specimen; GB= sequence from Genbank; P= published sequence by da Silva *et al.* (2012), but not from Genbank.

Continuation of Figure 2.9

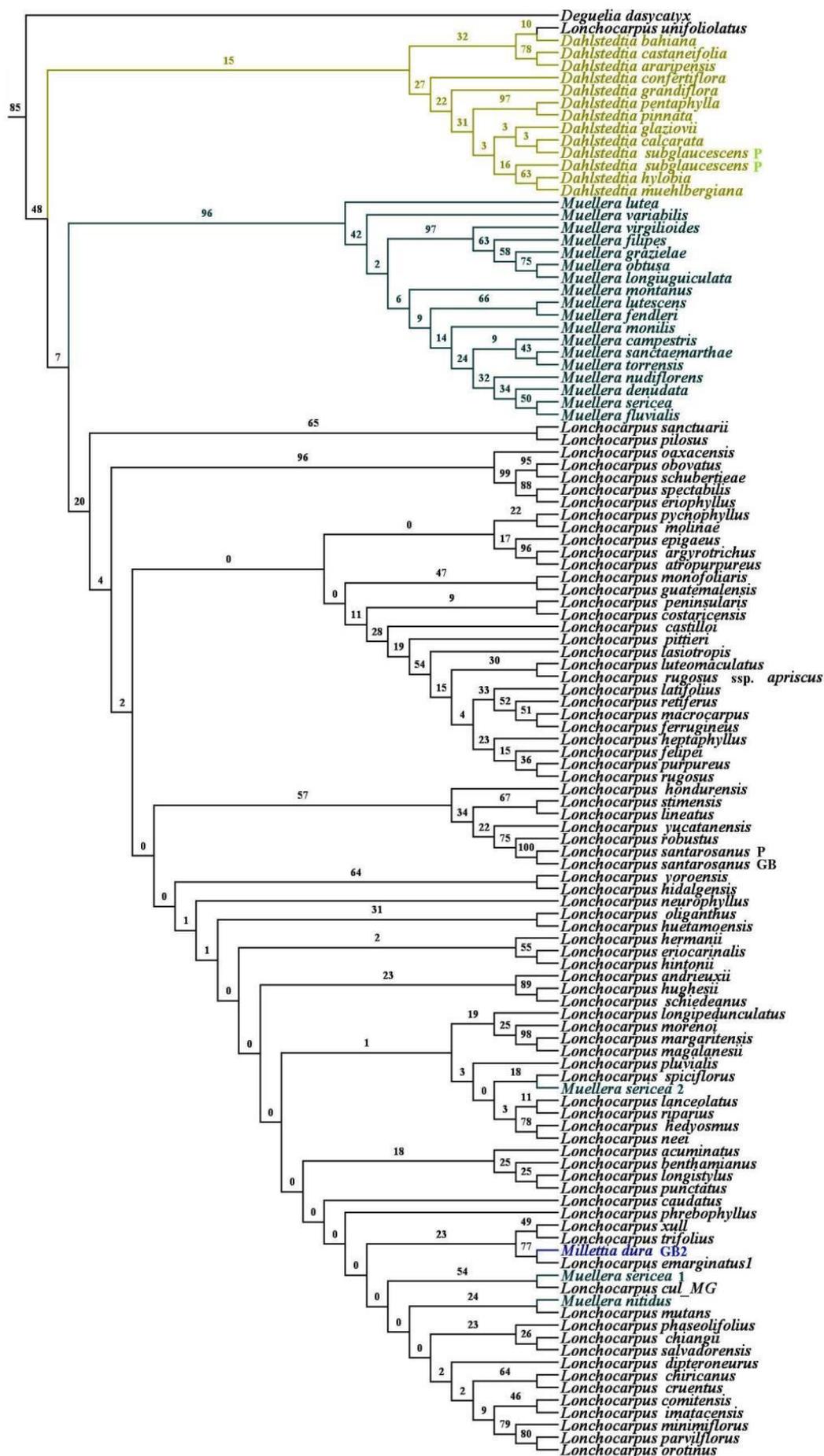


Figure 2.10 Species relationships within clade 2, recovered in the Maximum Likelihood analysis of sequence data from the combined chloroplast regions (*matK* and *trnL-F*). Bootstrap values are shown over the branches, and the *Millettia* species are shown in blue. Letters after species names where there is more than one sequence for a species are used as follows: GB= sequence from Genbank; P= published sequence by da Silva *et al.* (2012), but not from Genbank.

Millettioid genera *Afgekia*, *Callerya* and *Wisteria* are placed here, as would be expected based on previous studies. Our study challenges the placement of *Antheroporum*, a genus that Schrire (2005b) placed tentatively in the IRLC Millettoids, indicating uncertainty with a “?”. This study includes new sequence data for Thai specimens of *Antheroporum glaucum* Z Wei and *Antheroporum pierrei* Gagnep., both seen in the field, vouchered and identified with some confidence. The *ITS* data from these Thai sequences were placed in *Millettia s.str.*, and *trnL-F* sequences have the same placement. Placement of *Antheroporum* in *Millettia s.str.* was also supported by another *matK* sequence submitted to the legume Phylogeny Working Group for inclusion in their latest analysis (LPWG, 2017). However, a *matK* sequence of *Antheroporum glaucum* and another of *Antheroporum pierrei*, both generated from Thai plants were nested in *Aganope*. These strongly conflicting findings should be attributed to laboratory error, and prior to publication of this study another total evidence analysis excluding these two problematic sequences carried out. The poor support (31% BS) for *Millettia s.str.* in the total evidence tree might be attributed to inclusion of this doubtful *matK* sequences. The original *ITS* sequence (not included in the *ITS* phylogeny presented here, but included in previous analyses) which led Schrire (2005b) to place *Antheroporum* in the IRLC has been removed from Genbank based on findings presented here.

The composition of the BMP group is clarified in our study. The genera *Disynstemon*, *Leptoderris*, *Platysepalum* and *Sylvichadsia* were tentatively placed in this group, which was represented as monophyletic in the summary tree in Legumes of the World (Schrire, 2005b). Our study suggests that this group is not be monophyletic, and confirms that three of the genera tentatively placed here belong in *Millettia s.str.*: *Disynstemon*, *Leptoderris*, *Platysepalum* and *Sylvichadsia* remain in the BMP. The status of the BMP as a paraphyletic grade highlights some novel and unstable relationships: we show *Schefflerodendron* is sister to the IRLC clade, and *Disynstemon* finds an unstable position, sometimes as sister to the “*Abrus* plus BMP plus Millettoid *s.str.*” Group.

2.4.2 Genera outwith the Millettoid *s.str.* clade

Figures 2.2, 2.7 and 2.12 show the detail of the relationships outwith the Millettoid *s.str.* Group, in phylogenies with the monophyletic Millettoid *s.str.* Group collapsed. Here we

discuss the status of the genera, whether monophyletic or not, within the BMP grade and within the IRLC.

Of the three IRLC clade genera sampled, only *Wisteria* is monophyletic (99%, 37% and 99% BS in the *ITS*, combined chloroplast and total evidence phylogenies respectively). *Callerya* and *Afgekia* are polyphyletic in all topologies, so generic limits should be revised. This task is likely to be accomplished soon as part of a revision of the Wisterieae (Schrire *et al.*, pers. comm.).

Relationships within the BMP grade find notably poor support. The genera in this grade are *Aganope*, *Austrostenisia*, *Craibia*, *Craspedolobium*, *Dalbergiella*, *Dewevrea*, *Disystemon*, *Platycyamus* and *Schefflerodendron*. A single sequence of *Callerya* is placed here, nested in the otherwise monophyletic *Aganope*. This placement is according to Genbank submissions of *ITS* and *matK* sequences by Roeder and Slik in 2013; these sequences were cited in a paper by Roeder *et al.* in 2015, but as *Millettia bonatiana*. Another doubtful identification of a specimen cited by these same authors also has a voucher lodged in Herbarium of Xishuangbanna Tropical Botanical Garden (HITBC), also collected by Mensong (see Chapter 4 of this thesis). Neither the suspect *Antheroporum matK* sequence generated here nor the *Millettia bonatiana* sequences cast real doubt on the monophyly of this genus. Considering the other genera of the BMP grade sampled here, only two, *Austrostenisia* and *Craibia*, are represented by more than one sequence; all these congeneric and other conspecific sequences are recovered in monophyletic groups in all analyses.

2.4.3 The Core Millettieae comprises two sister clades

In order to describe the relationships within the Millettioid *s.str.* Group we recognise two main groups, numbered 1 and 2 in Figures 2.1, 2.6 and 2.11. The species relationships within Group 1, as recovered in the *ITS*, combined chloroplast and total evidence phylogenies are shown in Figures 2.3, 2.8 and 2.13. The clade 2 relationships are shown in Figures 2.4 & 2.5, 2.9 & 2.10 and 2.14 & 2.15. Support for these groups is as follows: Group 1: 57 %, 100% and 90%; Group 2: 74%, 94% and 53% for the *ITS*, combined chloroplast and total evidence phylogenies respectively.

Inspection of these clades show that they correspond to the Canavanine Group and the Non-canavanine Group, with some notable differences to these groups as conceptualized in Legumes of the World (Schrire, 2005b). The Canavanine Group *sensu* Schrire included *Millettia p.p.*, *Fordia p.p.* plus the genera *Philenoptera* and *Platysepalum*. Inclusion of *Leptoderris* is a novel hypothesis put forward here, otherwise we concur with the delimitation of this group (referring *Fordia* to *Millettia*). The Non-canavanine Group *sensu* Schrire includes several genera. Our delimitation of this group differs by placing *Sylvichadsia* in this group. Aside from clarifying the placement of *Leptoderris* and *Sylvichadsia*, the phylogeny presented here places many *Millettia* in the Canavanine or Non-canavanine Group for the first time. The more robust delimitation of the two groups makes a review of the phylogenetic distribution of canavanine across the Core Millettieae possible. This study is presented in Chapter 3.

2.4.4. The Core Millettieae: genera other than *Millettia*

The Millettoid clade includes 22 genera other than *Millettia*. In the *ITS* phylogeny Group 1 includes *Millettia* species plus *Leptoderris*, *Fordia p.p.*, *Philenoptera p.p.* and *Platysepalum* (Figures 2.3) and Group 2 comprises *Millettia* species plus *Antheroporum*, *Dahlstedtia*, *Deguelia*, *Fordia p.p.*, *Hesperothamnus*, *Lonchocarpus*, *Meullera*, *Philenoptera p.p.*, *Piscidia*, *Pongamiopsis*, *Solori*, *Sylvichadsia* and *Tephrosia* & allies (Figures 2.4). The total chloroplast phylogenies do not include specimens to represent *Platysepalum*, and place all the specimens of *Philenoptera* in Group 1, but otherwise agree with the placement of the genera in the two main lineages of *Millettia s.str.* (Figures 2.8 and 2.9). Aside from these placements into two main groups, the phylogenies reveal some sister relationships between genera. In Group 1 (Clade 1) *Leptoderris* and *Philenoptera* are sisters (Figures 2.3, 2.8 and 2.13; BS 30%, 71% and 48% in the *ITS*, combined chloroplast and total evidence trees respectively). Also in Group 1 (Clade 1), *Platysepalum* is weakly recovered to a lineage of *Millettia*. In Group 2 (Clade 2), with few exceptions, all genera were placed with lineages or species of *Millettia* as their sisters (Figures 2.4 & 2.5, 2.9 & 2.10 and 2.14 & 2.15). The exceptions included the relationships of the genera within the *Tephrosia* clade, and the relationships in the *Lonchocarpus/Dahlstedtia/Deguelia* clade (Group). In the latter case, *Dahlstedtia* and

Lonchocarpus were sisters (BS 62%, 48% and 23% in *ITS*, combined chloroplast and total evidence trees respectively).

As well as considering their placements and relationships, we were able to assess which of these 22 genera were monophyletic. Single sequences represented the small genera *Hesperothamnus*, *Pongamiopsis*, *Ptychlobium* and *Sylvichadsia*, so their monophyly was not tested. Of the remaining 18 genera, 11 were recovered as monophyletic according to the *ITS* and total evidence analyses, though not the same 11 genera (Table 2.2; Figures 2.3 and 2.4 for *ITS* and 2.13 and 2.14 for total evidence). The monophyly of fewer genera could be assessed by the combined chloroplast data, because this partition had the lowest sampling. Table 2.2 identifies several genera which appear to be need of revision, or at least further consideration: *Derris*; *Fordia*; *Philenoptera*; *Ptychlobium* and *Requienia*.

We consider the genus *Derris* in some detail in Chapter 4. The polyphyly of *Fordia* is an unequivocal outcome of this study. Interestingly, species of genus *Imbralyx* Geesink, a genus described by Geesink (1984), were transferred to *Fordia* by Schot in 1991. A more complete analysis of *Millettia* is needed before it can be decided whether species transferred by Schot might indeed form part of a resurrected *Imbralyx*. In any case, the type species of *Fordia* appears to belong with *Millettia*.

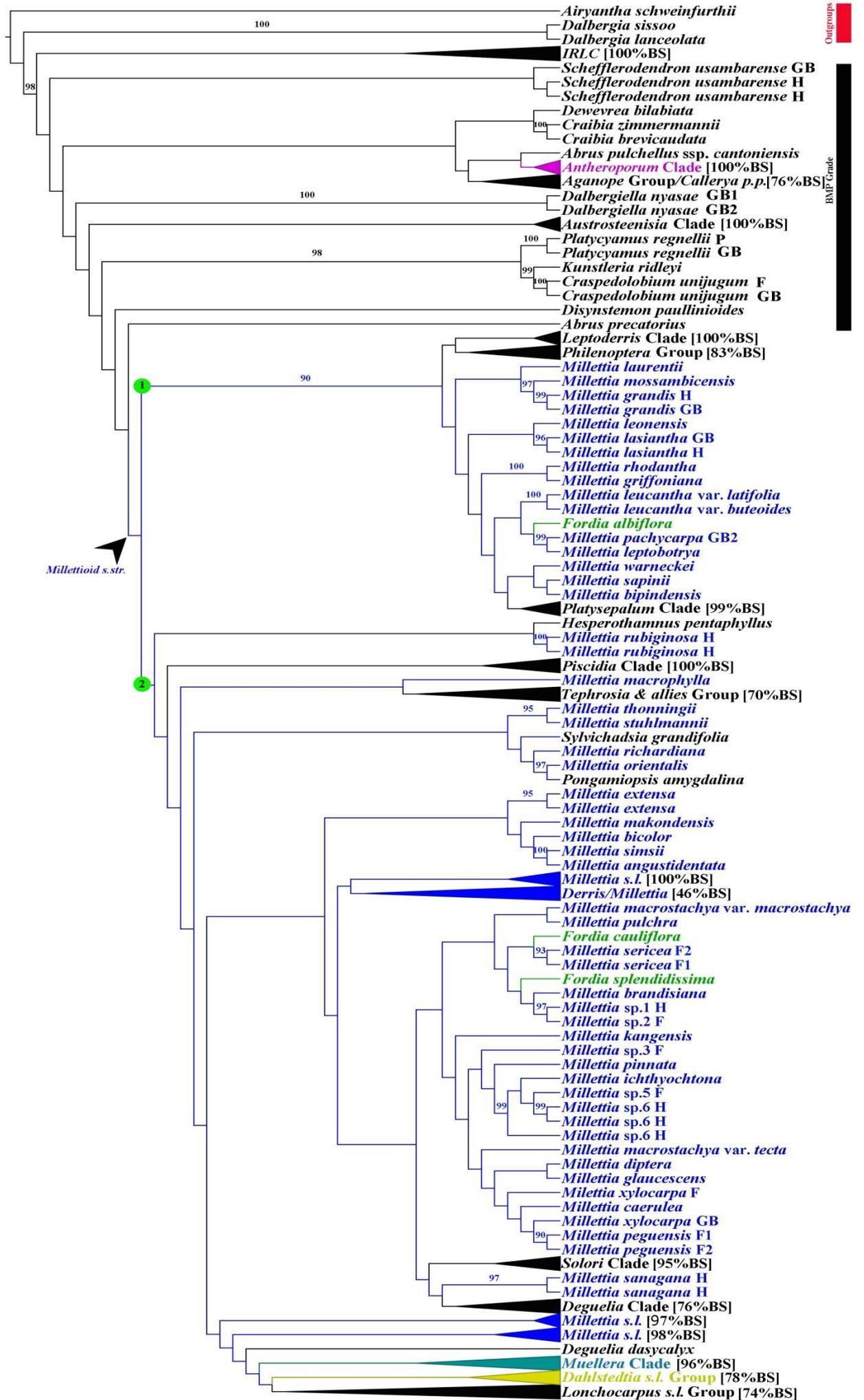


Figure 2.11 Maximum Likelihood summary phylogeny showing the relationships between the major clades recovered in the analysis of sequence data from total evidence. The Millettoid *s.str.* Group *sensu* Schrire and the basal Millettoid and Phaseoloid (BMP) group *sensu* Schrire are indicated, and the IRLC is collapsed. Lineages collapsed with bootstrap support less than 90% are called “Group” here. Most *Millettia* with bootstrap support less than 90% are shown. Monophyletic genera are shown collapsed in colour, as are some clades which include predominantly species of one or few genera but are not monophyletic. All clades collapsed with bootstrap values greater than 90% and indicated in blue include only or predominantly species of *Millettia s.l.* Clades 1 and 2 are indicated here for the purpose for delimiting subtrees for illustration in subsequent figures. Only bootstrap values greater than 90% are shown, either above the branches or in square brackets after the clade name for collapsed clades. Poorly supported branches, bootstrap values lower than 90%, are not shown. Letters after species names where there is more than one sequence for a species are used as follows: H= sequence generated in this study from herbarium specimen; F= sequence generated in this study from field-collected specimen; GB= sequence from Genbank; P= published sequence by da Silva *et al.* (2012), but not from Genbank. Otherwise the sources of all sequences can be seen in Appendix 2.1-2.3.

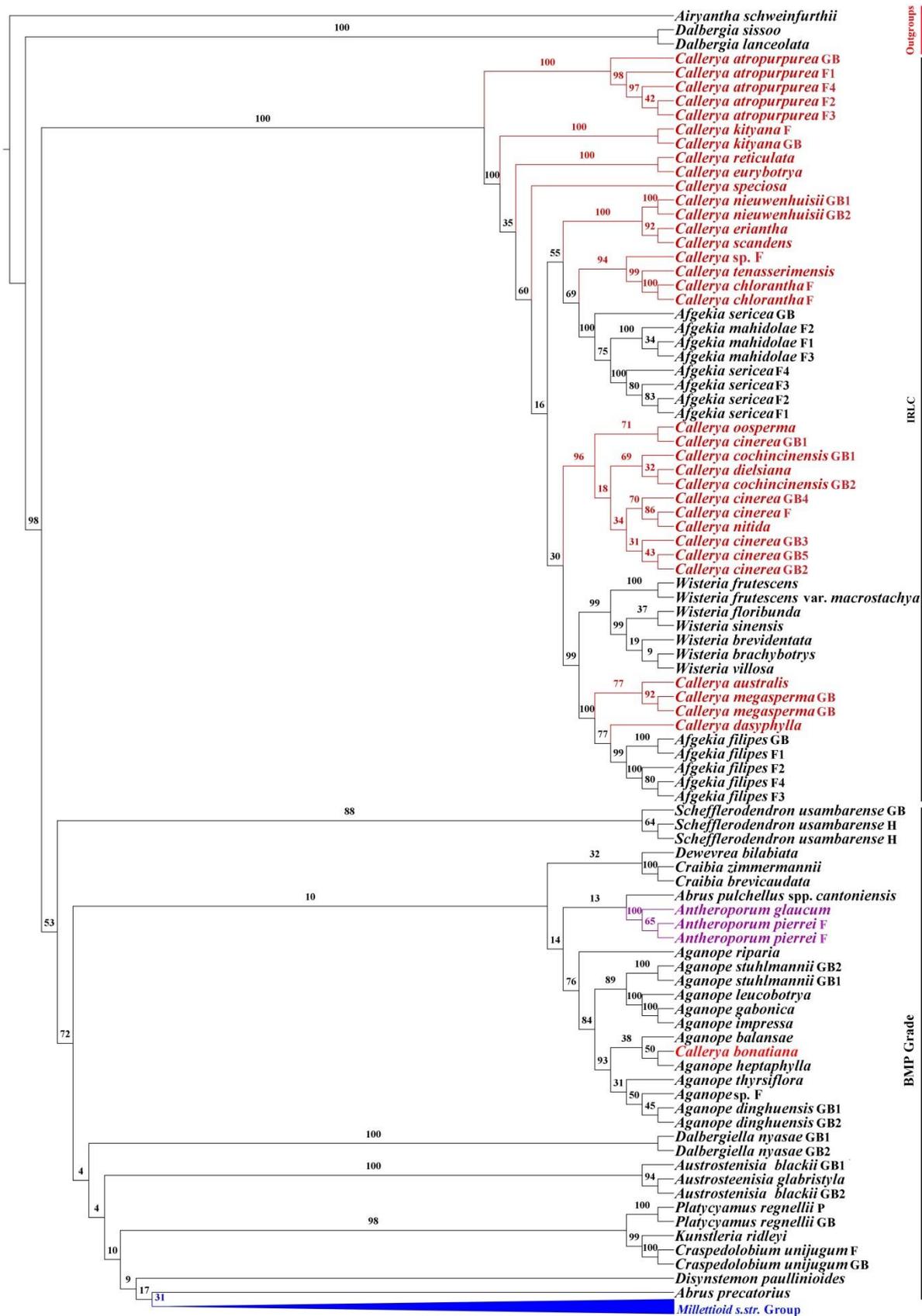
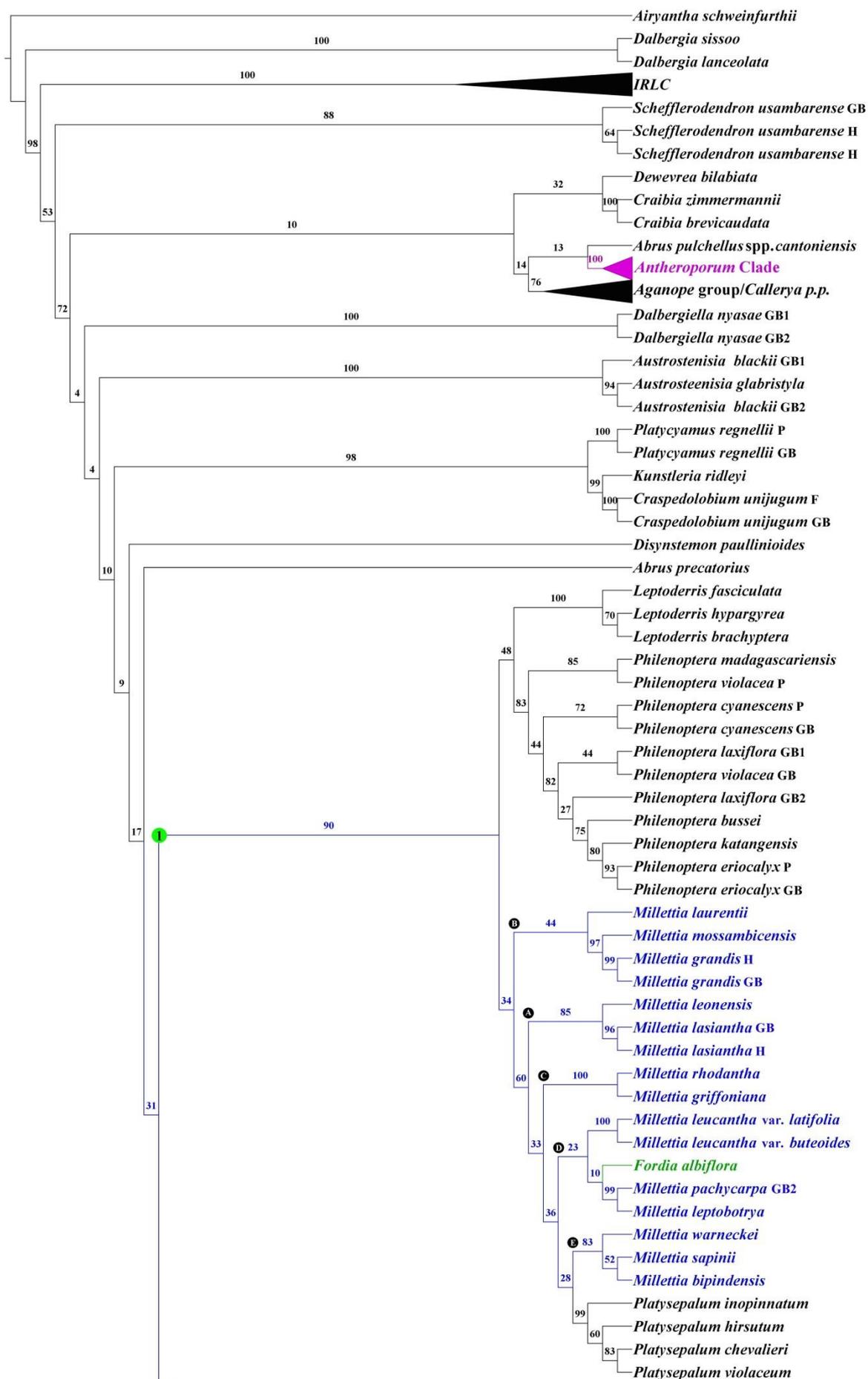


Figure 2.12 Maximum Likelihood phylogeny with the Millettoid *s.str.* Group collapsed, in order to illustrate species relationships outwith the Millettoid *s.str.* Group. The IRLC (92% BS) is indicated with a bar. The Basal Millettoid and Phaseoloid (BMP) Clade is also indicated. Only the Millettoid *s.str.* clade (shown blue) includes species of *Millettia*. Species of genus *Callerya* are indicated in red to highlight the polyphyletic nature of this genus. Numbers above branches indicate Bootstrap support values (BS). Letters after species names where there is more than one sequence for a species are used as follows: H= sequence generated in this study from herbarium specimen; F= sequence generated in this study from field-collected specimen; GB= sequence from Genbank; P= published sequence by da Silva *et al.* (2012), but not from Genbank.



2 Figure 2.14 Species relationships within Clade 2

Figure 2.13 Species relationships within Group 1, recovered in the Maximum Likelihood analysis of total evidence. *Millettia* subgroups are indicated A through to E as in Table 2.4. Bootstrap values are shown over the branches, and the *Millettia* species are shown in blue. Letters after species names where there is more than one sequence for a species are used as follows: H= sequence generated in this study from herbarium specimen; F= sequence generated in this study from field-collected specimen; GB= sequence from Genbank; P= published sequence by da Silva *et al.* (2012), but not from Genbank.

From Figure 2.13

2

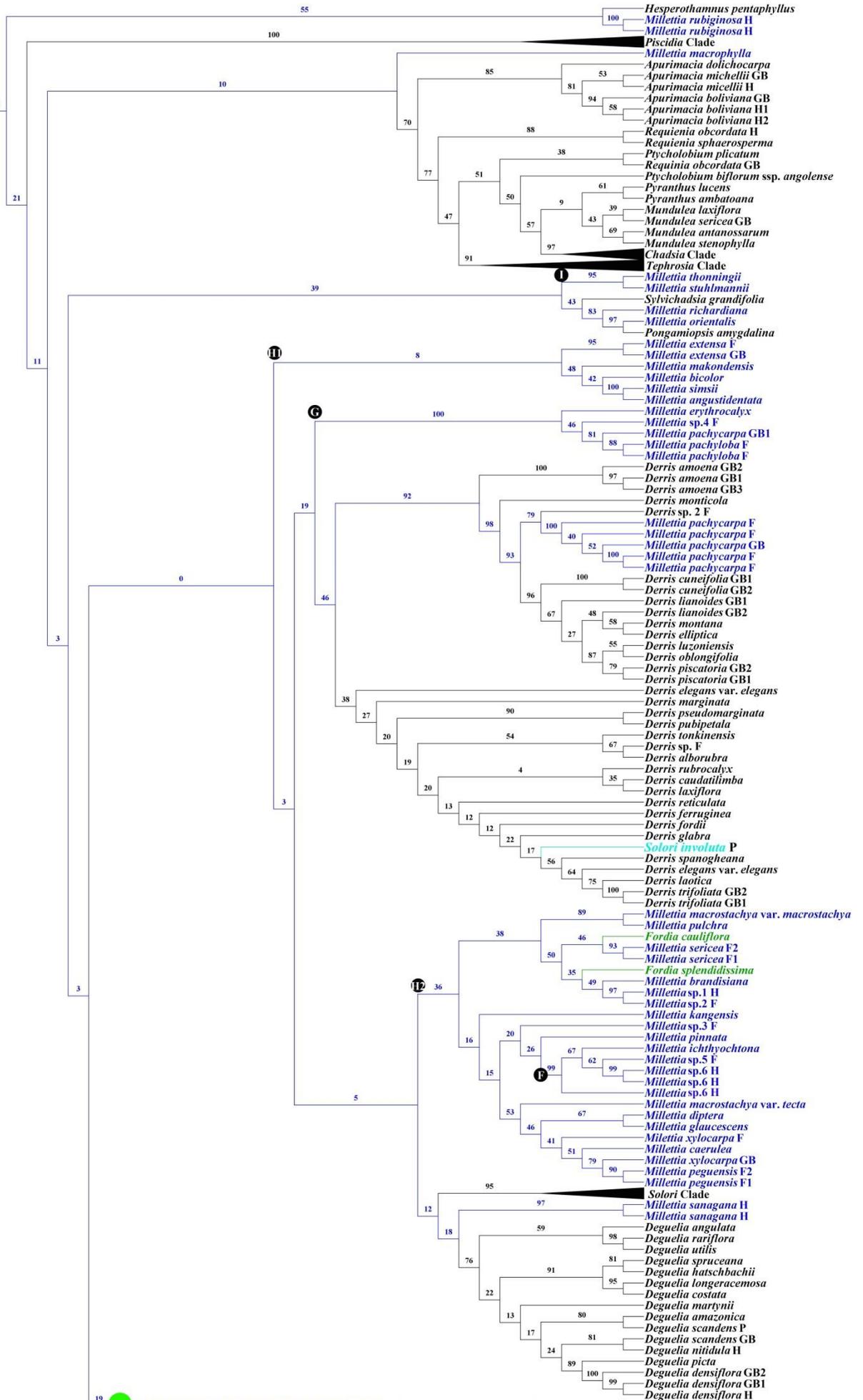


Figure 2.15 Species relationships within Clade 2 (Contin.)

Figure 2.14 Species relationships within Group 2, recovered in the Maximum Likelihood analysis of total evidence. *Millettia* subgroups are indicated F through to I as in Table 2.4. Species relationships within the *Derris/Millettia* subgroup showing *Millettia pachycarpa* sunken within the subgroup. Bootstrap values are shown over the branches, and the *Millettia* species are shown in blue. Letters after species names where there is more than one sequence for a species are used as follows: H= sequence generated in this study from herbarium specimen; F= sequence generated in this study from field-collected specimen; GB= sequence from Genbank; P= published sequence by da Silva *et al.* (2012), but not from Genbank.

Continuation from Figure 2.14

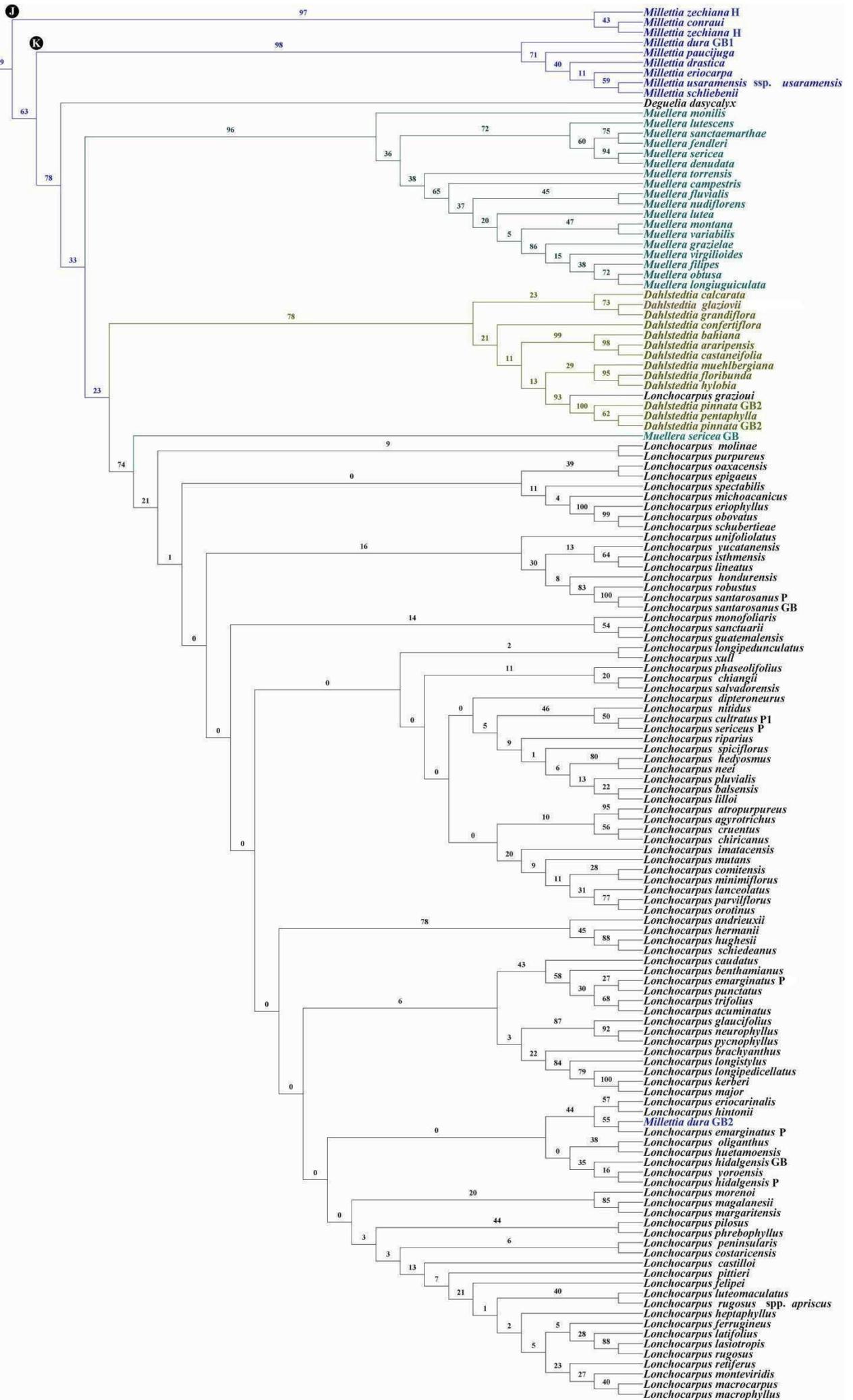


Figure 2.15 Species relationships within Group 2, recovered in the Maximum Likelihood analysis of total evidence. *Millettia* subgroups are indicated J through to K as in Table 2.4. Bootstrap values are shown over the branches, and the *Millettia* species are shown in blue. Letters after species names where there is more than one sequence for a species are used as follows H= sequence generated in this study from herbarium specimen; F= sequence generated in this study from field-collected specimen; GB= sequence from Genbank; P= published sequence by da Silva *et al.* (2012), but not from Genbank.

Table 2.2 Genera placed in the Millettoid *s.str.* Group (Clade). If the genus is recovered as monophyletic in our analysis we present the bootstrap support (%). If the genus is recovered as polyphyletic or paraphyletic we report its status here; where only one sequence representing one species is included in our analysis we note “single sample”.

Genus	Status in <i>ITS</i> phylogeny	Status in combined chloroplast phylogeny (<i>matK+trnL-F</i>)	Status in total evidence phylogeny (<i>ITS+matK+trnL-F</i>)	Comments
<i>Antheroporum</i>	100	polyphyletic	100	The Genbank sequences for <i>ITS</i> originally included to represent <i>Antheroporum</i> included a sequence generated from a mis-identified specimen and placed in the IRLC; this sequence has since been removed from Genbank, but there are two <i>matK</i> sequences generated for this study which still place two species of <i>Antheroporum</i> within <i>Aganope</i> , one of <i>Antheroporum glaucum</i> and another of <i>Antheroporum pierrei</i> , both Thai plants. These strongly conflicting findings should be attributed to laboratory error.
<i>Apurimacia</i>	98	62	85	There is no reason to think this genus would not be monophyletic.
<i>Chadsia</i>	97	single sample	97	There is no reason to think this genus would not be monophyletic.
<i>Dahlstedtia</i>	97	paraphyletic	paraphyletic	This genus is rendered polyphyletic by the placement of <i>Lonchocarpus unifoliolatus</i> ; three sequences were generated by da Silva <i>et al.</i> (2012). An <i>ITS</i> sequence generated by them is placed as expected in <i>Lonchocarpus</i> . This surprising conflict need not be explained in an analysis for publication if the analysis excluded this species.

Table 2.2 Continued.

Genus	Status in <i>ITS</i> phylogeny	Status in combined chloroplast phylogeny (<i>matK+trnL-F</i>)	Status in total evidence phylogeny (<i>ITS+matK+trnL-F</i>)	Comments
<i>Deguelia</i>	64	polyphyletic	polyphyletic	<i>Deguelia</i> is rendered polyphyletic in the total evidence and combined chloroplast trees because one species of <i>Deguelia</i> has unexpectedly relationships as sister to the whole <i>Lonchocarpus/Dahlstedtia/Deguelia</i> according to a single <i>matK</i> sequence from Genbank. There is no <i>ITS</i> sequence for this species, but there is a <i>trnL-F</i> sequence generated by da Silva (2012) according to their table of samples but it does not include in their tree. Further investigation of this species is required to resolve the status of this genus.
<i>Derris</i>	paraphyletic	paraphyletic	paraphyletic	This genus is paraphyletic in all analyses; a single <i>ITS</i> sequence of <i>Solori</i> and all sequences for all regions representing <i>Millettia pachycarpa</i> are nested here. <i>Derris</i> is the focus of further discussion in Chapter 4.
<i>Fordia</i>	polyphyletic	polyphyletic	polyphyletic	This genus is polyphyletic in all analyses; it is therefore in need of revision, particularly as species are placed in both Clade 1 and Clade 2 of the Core Millettieae, with species of <i>Millettia</i> .
<i>Hesperothamnus</i>	single sample	single sample	single sample	-
<i>Leptoderris</i>	93	100	100	There is no reason to think this genus would not be monophyletic.
<i>Lonchocarpus</i>	99	polyphyletic	polyphyletic	<i>Lonchocarpus</i> is rendered polyphyletic in the chloroplast tree because two species of <i>Muelleria</i> (<i>M. sericea</i> and <i>M. nitidus</i>) and one species of <i>Millettia</i> (<i>M. dura</i>) are nested in this genus. Regarding neither <i>M. sericea</i> nor <i>M. nitidus</i> are names that have been used for <i>Muelleria</i> , but both epithets have been validly published and are accepted names for <i>Lonchocarpus</i> species, suggesting an error in the Genbank submission. Both these sequences were uploaded by da Silva (2012). Regarding <i>Millettia dura</i> , there are two sequences representing this species in any tree, one is a <i>matK</i> sequence included in Hu <i>et al.</i> 's (2000) study falling in <i>Lonchocarpus</i> and the other is an <i>ITS</i> sequence uploaded by da Silva (2012) and this is placed with other species of <i>Millettia</i> (Clade K).

Table 2.2 Continued.

Genus	Status in <i>ITS</i> phylogeny	Status in combined chloroplast phylogeny (<i>matK+trnL-F</i>)	Status in total evidence phylogeny (<i>ITS+matK+trnL-F</i>)	Comments
<i>Muelleria</i>	paraphyletic	polyphyletic	polyphyletic	There are two <i>ITS</i> sequences nested in <i>Muelleria</i> : <i>Philenoptera madagascariensis</i> and <i>Philenoptera violacea</i> , both from da Silva <i>et al.</i> , (2012). Another <i>ITS</i> sequence of <i>P. violacea</i> , (from Sirichamorn <i>et al.</i> , 2012) is found with the remainder of the <i>Philenoptera</i> . As noted above, there are two chloroplast sequences uploaded to Genbank as <i>Muelleria</i> (<i>M. sericea</i> and <i>M. nitidus</i>), that are almost certainly <i>Lonchocarpus</i> species. Apart from the placement of these two, the genus is monophyletic in the chloroplast phylogeny.
<i>Mundulea</i>	polyphyletic	single sample	43	There are four <i>ITS</i> sequences <i>Mundulea antanosarum</i> , <i>M. laxiflora</i> , <i>M. sericea</i> and <i>M. stenophylla</i> the first couple species is from our study while the last from Genbank. All species are sister to monophyletic genus <i>Chadsia</i> . A single sequence data from Genbank of <i>Mundulea</i> , <i>M. sericea</i> , is sister to <i>Ptychlobium biflorum</i> ssp. <i>angolense</i> .
<i>Philenoptera</i>	polyphyletic	79	83	As noted, there are two <i>ITS</i> sequences nested in <i>Muelleria</i> : <i>Philenoptera madagascariensis</i> and <i>Philenoptera violacea</i> , both from da Silva <i>et al.</i> (2012), but another sequence of <i>P. violacea</i> (from Sirichamorn <i>et al.</i> , 2012) is found with the remainder of the <i>Philenoptera</i> . Chloroplast sequence data from <i>Philenoptera violacea</i> and <i>P. madagascariensis</i> are placed with other <i>Philenoptera</i> outside of the <i>Muelleria</i> clade. Both da Silva <i>et al.</i> , (2012) and Sirichamorn <i>et al.</i> (2012) generated <i>P. violacea</i> sequences. da Silva <i>et al.</i> , (2012) sequenced <i>P. madagascariensis</i> .
<i>Piscidia</i>	100	100	100	There is no reason to think this genus would not be monophyletic.
<i>Platysepalum</i>	99	not sampled	99	There is no reason to think this genus would not be monophyletic.
<i>Pongamiopsis</i>	single sample	single sample	single sample	-

Table 2.2 Continued.

Genus	Status in <i>ITS</i> phylogeny	Status in combined chloroplast phylogeny (<i>matK+trnL-F</i>)	Status in total evidence phylogeny (<i>ITS+matK+trnL-F</i>)	Comments
<i>Ptychobium</i>	single sample	single sample	polyphyletic	Different species have been sampled for different regions and the two species are not sisters in the total evidence phylogeny
<i>Pyranthus</i>	50	not sampled	61	There is no reason to think this genus would not be monophyletic.
<i>Requienia</i>	93	single sample	polyphyletic	Although the two species sampled for <i>ITS</i> (<i>R. obcordata</i> – with two sequences - and <i>R. sphaerosperma</i> with one) are monophyletic, the two specimens of <i>R. obcordata</i> are separated in total evidence analysis. It appears that <i>Ptychobium</i> , <i>Requienia</i> and <i>Tephrosia p.p.</i> find close relationship with each other.
<i>Solori</i>	polyphyletic	100	95	Aside from the placement of a single <i>ITS</i> sequence of <i>Solori involuta</i> in <i>Derris</i> , the remaining ten sequences of <i>Solori</i> comprise a well-supported monophyletic group. This sequence is generated by da Silva (2012), but in the study of Sirichamorn (2014) the same species is placed with other <i>Solori</i> sequences, casting doubt on the validity of the da Silva sequence.
<i>Sylvichadsia</i>	single sample	not sampled	single sample	-
Core <i>Tephrosia</i>	97	89	91	A monophyletic core <i>Tephrosia</i> was recovered, with high support; species now placed in <i>Requienia</i> are found outside of this clade.

Philenoptera remains an enigmatic genus, based on the sequence data available to us. Although we included the same sequences to represent *Philenoptera* as da Silva *et al.* (2012) and did not add further sequences to represent this genus, our phylogenetic placement of these sequences differs from the relationships they report. In our study *ITS* sequences are placed in two clades. Intriguingly da Silva *et al.* (2012) do report instability in the placement of genus *Philenoptera* between their chloroplast and *ITS* topologies, but do not show the relationships for *ITS* in their publication. Either da Silva's *ITS* sequences for the two species nested in *Muelleria* should be disregarded, or further sequencing of this genus to resolve these issues. This might be a question resolved in discussion with da Silva *et al.* (2012). For reference, a summary of the placement of *Philenoptera* sequences in their study and in our analysis is presented in Table 2.3. We did find that the sequences made available by da Silva *et al.* (2012) had some quality issues, for example the *trnL-F* sequences were made contiguous in the wrong orientation. This issue should be corrected before others attempt to use their data.

Species-rich *Tephrosia* is associated with six other small genera (*Apurimacia*, *Chadsia*, *Mundulea*, *Ptychlobium*, *Pyranthus* and *Requienia*). It appears that *Ptychlobium*, *Requienia* and *Tephrosia p.p.* find close relationship with each other, and may be the need of revision, but such a study would depend on much denser sampling of *Tephrosia*.

2.4.5 The Millettoid clade: placement of *Millettia* species

In the *ITS* phylogeny all the *Millettia* sequences included fell into the Millettoid *s.str.* Group where they are placed distributed between the Groups we refer to as Group 1 and Group 2, and in eleven groups we refer to here differently as Clade (with bootstrap values higher than 90%) or Subgroup (with bootstrap values less than 90%) A to K (Figures 2.3 & 2.4). The combined chloroplast and total evidence phylogenies also placed all the species of *Millettia* in the Millettoid *s.str.* Group. This is one of the most important findings reported here, as it strongly suggests that future studies of *Millettia* can reasonably be restricted to this group. Overall however, the membership of Groups (Clades) A through to K differs between the *ITS*, combined chloroplast and total evidence trees. Support, which was generally low, also differed. It should be noted that far fewer species were sequenced for the chloroplast regions. The total evidence tree places all the species that were sampled for *ITS*, though

most *Millettia* are placed only according to their *ITS* sequence data because chloroplast data were missing. Thus, the placement of the majority of the *Millettia* is based on a single region.

Table 2.3 *ITS* sequences of *Philenoptera* and their placement in our analysis (ML) as compared to analyses performed by da Silva *et al.* (2012). Abbreviation for P refers to published sequence by da Silva *et al.* (2012), and GB refers to sequence obtained from Genbank.

Species name	Genbank accession/authors	Placement in da Silva <i>et al.</i> <i>ITS</i> study	Placement in present study (ML)
<i>Philenoptera cyanescens</i> P*	da Silva <i>et al.</i> (2012); not on Genbank but in the da Silva <i>et al.</i> (2012) alignment and attributed to a Berlin specimen	Sister to the <i>Muelleria</i> clade.	Basal, in the smaller of two groups comprising the Millettoid <i>s.str.</i> Group
<i>P. cyanescens</i> GB*	AF534802.1/Kim, J.H. & Chase, M.W. (2002)	-	Basal, in the smaller of two groups comprising the Millettoid <i>s.str.</i> Group
<i>P. eriocalyx</i>	AF467487/Hu <i>et al.</i> (2002)	Sister to the <i>Muelleria</i> clade.	Basal, in the smaller of two groups comprising the Millettoid <i>s.str.</i> Group
<i>P. laxiflora</i>	AF467488/ Hu <i>et al.</i> (2002)	Sister to the <i>Muelleria</i> clade.	Basal, in the smaller of two groups comprising the Millettoid <i>s.str.</i> Group
<i>P. madagascariensis</i>	da Silva <i>et al.</i> (2012)	Sister to the <i>Muelleria</i> clade.	Nested in the <i>Muelleria</i> clade.

Table 2.3 Continued.

<i>P. violacea</i> GB*	JX506439.1/Sirichamorn <i>et al.</i> (2012)	-	Basal, in the smaller of two groups comprising the Millettoid <i>s.str.</i> Group
<i>P. violacea</i> P*	da Silva <i>et al.</i> (2012)	Sister to the <i>Muelleria</i> clade.	Nested in the <i>Muelleria</i> clade.

Although support is low, indicating that ultimately more sequence data are needed to finally resolve the “*Millettia* problem”, it is of interest to examine the placement of the *Millettia* species sampled. Table 2.4 describes the groups (clades) A to K and the species placed in them. Whether there are phylogenetic patterns that correspond to biogeography or to sectional classifications (particularly Dunn’s 1912 treatment, the most complete one) is of interest. Of these 11 groups (clades), all are entirely comprised of species currently accepted as *Millettia* except for Subgroup D which includes one species currently accepted as *Fordia* and Subgroup H which includes two species of *Fordia*. Sequences of one species currently accepted as *Millettia*, *Millettia pachycarpa*, are also placed in the *Derris s.str./Millettia s.l.* Group. Four species, *Millettia macrophylla*, *Millettia orientalis*, *Millettia richardiana* and *Millettia sanagana*, shown in blue in Figure 2.1, are found outside of Groups (Clades) A to K. Every clade (or subgroup) including species of *Millettia* that is collapsed in Figure 2.1 and in Figure 2.11 is shown as a blue triangle; each of these subgroups are shown fully expanded in Figures 2.3-2.5 and in 2.13-2.15. Table 2.4 describes the relationships of the *Millettia* species illustrated in these Figures.

Placement of *Millettia* species in Group 1 (Clade 1) of the Core Millettieae is shown in Figures 2.3 and 2.13 and described in Table 2.4. Of the five clades of *Millettia* in Group 1 (Clade 1), only two find moderate to strong support, Subgroup A (78% and 85% in *ITS* and total evidence trees) and E (86% and 83% BS in *ITS* and total evidence trees). Subgroup A comprises a sister pair, *M. leonensis* and *M. lasiantha*, both African species. Subgroup E

comprises three African species of *Millettia*, *M. bipindensis*, *M. sapinii* and *M. warneckei*. In terms of biogeography, Group 1 is an African clade, in terms of *Millettia* species, with the exception of Subgroup D which is Asian. In terms of previous taxonomic treatments, it is noticeable that all the species in Clade E were placed in Dunn's Sect. *Efulgentes* (Dunn, 1912), though one other species of this section was placed elsewhere, in Clade C. Another notable Clade, the Asian Clade D comprises species placed in Dunn's Sect. *Albiflorae* plus another white-flowered species, *M. leucantha*. Geesink (1984) described a new genus, *Imbralyx*, for Dunn's Sect. *Albiflorae*, all with white flowers. The characters highlighted by Geesink (1984) for *Imbralyx* could be synapomorphies for the clade of white-flowered species, and this should be considered.

Table 2.4 The sectional classification, following Dunn (1912), of the *Millettia* species included in our study, indicating the clades recognized in this study and the distributions of the species. Distributions are described following World Geographical Scheme for Recording Plant Distributions for continents Brummitt (2001). Abbreviation for F (including number) refers to unnamed species from field collection and for GB refers to species obtained from Genbank.

Millettiod Group	subgroup name	Species	Dunn's (1912) section	Geographic distribution	Composition/support in total evidence phylogeny
Group 1	Subgroup A	<i>Millettia leonensis</i>	x	Africa	Same/85%
		<i>Millettia lasiantha</i>	<i>Sericantae</i>	Africa	
	Subgroup B	<i>Millettia grandis</i>	x	Africa	Includes <i>M. mossambicensis</i> /44%
		<i>Millettia laurentii</i>	<i>Compresso-Gemmae</i>	Africa	
	Subgroup C	<i>Millettia griffoniana</i>	x	Africa	Same/100%
		<i>Millettia rhodantha</i>	<i>Efulgentes</i>	Africa	
	Subgroup D	<i>Fordia (Millettia) albiflora</i>	<i>Albiflorae</i>		One sequence of <i>M. pachycarpa</i> (Genbank KR531231.1), probably

Table 2.4 Continued.

Millettiod Group	subgroup name	Species	Dunn's (1912) section	Geographic distribution	Composition/support in total evidence phylogeny
Group 2		<i>Fordia (Millettia) leptobotrya</i>	<i>Albiflorae</i>	Asia	misidentified, appears here/23%
		<i>Millettia leucantha</i> var. <i>latifolia</i>	x	Asia	
		<i>Millettia leucantha</i> var. <i>buteoides</i>	x	Asia	
	Subgroup E	<i>Millettia bipindensis</i>	<i>Efulgentes</i>	Africa	Same/83%
		<i>Millettia sapinii</i>	<i>Efulgentes</i>	Africa	
		<i>Millettia warneckeii</i>	<i>Efulgentes</i>	Africa	
	Subgroup F	<i>Millettia ichthyochtona</i>	<i>Podocarpae</i>	Asia	Same/99%, but nested in another subgroup (H2)
		<i>Millettia</i> sp.5 F*	x	Asia	
		<i>Millettia</i> sp.6 F*	x	Asia	
	Subgroup G	<i>Millettia erythrocalyx</i>	x	Asia	<i>M. rubiginosa</i> drops out of this subgroup; one of two Genbank sequences of <i>M. pachycarpa</i> (HG004928.1) drop in/100%
		<i>Millettia pachyloba</i>	<i>Otosema</i>	Asia	
		<i>Millettia</i> sp.4 F*	x	Asia	
		<i>Millettia rubiginosa</i>	<i>Millettia (Typicae)</i>	Asia	
	Subgroup H1	<i>Millettia angustidentata</i>	x	Africa	Species in Subgroup H1 recovered as a subgroup but now separated from the remainder of subgroup H species but also with <i>M. extensa</i> as sister/48%
	<i>Millettia bicolor</i>	<i>Afroscandentes</i>	Africa		
	<i>Millettia makondensis</i>	x	Africa		
	<i>Millettia simsii</i>	x	Africa		

Table 2.4 Continued.

Millettioid Group	subgroup name	Species	Dunn's (1912) section	Geographic distribution	Composition/support in total evidence phylogeny
	Subgroup H2	<i>Millettia brandisiana</i>	<i>Millettia (Typicae)</i>	Asia	Same/36%, but Subgroup F and G are nested here
		<i>Millettia caerulea</i>	<i>Otosema</i>	Asia	
		<i>Fordia (Millettia) cauliflora</i>	x		
		<i>Millettia diptera</i>	x	Asia	
		<i>Millettia extensa</i>	<i>Otosema</i>	Asia	
		<i>Millettia glaucescens</i>	<i>Fragiliflorae</i>	Asia	
		<i>Millettia kangensis</i>	x	Asia	
		<i>Millettia macrostachya</i> var. <i>macrostachya</i>	<i>Millettia (Typicae)</i>	Asia	
		<i>Millettia pegeuensis</i>	<i>Fragiliflorae</i>	Asia	
		<i>Millettia pinnata</i>	x	Asia	
		<i>Millettia pulchra</i>	x	Asia	
		<i>Millettia sericea</i>	<i>Macrospermae</i>	Asia	
Subgroup 2		<i>Fordia (Millettia) splendidissima</i>	x		
		<i>Millettia</i> sp.1 F	x	Asia	
		<i>Millettia</i> sp.2 F	x	Asia	
		<i>Millettia</i> sp.3 F	x	Asia	
		<i>Millettia macrostachya</i> var. <i>tecta</i>	x	Asia	
		<i>Millettia xylocarpa</i>	<i>Fragiliflorae</i>	Asia	
	Subgroup I	<i>Millettia stuhlmannii</i>	<i>Compresso-Gemmae</i>	Africa	Same/95%
		<i>Millettia thoningii</i>	<i>Sericantae</i>	Africa	
	Subgroup J	<i>Millettia conraui</i>	<i>Sericantae</i>	Africa	Same/97%
		<i>Millettia zechiana</i>	<i>Sericantae</i>	Africa	
	Subgroup K	<i>Millettia drastica</i>	<i>Sericantae</i>	Africa	Same/98%
		<i>Millettia dura</i> GB	<i>Sericantae</i>	Africa	
<i>Millettia eriocarpa</i>		<i>Sericantae</i>	Africa		

Table 2.4 Continued.

Millettiod Group	subgroup name	Species	Dunn's (1912) section	Geographic distribution	Composition/support in total evidence phylogeny
		<i>Millettia paucijuga</i>	x	Africa	
		<i>Millettia schliebenii</i>	x	Africa	
		<i>Millettia usaramensis</i> ssp. <i>usaramensis</i>	<i>Sericantae</i>	Africa	

Placement of *Millettia* species in Group 2 of the Core Millettieae is shown in Figures 2.4 & 2.5 and 2.14 & 2.15, and described in Table 2.4. Again, there is relatively weak support for the backbone of this phylogeny, but here more *Millettia* clades are well supported. Subgroup F (99% BS in *ITS* and total evidence trees) is an Asian clade representing two of the new species, one from Thailand and one from Vietnam, described in Chapter 5, plus the species *Millettia ichthyochtona* from Vietnam. This clade is entirely Asian, but it is morphologically heterogeneous. For example, the inflorescence of *M. ichthyochtona* has indistinct brachyblasts with long pedicelled flowers while other two new species have distinguishable brachyblasts with short-pedicelled flowers, and fruit morphology of *M. ichthyochtona* differs by being falcate and thinly woody.

Subgroup G also finds support in *ITS* tree (90% BS), and includes the species *Millettia erythrocalyx* from Indo-china, *Millettia pachyloba* from Asia, a new species from Thailand and the type specimen of the genus, *M. rubiginosa* from India. However, in the total evidence tree the composition of this clade differs; the type species of the genus is only placed in the clade in the *ITS* tree, and in the total evidence tree a specimen of *M. pachycarpa* is placed in this clade. This *M. pachycarpa* is likely a misidentified specimen (see Chapter 4). Morphologically, these species, in contrast to *M. erythrocalyx*, are similar in leaf, flower and pod morphology by being leatheraceous texture and lustrous beneath of leaflets, the back of the standard with dense silky hairs and pods covered with dense hairs respectively. The unstable placement of the type species might be due to the difficulty in

sequencing the old material of this species. Only a partial sequence was included in this study, and although it falls in Subgroup G of Group 2 in the *ITS* tree, in the total evidence phylogeny it is sister to genus *Hesperothamnus*, together forming a basal clade in Group 2. This relationships of *M. rubiginosa* with a Mexican endemic genus *Hesperothamnus*, seems very likely. Notably, Geesink (1984) placed *Hesperothamnus* in a synonymy of genus *Millettia* because of no single morphological character difference, not even from the typical Sect. *Millettia (Typicae)*. However, the type species is not related to the species placed by Dunn (1912) in the same section, sect. *Millettia*. For example, *M. macrostachya*, which is placed in Subgroup H. It is also notable that the two varieties of *M. macrostachya* sampled here are not closely related. Morphologically, the variety *tecta* of *Millettia macrostachya*, endemic to Thailand, differs from the typical variety by having distinct basal callosities, robust and short inflorescences, and longer and thicker pods.

Subgroup H finds no support, nor neither do the subgroups it comprises, H1 and H2. H1 is an African and Asian Group, but H2 is notably entirely Asian, even when Subgroup F and Subgroup G are nested in it (in total evidence tree). Subgroup I is a species pair with 95% or 95% BS support in the *ITS* and total evidence trees respectively, but unclear placement, comprising two African species, *Millettia stuhlmannii* and *Millettia thonningii*. Subgroups J and K are successive sisters to the *Muellera/Philenoptera* plus *Dahlstedtia* plus *Lonchocarpus* group in both the *ITS* and total evidence trees. Though the groups themselves are strongly supported, their placement is not. However, each of the groups are Subgroup J (98% and 97% BS in *ITS* and total evidence trees) includes two African species, *Millettia zechiana* and *M. conraui*. Subgroup K (99% and 98% BS in *ITS* and total evidence trees) contains six African species, *Millettia drastica*, *Millettia dura*, *Millettia eriocarpa*, *Millettia panijuga*, *Millettia schliebenii* and *Millettia usaramensis* ssp. *usaramensis*. Subgroup H contains many sections, none monophyletic nor with support, but notably Subgroups J and K are comprised entirely of species of Dunn's Sect. *Sericantae*. There is one other species of Sect. *Sericantae* in Subgroup A (Group 1), so even this section is polyphyletic.

2.5 Conclusions

2.5.1 Future perspectives for the tribe Millettieae

The present study contributes much clearer understanding of the genera placed in the Millettoid *s.str.* Group, and those outside it, than was previously available. Some genera with doubtful placement by Schrire (2005b) are now confirmed as belonging to either the IRLC or the Millettoid *s.str.* Group. The genera with uncertain placement that now more robustly inferred are: *Antheroporum* and *Disynstemon* in the Basal Millettoid and phaseoloid group (BMP), and *Deguelia*, *Fordia*, *Leptoderris*, *Platysepalum* and *Sylvichadsia* in the Core Millettieae. The relationships within the Millettoid IRLC are an ongoing work which this thesis will contribute to (Schrire, pers. comm.). Future work is needed to more thoroughly understand the relationships between the Millettieae and the Phaseoleae subtribes & the Abreae nested in the Millettoids.

2.5.2 Taxonomic implications for the future classification of *Millettia*

Our most important findings, in terms of genus *Millettia*, are that: The genus is polyphyletic, as many previous authors have proposed. All of Dunn's sections for which we sampled more than species were polyphyletic. The species of *Millettia* are, however, restricted to the Core Millettieae, where they are dispersed between the two main lineages of this informal taxonomic group. The placement of the type specimen, *M. rubiginosa*, is somewhat doubtful because it differs in analyses, probably because only a very short sequence could be generated. The placement of the other species placed by Dunn (1912) with *M. rubiginosa* is in different clades to the type specimen, and in different clades to each other, making the identification of the lineage likely to include the type very difficult. Many of the clades of *Millettia* recovered here are weakly supported and their relationships are unclear, so that collecting more data is clearly a priority. Several putative new species are included in the phylogeny. Their placement determines how they are to be treated in this study, or elsewhere:

Millettia sp.1: this species is sister to another putatively new species, *Millettia* sp.2. It lies in Subgroup H, a clade with low support overall, in the Asian Subgroup H2 subclade. A species placed by Dunn (1912) in the Sect. *Typicae* is found here, but the type species itself is

elsewhere. Since this species is not likely in the same group as the type species, it is unlikely, unless the concept of *Millettia* is much expanded, to be a species of *Millettia* in the long term. However, at present the clade it falls into is too poorly identified, supported and described to be a segregate genus. Although this species is not described here because I don't have enough material yet, unless there is significant improvement of the phylogeny this species will be described as a *Millettia*.

Millettia sp.2: as *Millettia* sp.1, this species is not yet described, but will be described as a *Millettia* in the immediate future, noting that its name might be provisional if the generic concept of *Millettia* is narrowed.

Millettia sp.3: this species is also a Subgroup H species, therefore the arguments for naming it a *Millettia* are as for *Millettia* sp.1 and *Millettia* sp.2. However, in this case there was sufficient material to describe this new species. The taxonomic account is presented in Chapter 5.

Millettia sp.4: this new species falls into Subgroup G, a well-supported clade. The support for this group raises the possibility of recognizing it as a segregate genus, making new combinations and describing this new species with the new generic name. However, I decided against this because in the *ITS* tree this subgroup includes the type species, so by priority, it would keep the name *Millettia*. For this reason, this specimen is one of the cited specimens for a new species of *Millettia* described in Chapter 5.

Millettia sp.5: this specimen also falls into Subgroup H (F) and as for as for *Millettia* sp.1 and sp.2, this species will be described, perhaps provisionally, as a *Millettia*. I expect to describe the species in the next year, after I have returned to the collecting site to collect a flowering specimen to complement the fruiting specimen I already have.

Millettia sp.6: this specimen is described as a new species of *Millettia* (Chapter 5), for the same reasons as outlined for *Millettia* sp. 3.

In addition to the six species named in the phylogeny as *Millettia* sp., I included two species provisionally as *Derris* sp. The phylogeny confirms that these two species belong to *Derris*, and *Derris* sp.2 is described here (Chapter 4). *Derris* sp. 1. may be described, subject to the examination of further material.

2.5.3 Integrating the new phylogenetic hypothesis presented here with other data sets

In this thesis, it is possible to draw more robust inferences by combining the phylogeny presented here with other data sets. Chapter 3 reviews the literature on the distribution of canavanine, and relates that to the two lineages recovered in this study and referred to as clade 1 and clade 2 of the Core Millettieae. Chapter 4 investigates the *Derris* clade recovered here, and reviews previously studied and new morphological characters in the light of the new scheme of relationships. Also, taxonomic decisions and acts are made in the light phylogeny in this Chapter. Specifically, one new species of *Derris* is described in this chapter, and a new combination is made. Finally, Chapter 5 describes other new species that belong in the core Millettieae, but which as outlined in section 2.5.2 of this thesis, cannot be assigned to any genus with any certainty, and are therefore described as new species of *Millettia*.

Chapter 3 Informal groups in the “Core Millettieae”: a review of the occurrence of the non-protein amino acid canavanine in the light of a new phylogenetic hypothesis

3.1 Introduction

Increasingly, formal classifications are revised in order to reflect phylogeny, but often emerging phylogenetic hypotheses are unstable. Informal names are used to avoid the nomenclatural proliferation associated with the publication of formal names for groups which prove transient. The Leguminosae is one plant family where informal names are very commonly used to communicate clades that appear biologically meaningful, but which are poorly-supported or poorly-characterised phylogenetically. Cronk *et al.* (2006) used the Millettoids to exemplify the proliferation of such names in the Leguminosae; they noted *Deguelia* is placed by Lewis *et al.*, (2005) in a series of nested clades, the “Non-canavanine Group”, the “Core Millettieae”, the “MILLETTIOID *s.str.*” clade, the “MILLETTIOID *s.l.*” clade and the “50kb Inversion clade”. Named clades of this kind have been of great use in describing the emerging phylogenetic hypothesis on which a new sub-familial classification for the Leguminosae is based (LPWG, 2017). The informal nomenclatural hierarchy permits communication about generic relationships without requiring formal recircumscription of the clade every time a genus is added or removed (Cronk *et al.*, 2006).

Here I consider the “Canavanine and Non-canavanine Groups”. Canavanine is a Non-Proteinogenic Amino Acid (NPAAs) are simple amino acids not normally incorporated into proteins, serving as defense compounds and as nitrogen storage reservoirs (Wink, 2003). Canavanine is a structural mimic of arginine; its incorporation into protein leads to altered structure and disrupted function (Rossenthal, 1991). Hu *et al.* (2000) presented explicitly phylogenetic examinations of the distribution of canavanine. They sampled 14 species of the Millettoid *s.str.* group, encompassing a diversity of related taxa such that it was possible to identify a putative first appearance of NPAAs in the family. Wink (2013) used published data on the distribution of NPAAs and a much more densely sampled tree to reconsider the evolution of these metabolites. He was able to show that the Canavanine Accumulating Clade (or the NPAA Accumulating Clade) was more inclusive than the clade uniting the Millettoid *s.l.* and the Hologalegina sister groups, as proposed by Hu *et al.*,

(2000). The Canavanine Accumulating Clade *sensu* Wink (2013) also includes the Hypocalypteeae, Mirbelieae and Bossiaeeae. This group represents the largest radiation of papilionoid legumes (Wojciechowski *et al.*, 2004). Figure 3.2 shows Wink's (2013) hypothesis of the origin of canavanine.

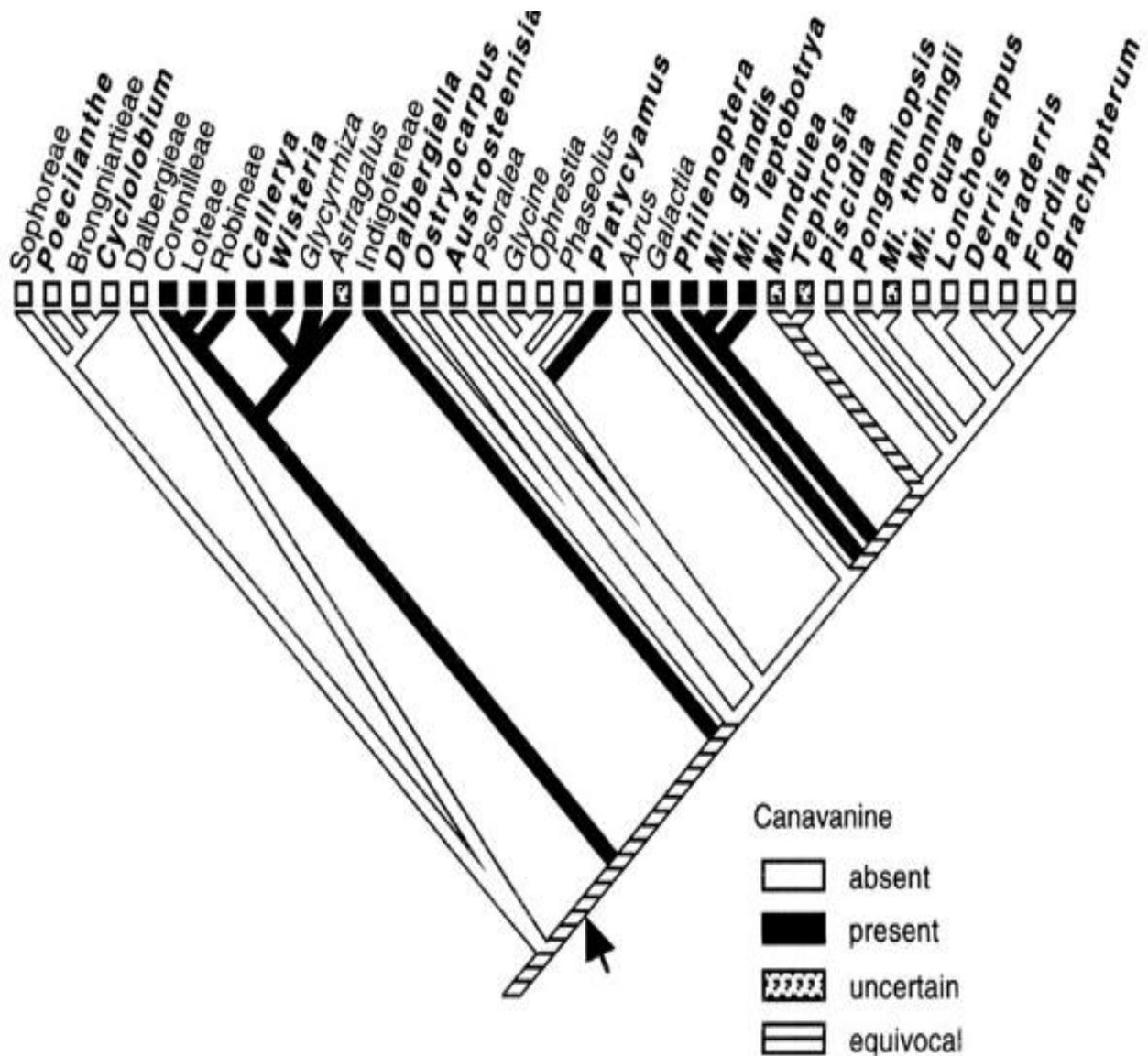


Figure 3.1 The first possible appearance of nonprotein amino acids in Papilionoideae. The appearance on canavanine is marked by an arrow. Figure taken from Hu *et al.* (2000).

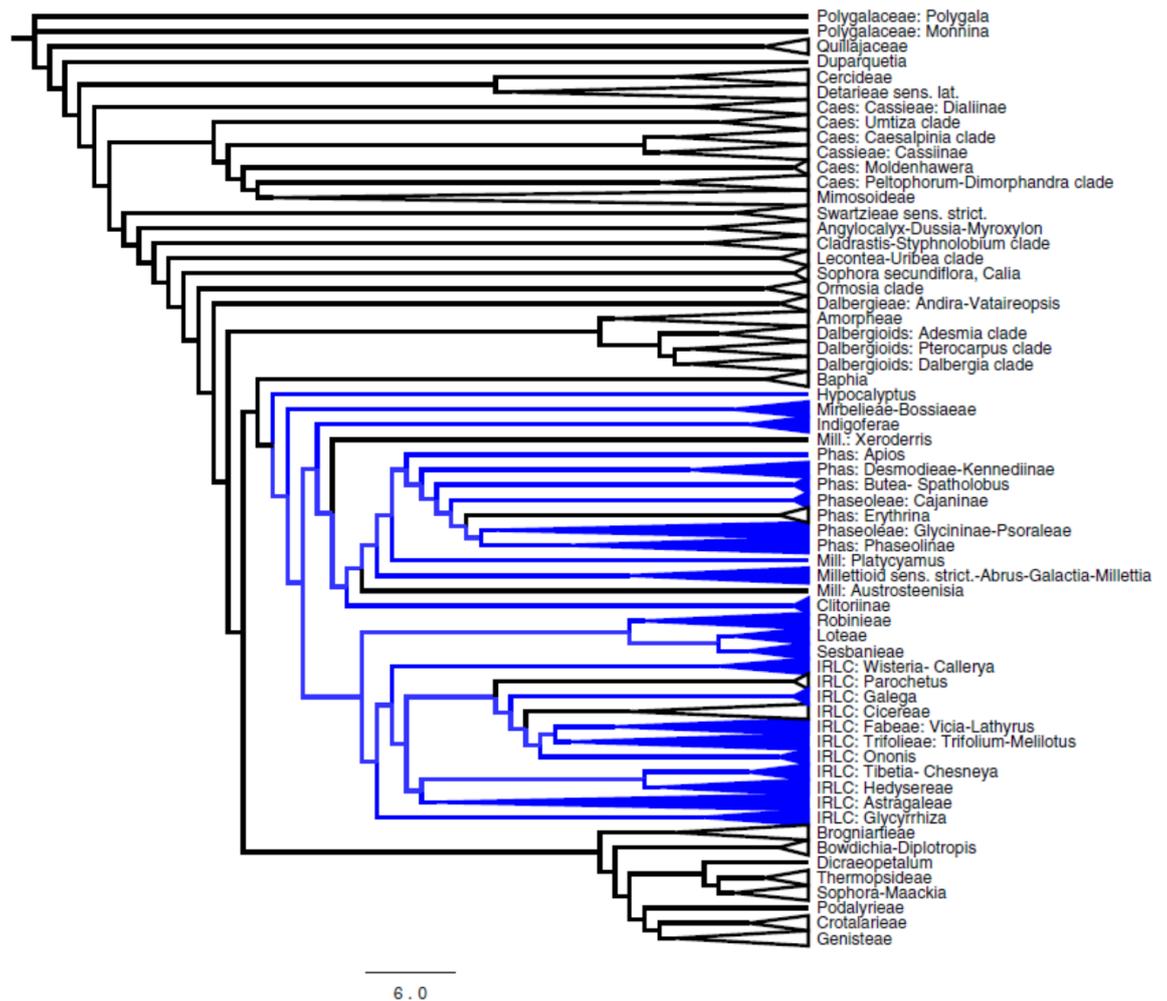


Figure 3.2. The phylogenetic distribution of canavanine accumulation. Blue colour indicates lineage made up of species that accumulate canavanine. Figure taken from Wink (2013).

The treatment of the Millettieae for Legumes of the World (Schrire, in Lewis *et al.*, 2005) first referred to the Canavanine Group and the Non-canavanine Group. Schrire (2005b) cited Evans *et al.* (1985) for the distribution of NPAAAs; this survey screened 310 species for the genera *Millettia*, *Tephrosia*, *Derris* and *Lonchocarpus* plus 25 minor, satellite genera. Several studies were reviewed to create a phylogenetic hypothesis: Lavin *et al.*, (1998), Hu *et al.* (2000), Hu *et al.* (2002) and Hu and Chang (2003). Sequence data from the *rbcL* gene (Hu & Chang, 2003), phytochrome nucleotide genes (Lavin *et al.*, 1998), the plastid *trnK-matK* region (Hu *et al.*, 2000) and the nuclear *ITS* region (Hu, 2000; Hu *et al.*, 2002) contributed to this hypothesis. The Canavanine Group comprised three genera, *Fordia p.p.*, *Millettia p.p.* and *Philenoptera*, and the Non-canavanine Group comprised 21 genera (Figure 3.3).

The purpose of this Chapter is to review the literature describing the distribution of Canavanine and explore the distribution of this non-protein amino acid in the light of the

new phylogenetic hypothesis presented in Chapter 2. Specifically, the distribution of Canavanine in the Core Millettieae, thus the hypothesis that a Canavanine-containing group can be more rigorously tested exploiting the new phylogeny and the considerable literature describing the presence or absence of canavanine.

3.2 Materials and Methods

3.2.1 Phylogenetic tree

A molecular phylogenetic tree representing 367 species (435 sequences) belonging to Millettoid group, including outgroups was used in this study. It was reconstructed using Maximum Likelihood criteria from the combined dataset of chloroplast DNA (*matK* and *trnL-F*) and nuclear DNA (*ITS*) markers as described in chapter 2. This tree has two clades, referred to as clade 1 and clade 2 which correspond to the Canavanine Group and Non-canavanine Group *sensu* Schrire (2005)

3.2.2 Survey of literature

Two matrices were compiled based on literature which identified five sources of presence/absence data for canavanine. The first summarised all the data in the literature, and the second only included taxa sampled in the phylogeny. Species names were recorded as in the source publication but also as accepted names according to the Plant List and most recent publications whether the specimen was vouchered was also recorded.

3.2.3 Ancestral state reconstruction

The 50% Majority rule consensus tree from Maximum Likelihood analysis was launched and analysed in Mesquite version 3.10 (Maddison & Maddison, 2015). The character the presence or absence of protein canavanine amino acid coded as absent (0), present (1) and species appearing twice in the literature, having and lacking canavanine were scored as polymorphic. The "Trace Character Over Trees" option was employed to reconstruct the ancestral state. Under Likelihood Ancestral State criteria, the tree was visualized as Balls and Sticks tree drawing, this mode is operated in the "Tree form" menu.

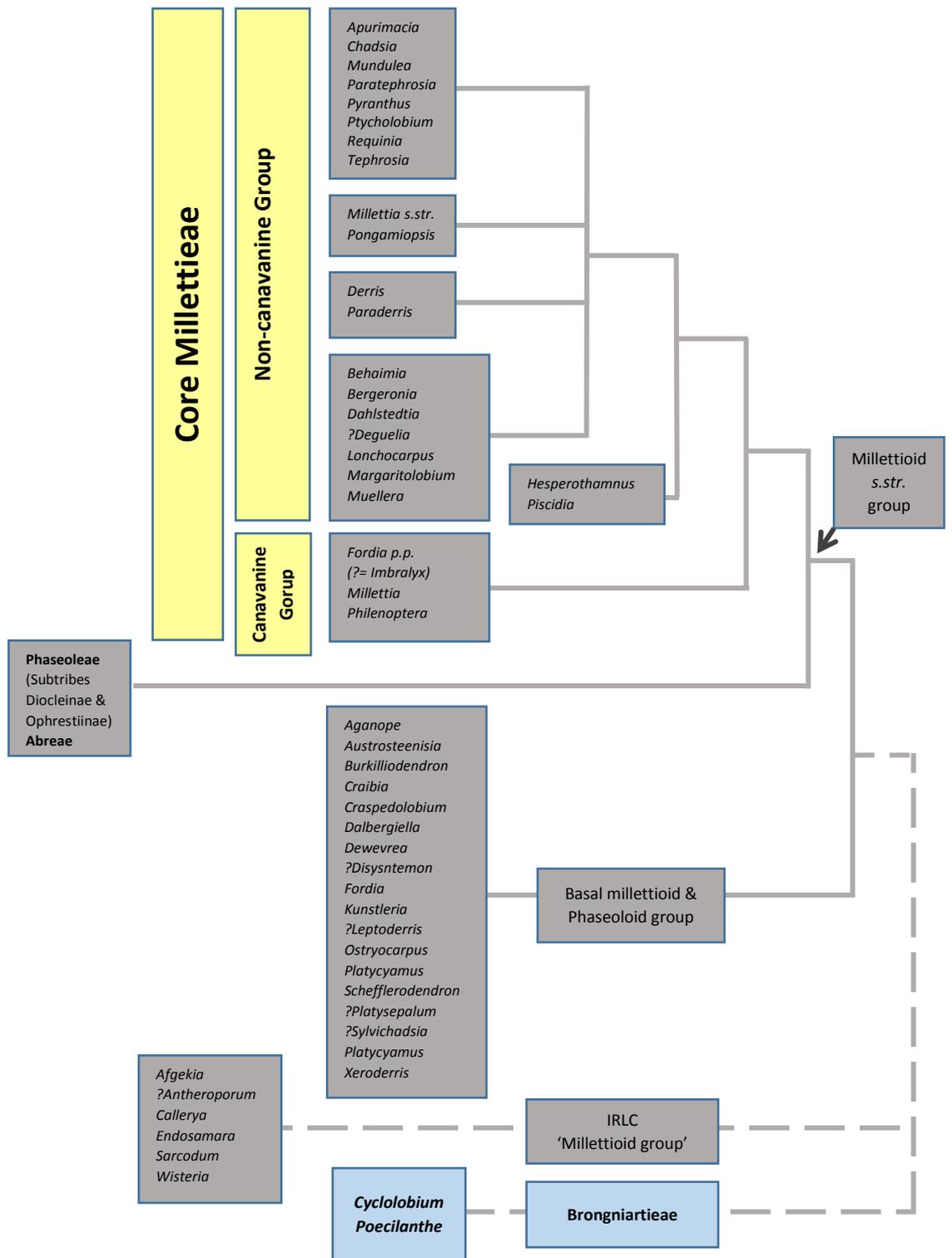


Figure 3.3. Diagram of relationships between informal groups within the traditional circumscription of tribe Millettieae after Evan *et al.* (1985); Lavin *et al.* (1998); Hu *et al.* (2000); Kajita *et al.* (2001); Hu *et al.* (2002); Hu & Chang (2003), (applied from Schrire, 2005b).

3.3 Results

The literature survey was made from the sources listed in Table 3.1. The results of the literature survey are presented in full in Electronic Appendix 3.1, and in Appendix 3.1 which lists all the species sampled in the phylogeny and indicates whether, under any synonym, they have been screened for canavanine. The Phytochemical Dictionary (Bisby and Harbourne, 1994) is a secondary source, and cites the original publication from which the entries were compiled. These original publications are indicated in Electronic Appendix 3.1. The names used in the source publications are recorded in the Electronic Appendix 3.1, as are the currently accepted names following The Plant List (The Plant List, 2016) with some modifications to reflect recent studies not yet incorporated. All accepted names used match those which are used in Chapter 2. Appendix 3.2 lists all the genera surveyed by Bell *et al.* (1978) including those genera lying outside of the group sampled by the phylogeny presented in Chapter 2.

Table 3.1 The sources of the data describing presence or absence of canavanine. Sources marked * cite voucher specimens.

Publication
Bisby & Harbourne (1994) Buckingham, J & Harborne, J. B. (Jeffrey B.) & Bisby, F. A & Southon, I. W. (Ian W.) & Zarucchi, James Lee <i>et al.</i> (1994). <i>Phytochemical dictionary of the Leguminosae</i> (1 st ed). Chapman & Hall, London ; New York
Bell <i>et al.</i> (1978). Systematic significance of canavanine in the Papilionoideae. <i>Biochemical Systematics and Ecology</i> 6: 201-212.
*Evans, S.V., Fellows, L.E. and E.A. Bell. 1985. Distribution and systematic significance of basic non-protein amino acids and amines in the Tephrosieae. <i>Biochemical Systematics and Ecology</i> 13: 271–302.
Fellows, L.E., Polhill, R.M. and E.A. Bell. 1978. 3-[2-Amino-2-imidazolin-4-yl] alanine, 2-[2-amino-2-imidazolin-4-yl] acetic acid, 2-aminoimidazole and other guanidine derivatives in the Tephrosieae. <i>Biochemical Systematics and Ecology</i> 6 (93): 213-215.
Tschiersch, B. (1959). Uber Canavanin. <i>Flora</i> 147: 405-416.

In total, 136 species (137 taxa) (37%) of the 367 species included in the phylogeny had been screened for canavanine. Of these, 128 (94%) had identifications supported by cited voucher specimens. In addition to the 367 species included in the phylogeny, data on the presence or absence of canavanine was available for 167 additional species (172 taxa) which represent taxa in our study, but not in the phylogeny. Of these 167 species, 24 species (25 taxa) represented genus *Millettia*.

Considering the species in the phylogeny for which biochemical data are available, we assigned each species to clade 1, putatively the Canavanine Group of the Core Millettieae or to clade 2, putatively the Non-canavanine Group of the Core Millettieae. Clade 1 (the Canavanine Group) includes 30 species in our phylogeny, of which 16 have been screened. Sequences from Genbank putatively from *Millettia pachycarpa* were recovered in Clades 1 and 2; in Chapters 2 and 4 it is demonstrated that this species should be placed in Clade 2 and the species is considered here only as a non-canavanine species in Clade 2 (the Non-canavanine Group). Three lack canavanine (*Leptoderris fasciculata*, *Millettia mossambicensis* and *Millettia grandis*); 12 have canavanine (*Fordia albiflora* (Prain) U.A. Dasuki & A.M. Schot, *Millettia griffoniana* Baill., *Millettia lasiantha* Dunn, *Millettia laurentii* De Wild., *Millettia leucantha* Kurz var. *latifolia* (Dunn) Lôt, *Millettia rodantha* Baill., *Philenoptera cyanescens* (Schumach. & Thonn.) Roberty, *Philenoptera ericalyx* (Harms) Schrire, *Platysepalum chevalieri* Harms, *Platysepalum violaceum* Welw. ex Baker var. *vanhouttei* (De Wild.) Hauman, *Platysepalum hirsutum* (Dunn) Hepper and *Philenoptera bussei* (Harms) Schrire. One reported the presence and the absence canavanine (*Millettia pachycarpa* Kurz).

Clade 2 (the Non-canavanine Group) includes 309 terminals in our phylogeny. Of these there are two have canavanine (*Millettia stuhlmannii* and *Deguelia scandens*). Of the remaining 307, we have data indicating the absence of canavanine for four of them. Table 3.2 summarises these results.

The reconstructions of ancestral states in Mesquite were unsatisfactory with a failure to recover states for nodes beyond sister pairs or triplets at the tips of the tree, likely because of the high proportion, more than 50%, of missing data for the presence or absence of canavanine. Nevertheless, the Balls and Stricks ML ancestral reconstructions shown on the tree in Electronic Appendix 3.1.

3.4 Discussion

3.4.1 The canavanine and non-canavanine clades

I recovered two clades in my phylogenetic study (Chapter 2), clade 1 and clade 2, that corresponded with Schrire's (2005b) concept of the Canavanine and Non-canavanine Groups. The phylogeny I reconstructed has much denser sampling of the Core Millettieae and therefore of these two clades than any previous study. Therefore a literature survey of the distribution of canavanine made it possible to consider whether these two clades really are characterised by the presence or absence of this NPAA. The study found that almost 50% of the species sampled in the phylogeny had been screened for canavanine. The pattern of the distribution of canavanine matched the phylogeny well, but not perfectly. The survey found three species without canavanine in the Canavanine Group, and two species with canavanine in the Non-canavanine Group.

Table 3.2 The species accumulating canavanine but in the Non-canavanine Group, and the species lacking canavanine but placed in the Canavanine Group in the phylogeny. Polymorphic species appear twice in the literature with conflicting results.

Status	Clade 1 (the Canavanine Group)	Clade 2 (the Non-canavanine Group)
+ve or equivocal for canavanine	12	<i>Millettia stuhlmannii</i> Taub. <i>Deguelia scandens</i> Aubl.
Polymorphic	<i>Millettia grandis</i> Skeels <i>Millettia pachycarpa</i> Benth.	<i>Millettia pachycarpa</i> Benth. <i>Millettia thonningii</i> Baker <i>Millettia xylocarpa</i> Miq. [syn. <i>Millettia decipens</i> Prain; <i>Millettia hemsleyana</i> Prain; <i>Millettia pubinervis</i> Kurz] <i>Tephrosia villosa</i> (L.) Pers. [syn. <i>Tephrosia incana</i> (Roxb.) Sweet]
-ve or equivocal for canavanine	<i>Leptoderris fasciculata</i> (Benth.) Dunn <i>Millettia mossambicensis</i> J.B. Gillett <i>Millettia grandis</i> Skeels	85

This raises a number of questions. Are the canavanine data sufficiently robust? In other words could the imperfect match be attributed to error rather than to evolutionary reversals (homoplasy)? Secondly, should these clades continue to be referred to as the Canavanine and Non-canavanine Groups?

- How confident is in the placement of species with lacking canavanine in the Canavanine Group (Clade 1)? How confident are we that they do not accumulate canavanine?

Leptoderris fasciculata, is one of three species of genus *Leptoderris* in the Canavanine Group included in the phylogeny, and the only one in the phylogeny screened for canavanine. According to Evans *et al.* (1985) all seven species of the genus that they examined lack the non-protein amino acid canavanine. It is likely therefore that this genus which is clearly placed in the Canavanine Group *sensu* Schrire (2005b) does not accumulate this chemical. The two other species in clade 1 lack canavanine, *Millettia mossambicensis*, of African *Millettia* (Sect. *Compresso-Gemmatae*) and *Millettia grandis* of the same section. Although Sect. *Compresso-Gemmatae* is morphologically and chemically variable (Evan *et al.*, 1985), the phylogenetic study showed that *Millettia mossambicensis* forms a clade with two other members of the section in the treatment of Dunn (1912), namely *M. grandis* and *M. laurentii* (Mattapha *et al.*, in prep., also Chapter 2). Therefore it is strongly believed that the specimen cited in the molecular study is correctly identified. Because the sister pair, *M. grandis* and *M. mossambicensis* have both been shown to lack canavanine also supports the view that the reported lack canavanine is correct. However, on the other hand, it is notable that the specimen Evans *et al.* (1985) screened was a sterile one. Nevertheless, overall it appears that there has been at least two losses of canavanine accumulation in the Canavanine Group.

- How confident could we be in the placement of species with canavanine in the Non-canavanine Group (Clade 2)? How confident are we that they accumulate canavanine?

Millettia stuhlmannii is one of the two species with canavanine in this clade. All the other species of *Millettia s.l.* in Clade 2 lack canavanine accumulation. Both Fellows *et al.* (1978) and Evans *et al.*, (1985) reported the same finding of presence of canavanine in *M. stuhlmannii*. Therefore, it is likely that the report of canavanine accumulation in seeds of *Millettia stuhlmannii* is correct. However, analyses of canavanine for the sister taxon of

Millettia stuhlmanii, *M. thonningii*, are inconclusive. Canavanine was reported as present in this species by Bell *et al.* (1978) but absent by Evans *et al.* (1985). Since only Evans *et al.*'s (1985) study cited a voucher, this might be considered the more reliable report. Alternatively, the conflicting reports might point to real polymorphism.

The other species with canavanine in the Non-canavanine Group is *Deguelia scandens*. Canavanine was detected in *Deguelia scandens* at very high levels (ranging from 0.5 - 2% and >2.0%) by Evans *et al.* (1985) who sampled from three different plants to represent *Derris guianensis* Benth., *Derris longifolia* Benth. and *Derris negrensis* Benth. All are now considered synonyms of *Deguelia scandens*. The placement of *Deguelia* in the Non-canavanine Group (Clade 2) seems robust since 17 species of *Deguleia* are placed here, in two clades. It seems highly probable that this placement of species accumulating canavanine is correct.

- Species not sampled in the phylogeny but of note – canavanine accumulation in species of *Lonchocarpus*, *Mundulea* and *Tephrosia*

Lonchocarpus is unequivocally placed in Clade 2, the Non-canavanine Group. However, canavanine does accumulate in *Lonchocarpus bussei* Harms, *Lonchocarpus capassa* Rolfe, *Lonchocarpus laxiflorus* Guill. & Perr. and *Lonchocarpus nelsii* (Schinz) Heering & Grimme. Interestingly, according to Evans *et al.*'s chemical survey (1985) those *Lonchocarpus* show the presence of canavanine and arginine but absence of other NPAAAs. This has similarity to some genera in clade 1, namely *Fordia s.l.*, *Millettia s.l.*, *Platysepalum* and *Wisteria*. Birdsong *et al.* (1960) also reported canavanine in *Lonchocarpus* sp. Turner and Harborne (1967) reported canavanine in *Mundulea* sp., though the four species of this genus sampled in the phylogeny (Chapter 2) are also placed in clade 2. In *Mundulea sericea*, canavanine was absent according to Bell *et al.*, (1978) and Evans *et al.*, (1985), but present according to Rao (1983). Similarly, *Tephrosia* is certainly in Clade 2 but Gomez-Garibay *et al.* (1985) cited in Bisby and Harborne (1994) found canavanine in *Tephrosia watsoniana* (Standl.) J.F. Macbr. Canavanine is also reported in *Tephrosia grandiflora* and *Tephrosia incana* (Bell *et al.*, 1978), but Evans *et al.* (1985) showed the lack of canavanine for these two species.

A clear picture is emerging – as more data accumulates it appears that there is rather a lot of homoplasy in regard to the accumulation of canavanine in the two clades informally known as the Canavanine Group and the Non-canavanine Group. Hu *et al.* (2000) noted that some

dispute regarding the presence/absence of canavanine can be found in the literature, and this might be attributed to misidentification of taxa sampled for the compound. My review of the apparently anomalous taxa suggests that there is good evidence that there is evolutionary gain and loss of canavanine accumulation in the Core Millettieae. For example, I can make a strong case for loss of canavanine accumulation in *Leptoderris*. Hu *et al.* (2000), citing Rao (1983) also noted that apparent discrepancies in the literature as to whether species accumulated canavanine could be because there is variation within populations. This does seem to be the case for at least some of the apparently anomalous species, which are particularly problematic. For example *Mundulea* and *Tephrosia* species, which may or may not accumulate canavanine according to different sources, are found in a clade where canavanine accumulation is not expected. Hu *et al.* (2000) proposed that these equivocal species might be in a transitional state of using either canavanine or other non-protein amino acids for chemical defences or storage.

3.4.2 The naming of the informal clades in the Core Millettieae

Within the core-Millettieae comprising *ca.* 22 genera, Schrire (2005b) named two informal groups, the Canavanine Group with 3 genera and the Non-canavanine Group with *ca.* 21 genera in 5 subgroups. The informal clade names “Canavanine Group” and “Non-canavanine Group” have been useful. These sister taxa, aside from some genera, are the only taxonomically useful monophyletic groups to emerge from my phylogenetic studies of the Core Millettieae (Chapter 2). Here I consider whether it is useful to continue to refer to these clades as the Canavanine Group and the Non-canavanine Group, or whether there are viable alternative names.

Clade 1, the Canavanine Group

There are some differences between the Canavanine Group as conceptualized by Schrire (2005b) and Clade 1 recovered here, since the genera *Leptoderris* and *Platysepalum* from the Basal millettoid & phaseoloid group proposed by Schrire (2005b) are placed in this clade with robust support even though other deep branches in my phylogeny are less well supported (Chapter 2). The placement of these two African genera was previously uncertain (Schrire, 2005b).

There are arguments for and against calling this clade the Canavanine Group. My review shows there are species and indeed probably whole genera in this clade that do not accumulate canavanine, rendering clade 1 inconsistent for the presence of canavanine. In fact if no *Leptoderris* accumulate canavanine then probably half of the species lack canavanine. It could be argued that referring to this clade as the Canavanine Group is not very useful for another reason, because there are so many other species outwith the Core Millettieae that accumulate canavanine, so that the Canavanine Group might be confused with the “Canavanine Accumulating Clade” *sensu* Wink (2013). The arguments for continuing to refer to this clade as the Canavanine Group are 1. there may be no other characteristic uniform across the clade that might provide a better name, 2. in any case, there is not necessarily an expectation that all the species in the Canavanine Group would accumulate canavanine since there is an appreciation that these characters are to some extent homoplastic and 3. eight species of *Millettia* not sampled in phylogeny are reported to present canavanine, namely *M. chrysophylla* Dunn, *M. dinklagei* Harms, *M. hylobia* Hauman, *M. irvinei* Hutch. & Dalziel, *M. japonica* (Siebold & Zucc.) A. Gray [basion. *Wisteria japonica* Siebold & Zucc.], *M. lucens* (Scott-Elliot) Dunn, *M. puguensis* J.B. Gillett, and *M. urophylloides* De Wild. These species may fall into clade 1 thereby providing more justification for continuing to refer to the Canavanine Group. Nevertheless, here I consider some alternatives:

- **The Imbralyx Group.** Geesink (1984) created this genus to include the same taxa as Dunn’s Sect. *Albiflorae*, which includes four species, *Millettia albiflora* Prain, *M. letobotrya* Dunn, *M. nivea* Dunn and *M. unifolilata* Prain (Dunn, 1912). He considered the species in this group to share imbricate calyx lobes in bud. Since *Imbralyx sensu* Geesink is placed in clade 1, I examined the buds of other species placed here. This character is not uniform across the clade. Therefore there is little justification for this name.
- **The Albiflora Group.** Dunn (1912) referred to Sect. *Albiflorae*. All of the species placed in this section were transferred to *Fordia* by Dasuki & Schot (1991). Two of these species of *Fordia* were placed in clade 1 in the new phylogeny, as was *Millettia leucantha* which has white flowers similar to those of the *Fordia* species in this clade. However, this clade of white-flowered species comprises only a small part of the clade overall, and the proportion of species without white flowers is greater than the

proportion of species not accumulating canavanine. Therefore there is little justification to prefer this name.

- **The Intermediate-Canavanine Group.** This new name reflects that this clade is a transitional group between the Millettoid *s.str.* group and the Basal millettoid & phaseoloid group. It may be considered transitional in terms of the presence of Canavanine, with loss of canavanine partial in this group and more complete in the Non-canavanine Group.
- **No name.** Schrire (2005b) may have coined the name Canavanine Group to provide symmetry with respect to the Group's sister clade that he designated the Non-canavanine Group. The application of most informal names to clades has not generated names for other sister clades, for example, legume systematists do not refer to the non-Core Millettieae, nor the non-50kb Inversion clade for the respective sisters of these informal groups. Thus there might be a precedent for not naming this clade if the existing name was considered confusing.

Ultimately, the decision may emerge from the community, with interested parties contributing views, as has been the case for the subfamilial classification of the families (LPWG, 2017).

Clade 2, the Non-canavanine Group

It is apparent that very few species in this clade accumulate canavanine. I suppose only nine exceptions. Two are new placements of Non-canavanineproducers in this clade: *Millettia stuhlmannii* and one species of *Deguelia*, *Deguleia scandens*. Neither *Millettia stuhlmannii* nor genus *Deguleia* were placed in any phylogeny with certainty at the time Schrire (2005b) delimited the Non-canavanine Group. The other anomalous canavanine accumulators, five *Lonchocarpus*, one *Mundulea* and one *Tephrosia* were already placed in this clade at the time it was designated the Non-canavanine Group. Unlike Clade 1, my new phylogenetic hypothesis doesn't result in a significant change to the proportion of species in this group with anomalous canavanine status. Also, unlike Clade 1, the proportion of species in the clade that have canavanine status that doesn't match the informal group name is very small. There is no justification for renaming this informal group.

Chapter 4 Molecular phylogenetic and morphological evidence for new species in *Derris* (Leguminosae; Millettieae) with consideration of implications for the *Derris* concept

4.1 Introduction

The genus *Derris* is one of the many enigmatic genera in the tribe Millettieae *sensu* Geesink (1984), in that it has a history of problematic circumscription (Bentham, 1860; Geesink, 1984; Adema 2003a & 2003b). The genus and closely related genera have recently been investigated by Sirichamorn *et al.* (2012, 2014). They used nuclear and chloroplast markers to inform generic classification within the tribe. Twenty four species were recognised in *Derris*, following reinstatement of the segregate genus *Solori*, and placement of the genus *Paraderris* in synonymy under *Derris* (Sirichamorn *et al.*, 2012, 2014). The *Paraderris* subclade of the *Derris s.str.* clade was monophyletic, and sister to the remainder of *Derris*. Combined analyses of morphological and molecular data revealed the characters supporting the clades. Winged pod morphology and the liana habit emerged as synapomorphies for *Derris s.str.* (including *Paraderris*). A key to genera was provided, to distinguish between genera *Solori*, *Aganope* and *Derris*. However, the authors of *Derris s.str.* (Sirichamorn *et al.*, 2014) recognised that many characters have evolved several times independently in the tribe Millettieae; indeed there have been multiple reversals to winged fruits (with a single wing along the upper suture) within *Derris s.str.* At higher taxonomic levels, Hu *et al.* (2000) showed that winged fruits have little taxonomic value in the classification of Millettieae. The liana habit, whilst common to all *Derris s.str.* species is commonly found in other genera of tribe Millettieae.

Although the genus *Derris* and its allied genera were comprehensively sampled by Sirichamorn *et al.* (2012, 2014), few species of *Millettia s.l.* were sampled in their phylogenies. As part of a wider survey of genus *Millettia* (Mattapha *et al.*, in prep.) we reconstructed a phylogeny sampling all the published sequences of Sirichamorn *et al.* (2012, 2014), but also including a comprehensive sampling of genus *Millettia* Wight & Arn., a genus shown to be polyphyletic in many previous studies (Käss & Wink, 1995, 1996; Doyle *et al.*, 1997, 2000; Kajita *et al.*, 2001; Hu & Chang, 2003). Our sequence data was newly generated from taxa selected to represent the biogeographic and morphological diversity in this complex genus. Here we present a subset of the data generated from that wider analysis (Mattapha *et al.*, in prep.) sufficient to incontrovertibly place a species of *Millettia* in *Derris*

s.str. The main objective of the present study is to make the case for the transfer of *Millettia pachycarpa* Benth. to *Derris s.str.*, based on molecular phylogenetic data. A new combination incorporating the original species epithet is precluded on nomenclatural grounds because the name *Derris pachycarpa* Merr. (1922) already exists, even though that now is recognized as a synonym of *Derris montana* Benth. (1852). We also describe a new species, of *Derris*, based on a surprising placement in our phylogeny since its mature fruit wing morphology is so different to the winged fruits of all other species consider to belong to the genus. Inclusion of these two species in *Derris* requires a recircumscription of the genus, especially with regard to fruit morphology. Our secondary goal is therefore to review the previously understood morphological concept of *Derris*, informed by the new molecular phylogenetic data.

4.2 Material and Methods

Sampling for this study was based on a RAxML analysis of all new and published data for the core Millettieae and its relatives (218 *trnL-F* sequences, 292 *matK* sequences and 357 *ITS* sequences; Mattapha *et al.*, in prep.). The wider study showed that *Derris s.str.* is not monophyletic unless the species *Millettia pachycarpa* is included within it. Following this test of the monophyly of *Derris*, we reanalysed a subset of the data presented here, to include Sirichamorn *et al.*'s (2012) sampling of *Derris*, *Solori* and *Fordia* (but not *Millettia pinnata*, the sister to *Fordia* in Sirichamorn *et al.*'s analysis). We included *Millettia glaucescens* Kurz as an outgroup. Our higher-level analysis resolved this winged species of *Millettia* in the same clade as *Fordia* and *Millettia pinnata*. Genbank sequences of *Millettia pachycarpa* were excluded from the analysis because the higher-level study cast doubt on their identification. The *ITS* and *matK* sequences for two plants had been published by Huang *et al.*, (2015) as KR532403.1 and KR531231.1 (J695) and KR532404.1 and KR531232.1 (J698) respectively; *ITS* and *matK* sequences for the third were uploaded by Roeder *et al.* (2015) as HG004810 and HG004928. The sequences from Huang *et al.* (2015), in our higher-level analysis grouped with other *Millettia* sequences, phylogenetically distant from the *Derris* clade. Huang *et al.*, (2015) report using a two-step process of reciprocal illumination to identify sterile woody plants in their barcoding study of trees of Xishuangbanna Nature Reserve, Southwest China. Incorrect identifications might result where the reference DNA database used to prompt examinations of herbarium material was poorly sampled, and also because sterile specimens can appear very similar, especially in Millettoid legumes. Roeder *et al.*'s (2015) *matK*

sequence grouped with two sequences of *Millettia pachyloba* in our densely sampled analysis (Mattapha *et al.*, in prep.). *Millettia pachyloba* Drake and *M. pachycarpa* have similar leaflet and fruit characters, and it seems likely that the name *M. pachycarpa* for Roeder's sequence has been used in error for a specimen of *M. pachyloba*.

We sampled and sequenced one plant to represent *Millettia pachycarpa* and one plant to represent the putative new species. Leaf material of *Millettia pachycarpa* was collected in silica gel in the field in Chiang Mai province, Thailand into silica gel, and voucher specimens of the same plant, with both fruits and flowers, were collected. Similarly, leaf and voucher material was collected from the putative new species in Nan province, Thailand. DNA sequence data was generated for the two specimens. DNA was extracted using the DNeasy Plant kit (Qiagen, Hilden, Germany) following the manufacturer's instructions. Amplification of the *ITS* gene (regions 1 and 2 and the 5.8S gene) was performed using published primer sequences and conditions (Wojciechowski *et al.*, 1993 & 1999). For *matK* and for *trnL-F* amplification, primers and conditions followed da Silva *et al.*, (2012). Sequencing of forward and reverse strands of all amplicons was performed by Source Bioscience (Oxford). The programme DNA Baser v4 (DNA Sequence Assembler v4, 2013) was used to assemble complementary strands and verify base calling. Voucher information and Genbank accession numbers are provided in Appendix 4.1. Alignment was carried out using the published sequences using the programme Bioedit ver. 7.2.5.0 (Hall, 1999). Prior to Bayesian analysis, MrModeltest v.2.2 (Nylander, 2004) was used to find the best fit substitution model; the best-fit models of molecular evolution selected using the Akaike information criterion (AIC) were as follows: GTR+I+G for *ITS* and *matK* and GTR for *trnL-F*. A partitioned Bayesian analysis was performed with the program MrBayes v.3.1.2 (Ronquist and Huelsenbeck, 2003). The analysis used 4 chains, and ran for 50,000,000 generations. Twenty-five percent of trees were excluded as burn-in trees before calculating a majority rule consensus tree.

The 29 morphological characters scored for *Derris* and allies by Sirichamorn *et al.* (2014) were scored here for *Millettia pachycarpa*, *Derris montana* and the putatively closely related new species. Any morphological differences between *Millettia pachycarpa* and *Derris montana* were noted, and evidence for the species status of the putative new species sought from these and additional characters. Protologues and type specimens for *Millettia pachycarpa* and *Derris montana* were scrutinized before preparing full accounts of the

species including synonymy. The treatment for *Millettia pachycarpa* considers the Thai distribution, and the morphology of the species in Thailand. The putative new species is endemic to Thailand.

4.3 Results

The analyses performed for this study included 43 *ITS* sequences, 43 *matK* and 39 *trnL-F* sequences. The combined matrix comprised 45 taxa and 3632 sites of which 2848 were constant, and of the variable sites 407 were parsimony informative. Figure 4.1 shows the results of the analysis of total evidence Bayesian analysis. The tree files for the total combined analysis, for the *ITS* analysis and the combined chloroplast analysis are presented in the Electronic Appendix 4.1. Genbank accession details for all the sequences included, whether previously published or newly generated, are also presented in the Appendix 4.1. All the phylogenies show *Millettia pachycarpa* and the new species as sister species to be sister species nested within *Derris sensu* Sirichamorn *et al.* (2012 & 2014), and placed in the *Paraderris cuneifolia*-group *sensu* Adema (2003a). **Table 1** summarises the differences between *M. pachycarpa* Benth. and *Derris montana* Benth., Based on Bentham's protologues of the two species, and also includes an assessment of *Derris pachycarpa* Merr., which justified its recognition as a synonym of *Derris montana*, and it being taxonomically distinct from *Millettia pachycarpa*. **Table 4.2** describes the morphological differences between *Derris lithocarpa* (the new name proposed here for *Millettia pachycarpa*) and the new species *Derris constricta*. The morphological matrix based on Sirichamorn *et al.* (2012) is presented in **Table 4.3**.

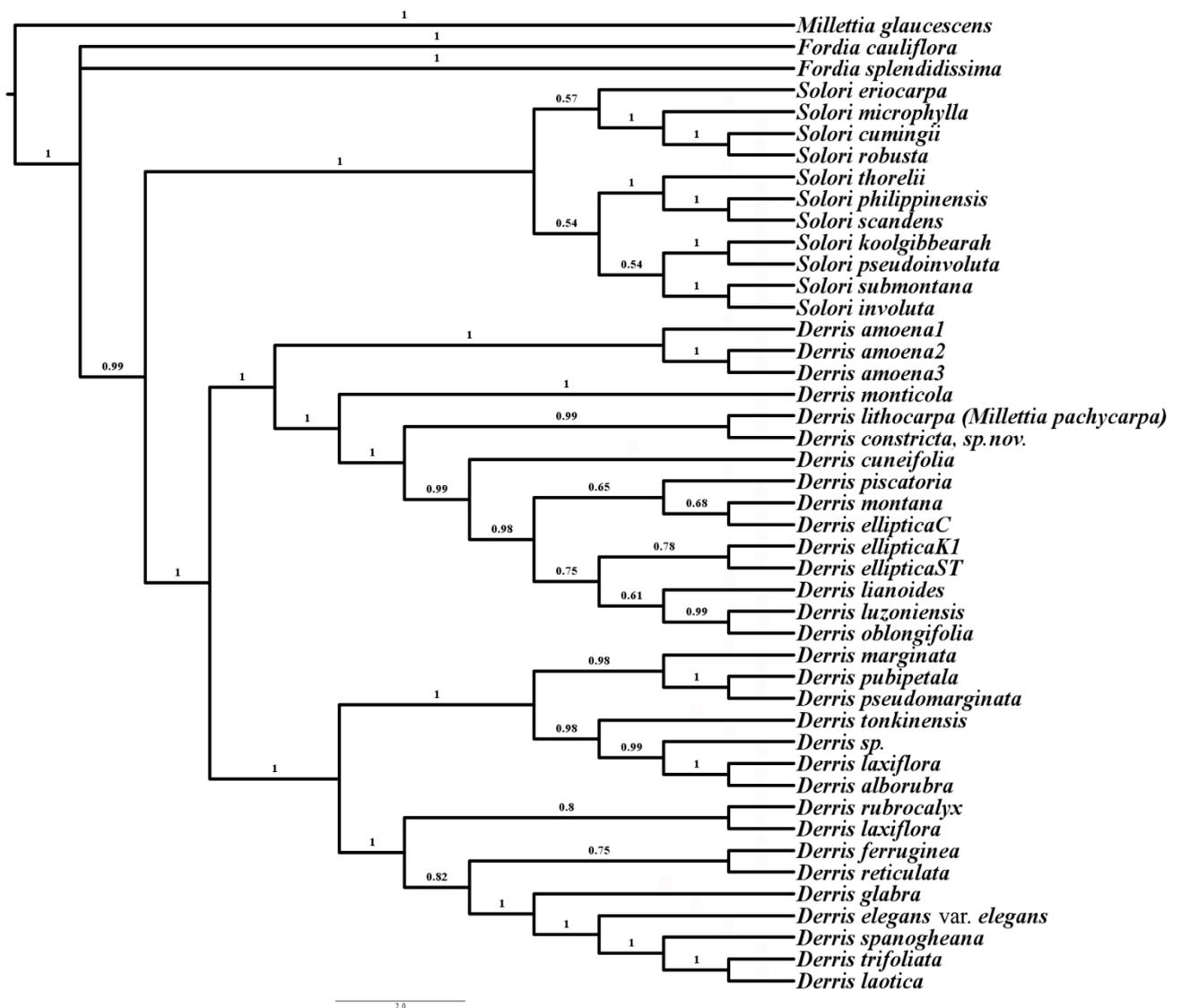


Figure 4.1 Bayesian majority rule consensus tree summarizing post burn in trees following a combined analysis of three regions, nuclear: *ITS/5.8S*; chloroplast: *trnK-matK* & *trnL-F*. Values above branches are posterior probabilities. The arrow indicates the phylogenetic position of *Derris lithocarpa* (*Millettia pachycarpa*) and the new species, *Derris constricta*. Information of *Derris amoena* (numbers 1-3) and *Derris elliptica* (codes C, K1 & ST), provides in the appendix 4.1.

Table 4.1 Comparison of protologues and types for *M. pachycarpa*, *Derris montana* and *D. pachycarpa*.

	<i>Millettia pachycarpa</i> Benth.	<i>Derris montana</i> Benth.	<i>Derris pachycarpa</i> Merr.
Author(s) of name date and place of publication	Bentham, Pl. Jungh. 2: 250. 1852	Bentham, Pl. Jungh. 2: 253. 1852	Merrill, J. Asiat. Soc. (Straits) 86: 312. 1922.
Type specimen	<i>Jenkins</i> s.n.	<i>Junghuhn</i> , s.n.	<i>Ramos</i> 1250 & 1257
Type locality	Assam, India	Sabah, Batu Lima, Malaysia (Borneo)	British North Borneo, Malaysia
Type specimens	flowers, no fruit; fruits described	fruits, no flowers; flowers unknown	fruits, no flowers; flowers unknown
Leaflets	7-11, obovate- elliptic, acuminate, obtuse, veins elevate	7-9, oblong, acuminate, branches verrucose	7-9, elliptic-ovate to oblong-elliptic, chartaceous, smooth, shining, brownish-olivaceous
Indumentum of petioles and inflorescence branches	rusty-villous hairs	entirely glabrous	entirely glabrous, so far as known
Inflorescences	loose panicles, axillary	loose racemes, hardly branched	unknown
Pedicels	subfascicle, twice longer than calyx	scarcely longer than the calyx	unknown
Calyx	twice longer than lobes	no data	unknown
Standard	sericeous, pubescent	presence basal callosities at base inside	unknown
Ovary	unknown	tomentose <i>ca.</i> 8 ovules	unknown
Pods	gross, coarse, subfalcate, very fleshy, almost drupaceous, tardily dehiscent	unknown	oblong to oblong-elliptic, inflated, brown, smooth, shining
Seeds	1-2	unknown	1

Table 4.2 Morphological comparison of *Derris lithocarpa* (*Millettia pachycarpa*) and the new species, *Derris constricta*, now placed in *Derris*. *We describe the stamens of *Derris constricta* here as pseudomonadelphous; in this we follow Tucker (1987) he introduced the term for initially diadelphous androecia with surface fusion at later developmental stages.

Characters	<i>Derris lithocarpa</i>	<i>Derris constricta</i>
Habit	lianas	lianas
Young twigs/mature twigs	densely ferruginous/corky	hairy/corky
Number of leaflets	9–15	9–13
Size of leaflets (cm)	(4–) 7–12 by 3–5	10–12 by 2.5–3
Leaf texture	coriaceous	chartaceous
Secondary veins	10–13 pairs	8–14 pairs
Inflorescence type	pseudoracemes (inflorescence with single axis) or pseudopanicles (two axes), sometimes on the same plant	pseudoracemes
Indumentum on inflorescences	densely hairy with ferruginous hairs	densely hairy without ferruginous hairs
Length of secondary axes in pseudopanicles (cm)	up to 30	no pseudopanicles
Brachyblast	wart-like or knob like, bearing 2–6 flowers	wart-like or knob like to subglobular, bearing 2–3 flowers
Calyx tube (mm)	4–5 mm long, densely hairy on outer surface, glabrous on inner surface	2.5 mm long, hairy on outer surface, hairy on upper part on inner surface
Standard (mm)	16–17 x 15–16	10–11 x 9–10
Basal callosities	absent	absent
Stamens	diadelphous (9+1)	pseudomonadelphous*
Length of fenestrae (mm)	-	2–4
Disc	absent	absent
Pods	tardily dehiscent, 9–17 x 1.5–4 cm, woody, corky	tardily dehiscent, 9–10 x 2.5–3.5 cm, woody, not corky
Shape of pods	cylindrical, ovoid if one-seeded	laterally compressed, elliptic if one-seeded
Wing(s) on pods	absent, or if sometimes present when fruits very young	absent, or if present when fruits very young
Seeds	bi-lobed with a deeply indented (indented up to 1.5 cm) central hilum	bi-lobed with a deeply indented (indented up to 1 cm) central hilum

Table 4.3 The morphological matrix based on Sirichamorn *et al.*'s characters. Morphological characters for *Derris constricta* are scored from the five specimens collected from the single tree sampled and included in the phylogeny; *D. lithocarpa* is scored from the set of voucher specimens cited in the taxonomic treatment, including the specimens sampled for phylogeny reconstruction; morphological characters for *Derris montana* are reproduced from Sirichamorn *et al.* and the genus *Derris s.str.* morphological characters are compiled from Sirichamorn *et al.*'s character matrix for all *Derris* including *Derris montana*. A slash indicates polymorphic species, so that 0/1 indicates there are species of *Derris* which are polymorphic for states 0 and 1 of a character, whereas 0,1 indicates that there are species of *Derris* scored 0 and species of *Derris* scored 1. *a new character state is necessary to describe the variation in the new species, *Derris constricta*. † We find *Derris constricta* is pseudomonadelphous; following Sirichamorn *et al.* (2014) we score pseudomonadelphous species as monadelphous here. †States found in *Derris constricta* or *Derris lithocarpa* but not in *Derris s.str.*

Character	<i>Derris constricta</i>	<i>Derris lithocarpa</i>	Genus <i>Derris s.str.</i>
1. Habit: (0) tree; (1) small tree/shrub; (2) liana.	2	2	2
2. Leaflet arrangement: (0) alternate; (1) opposite.	1	1	1
3. Stipellae: (0) present; (1) absent.	1	1	0,0/1,1
4. Reddish pigments in young leaves: (0) present; (1) absent.	0	0	0,1
5. Type of inflorescence: (0) true panicle; (1) intermediate between true panicle and pseudoraceme or pseudopanicle; (2) pseudoraceme or pseudopanicle; (3) simple raceme.	2	2	0,1,2
6. Shape of brachyblast: (0) brachyblast absent; (1) knob-like to cylindrical; (2) elongate cylindrical.	1	1	0,1,1/2,2
7. Flower position on the brachyblast: (0) brachyblast absent; (1) throughout the brachyblast; (2) at the apex of the brachyblast.	2	2	1,1/2,2
8. Number of flowers per brachyblast: (0) brachyblast absent; (1) 2 or 3/brachyblast, rarely 4 or 5; (2) more than 5.	1	1,2	0,1,1/2,2
9. Flower bract: (0) larger than corresponding flower buds; (1) smaller than corresponding flower buds.	1	1	1
10. Indumentum of calyx inside: (0) glabrous; (1) with some hairs; (2) densely hairy*.	2 [†]	0	0,0/1,1
11. Length of standard petal: (0) up to 10 mm; (1) more than 10 mm.	1	1	0,0/1,1
12. Presence of standard basal callosities: (0) absent or indistinct; (1) present.	0	0	0,1

Table 4.3 Continued.

Character	<i>Derris constricta</i>	<i>Derris lithocarpa</i>	Genus <i>Derris</i> s.str.
13. Adhesion of wings and keel petals: (0) free or irregularly adherent; (1) adherent with sculptured part of wing petals or with lateral pockets.	1	0 [†]	1
14. Presence of lateral pockets on wing or keel petals: (0) absent; (1) present.	1	0	0/1,1
15. Degree of filament fusion: (0) diadelphous 5+5; (1) diadelphous 9+1; (2) monadelphous [‡] .	2	2	2
16. Indumentum of anther and connective tissue: (0) glabrous; (1) hairy.	0	0	0,0/1,1
17. Floral disc shape: (0) absent, indistinct or simply annular; (1) with 10 free finger-shaped glands; (2) tubular and/or lobed; (3) with 2 glands, one adaxial, one abaxial to the base of the upper filament; (4) with 10 nectary lobes at the base of the filaments.	0	0	0,2
18. Vexillary stamen: (0) free from the standard; (1) adnate to the standard.	0	0	0
19. Number of ovules: (0) 1 or 2; (1) 3-7; (2) 8-12; (3) more than 12.	1	0/1	0,0/1,1
20. Pod shape: (0) round; (1) elliptic; (2) strap-like.	1,2	0,2	0,0/1,1,1/2,2
21. Pod wings: (0) wingless; (1) wing only along upper suture; (2) wings along both sutures; (3) 4 wings, (4) wing only along lower suture*.	0,2,4 [†]	0,2	0/1/2,1,2
22. Seed chamber: (0) absent or indistinct; (1) present.	0	0	0
23. Position of seed hilum: (0) distinctly eccentric: more than 45 degrees of the equatorial axis; (1) central or slightly eccentric: between 0–45 degrees of the equatorial axis.	1	1	1
24. Seed position in pod: (0) central; (1) scattered.	1	1	0,0/1,1
25. Leaf texture: (0) chartaceous; (1) subcoriaceous to coriaceous.	1	0	0,0/1,1
26. Colour of dry specimens: (0) usually turning blackish; (1) not turning blackish.	1	1	1
27. Lateral veins: (0) anastomosing near margin; (1) anastomosing in margin.	0	0	0,0/1,1
28. Wing petal characteristics: (0) not rolling backward; (1) rolling backward towards calyx.	0	0	0,0/1,1
29. Pod dehiscent: (0) dehiscent; (1) indehiscent.	0 [†]	0 [†]	1

4.4 Discussion

Sampling of *Derris* and *Millettia* for a phylogenetic analysis of *Millettia* and the Millettoid legumes (Mattapha *et al.*, in prep.) identified one species of *Millettia*, *M. pachycarpa* Benth., unequivocally nested within the *Derris* clade. To maintain a monophyletic *Derris*, a new combination for this *Millettia* name is needed in *Derris*. Since the name *Derris pachycarpa* (1922) is already validly published for another species of the genus, we provide a new specific epithet for the species *Millettia pachycarpa* when it is transferred to *Derris*. Additionally, sequences from a new species of *Derris* place it as sister to *Millettia pachycarpa*.

4.4.1 The name *M. pachycarpa* is not applied to the same entity as the name *D. montana*, and *D. pachycarpa* is correctly synonymised under *D. montana*

Our molecular evidence (Figure 4.1) shows that although *Millettia pachycarpa* is nested in *Derris*, it is not sister to *Derris montana*, which is the correct name for *Derris pachycarpa* Merr., supporting the view that the names *Derris pachycarpa* Merr. and *Millettia pachycarpa* Benth. are not applied to the same entity. Here we provide further evidence that *M. pachycarpa* is distinct from *Derris montana*, by reviewing the protologues and type specimens for these two names and for *Derris pachycarpa* Merr. to be sure that these are two distinct species and that *Derris pachycarpa* Benth. is correctly synonymized (Table 2). *Millettia pachycarpa* Benth. was first described by Bentham (1852), based on *Jenkins* s.n., a flowering specimen collected in Assam in India. Its woody, cylindrical pods, unwinged along the sutures, meant it was a poor fit to Wight & Arnott's (1834) generic concept of *Millettia*. In consequence the species was placed elsewhere by subsequent authors. First, Kuntze (1891) placed it in his genus *Phaseolodes*, next it was transferred to *Pongamia* by Hayata (1913), and then to *Whitfordiodendron* by Ohwi (1936). Geesink (1984) synonymised *Pongamia* under *Millettia*, and *Whitfordiodendron* under *Callerya*. *Millettia pachycarpa* Benth. thus became an accepted name under the revised concept of genus *Millettia*. *Derris pachycarpa* Merr. (Merrill, 1922) was described based on a specimen from Borneo. Adema (Adema, 2003) placed the name *Derris pachycarpa* Merr. into synonymy, under *Paraderris montana* (Benth.) Adema. (Adema), without reference to any morphological characters supporting this transfer. Sirichamorn *et al.* (2014) placed *Paraderris* into synonymy under

Derris and thus recognized *Derris montana* Benth., with both *Paraderris montana* and *Derris pachycarpa* as synonyms. Comparison of the protologues of *Derris montana* and *Derris pachycarpa* (Table 2), and examination of the type specimens, support Adema (2003b) and Sirichamorn *et al.* (2014) in recognizing Merrill's species as a synonym.

4.4.2 *Millettia pachycarpa* should be transferred to *Derris*, with a new specific epithet

Having investigated the history of all three names (*Millettia pachycarpa* Benth., *Derris montana* Benth. and *Derris pachycarpa* Merr.) and re-evaluated the decision to consider *Derris pachycarpa* Merr. as a synonym of *Derris montana* Benth., we are confident that *Millettia pachycarpa* Benth. is indeed a different species that should be transferred to *Derris*. A new specific epithet for *Millettia pachycarpa* is necessary; because the name *Derris pachycarpa* is already occupied; we propose the name *Derris lithocarpa* here referring to the fruits being hard (litho=stone, carpa=fruit).

4.4.3 A new species, *Derris constricta*, sister to *Derris lithocarpa*, is described

In our phylogeny, a specimen sister to *Derris lithocarpa* represents but recovered as its sister represented a putatively new species (Figure 4.1). Here we outline morphological characters which differ between *Derris lithocarpa* and this new entity, justifying its recognition as a new species, *Derris constricta* (Table 4.3). *Derris constricta*, unlike *Derris lithocarpa* lacks dense ferruginous hairs on its inflorescences; it has much smaller flowers (10–11 x 9–10 mm vs 16–17 x 15–16 mm), and its elliptic pods, which are flattened if one-seeded (vs oblong and subglobose if 1-seeded in *Derris lithocarpa*). *Derris lithocarpa* inflorescences may have one or two axes, and if the latter then the first axis is much reduced. Both inflorescence types may be found on an individual specimen of *Derris lithocarpa*, whereas no inflorescences with two axes have been observed in *Derris constricta*.

4.4.4 The addition of two species to *Derris s.str.* has implications for the *Derris* concept

Here we consider the implications to the circumscription of *Derris* when adding *Derris constricta* and *Derris lithocarpa* to the genus. Four of the 29 characters surveyed in the comprehensive morphological survey of Sirichamorn *et al.* (2014) exhibit character states not found by them in *Derris s.str.* despite strong evidence presented here that these two species are placed in the strongly supported *Derris s.str.* clade. These four characters are the indumentum inside the calyx, the adhesion of wings and keel petals, pod dehiscence and pod wings (Table 4.3). These characters, at least the latter three, except for the first, are systematically significant since they describe qualitative differences. However, delimitation of characters and character states is highly subjective (Hawkins, 2000), and apparently qualitative differences between taxa may appear so simply because of the semantic discontinuities of botanical terminology (Stevens, 1991). We show that the circumscription of *Derris* should be modified in light of the densely hairy inner surface of the calyx (found in *Derris constricta*), and not found in any other species of the genus. Degree of indumentum is a character that might be expected to show continuous variation and therefore not to be of great taxonomic use. Indeed, although Sirichamorn *et al.* (2014) scored this character for their morphological matrix, it was not used in the key for Asian *Derris* and its allies, *Aganope*, *Derris* and *Solori*, nor in their descriptions.

The free or fused wing and keel petal character is a more clearly delimited and therefore more taxonomically useful one. In their description of *Derris* Sirichamorn *et al.* (2014) note wings and keel petals are adherent by lateral pockets or hooked together by auricles or twisted claws. In *Derris lithocarpa* wings and keel petals appear to be free, although it is difficult to determine even in the field whether there is any weak hooking together of the petals. The wings of *Derris lithocarpa* are auriculate, and in mature flowers apparent separation of weakly associated structures could be attributed to pollinator visitation. The keel and wing fusion character is used by Sirichamorn *et al.* (2014) in their key for Asian *Derris* and its allies, *Aganope*, *Derris* and *Solori*: in the first couplet of the key genus *Aganope* is characterized by wings free from keel petals. Inclusion of *Derris lithocarpa* in *Derris* means the species placed in *Derris* are no longer exclusively with adnate wing and keel petals and the key may thus require minor modification.

The third character we highlight here is fruit dehiscence. Defining dehiscence is difficult “because the tardy condition can be found in indehiscent pods” (Hu *et al.*, 2000), suggesting

there may be a continuum between tardily dehiscent and indehiscent pods where some fruits show valve separation after fruits have fallen, or only after the pericarp is partly broken down. Both *Derris constricta* and *Derris lithocarpa* have thick pods that on maturity, when wings are no longer apparent, split along both sutures after the fruits have fallen. In their study, most of the species scored by Sirichamorn *et al.* (2014), were scored as indehiscent (including all *Aganope*, *Austrostenisia*, *Deguella*, *Derris* (incl. *Paraderris*), *Kunstleria*, *Leptoderris*, *Lonchocarpus*, *Philenoptera*, *Pongamiopsis*, *Ostryocarpus* and *Solori*), with *Fordia cauliflora*, *Millettia pinnata* and *Neodunnia richardiana* the exceptions. It is possible that the tardily dehiscent fruits of *Derris constricta* and *Derris lithocarpa* might fall within Sirichamorn *et al.*'s (2012) definition of indehiscent. However, *Derris lithocarpa* was placed in *Millettia* as *Millettia pachycarpa* by Bentham because of its tardily dehiscent pods. Ultimately, whether fruits dehisce or not may be an evolutionarily labile character, perhaps linked to ecological environment. Presence of absence of dehiscence is one of the overweighted fruit characters that has resulted in a number of errors in species placement in genera and tribes in the Leguminosae (Polhill *et al.*, 1981).

Another possibly misleading fruit character is the presence or absence of wings. *Derris lithocarpa* has a wing-like crest or woody wing along the lower, or both sutures, when young, but wings are not apparent on the mature pods. The presence of the wing on younger fruits, but absence on older pods has been observed in the field on the same individual plant. In some herbarium collections, e.g. *H.B.G. Garrett* 714 (BKF, E, K), younger fruits with, and older fruits without, wings are observed on the same sheet. In regional floras, including the Forest Flora of British Burma (Kurz, 1877), the Flora of British India (Baker, 1879), Flore Générale de L'Indo-Chine (Gagnepain, 1916), Flore du Cambodge, du Laos et du Vietnam vol. 30 (Lôc and Vidal, 2001) and Flora of China (Wei & Pedley, 2010), the fruits of *Millettia pachycarpa* (= *Derris lithocarpa*) were not described as winged. *Derris constricta* sometimes has a very narrow wing along both sutures. In evolutionary studies (Sirichamorn *et al.*, 2012; 2014) of *Derris s.str.* and its allies fruits with a wing along both sutures is a synapomorphy for the genus, although this character also occurs in *Aganope*, and with and there have been multiple reversals to fruits with a wing along only the upper suture. The inclusion of *Derris lithocarpa* as a species of *Derris* with its fruits which may have a wing only along the upper suture, extends the fruits variation encountered in the genus. The fruits wings are generally thought to have a role in dispersal (Hu *et al.*, 2000;

Sirichamorn *et al.*, 2014), and the papery fruits of *Derris* may be adapted to wind or water dispersal. Whether or not the fruits of *Derris constricta* and *Derris lithocarpa* are winged, by virtue of their woodiness and dehiscence, these species apparently have a different dispersal mechanism to the remainder of the species in the genus.

One variable and possibly systematically useful character not scored by Sirichamorn *et al.* (2012, 2014) but observed here in *Derris constricta* and *Derris lithocarpa* is seed shape. These two species both have seeds that are deeply indented at the point of hilum attachment. We describe these as flattened, bi-lobed seeds. We observed seed shape in other species of *Derris* and found that this character was common but not universal in the genus (Figure 4.2). Flora treatments have described the deeply indented seed morphology in *Derris hancei* Hemsl. (*Paraderris hancei* (Hemsley) T. C. Chen & Pedley) (Flora of China, Wei & Pedley, 2010), *Derris caudalimba* F.C. How (Flora of China, Wei & Pedley, 2010) and *D. acuminata* Benth. (Flore du Cambodge, du Laos et du Vietnam, Lôt & Vidal, 2001). Since we are not aware of this distinctive seed shape in other Millettieae (but see below), it is possible that further phylogenetic studies would reveal the deeply indented seed shape to be a synapomorphy for *Derris s.str.* with reversals to a bean-shaped seed.

Because of the distinctive suite of morphological characters possessed by *Millettia pachycarpa*, (here renamed *Derris lithocarpa*, it had never previously been considered to be closely allied to *Derris*. It was only through molecular phylogenetic study that this the correct taxonomic placement was revealed. Sirichamorn *et al.* (2014) noted that the genus *Derris* lacks distinct morphological characters, being characterized entirely by pleisomorphic or homoplasious characters found throughout the tribe Millettieae. Nevertheless, at the outset of their study the genus was considered sufficiently distinct from *Millettia* to warrant only a single exemplar of the latter being included in their morphological and molecular analyses. Sampling *Millettia* more extensively in molecular studies than ours (Mattapha *et al.*, in pre.) might reveal further species that should be transferred to *Derris*. For example, *D. constricta* is similar to *Millettia entadoides*, a species from Yunnan, China, but differs in branch and fruit colour, pubescence of leaflet lower surfaces, inflorescence length and calyx, including calyx lobe characters. Unfortunately, available specimens and published descriptions of *Millettia entadoides* are inadequate to support transfer of this species to *Derris* at the present time, and lack of material precluded molecular phylogenetic study. Nevertheless,

Millettia entadoides shares the flattened bi-lobed seed shape with many *Derris* species and a future transfer to *Derris* is possible.



Figure 4.2 Seed shapes in *Derris*. Seeds are either deeply indented or shallowly indented. Deeply indented seeds: A. *Derris cuneifolia* (C.B.Clarke, 17266, K), B. *D. constricta* (S. Mattapha 1102, this study), C1- C3. *D. lithocarpa* (Meebold 7123, K), D.1-D2. *D. henryi* (A.Henry 9398, K), E. *D. marginata* (S.C., P-P00700385). Shallowly indented seeds: F. *D. elegans* (P.Chai, S.34691, K), G. *D. elliptica* (Put 4, K), H. *D. fordii* (C.Ford 55, K) and I. *D. trifoliata* (Bourul 2429, K).

4.5 Taxonomic treatment

4.5.1 *Derris lithocarpa* (Benth.) Mattapha & Hawkins, *com.nov. et nom.nov.* — *Millettia pachycarpa* Benth., Pl. Jungh. 2: 250. 1852. **Type:**— India, Assam, *Jenkins* s.n. (holotype not seen; isotypes L, P!-2 sheets).

— *Phaseolodes pachycarpum* (Benth.) Kuntze, Revis. Gen. Pl. 1: 201. 1891

— *Pongamia taiwaniana* Hayata, Icon. Pl. Formosan. 3: 79. 1913. Type-Protologue.

— *Millettia dunnii* Merr., Philipp. J. Sci. 13(3): 139. 1918. Type: China (Kwangtung), in thickets near So Liu Koon, alt. 200 m., *Merrill* 10861 (not designated); *Levine* 1371 (MO, syntype).

— *Millettia taiwaniana* (Hayata) Hayata, Icon. Pl. Formosan. 9: 22. 1920.

— *Whitfordiodendron taiwanianum* (Hayata) Ohwi, J. Jap. Bot., 12(9): 660. 1936.

— *Millettia fooningensis* Hu, Acta Phytotax. Sin. 3(3): 360. 1955. Type: China (Yunnan), Funing, 550 m, 11 April 1940, *C.W. Wang* 88378 (holotype PE).

Woody climber; young twigs covered with ferruginous hairs. **Leaves** imparipinnate, spirally arranged; petioles 6–10 cm long, densely hairy; rachis 6–12 cm long, shallowly grooved above. Leaflets 9–15 per leaf, opposite, reddish when young; petiolules 4–5 mm long, hairy; lamina elliptic to oblong, terminal leaflet narrowly obovate, slightly larger than lateral ones, (4–) 7–12 x 3–5 cm, apex acute or retuse, base cuneate, margin entire, upper surface glabrous, lower surface densely hairy; secondary veins 10–12-paired, coriaceous; stipels minute, caducous. **Pseudoracemes/pseudopanicles** 7–20 cm long, axillary, densely hairy, thick; secondary axes up to 30 cm long, usually longer than main axis. **Brachyblasts** wart-like or knob like, each bearing ca. 2–6 flowers. Flowers pinkish; bracts triangular or ovate, 13–2.5 x 1.5–2 mm, apex acute, margin hairy, densely hairy on outer surface, glabrous on inner surface; bracteoles similar to bracts, inserted at base of calyx or on pedicel below calyx tube. **Pedicels** 5–8 mm long, densely hairy. **Calyx:** tube 4–5 mm long, reddish, densely hairy; lobes 5, upper lobes minute, connate, median lobes and lower lobe slightly larger, ca. 2 x 2 mm, apex acute, margin hairy, densely hairy on outer surface, glabrous on inner surface. **Corolla** pinkish to purple: standard petal orbicular, pink with a green blotch on the ventral face at base, 16–17 x 15–16 mm; claw ca. 5 mm long, apex retuse, base inflexed without basal callosities, margin inflexed, both sides glabrous; wings oblong, 15–16 by 4–5 mm; claw 6–7 mm long, base auriculate, with ca. 1 mm long auricles, apex rounded, margin entire, both

sides glabrous; keel falcate, 14–15 by 5–6 mm; claw *ca.* 7 mm long, apex rounded, base tapering to the claw, both sides glabrous. **Stamens** diadelphous; staminal tube 15–17 mm long, glabrous; free portion of stamen filaments 4–5 mm long; anthers oblong to saggitate, *ca.* 1.5 x 0.5 mm. **Disc** lacking. **Ovary** densely hairy, 5–6 mm long, 1–5-ovulate; style 13–14 mm long, hairy at base and along curved section. **Pods** oblong, constricted between seeds, subglobose if 1-seeded, woody, 9–17 x 1.5–4 cm, rugose, corky, lenticellate, tardily dehiscent; wings absent or sometimes present on upper and lower sutures when fruit very young. **Seeds** 1–5 per fruit, laterally compressed, bi-lobed with a deeply indented (indented up to 1.5 cm) central hilum, 2–4 x 2–3 cm, often truncate when seed closely packed in pods; testa dark brown.

Distribution:— India (type), Bangladesh, Bhutan, Nepal, Myanmar, China, Laos, Vietnam.

Thailand:— NORTHERN: Mae Hong Son, Chiang Mai, Phayao, Nan, Lampang.

Habitat & Ecology:— Scrub jungle and evergreen forest, alt. 500–1,700 m.

Phenology:— Flowering: February–April; fruiting: May–July.

Notes:— *Derris lithocarpa* (Benth.) Mattapha & Hawkins is characterized by its intermediate form of inflorescences with wart-like or knob-like brachyblasts bearing *ca.* 2–6 flowers; pods woody, oblong, constricted between seeds, subglobose if 1-seeded. Because the specific epithet *pachycarpa* was already occupied in the genus *Derris*, we here propose the name *Derris lithocarpa* as a new name referring to the woody pods of the species.

Field notes:— A large woody climber with ferruginous hairs on young twigs. Leaves consist of 9–15 leaflets, these reddish when young. The calyx is reddish with dense hairs on its outer surface. Flowers are pinkish and glabrous.

Representative specimens examined (Thailand):— *Garett* 714 (BKF, E, K-2 sheets); *A.F.G. Kerr* 1770 (BM, K), 5423 (BK, BM, K); *C. Maknoi* 1336 (BH-CMU); *J.F. Maxwell* 03-46 (BH-CMU), 09-163 (BH-CMU), 89-1087 (E), 90-396 (E), 91-289 (BKF, E-2 sheets, P-2 sheets), 97-483 (BKF, BH-CMU), 97-1007 (BKF, BH-CMU), 97-787 (BKF); *I.C. Nielsen*, *R. Pooma*, *N. Koonkhunyhod* & *M. Phuphat* 1856 (BKF-3 sheets); *C. Phengkklai*, *F. Konta* & *S. Khao-lam* 10825 (BKF); *R. Pooma* 339 (BKF, BH-CMU), 395 (BKF); *R. Pooma*, *A. Mauric* & *M. Greijmans* 1481 (BH-CMU); *J. Sadakorn* 482 (BK); *T. Smitinand* 10251 (BK); *J.P. Srisang* & *S. Watthana* 704 (BH-CMU); *S. Sutheesorn* 2449 (BK); *Winit* 1318 (BK, K); *S.*

Watthana 308 (QBG); *Th. Wongprasert* 045-35 (BKF-2 sheets); *Th. Wongprasert & S. Khao-lam* 038-85 (BKF-2 sheets).

4.5.2 *Derris constricta* Mattapha & Hawkins, *sp.nov.*

Type:— Thailand, Bougluea, Doi Phu Ka National park, Nan, hilly roadsides between Doi Phu Ka national park and Bougluea district, at km42, alt. 1,168, 19°10'29.7" N 101°08'17.0"E, S. *Mattapha* 1102 (holotype BKF; isotypes BK, K, KKU, L, P, RNG, P). Figures 4.3 & 4.4

Woody climber; young twigs hairy, distinctly corky when mature. **Leaves** imparipinnate, spirally arranged, reddish when young, brownish when dry; petioles 7–10 cm long, hairy; stipules ovate to triangular, 2–3 x 1.5–2 mm, apex acuminate, margin hairy, outer surface hairy, inner surface glabrous, caducous; rachis 6–10 cm long, shallowly grooved above, sparsely hairy. **Leaflets** 9–13 per leaf, opposite; petiolules 5–6 mm long, hairy; lamina elliptic to oblanceolate, sometimes narrowly obovate, 10–12 x 2.5–3 cm, terminal leaflets equalling laterals, apex acuminate to caudate, base cuneate, rarely slightly oblique, margin entire, upper surface glabrous, lower surface hairy with appressed hairs when young, glaucous; secondary veins 8–14-paired; lateral veins anastomosing near margin; stipels absent or minute caducous, 0.1–0.2 mm long, hairy. **Pseudoracemes** 20–30 cm long, axillary, densely hairy, but without ferruginous hairs. **Flowers** white with a green blotch at the base, arising from brachyblast apex. **Brachyblasts** wart-like or knob like to subglobular, 2–3 x 2–3 mm, bearing 2–3 flowers each; bracts broadly ovate, *ca.* 1 x 1 mm, apex rounded, margin densely hairy, outer surface densely hairy, inner surface glabrous, caducous; flower bracts similar to bracts; bracteoles inserted at base of calyx or top of pedicel, similar to bracts. **Pedicels** 4–5 mm long, densely hairy. **Calyx** cup-shaped; tube *ca.* 2.5 mm long, red; upper 2 lobes, connate, slightly separate at apex; lower 3 lobes, 1 x 0.8–1 mm, hairy on outer surface, hairy on upper part on inner surface. **Corolla:** standard petal white with a green blotch at base on dorsal face, suborbicular, 10–11 x 9–10 mm; claw *ca.* 2 mm long, apex retuse or emarginate, base not auriculate without callosities, margin entire, both sides glabrous; wings oblong, 7–8 x *ca.* 3 mm, not rolling backward; claw 3–4 mm long, base auriculate with *ca.* 0.8 mm long auricles, apex obtuse, sometimes almost acute, margin entire, glabrous but for a tuft of hairs at apex on both surfaces; keel 7–8 x *ca.* 4 mm; claw *ca.* 3 mm long, apex rounded, base auriculate, margin entire, glabrous but for a tuft of hairs at apex on both surfaces; lateral pocket-like *ca.* 1–2 mm long. **Stamens** pseudomonadelphous with basal fenestrae 2–4 mm

long; staminal tube 7–9 mm long, glabrous; vexillary stamen separated at base but adnate to others higher up; filaments 3–4 mm long, glabrous; anthers oblong, 0.7–0.8 x *ca.* 0.5 mm. **Disc** lacking. **Ovary** densely hairy, 7–8 mm long, (1–)4-ovulate; style 5–6 mm long, glabrous. **Pods** laterally compressed, cylindrical, straight to slightly falcate, often constricted between seeds, elliptic when 1-seeded, 9–10 x 2.5–3.5 cm, hairy, woody, tardily dehiscent, wingless or with obscure wings along both sutures, dark brown (never yellow). **Seeds** 1–4 per fruit, laterally compressed, bi-lobed with deeply indented (often up to 1 cm) central hilum, 3.5–4 x 2.5–3 cm, often truncate when seed closely packed in pods.

Distribution:— Only known from Thailand (Bougluea, Doi Phu Ka National park, Nan).

Habitat & Ecology:— Hillside evergreen forest, elevation of 750–1,168 m.

Phenology:— Flowering May–July; fruiting August–October.

Notes:— *Derris constricta* Mattapha & Hawkins is closely related to *Derris lithocarpa* by which it differs in lacking ferruginous hairs on young branches, leaflets and inflorescences, by its much smaller flowers 10–11 x 9–10 mm (vs 16–17 x 15–16 mm) and the shape of its pods which are laterally compressed to more or less cylindrical and slightly falcate (elliptic if containing only one seed). It is also morphologically similar to *Millettia entadoides* Z. Wei in leaflet shape and fruit type, but differs in its dark brown branches (yellow in *M. entadoides*), adpressed hairs on the lower surface of its leaflets (glabrous in *M. entadoides*), longer (20–30) inflorescences (12–15 cm in *M. entadoides*), shorter calyx tube with distinct calyx lobes (tube 4–5 mm long with obscure lobes in *M. entadoides*) and dark brown pods (yellow in *M. entadoides*).

Conservation and threats:— *Derris constricta* & Hawkins is currently known from only two localities, restricted to the North of Thailand. The type locality is in Doi Phu Ka national park, Nan province, where only a few individuals are known. The second locality is in open mixed evergreen forest by a stream beside Pai-Watchan road, Mae Hong Son province. Although just two localities are recorded, we believe that the species may be abundant in the forests and national parks of the North of Thailand and possibly in Myanmar and Northern Laos. We consider the conservation status of the species currently to be Data Deficient (DD) (IUCN, 2016).

Field notes.— A woody climber; old branches are remarkably corky. Leaves have 9–13 elliptic to oblanceolate leaflets which are glaucous beneath. Inflorescences are *pseudoracemes*, flowers white with a green blotch at the base of the standard petal; flowers

emerge directly from the apex of the brachyblast. Pods are laterally compressed, or more or less cylindrical, straight to slightly falcate, often constricted between seeds (elliptic when 1-seed).

Additional specimen examined:— *R. Pooma*, *A. Mauric* & *M. Greijmans* 1481 (BKF, CMU), Pai-Watchan Road, Mae Hong Son province, 3 March 1997, alt. 750.

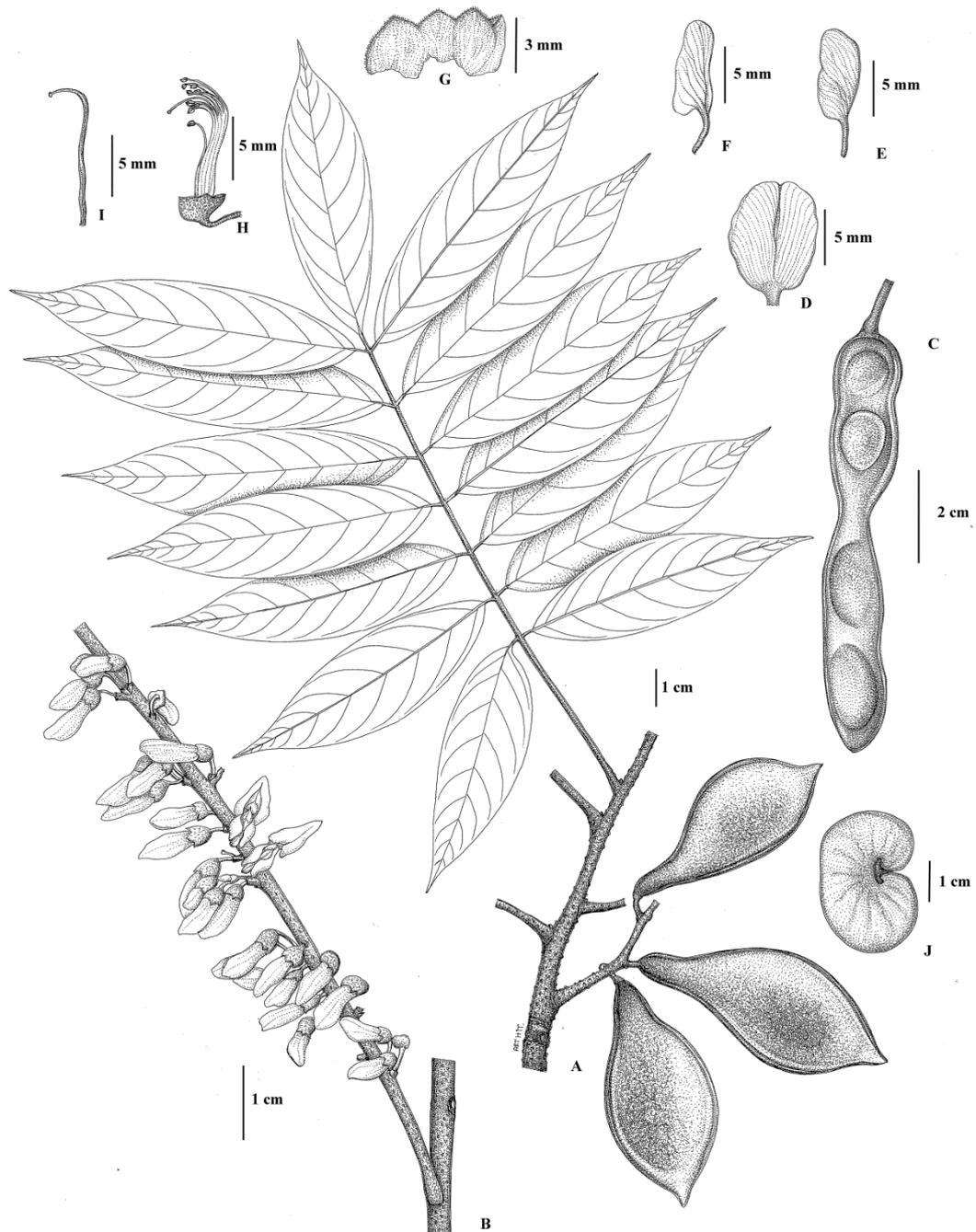


Figure 4.3 *Derris constricta* Mattapha & Hawkins A. leaflets and one-seeded pods; B. Inflorescence showing flowers arising from short brachyblasts; C. Pod containing 4 seeds; D. Standard petal, inner surface; E. Keel; F. Wing; G. Calyx opened out, inner surface; H. Staminal sheath; I. Gynoecium; J. Seed. Drawn by Arthit Kamgamnerd.

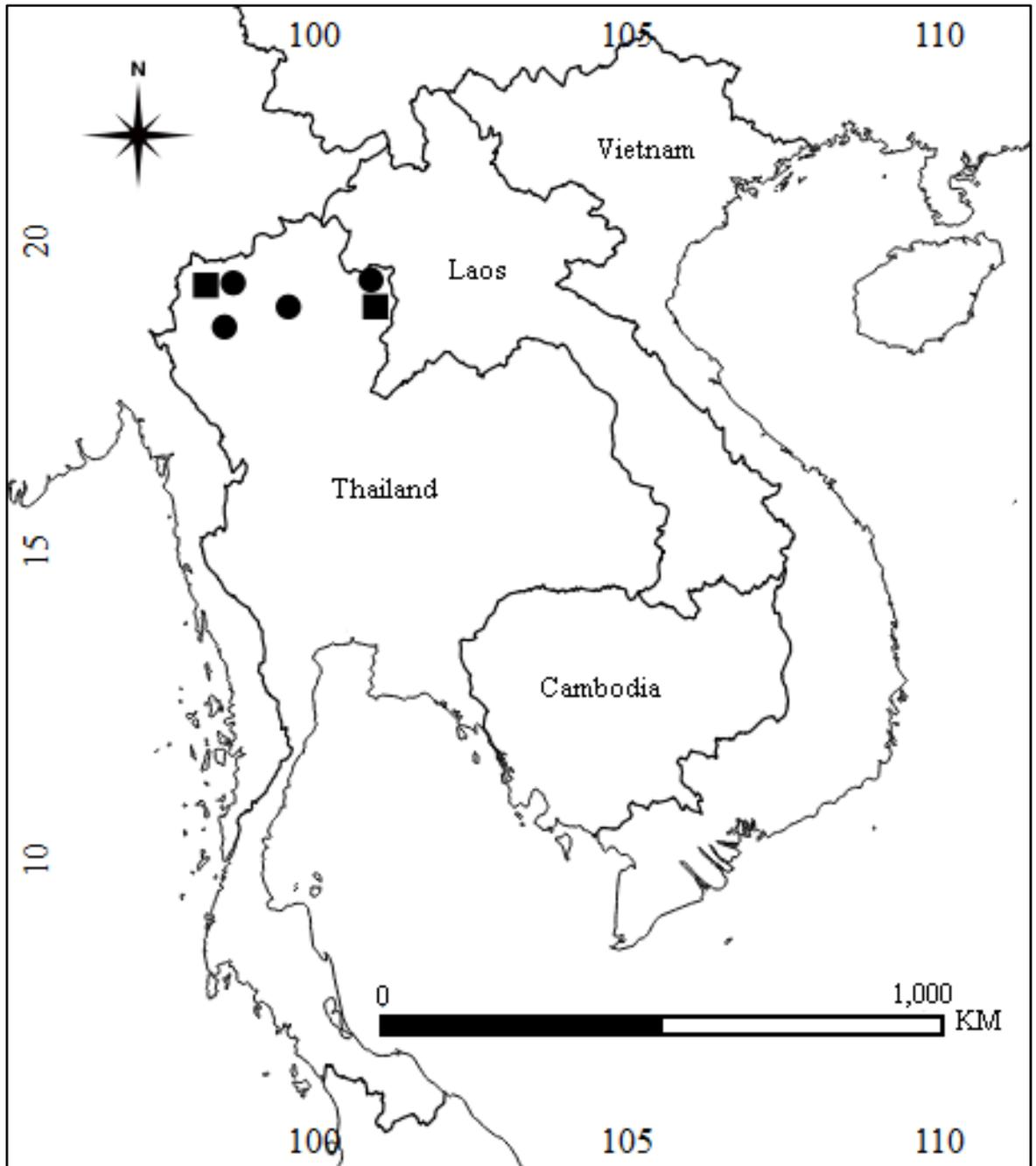


Figure 4.4 Known distributions of *Derris constricta* Mattapha & Hawkins (■) and *Derris lithocarpa* (Benth.) Mattapha & Hawkins in Thailand (●). The map was created using QGIS version 2.14.1-Essen (QGIS, 2016).

Chapter 5 The taxonomic treatment: New species of *Millettia* in Thailand and Vietnam

Abstract. Three new species of genus *Millettia*; *M. calcicola* Mattapha & Hawkins, *M. fulva* Mattapha, Forest & Hawkins and *M. khaoyaiensis* Mattapha & Hawkins, are newly described and illustrated. Key diagnostic characters of these species are also provided and compared to its closest species. All species appear to be restricted in a single locality, the first species to peninsular Thailand, the second to the Khao Yai national park, north-eastern Thailand and the latter to central Vietnam.

5.1 Introduction

Millettia was first described by Wight and Arnott (1834), based on two species; *M. rubiginosa* Wight & Arn. and *M. splendens* Wight & Arn. The concepts of the genus are further broader sense when Dunn's monograph (1912) made in the geographically large scale of species, along with infrageneric classification as segregating into 16 sectional groups. Notwithstanding, the genus is not well satisfactory classification of the most complicate genus in the tribe *Millettieae sensu* Geesink (1984) because the relationships among sections and species are confused and delimited in many exceptions which appear many taxonomic changes and redefinition of Dunn's traditional concept (1912) by different authors, namely Baker (1929), Gillett (1961), Geesink (1981, 1984), Wei (1985), Dasuki & Schot (1991), Adema (2000b) and Mollel & Adema (2006).

Working within the current generic framework of *Millettia*, we follow the concepts of the most recent taxonomic treatments beyond Dunn's (1912) and molecular phylogenetic work (Mattapha *et al.*, in press) for the describing anomalous new species, two of Thailand and one of Vietnam. Moreover, due to the need of complete collections, further new species discovered from Thailand will be being described in further papers for the forthcoming Flora of Thailand's account.

5.2 Material and method

All species of the genus *Millettia* described have been studied in the field of Thailand and herbaria: BK, BKF, BM, CMU, K, KKU, L, P, PSU & QBG. Herbarium abbreviations follow Thiers (continuously updated). The species identification is confirmed by keying and comparison of descriptions in regional Floras together with voucher and type specimens of the genus and its closely related genera. The putative species are examined and described mainly at Biological school, University of Reading. The distributions of three new species are mapped using QGIS version 2.16.2 (2016) (Figure 5.4).

5.3 Taxonomic treatment

5.3.1 *Millettia calcicola* Mattapha & Hawkins, *sp.nov.*

Type:— Thailand, Trang, Huai Yot, Wat Tham I-So temple, 14 June 2006, 90 m alt., 7 °42'07" N, 99 ° 36'43"E, K. Williams, R. Pooma & M. Poopath 1750 (holotype BKF!). Figure 5.1.

Small shrub *ca.* 4 cm high; young twigs densely hairy with reddish hairs. **Leaves** imparipinnate, spirally arranged; petioles 3–4 cm long, finely hairy; stipules triangulare, 1–1.5 x 1 mm, margin hairy, outside densely hairy, inside glabrous; rachis 6–18 cm long, shallowly grooved above; ultrajugal part up to 5 mm long. **Leaflets** 23–29, opposite; petiolules 4 mm long, hairy; laminar elliptic, oblong to lanceolate; terminal leaflet slightly larger than lateral ones, narrowly obovate to elliptic, 3–5 x 1.3–2 cm, apex acuminate, base rounded, margin hairy; upper surface densely hairy, lower surface densely hairy; secondary veins 7–10-paired; stipels setaceous, *ca.* 0.5 mm long, hairy. **Inflorescences** pseudopaniculate, 10–15 cm long, axillary, densely hairy with reddish hairs. **Secondary axes** up to 4 cm long, a few branches at lower part of main axes and longer than terminal part of main axes. **Peduncle** *ca.* 5 cm long. **Flowers** purple. **Brachyblasts** slender, elongate cylindrical, branch-like, up to 1 cm long, bearing 5–8 flowers never knob-like or wart-like; bracts orbicular, 0.5 x 0.5 mm, apex rounded, margin densely hairy, outside densely hairy, inside glabrous; bracteoles inserted at top of pedicel, similar to bracts. **Pedicels** *ca.* 3 mm long, densely hairy. **Calyx** cup-shaped, red; tube 3 mm long; upper 1–2-lobes, connate, slightly

separate at apex; lower 3 lobes, minute, outside densely hairy, inside glabrous. **Corolla** pink to purpule: standard petal pink to purple, suborbicular, 9–10 x 8–9 mm; claw *ca.* 2.5 mm long, apex retuse, base auriculate forming basal callosities with *ca.* 1 mm long auricles, glabrous, margin entire, outside sparsely hairy, inside glabrous to sparsely hairy; wings subfalcate, *ca.* 8 x 3 mm; claw *ca.* 3 mm long, base auriculate, with *ca.* 0.5 mm long auricles, apex acute to rounded, margin entire, hairy along median lines and lower part on the dorsal face; keel *ca.* 7 x 3 mm; claw *ca.* 4 mm long, apex rounded, base tapering to claw, margin entire, both sides hairy at apex. **Stamens** monadelphous (10); staminal tube 8–9 mm long, glabrous; filaments 2–3 mm long, glabrous; anthers subsagittate, *ca.* 0.5 x 0.3 mm. **Disc** absent. **Ovary** densely hairy, *ca.* 4 mm long, 5-ovulate; style 7–8 mm long, glabrous. **Pods** laterally compressed, oblong, 4–7 x 1.8–2 cm, dehiscent, finely hairy. **Seeds** rounded, 1.2–1.7 x 1.2–1.3 cm.

Distribution:— Only known from the type locality.

Habitat & Ecology:— On limestone in evergreen forest, 90 m alt.

Phenology:— Flowering: May-July; fruiting: August-October.

Notes:— *Millettia calcicola* Mattapha & Hawkins is distinguished by numerous leaflets (23–29 leaflets), branch-like brachyblasts bearing 5–8 flowers and auricles of standard forming callosities basally. The species is discovered being a small shrub, as currently known only a single locality with three collections from southern Thailand. Since collections kept at BKF are collected without pods, it is identified as the genus *Derris* sp. The additional collection with unwinged pods, collected by Y. Sirichamorn YSM 2014-2, is confirmed that it is not appropriate to the generic concept of genus *Derris* as recently circumscribed by Sirichamorn *et al.* (2012) but it should be its closed genus. Consequently, phylogenetic results of *ITS* and chloroplast markers, *matK* and *trnL-F* have clearly shown that the species falls into *Millettia* clade (Mattapha *et al.*, in prep.). Therefore, we name here as “*calcicola*” referring to its habitat which the species grows naturally on the limestone mountain.

Field notes:— About 4-meter high shrub has morphological leaflets similar to those of *Millettia brandisiana* Kurz but differs by more thicker texture leaflets when mature and distinct veins on lower surface of leaflets. Inflorescences are axillary pseudopaniculate, never terminal, according to specimens cited here. The basally secondary axes of the inflorescences are a few

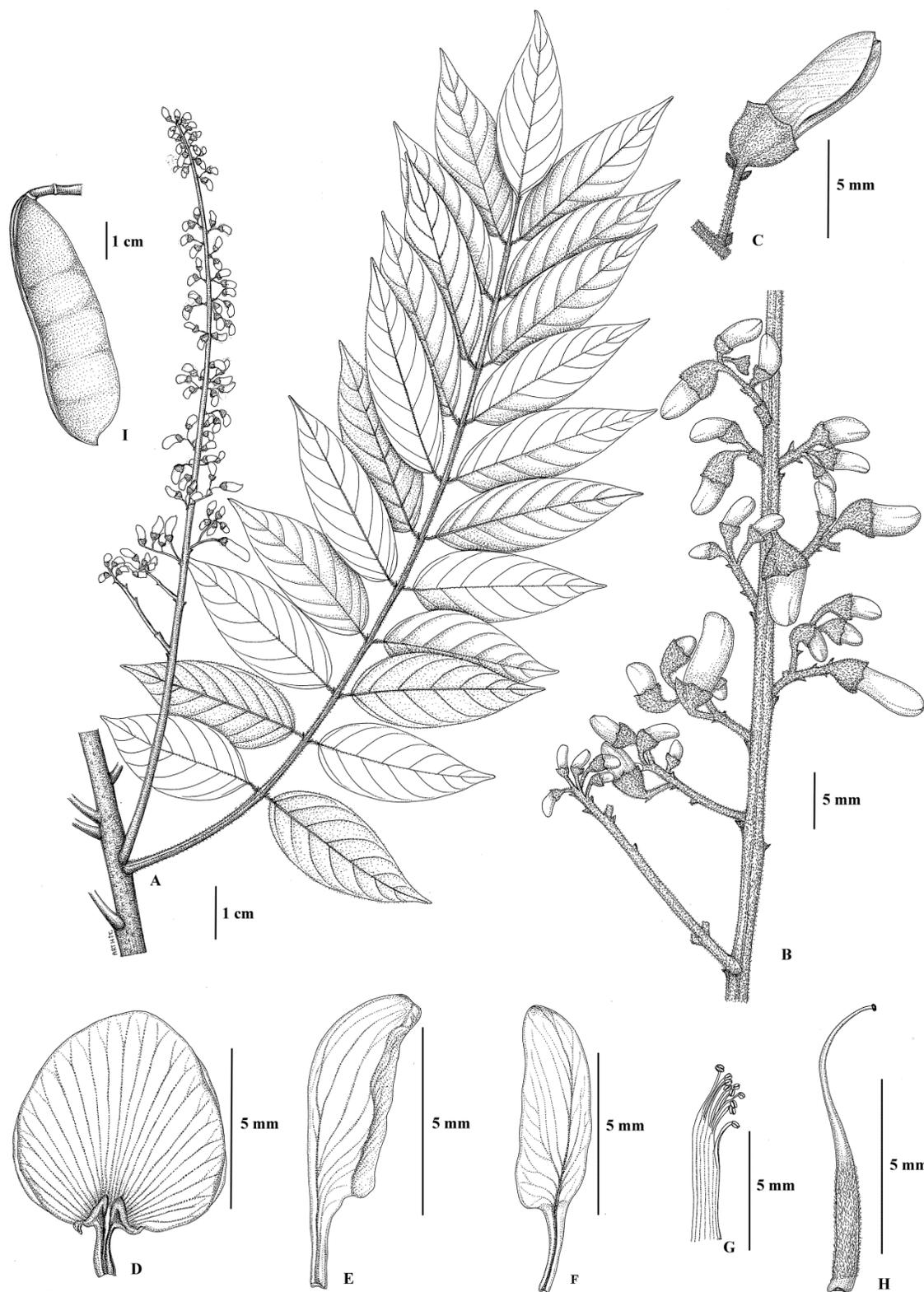


Figure 5.1 *Millettia calcicola* Mattapha & Hawkins. A. Leaf and pseudopaniculate inflorescence. B. part of inflorescence, showing branch-like brachyblasts. C. Flower bud. D. Standard. E. Keel F. Wing. G. Stamens. H. Ovary. and I. Pod. Drawn by Arthit Kamgamnerd.

and longer than the terminal ones. The brachyblasts are slender, elongate cylindrical and branch-like, never knob-like or wart-like.

Conservation and threats:— *Millettia calcicola* is currently only known from a single locality, seeming to be confined in Peninsular Thailand. We propose the conservation status of this species is Data Deficient (DD) (IUCN, 2016) as the appropriate assessment might be reconsidered in the future.

Representative specimens examined (paratypes):— *R. Pooma*, *K. Phattarahirankano*, *S. Sirimongkol* & *M. Poopath* 5637 (BKF, E, L); *Y. Sirichamorn* YSM 2014-2 (BK, BKF).

5.3.2 *Millettia fulva* Mattapha, Forest & Hawkins, *sp.nov.*

Type:— Vietnam, Quang Nam Đà Nẵng: Mt Ba Na (ca. 25 km from Tourane), 4 June 1927, *J. & M.S.Clemens* 3635 (Holotype P, MNHN-P-P02753627), between 15°59'50" N-16°00'50" N-, 107°58'00"E-108°02'20"E, alt. ca 1,000-1,460 m. Figure 5.2.

Climber. **Leaves** imparipinnate, spirally arranged; petioles up to 12 cm long, finely densely sericeous; stipules triangular to lanceolate, outside densely hairy, inside glabrous; rachis 5–10 cm long, shallowly grooved above; ultrajugal part ca. 1 cm long. **Leaflets** 7, opposite, fulvous or golden; petiolules 5–10 mm long, hairy; lamina elliptic to ovate, terminal leaflet slightly larger lateral ones, (8–) 15–20 x (2.5–) 5–6 cm, apex caudate, base cuneate to rounded, margin entire, hairy, upper surface glabrous, lower surface densely sericeous with adpressed hairs along veins, yellowish, lustrous; secondary veins 8–10-paired, anastomosing; stipels minute, caducous. **Inflorescences** pseudopaniculate, with pseudoracemes at the basal part, 13–20 cm long, axillary and terminal, densely sericeous. **Peduncle** up to 4 cm long. **Flowers** arising from brachyblast apex, **Brachyblasts** branch-like to slightly clavate, up to 5 mm long, bearing 7–10 flowers each; bracts to inflorescences similar to stipules; flower bracts ovate, 1.5 x 1.2 mm, apex acute, margin hairy, outside hairy, inside glabrous; bracteoles similar to flower bracts, 2–2.5 x 1.5–1.8 mm, inserted at base of calyx tube. **Pedicels** up to 1 mm long, densely hairy. **Calyx** cup-shaped; tube ca. 3 mm long; lobes minute, triangular 0.2–0.3 x ca. 0.5; upper lobes 2; lower lobes 3, apex acute, margin hairy, outside hairy, inside glabrous. **Corolla:** standard orbicular, 7–8 x 8–9 mm; claw ca. 1.5 mm long, apex emarginate, base rounded with a single callosity at base, margin entire, outside densely sericeous, inside glabrous; wings oblong, 5–6 x 2.5–3 mm; claw 2–3 mm long, base auriculate, with ca. 0.7 mm long auricles, apex rounded, margin entire, hairy

on lower half part on outer surface, inside glabrous, apex rounded, margin entire; keel oblong, 5–6 x 3–3.5 mm; claw 2–3 mm long, apex rounded, base minutely auriculate, margin entire, both sides glabrous; forming a lateral pocket *ca.* 3 mm long. **Stamens** diadelphous (9+1); staminal tube 7–8 mm long, glabrous; filaments 1–1.5 mm long; anthers 1–1.5 x 0.3–0.4 mm, glabrous. **Disc** absent. **Ovary** densely hairy with sericeous hairs, *ca.* 10 mm long, 2–(3)-ovulate; style 2.5–3 mm long, glabrous. **Pods** unknown.

Distribution:— Only known from the type locality.

Habitat & Ecology:— Along roadsides by cabin in watercourse thicket.

Phenology:— Flowering: May–July.

Notes:— *Millettia fulva* Mattapha, Forest & Hawkins is long thought to be *Millettia sericea* in Indo-Chinese Floras in 1916 and 2001 which is described and referred to specimens cited same as this paper. At that time, the presence of densely sericeous hairs on the lower surface of leaflets is just *Millettia sericea* as only one known species to have this character in SE Asian *Millettia*, possibly leading to incorrect species identification. However, cited specimens are closely diagnosed and proved that this species differs completely from *M. sericea* in several reproductively morphological characters. The key characters differs from those *M. sericea*, such as ovate bracteoles distinctly inserted at base of calyx tube, the brachyblasts branch-like to slightly clavate, bearing 7–10 flowers. Interestingly, the standard has a markedly single callosity at base and the wings with dense hairs at the lower half part outside. Despite the lack of pod character, the phylogenetic analyses from *ITS* and *matK* have confirmed the taxonomic position of *Millettia fulva* which is nested within the *Millettia* clades (Mattapha *et al.*, in prep.). Therefore, just only flower collections are sufficient to justify its recognition of the generic status. Regarding the specific epithet, *fulva* refers its distinctly golden leaf colour. As far as known, geographical distribution of *M. fulva* is confined to central Vietnam but of *M. sericea* is found from India through the southern Thailand to the Malesian region. The coordinates given above are estimated from where the type locality is.

Field notes:— The species is morphologically characterized by being liana habit, having golden-like leaflets, leaflet apex being distinct caudate, ovate bracteoles and the distinct single callosity at the base of the inner side of the standard petal.

Table 5.1. Morphological comparison of *Millettia fulva* and *M. sericea*.

Characters	<i>M. fulva</i>	<i>M. sericea</i>
Habit	liana	liana
Numbers of leaflets	7	5–11
Size of leaflets	(8–) 15–20 x (2.5–) 5–6 cm	(5–) 8–20 x (2–) 4–9
Shape of leaflets	elliptic to ovate	obovate to elliptic
Lower surface of leaflets	densely sericeous with adpressed hairs along veins, yellowish, lustrous	densely sericeous with slightly yellowish colour
Colourness of young leaflets	fulvous or golden, lustrous on both surfaces	yellowish in very young leaflets turning green on upper surface
Stipels	present, minute	absent
Flowers born on brachyblasts	scatteringly	apically
<i>Brachyblasts</i>	branch-like to slightly clavate, up to 5 mm long, bearing 7– 10 flowers	wart-like, bearing <i>ca.</i> 10 or more flowers
Callosities of standard	a single callosity at base	without basal callosities
Wing petals	hairy at lower half part outside, glabrous inside	glabrous outside and inside
Keel petals	glabrous outside and inside	glabrous inside, hairy outside at apex and base; forming lateral pocket 3 mm long.
Shape of pods	unknown	elliptic to more or less strap like shaped, sometimes pods are thinly winged or crested along lower suture when fully developed but not often seen, densely hairy with ferruginous hairs

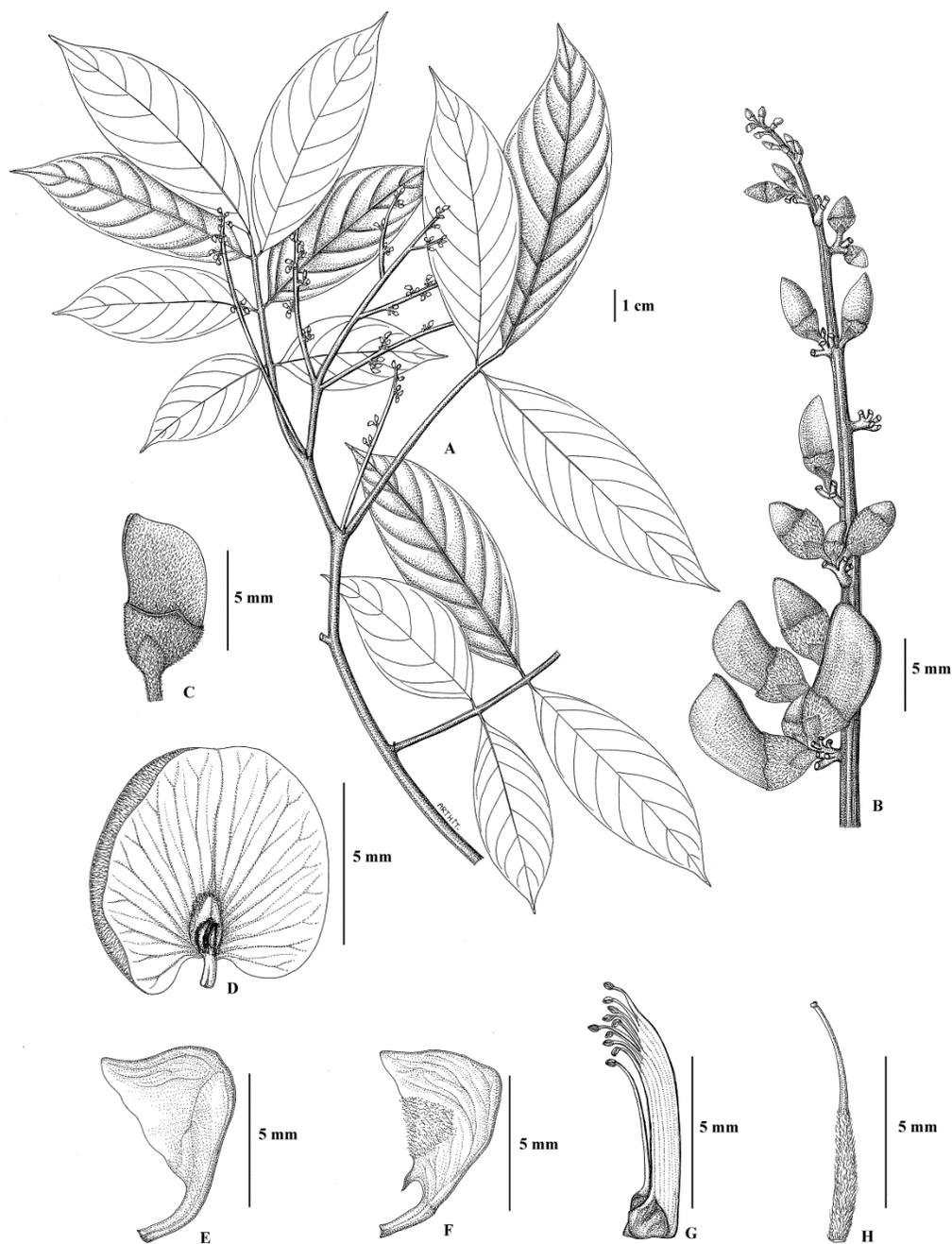


Figure 5.2 *Millettia fulva* Mattapha, Forest & Hawkins. A. Twig with axillary inflorescences. B. Inflorescence with brachyblasts bearing flowers apically. C. Flower, a side view showing a bracteole D. Standard showing a basal callosity inside. E. Keel, outside view. F. Wing, outside view. G. Diadelphous stamens H. Ovary. Drawn by Arthit Kamgamnerd.

Conservation and threats:— The species seems to be endemic to central Vietnam as all collections are recorded from the same locality. According to IUCN Red List (2016), it is evaluated the conservation status here as Data Deficient (DD).

Representative specimens examined (paratypes):— Vietnam, Bả Ka, 1911-11-11, *H. Lecomte & A. Finet* 1192 (P, MNHN-P-P02753625); Thua Thiên-Huê: Thua Luu, *A.J.B. Chevalier* 37047, 1918-5-16 (P-sheets, MNHN-P-P02753623, MNHN-P-P02753624 & MNHN-P-P02753626).

5.3.3 *Millettia khaoyaiensis* Mattapha & Hawkins, *sp. nov.*

Type:— Thailand, Nakhon Ratchasima Khao Yai national park, by roadsides near Pha Dieo Dai cliff, Khao Khieo, military delay station area, 19 October 2014, alt. *ca.* 1,000-1,200, 14°22'0.96" N, 101° 24'18.81"E, *S. Mattapha* 1109 (holotype BKF; isotypes BK, BM, E, K, KKU, L, P). Figure 5.3.

Woody climber; young twigs densely hairy. *Leaves* imparipinnate, spirally arranged; petioles 4–7 cm long, densely hairy; stipules broadly ovate, 5–6 x 3–3.5 mm, apex acute, margin entire, outside densely hairy, glabrous to sparsely hairy upper part, outside densely hairy at base below attachment, persistent; rachis 3–7 cm long, shallowly grooved above, densely hairy. *Leaflets* 7–9, opposite, yellowish when young; petiolules 6–8 mm long, densely hairy; terminal leaflet obovate; lateral ones elliptic to narrowly ovate; (5–) 7–12 (–18) x (2–) 4–5 (–7) cm, apex acute, base cuneate, rounded, margin undulate; upper surface glabrous, hairy along veins, lower surface densely sericeous to brown silvery hairy; secondary veins 10–12-paired; stipels setaceous 3–4 mm long; leatheraceous. **Inflorescences** pseudoracemose (3–) 10–30 cm long, tomentose; pseudopaniculate up to 65 cm long; peduncle up to 22 cm long; rachis 40 cm long. **Secondary axes** up to 25 cm long, axillary and terminal, densely hairy, dark brown when dried. **Peduncle** up to 1.5 cm long. **Flowers** pink to purple, apically born on brachyblasts. **Brachyblasts** globular-shaped, bearing 3–8 flowers; stipe 3–4 mm long; head up to 3 mm long; bracts ovate, 2–2.5 x 1–1.5 mm, apex acute, margin hairy, outside densely hairy, inside glabrous; bracteoles ovate, inserted at base of calyx tube, *ca.* 1 x 1.5 mm, similar to bracts. **Pedicels** 2 mm long, densely hairy. **Calyx** cup-shaped; tube 3 mm long; upper 2-lobed, minute, separate at apex;

lower 3-lobed, minute, middle lip longest *ca.* 1 mm long, margin hairy, outside densely hairy, inside glabrous. **Corolla** purple to pink; standard broadly ovate to orbicular, 9–10 x 9–10 mm; claw *ca.* 2 mm long, apex emarginate, base cuneate without basal callosities, margin entire, inside glabrous, outside densely brown sericeous, purple, greenish at middle; wings triangular-like, 10–11 x 4–4.5 mm; claw 3.5–4 mm long, base truncate with 0.5 mm long auriculate, apex acute, margin entire, inside glabrous, outside densely hairy at base and apex, sparsely hairy along median line; keel 8–9 x 4–4.5 mm; claw 4.5–5 mm long, apex acute, base truncate, margin entire, inside glabrous, outside densely hairy along median line. **Stamens** diadelphous (9+1); staminal tube 10–11 mm long, glabrous; filaments 3–4 mm long, glabrous; anthers oblong, *ca.* 1 x 0.5 mm, apiculate at apex, glabrous. **Disc** absent. **Ovary** densely hairy, *ca.* 7 mm long, 3–6-ovuled; style 5–6 mm long, glabrous. **Pods** laterally compressed, 8–9 x 2–2.5 cm, densely brown tomentose. **Seeds** circular, more or less laterally compressed, 1.2–1.4 x 1.2–1.3 cm.

Distribution:— Only known from the type locality.

Habitat & Ecology:— Dry evergreen forest, elevation of 1,000–1,100 m.

Phenology:— Flowering May–July; fruiting August–October.

Notes:— *Millettia khaoyaiensis* Mattapha & Hawkins is closely allied to *M. sericea* (Vent.) Benth., a species apparently confined to the southern Thailand and the Malesian region by its sericeous lower surface of leaflets. However, it differs from the latter by narrower leaflets, more secondary pairs of veins (10–12 vs 8–10) globular-shaped brachyblasts containing 3–8 flowers (vs *ca.* 10 or more), larger flowers apically born on the brachyblasts and brown tomentose pods (vs dark-reddish sericeous in *M. sericea*). *Millettia khaoyaiensis* also most resembles an Indian species *M. splendens* Wight & Arn., however, it is distinguished by having less numbers of secondary nerves (10–12 vs 15–25), smaller leaflet size and diadelphous stamens.

Field notes:—The species can be easily recognized by being a liana habit, yellowish leaflets when very young and turning sericeous when fully mature on lower surface, undulate margin of leaflets and presence of stipels. The inflorescences can be intermediately formed between pseudoracemose and pseudopaniculate types which is the latter its length can be up to 65 cm long. The flowers are pink to violet, apically born on the brachyblasts. The pods are laterally compressed with dense brown tomentose hairs.

Conservation and threats:— The species appears to be restricted to the national park in evergreen forest. The specimens represented here were collected in the most accessible in the national park. According to IUCN Red List criteria (2016), we propose the conservation status here as Data Deficient (DD). It is highly possible to have abundant population in other areas within the national park. Therefore, its conservation status will be re-evaluated in further assessment when necessary.

Representative specimens examined (paratypes):— Thailand, Nakhon Ratchasima, Khao Yai National park, Pha Dieo Dai, Khao Khieo, military delay station area, 14°21.57 ' N, 101° 24.08' E, alt. ca 1,110, 19 December 2005, *R. Pooma*, *K. Phattarahirankanok*, *S. Sirimongkol* & *M. Poopath* 5900 (BKF-SN182273); Thailand, Nakhon Ratchasima, Khao Yai National park growing by streams, 9 July 1963, *Kasem* 404 (BK-SN212252).

5.4 Discussion

The circumscription of the genus *Millettia* has not been well satisfactory, even though it was established nearly 200 years ago by Wight and Arnott (1834). As the concepts of the genus *Millettia* were attempted to clarify several times from outstandingly previous taxonomic work by Baker (1929), Gillett (1961), Geesink (1981, 1984), Wei (1985), Dasuki & Schot (1991), Adema (2000b) and Mollel & Adema (2006). The current phylogenetic studies of Hu *et al.*, (2000) and Wojciechowski *et al.*, (2004), Käss & Wink (1995 & 1996), Doyle *et al.* (1997 & 2000), Kajita *et al.* (2001), Hu & Chang (2003) and Mattapha *et al.* (in prep.) has undoubtedly resulted that the genus is highly polyphyletic, suggesting to the requirement of a new classification.

However, the new species described here are based on the molecular analyses from our study. The phylogenetic placement shows that they are sunk in *Millettia*, clade 2 of the *Core Millettieae* (Chapter 2). Therefore, this result convinces us to describe as new under the concept of the genus *Millettia*, despite the fact that the phylogenetic study with more global samplings and molecular markers is needed for understanding of the relationships within the genus and other genera in the tribe Millettieae.

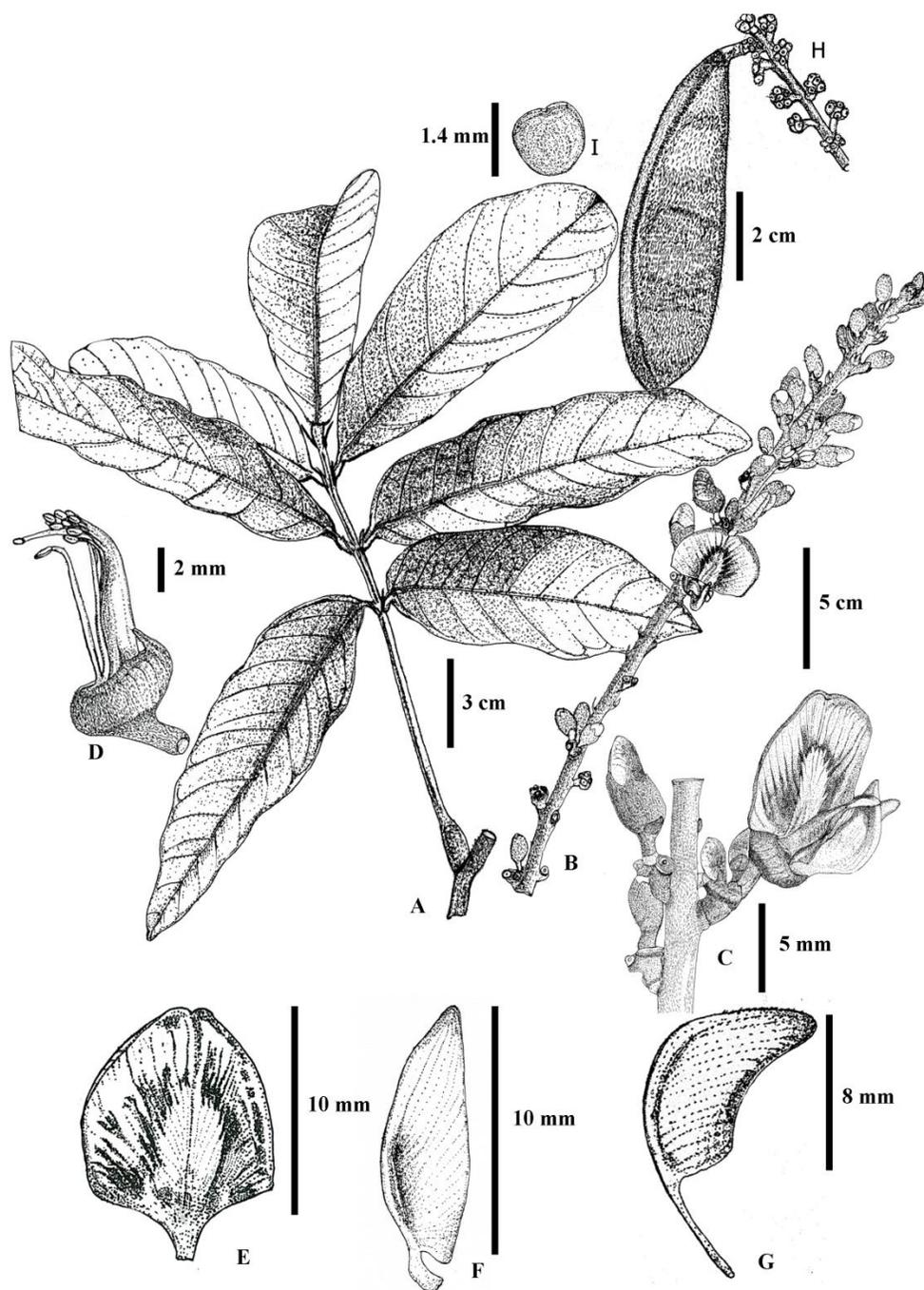


Figure 5.3 *Millettia khaoyaiensis* Mattapha & Hawkins. A. Leaflets. B. Inflorescence. C. part of inflorescence showing brachyblasts and flower side view. D. Calyx tube with stamens and ovary inside. E. Standard. F. Wing. G. Keel. H. Pods with globularly shaped persistent brachyblasts. I. Seed. Drawn by Sawai Mattapha.

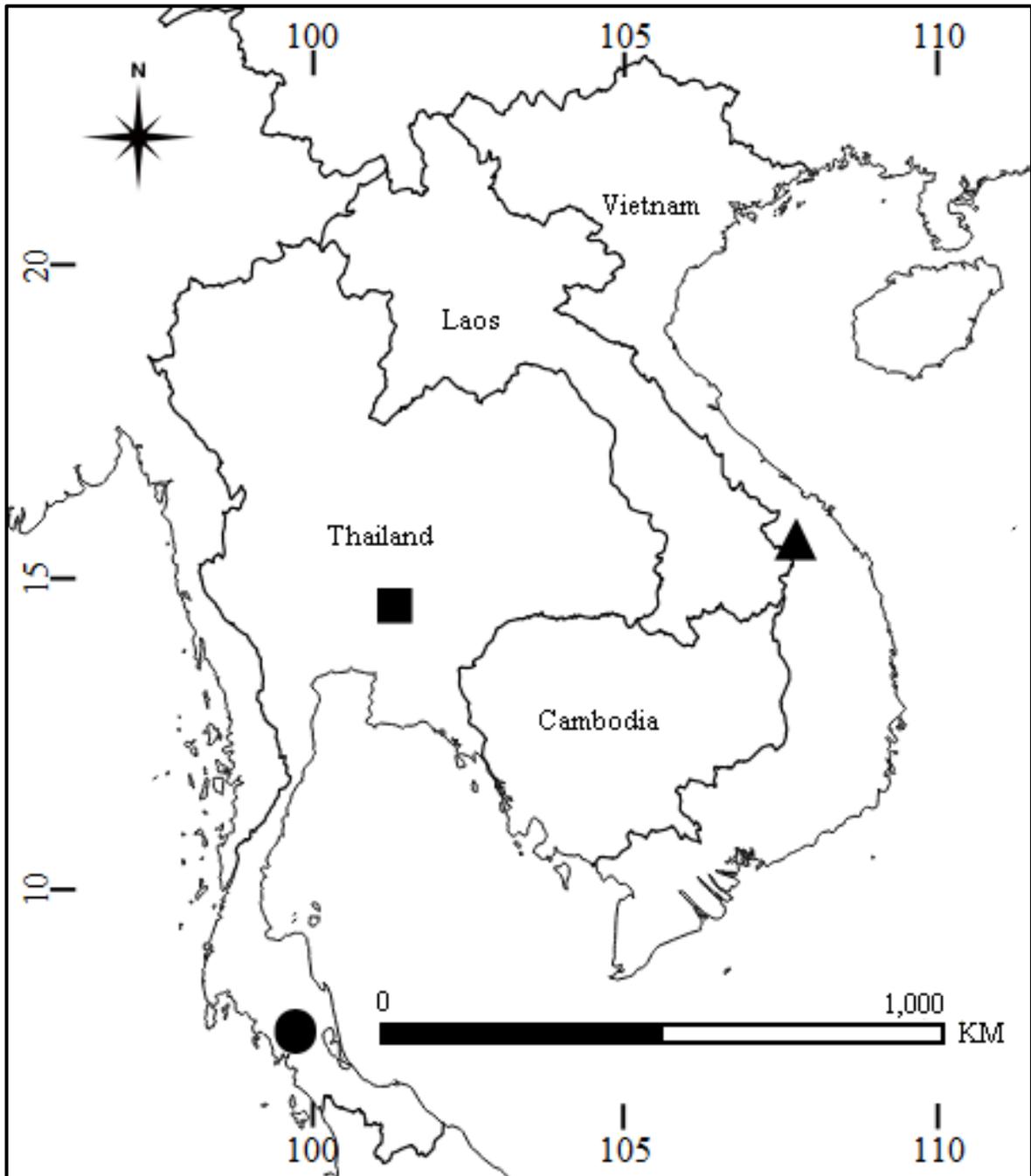


Figure 5.4 Known distributions of three new species of genus *Millettia* as a single locality for each species; *M. calcicola* Mattapha & Hawkins (●), *M. khaoyaiensis* Mattapha & Hawkins (■) and *M. fulva* Mattapha, Forest & Hawkins (▲).

Chapter 6 Discussion

6.1 Overview of the work completed to date

At the outset, the goal of this PhD study was to contribute to a new taxonomy of the Millettieae tribe, a tribe known to be particularly taxonomically complex, and to include a large genus known to be polyphyletic. The taxonomic problems that needed to be addressed were significant, but the intention was that a molecular phylogeny across the whole tribe would help to clarify generic limits. The focus of this work then was to reconsider generic limits as a goal in itself, but also so that the new species described for the Flora of Thailand could be placed in robust genera.

The PhD project proved challenging for several reasons. Many problems were encountered when trying to include samples in a molecular phylogeny. Collections were old, and had degraded DNA. I faced many problems with contaminated PCR products because I was working with very low molecular weight DNA. Whole data sets had to be re-collected using the best protocols to prevent contamination. This cost a lot of time and money. Once I had the phylogeny, manipulating and interpreting it was very difficult. Interpretation was difficult because Genbank sequences were often from misidentified plants. Many genera were polyphyletic. Conflict between partitions added to the difficulties in interpretation. The biggest challenge was that the molecular phylogeny I built did not present easy answers to the taxonomic questions that I wanted to answer.

Two taxonomic questions at different levels of the taxonomic hierarchy are addressed in the preceding chapters – at the level of major lineages within tribes (Chapter 3), and at the level of genus (Chapter 4). The treatment in Chapter 3 for the informal groupings makes an important contribution by clarifying which genera belong in informal groups, but ends with a question – what should these lineages be called? Chapter 4 presents a reconsideration of genus *Derris*, but ultimately the question of whether *Derris* should be recognised at all is side-stepped. Chapters 4 and 5 present new species for the Flora of Thailand, but the generic placement for these new species might yet prove to be provisional, since generic limits remain unsatisfactory. In this way the work to date presents new data and new findings, but the taxonomy remains a work in progress. In the next section (6.2) we review the “big question” of how genera should be delimited in the tribe.

6.2 What should be the ultimate fate of the genus *Millettia* and its allied genera in *Millettia s.str.* group

The case of *Millettia* is reviewed here in the light of other classifications informed by phylogenies of polyphyletic genera and their allies. We identify two case studies which exemplify alternative strategies for dealing with the *Millettia s.str.*; recent studies have resulted in the recognition of segregate genera in the *Caesalpinia* group, but have

Option 1. Recognising many segregate genera. This approach is exemplified by the recent treatments of the *Caesalpinia* group (Lewis, 2005; Gagnon *et al.*, 2013). The *Caesalpinia* group includes several segregate genera of *Caesalpinia s.l.*, interspersed with genera part of the *Caesalpinia* group but not part of *Caesalpinia s.l.* In this case, a comprehensively sampled and well-resolved phylogeny (Gagnon *et al.*, 2013) revealed that *Caesalpinia s.l.* was not monophyletic, though five genera previously reinstated by Lewis (2005) did comprise well-supported clades with good diagnostic morphological characters. Probably three segregate genera which were not monophyletic still need to be subdivided, and the resultant genera might be expected to lack the clear morphological characters of those which were initially recovered as monophyletic. The *Caesalpinia* group comprises 21 genera and 150 species, and 25 generic names have been, at one time or another, placed in synonymy under a broadly circumscribed *Caesalpinia s.l.* Figure 6.1 shows the phylogeny of the *Caesalpinia* group as presented by Gagnon *et al.*, (2013).

Option 2. Recognising one super-genus. This approach is exemplified in the work of the Global Carex Group, who in 2015 formally included four satellite genera (*Cymophyllus*, *Kobresia*, *Schoenoxiphium*, and *Uncinia*) in the genus *Carex*, which now includes more than 2,000 accepted species. Although aiming ultimately to devise a classification that was most likely to provide nomenclatural stability, to transfer the satellite genera to *Carex* required 130 nomenclatural changes. The decision to reclassify was based on lengthy discussions at international gatherings. Though a case was made that better sampling might reveal new clades that were supported and should be segregated from *Carex*, the consensus was that this would not be the case. The arguments for one genus were made on the grounds that were problems with recognizing each of the four major clades as distinct genera (insufficient morphological characters for one “problem” clade) and even more difficulties with recognizing three of the major clades and segregating the problem clade into more than a

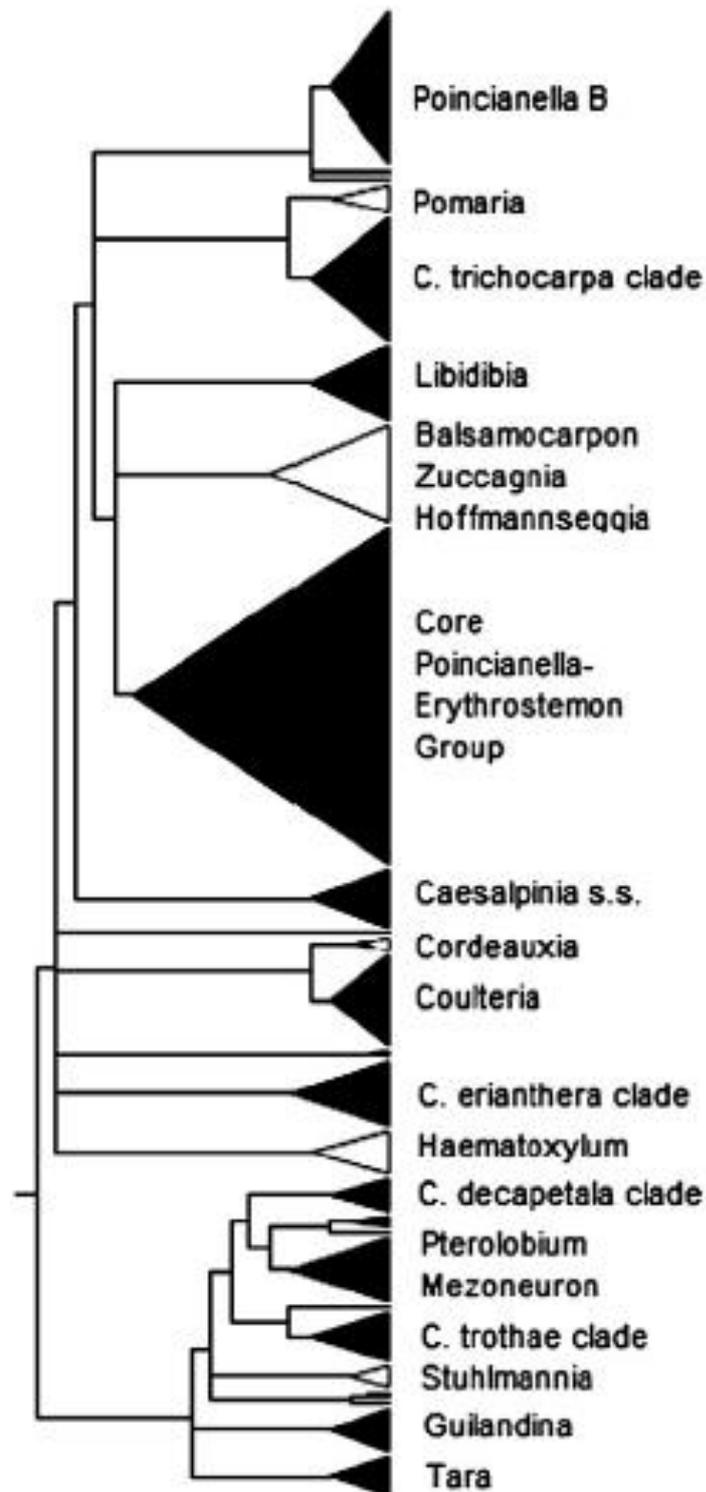


Figure 6.1 The phylogeny of the *Caesalpinia* group. Clades coloured in black comprise only members of *Caesalpinia s.l.* Clades, in white represent genera that are part of the *Caesalpinia* Group, but not *Caesalpinia s.l.* (taken from Gagnon *et al.*, 2013).

dozen segregate genera in order to recognise lineages with morphological support. The Global *Carex* Group envisage natural sectional groups in the genus will be recognised in the future based on extensive sampling and placement of species in molecular phylogenies. Figure 6.2 shows the summary phylogeny of *Carex* (family Cyperaceae), from the Global *Carex* Group, 2016.

6.3 Which of these two approaches seems most appropriate in the case of *Millettia s.str.*?

Millettia s.str. comprises 777 species, including the 23 currently-accepted genera and the 153 accepted species of *Millettia*. Half of these genera are not monophyletic, and genus *Millettia* is strongly polyphyletic, with species placed in multiple lineages that are neither morphologically nor geographically coherent. Taxonomic changes to reflect the emerging phylogenetic hypothesis might result in a proliferation of genera that are difficult to characterise under Option 1, or the loss of genera that are well-supported and well-known under Option 2. It is doubtful that sinking 22 genera into a super-genus *Millettia* would be attractive. However, on the other hand, raising many of the clades that would have to be recognised to retain these “good” genera would result in the proliferation of segregate genera lacking good morphological characters and which in many cases are not geographically coherent either.

It is beyond the scope of a PhD study to make a decision which, under either option, would result in significant nomenclatural change. In any case, arguably more data is needed before a decision could be made. It is proposed that at a future meeting of the Legume Phylogeny Working Group (LPWG) the work described here is presented and discussed. There is a precedent in the legumes community to agree on taxonomic decisions (LPWG, 2017). Nevertheless, in the meantime, changes to the delimitation of genus *Derris* are made (Chapter 4). This is because at the present time there is strong evidence that the recently re-delimited genus *Derris sensu* Sirichamorn (2014) is not monophyletic. Whether or not, ultimately, this genus is retained or becomes a section within a super-genus *Millettia*, this clarification will be of use to those using his treatment.

is difficult to predict where many unsampled species of *Millettia* would be placed. Resolution and support of the phylogeny should be improved by increasing sampling of gene regions.

In Asia, fresh material of the genus and its allies used in this study represent mainly the field collections in Thailand which is just less than 50% of species numbers as recorded from taxonomic treatments (approximately 40-50 spp. in Asia). Many species of *Millettia* in Asia remain unsampled, some of which are endemic and confined to some countries, such as *Millettia nepalensis* R.N. Parker found in Nepal, *Millettia merrillii* Perkins, *Millettia platyphylla* Merrill ex Dunn and *Millettia tenuipes* Merr. in the Philippines, and undescribed new species in Thailand and elsewhere. Interestingly, in China there are six endemic species of *Millettia*, of which *M. entadoides* Z. Wei seems to have seed morphological similarities with genus *Derris*, as discussed in Chapter 4. In Africa, this study depended on leaf material from herbaria, but mainly from Kew herbarium, most of them were collected for many years ago, and their DNA was degraded. Some African sections proposed Dunn (1912) were not sampled and some that were sampled were not successfully amplified. Consequently, the lack of plant material of the molecular study in phylogenetic context in this study across the Millettioids means understanding of the natural relationships within the group is incomplete. Hence, a priority for molecular phylogenetics of the Millettioid group is more taxon sampling from either field collections or various herbaria.

In the case that the genera are segregated and new genera described (Option 1), it would be important to know which lineage of *Millettia* would take the name *Millettia* because it includes the type. In this study, one sequence from a solitary specimen of the type species of the genus *Millettia*, *M. rubiginosa* Wight & Arn., was used to reconstruct the phylogenetic tree, and placement was uncertain because the sequence generated was very short. Material of the type species was obtained from Leiden herbarium (L) in the Netherlands, and the specimen provided quite poor quality DNA. Because this specimen is old the poor condition might be due to age or preservatives (Bakker, 2015). Therefore, a priority task is identify sources of fresher leaf material or to use molecular techniques that can get usable data from poor specimens. Unfortunately, *M. rubiginosa* is highly likely to be confined to south India, since it never been recorded in any neighbouring regional floras, and all the specimens examined from Kew (K), Leiden (L) and Paris (P) appear in poor condition, and it doesn't seem that any specimen has been collected from the type locality in recent years. Therefore new methods might be a more plausible way forward.

The data set used for phylogeny reconstruction added more *ITS* than *trnL-F* and *matK* sequences. The *trnL-F* and *matK* sequences were only generated from field-collected plants. Therefore, because many more *ITS* sequences were collected from herbarium specimens the final data set includes a lot of missing data for *trnL-F* and *matK*. More sequences of chloroplast regions for reconstruction of the phylogenetic tree to make more robust the hypothesis for genus *Millettia* are undeniably needed. In relation to this, it will be a fundamental key for interpretation of evolutionary history within the genus to combine of chloroplast DNA which is usually maternally inherited and nuclear DNA which is paternally and maternally inherited.

Even complete sampling of the *ITS*, *trnL-F* and *matK* sequences for all samples may not yield a satisfactory phylogeny. Ultimately more gene regions may be needed. Total genomics in the genus *Millettia* will be also additionally analysed to be able gain more robust the relationships and to provide the species tree. The studying of the gigantic genus *Millettia* is a financial investment; so, NGS technology could be a potential tool to allow us to sequence DNA that is much more informative than the previously used Sanger sequencing. Examples of NGS-based phylogenies that resolve species relationships are now plentiful, though many are of smaller genera (e.g. Folk *et al.*, 2015; Nicholls *et al.*, 2015).

6.4.2 Homoplasmy in the Millettieae

6.4.2.1 No good morphological characters?

For taxonomic purposes, identifying the characters that support groups is of paramount importance, and many taxonomists are reluctant to describe taxa based only on molecular characters. Cryptic taxa, those which lack “good characters”, nevertheless are sometimes recognised (Kadereit *et al.*, 2012). Hu *et al.* (2000) showed the distribution of four significant morphological characters in the tribe Millettieae and its allies, namely paniculate inflorescence and pod morphologies, are not synapomorphies for Millettieae *sensu* Geesink (1984) since none of the characters can distinguish a specific clade. Hu *et al.* (2000) also displayed a pseudoraceme/pseudopanicule clade that can be recognized the Core Millettieae/Phaseoleae clade but these characters are absent in some *Millettia*, such as *M. kangensis* Craib (pers. obs.). Pod morphology is one of the distinctive characters used in delimitation the tribal classification for many taxonomists in previous studies (Bentham (1860); Bentham & Hooker (1865); Polhill (1981); Geesink (1984), such as the

presence/absence of winged pods and dehiscence/ indehiscence of pods. However, pod character is considered to be a little value in the classification of the tribe Millettieae (Hu *et al.*, 2000). For example, winged pods might be a general adaptation for wind or water dispersal as have evolved several times in legumes (Hu *et al.*, 2000) and also genus *Derris* (Sirichamorn *et al.*, 2014). Another example, pod dehiscent is problematic for generic delimits because the delayed condition can be misinterpretation in true indehiscent pods (Hu *et al.*, 2000). This statement is true when our findings resulted the phylogenetic placement of *Millettia pachycarpa* in *Derris sensu* Sirichamorn (2014), see Chapter 4. This present study strongly suggests that no unique character is informative of generic limits for the genus *Millettia* and its allies in the tribe Millettieae. Nonetheless, other characters, such as imbricate calyx in buds, shapes of brachyblasts, seed shapes, chromosome numbers and wood anatomy may be likely informative characters to support the generic circumscription of the tribe but have not been tested yet.

6.4.2.2 Phytochemistry; more screening of canavanine – probably not useful?

At the outset of our study we expected to find many lineages which lacked morphological characters. However, it was possible that biochemistry might be more phylogenetically constrained, and there might be phytochemical characters supporting cryptic groups. Canavanine, the Non-Protein Amino Acid Accumulating (NPAAA), has been widely applied to promote to be a phytochemically systematic character in tribal classification of Millettieae (also Tephrosieae) (Bell, 1981; Bell *et al.*, 1978; Birdsong *et al.*, 1960; Evans *et al.*, 1985). Recently, this character has been proven to be a strong systematic character to delimit the generic circumscription in a polyphyletic genus *Pueraria* of the tribe Phaseoleae (Lackey, 1977; Ashley *et al.*, 2016). However, our molecular phylogenetic study has not strongly reinforced the hypothesis that canavanine could clarify the classification of the Core Millettieae proposed by Schrire (2005b) with many exceptions when more widely sampled than previous studies (see Chapter 3).

6.5 Beyond taxonomy

This study has focussed on generating phylogeny to guide classification. Phylogenies have many other purposes. Leguminosae has become a model family for understanding many aspects of plant evolution, such biogeography (Lavin and Matos, 2008; Lavin *et al.*, 2000;

Schrire *et al.*, 2005a); Klitgard *et al.*, 2013; Vatanparast *et al.*, 2013). The genus *Millettia s.l.* (incl. *Fordia*) is estimated to comprise approximately 150 spp., distributed in the tropical old world, of which about 65 spp. in Africa and Madagascar and about 40-50 spp. in Asia (Schrire, 2005b). This total number given is based on current literature reviews and herbarium collections by Schrire (2005b). In our phylogeny, the genus *Millettia* was sampled to represent its full distribution, but sampling represents lower less than 50% of the total number of species in each region. There is no doubt that the Millettieae are extremely evolutionarily interesting from a biogeographic point of view; a priority for future study would be to use a better-resolved and sampled tree to address biogeographic questions. The Millettieae also include many species locally economically important for their toxic properties. In particular, *Millettia* and allied genera are used as fish poisons (Gillett *et al.*, 1971; Boiteau 1986; Lock, 1989; Andel, 2000) and as insecticides (Debray *et al.*, 1971; Dupuy, 2002; Lalchandama, 2011; Gong *et al.*, 2015). Some species are also used medicinally (Hamid, 1999; Banzouzi *et al.*, 2008). These uses have resulted in research into the properties of these plants (Lawal *et al.* (2010); Sultana *et al.* (2014). An emerging area of research is to understanding traditional use in a phylogenetic context (Saslis-Lagoudakis, 2011). This would be an interesting research direction for the Millettieae.

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Appendices

Appendix 2.1 List of species, sources, voucher specimens and herbarium where species deposited, locality and the accession numbers for sequences obtained from Genbank (<https://www.ncbi.nlm.nih.gov/>). Abbreviations for GB indicate the source from Genbank and P from the existing publication of da Silva *et al.*, (2012). Herbarium abbreviations follow Thiers (continuously updated), <http://sweetgum.nybg.org/ih/>, given in the parentheses.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Abrus precatorius</i>	<i>Abrus precatorius</i> L.	GB	<i>Hu</i> 1136	x	x	AF142705	x
<i>Abrus precatorius</i>	<i>Abrus precatorius</i> L.	GB	<i>Thorne et al.</i> 6791 (BRY)	x	x	x	EF543423
<i>Abrus pulchellus ssp. cantoniensis</i>	<i>Abrus pulchellus</i> Wall. ex Thwaites <i>ssp. cantoniensis</i> (Hance) Verdc.	GB	<i>PS0233MT01</i>	x	GU217614	x	x
<i>Afgekia filipes</i>	<i>Afgekia filipes</i> (Dunn) R. Geesink	GB	<i>Maxwell</i> 90-246 (L)	Thailand	X	x	x
<i>Afgekia sericea</i>	<i>Afgekia sericea</i> Craib	GB	<i>John Mood</i> 85S47	x	x	KF294875	x
<i>Afgekia sericea</i>	<i>Afgekia sericea</i> Craib	GB	SN [taxon: 132428]	Thailand	AH010784	x	x
<i>Aganope balansae</i>	<i>Aganope balansae</i> (Gagnep.) Lôt	GB	<i>Poilane</i> 26751 (P)	Vietnam, Tonkin	JX506433	JX506601	JX506489
<i>Aganope dinghuensis</i> GB1	<i>Aganope dinghuensis</i> (P.Y. Chen) T.C. Chen & Pedley	GB	<i>SCBGP2931</i>	China, Dinghushan National Nature Reserve	KP092717	x	x

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Aganope dinghuensis</i> GB2	<i>Aganope dinghuensis</i> (P.Y. Chen) T.C. Chen & Pedley	GB	SCBGP2932	China, Dinghushan National Nature Reserve	KP092718	KP093760	x
<i>Aganope gabonica</i>	<i>Aganope gabonica</i> (Baill.) Polhill	GB	Karmann s.n. (L)	Gabon, Franceville	JX506438	JX506605	x
<i>Aganope heptaphylla</i>	<i>Aganope heptaphylla</i> (L.) Polhill	GB	Santisuk 688 (L)	Thailand, Ranong province	JX506432	JX506600	JX506488
<i>Aganope impressa</i>	<i>Aganope impressa</i> (Dunn) Polhill	GB	Dubois s.n. (L)	Democratic Republic of the Congo, Luki	JX506436	JX506604	JX506492
<i>Aganope leucobotrya</i>	<i>Aganope leucobotrya</i> (Dunn) Polhill	GB	Versteegh <i>et. al.</i> 150 (L)	Cote d'Ivoire, Grand Bassam	JX506437	x	x
<i>Aganope riparia</i>	<i>Aganope riparia</i> [Ostryocarpus riparius Hook.f.]	GB	Maesen 7524 (WEG)	Benin, Ouémé,	JX506431	JX506599	JX506487
<i>Aganope stuhlmannii</i>	<i>Aganope stuhlmannii</i> (Taub.) Adema	GB	Versteegh & <i>al.</i> 456 (L)	Ivory Coast, Korhogo	JX506435	JX506603	JX506491
<i>Aganope stuhlmannii</i> GB1	<i>Aganope stuhlmannii</i> (Taub.) Adema	GB	Corby 2162 (K)	x	AF467485	AF142708	x
<i>Aganope stuhlmannii</i> GB2	<i>Aganope stuhlmannii</i> (Taub.) Adema	GB	OM2398	x	x	JX517470	x
<i>Aganope thyrsoflora</i>	<i>Aganope thyrsoflora</i> (Benth.) Polhill	GB	Y. Sirichamorn YSM 2009-22 (L)	Thailand, Songkhla province	x	JX506602	JX506490

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (ITS/matK/trnL-F) and from publication (da Silva et al. (2012))		
					ITS	matK	trnL-F
<i>Airyantha schweinfurthii</i>	<i>Airyantha schweinfurthii</i> (Taub.) Brummitt	GB	D.J.Harris 731 (K)	Central African Republic, Dzanga-Sangha National	EF457704	JX295897	x
<i>Apurimacia boliviana</i>	<i>Apurimacia boliviana</i> (Britton) Lavin	P	M.J. Silva & R.A. Camargo 1085 (UEC)	Brazil, Rio de Janeiro	x	da Silva et al. (2012)	x
<i>Apurimacia boliviana</i>	<i>Apurimacia boliviana</i> (Britton) Lavin	P	J.Hudson 1099 (K)	Peru, Cajamarca	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Apurimacia dolichocarpa</i>	<i>Apurimacia dolichocarpa</i> (Griseb.) Burkart	GB	x	x	x	FJ968527	x
<i>Apurimacia michellii</i>	<i>Apurimacia michellii</i> Harms	P	J.R.I. Wood et al. 18729 (K)	Bolivia, Cochabamba	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Austrosteenisia blackii</i>	<i>Austrosteenisia blackii</i> (F. Muell.) R. Geesink	GB	Australia Pedley 5005 (K)	x	x	x	AF311381
<i>Austrosteenisia blackii</i> GB	<i>Austrosteenisia blackii</i> (F. Muell.) R. Geesink	GB	Pedley 5005 (K)	x	AF467020	AF142707	x
<i>Austrosteenisia blackii</i> GB1	<i>Austrosteenisia blackii</i> (F. Muell.) R. Geesink	GB	x	x	AY124765	x	x
<i>Austrosteenisia stipularis</i>	<i>Austrosteenisia stipularis</i> (C.T. White) Jessup	GB	J. Wells QRS 63279	x	x	x	KC428453
<i>Callerya atropurpurea</i> GB	<i>Callerya atropurpurea</i> (Wall.) A. Schott	GB	Liston 876 (OSC)	Singapore	AF467023	AF142734	x
<i>Callerya atropurpurea</i> GB	<i>Callerya atropurpurea</i> (Wall.) Schott	GB	x	x	x	x	AF124242
<i>Callerya australis</i>	<i>Callerya australis</i> (Endl.) A. Schott	GB	Beesely	x	AF467024	x	x

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Callerya australis</i>	<i>Callerya australis</i> (Endl.) Schot	GB	<i>A Liston s.n.</i> (OSC)	x	x	JQ619953	x
<i>Callerya australis</i>	<i>Callerya australis</i> (Endl.) Schot	GB	x	x	x	x	AF124241
<i>Callerya bonatiana</i>	<i>Callerya bonatiana</i> (Pamp.) Lôt	GB	<i>Liana Mengsong</i> 7591 (HITBC)	China, Yunnan, Mengsong	HG004878	HG005006	x
<i>Callerya cinerea</i> GB1	<i>Callerya cinerea</i> (Benth.) Schot	GB	<i>Hu</i> 1196 (DAV)	China, Yunan	AF467026	x	x
<i>Callerya cinerea</i> GB2	<i>Callerya cinerea</i> (Benth.) Schot	GB	<i>Liana Mengsong</i> 214_9_9	China, Yunnan, Mengsong	HG004819	x	x
<i>Callerya cinerea</i> GB3	<i>Callerya cinerea</i> (Benth.) Schot	GB	<i>PS0309MT01</i>	x	FJ980295	x	x
<i>Callerya cinerea</i> GB4	<i>Callerya cinerea</i> (Benth.) Schot	GB	<i>Sino-British Plant Expedition Team</i> (1985) 0192 (K)	x	GQ246022	x	x
<i>Callerya cinerea</i> GB5	<i>Callerya cinerea</i> (Benth.) Schot	GB	<i>Pi-Chiang Team</i> 257 (KUN)	China, Yunan	AF467025	x	x
<i>Callerya cochinchinensis</i>	<i>Callerya cochinchinensis</i> (Gagnep.) A. Schott	GB	<i>Tang Shaoqing</i> 201152907 (GNU)	China	KF294864	KF294877	x
<i>Callerya cochinchinensis</i> GB1	<i>Callerya cochinchinensis</i> (Gagnep.) A. Schott	GB	<i>S. Tagane, H. Kanemitsu, V.D. Son, H. Tran, X.N. Loi, N.D. Thach, N. Dinh & P.N.H. Hieu</i>	Viet Nam, Mount Hon Ba, Khanh Hoa Province	x	LC080900	x
<i>Callerya dasyphylla</i>	<i>Callerya dasyphylla</i> (Miq.) A. Schott	GB	<i>A. Lamb</i> 395/91 (K)	x	GQ246023	x	x
<i>Callerya dielsiana</i> GB1	<i>Callerya dielsiana</i> (Harms) P.K. Lôt ex Z. Wei & Pedley	GB	SCBGP367_1	China, Dinghushan National Nature Reserve	x	KP093885	x
<i>Callerya dielsiana</i> GB2	<i>Callerya dielsiana</i> (Harms) P.K. Lôt ex Z. Wei & Pedley	GB	<i>Tang Shaoqing</i> 201152902 (GNU)	China	x	KF294878	x

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Callerya eriantha</i>	<i>Callerya eriantha</i> (Benth.) A. Schott	GB	<i>L. Lucas</i> 2694 (K)	x	GQ246026	x	x
<i>Callerya eurybotrya</i>	<i>Callerya eurybotrya</i> (Drake) A. Schott	GB	<i>Tang Shaoqing</i> 201161501 (GNU)	x	x	KF294879	x
<i>Callerya eurybotrya</i>	<i>Callerya eurybotrya</i> (Drake) A. Schott	GB	<i>Tao</i> 578 (KUN)	China, Yunan	AF467027	x	x
<i>Callerya kityana</i> GB	<i>Callerya kityana</i> (Craib) Schott	GB	<i>S. Tagane, H. Nagamasu, A. Naiki, S. Rueangruea, S. Suddee, N. Okabe, W. Keiwbang, J. Hemmarat & W. Supong</i> s.n.	Thailand, Suan Hin Pha Ngam Park, Suan Swan, Loei province	x	LC080902	x
<i>Callerya megasperma</i>	<i>Callerya megasperma</i> (F. Muell.) A. Schott	GB	<i>Liston</i> s.n. (OSC)	x	AF467028	x	x
<i>Callerya megasperma</i> GB	<i>Callerya megasperma</i> (F. Muell.) A. Schott	GB	<i>A. Liston</i> 325	China	x	EU424077	X
<i>Callerya nieuwenhuisii</i> GB1	<i>Callerya nieuwenhuisii</i> (J. J. Smith) A. Schott	GB	<i>Chew</i> 1013 (UC)	Malaysia, Sarawak	AF467030	x	x
<i>Callerya nitida</i>	<i>Callerya nitida</i> (Benth.) R. Geesink	GB	<i>Tang Shaoqing</i> 201160609 (GNU)	x	KF294869	KF294880	x
<i>Callerya oosperma</i>	<i>Callerya oosperma</i> (Dunn) Z. Wei & Pedley	GB	<i>Tang Shaoqing</i> 201161901.3 (GNU)	x	KF294871.1		
<i>Callerya reticulata</i>	<i>Callerya reticulata</i> (Benth.) Schott	GB	<i>Liston</i> 877 (OSC)	x	AF467031	AF142733	AF311380
<i>Callerya scandens</i>	<i>Callerya scandens</i> (Elmer) A. Schott	GB	<i>Ridsdale</i> 416 (UC)	Philippines, Palawan	AF467032	x	x
<i>Callerya speciosa</i>	<i>Callerya speciosa</i> (Champ. ex Benth.) Schott	GB	<i>Yu-Xi Team</i> 1029 (KUN)	China, Yunan	AF467033	x	x

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank ; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Chadsia grevei</i> GB	<i>Chadsia grevei</i> Drake	GB	x	x	AY009141	x	AY009135
<i>Chadsia versicolor</i>	<i>Chadsia versicolor</i> Bojer	GB	<i>Schrire</i> 2530 (K)	Madagascar	AF467037	x	x
<i>Craibia brevicaudata</i>	<i>Craibia brevicaudata</i> (Vatke) Dunn	GB	<i>Polhill & Robertson</i> 5296 (K)	x	AF467039	x	x
<i>Craibia brevicaudata</i>	<i>Craibia brevicaudata</i> (Vatke) Dunn	GB	OM1813	x	x	JX517315	x
<i>Craibia zimmermannii</i>	<i>Craibia zimmermannii</i> (Harms) Harms ex Dunn	GB	OM2230	x	x	JX518072	x
<i>Craspedolobium unijugum</i> GB	<i>Craspedolobium unijugum</i> (Gagnep.) Z. Wei & Pedley	GB	C1421	China	JF976163	JF953574	x
<i>Dahlstedtia araripensis</i>	<i>Dahlstedtia araripensis</i> (Benth.) M.J. Silva & A.M.G. Azevedo	P	<i>M.J. Silva et al.</i> 1202 (UEC)	Brazil, Bahia	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Dahlstedtia bahiana</i>	<i>Dahlstedtia bahiana</i> (A.M.G. Azevedo) M.J. Silva & A.M.G. Azevedo	P	<i>G.P. dos Cavalos</i> 1075 (ALCB)	Brazil, Bahia	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Dahlstedtia calcarata</i>	<i>Dahlstedtia calcarata</i> (F.J. Herm.) M.J. Silva & A.M.G. Azevedo	P	<i>W. Haber & E. Bello</i> 6873 (P)	Costa Rica, Monteverde	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Dahlstedtia castaneifolia</i>	<i>Dahlstedtia castaneifolia</i> (M.J. Silva & A.M.G. Azevedo) M.J. Silva & A.M.G. Azevedo	P	<i>G. Hatschbach</i> 44148 (MBM)	Brazil, Bahia	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Dahlstedtia confertiflora</i>	<i>Dahlstedtia confertiflora</i> (Benth.) M.J. Silva & A.M.G. Azevedo	P	<i>T.D. Pennington et al.</i> 12367 (K)	Peru, San Martin	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Dahlstedtia floribunda</i>	<i>Dahlstedtia floribunda</i> (Vogel) M.J. Silva & A.M.G. Azevedo	P	<i>M.J. Silva</i> 804 (UEC)	Brazil, Sao Paulo	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Dahlstedtia glaziovii</i>	<i>Dahlstedtia glaziovii</i> (Taub.) M.J. Silva & A.M.G. Azevedo	P	M.J. Silva 1077 (UEC)	Brazil, Rio de Janeiro	x	da Silva <i>et al.</i> (2012)	x
<i>Dahlstedtia grandiflora</i>	<i>Dahlstedtia grandiflora</i> (A.M.G. Azevedo) M.J. Silva & A.M.G. Azevedo	P	M.J. Silva 1084 (UEC)	Brazil, Rio de Janeiro	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Dahlstedtia hylobia</i>	<i>Dahlstedtia hylobia</i> (Harms) M.J. Silva & A.M.G. Azevedo	P	Marco Cerna <i>et al.</i> 373 (K)	Peru	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Dahlstedtia pentaphylla</i>	<i>Dahlstedtia pentaphylla</i> (Taub.) Burkart	P	M.J. Silva 946 (UEC)	Brazil, São. Paulo	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Dahlstedtia pinnata</i>	<i>Dahlstedtia pinnata</i> (Benth.) Malme	P	M.J. Silva 829 (UEC)	Brazil, Rio de Janeiro	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Dahlstedtia pinnata</i> GB	<i>Dahlstedtia pinnata</i> (Benth.) Malme	GB	H. C. de Lima 4-1 (RB)	Brazil	AF467042	x	x
<i>Dalbergia lanceolata</i>	<i>Dalbergia lanceolata</i> L.f.	GB	Y. Sirichamorn YSM 2009-02 (L)	Thailand: Phrae province	x	x	JX506541
<i>Dalbergia sissoo</i>	<i>Dalbergia sissoo</i> Roxb. ex DC.	GB	J.R. Abbott 23669 (FLAS)	x	x	GU135125	x
<i>Dalbergia sissoo</i>	<i>Dalbergia sissoo</i> Roxb. ex DC.	GB	J.P. Lemos Filho s.n.	Brazil, Bahia	EF451079	x	x
<i>Dalbergiella nyasae</i> GB 2	<i>Dalbergiella nyasae</i> Baker.f.	GB	x	x	AF534801	x	x
<i>Dalbergiella nyasae</i> GB1	<i>Dalbergiella nyasae</i> Baker.f.	GB	x	x	AF521795	x	X
<i>Dalbergiella nyasae</i>	<i>Dalbergiella nyasae</i> Baker.f.	GB	Muller 2686	x	x	AF142706	x
<i>Deguelia amazonica</i>	<i>Deguelia amazonica</i> Killip	P	H.S. Irwin <i>et al.</i> 55486 (FHO)	Brazil, Amazonas	x	da Silva <i>et al.</i> (2012)	X
<i>Deguelia angulata</i>	<i>Deguelia angulata</i> (Ducke) A.M.G. Azevedo	P	G.T. Prance <i>et al.</i> 5903 (P)	Brazil, Rondônia	x	x	da Silva <i>et al.</i> (2012)
<i>Deguelia costata</i>	<i>Deguelia costata</i> (Benth.) A.M.G. Azevedo	P	P.H. Melo <i>et al.</i> 548 (HBCB)	Brazil, Minas Gerais	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Deguelia dasycalyx</i>	<i>Deguelia dasycalyx</i> (Harms) A.M.G. Azevedo & R.A. Camargo	P	<i>R.M. Harley</i> 21253 (CEPEC)	Brazil, Bahia	x	x	da Silva <i>et al.</i> (2012)
<i>Deguelia densiflora</i>	<i>Deguelia densiflora</i> (Benth.) A.M.G. Azevedo	P	<i>E.S. Silva & J. Lima</i> R5815 (K)	Brazil, Amazonas	x	da Silva <i>et al.</i> (2012)	x
<i>Deguelia densiflora</i> GB2	<i>Deguelia densiflora</i> (Benth.) A.M.G. Azevedo ex Sousa	GB	<i>E.Guizar</i> 5187	Mexico, Hidalgo	KJ411650	x	x
<i>Deguelia hatschbachii</i>	<i>Deguelia hatschbachii</i> A.M.G. Azevedo	P	<i>M.J. Silva</i> 1286 (UEC)	Brazil, Rio de Janeiro	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Deguelia longeracemosa</i>	<i>Deguelia longeracemosa</i> (Benth.) A.M.G. Azevedo	P	<i>M.J. Silva</i> 1285 (UEC)	Brazil, Minas Gerais	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Deguelia martynii</i>	<i>Deguelia martynii</i> (A.C. Smith) A.M.G. Azevedo	P	<i>J.A. Ratter et al.</i> 6193 (K)	Brazil, Roraima	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Deguelia negrensis</i>	<i>Deguelia negrensis</i> (Benth.) Taub.	P	<i>C.A. Cid. & al.</i> 1424 (INPA)	Brazil, Pará	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Deguelia negrensis</i> GB2	<i>Deguelia negrensis</i> (Benth.) Taub.	GB	<i>Sastre C. & F.</i> 152 (L)	Brazil	x	JX506607	x
<i>Deguelia nitidula</i>	<i>Deguelia nitidula</i> (Benth.) A.M.G. Azevedo	P	<i>M.J. Silva</i> 1230 (UEC)	Brazil, São Paulo	x	da Silva <i>et al.</i> (2012)	x
<i>Deguelia picta</i>	<i>Deguelia picta</i> (Pittier) A.M.G. Azevedo	P	<i>Cárdenas & M. Peña</i> 3597 (VEN)	Venezuela, Ezequiel Zamora	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Deguelia pictus</i>	<i>Deguelia pictus</i> (Pittier) A.M.G. Azevedo	GB	<i>P. Tenorio</i> 20102	Mexico, Puebla	KJ411651	x	x
<i>Deguelia rariflora</i>	<i>Deguelia rariflora</i> (Benth.) A.M.G. Azevedo	P	<i>J. Lowe</i> 4283(FHO)	Brazil, Pará	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Deguelia rufescens</i>	<i>Deguelia rufescens</i> (Benth.) A.M.G. Azevedo	P	<i>G.T. Prance & al.</i> 15573 (NY)	Brazil, Amazonas	x	x	da Silva <i>et al.</i> (2012)

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Deguelia scandens</i>	<i>Deguelia scandens</i> Aubl.	P	<i>G.T. Prance et al.</i> 10187 (K)	Brazil, Roraima	x	da Silva <i>et al.</i> (2012)	x
<i>Deguelia spruceana</i>	<i>Deguelia spruceana</i> (Benth.) A.M.G. Azevedo	P	<i>L.R. Marinho & A. Camarão</i> 1282 (INPA)	Brazil, Pará	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Deguelia utilis</i>	<i>Deguelia utilis</i> (A.C.Sm.) A.M.G. Azevedo	P	<i>M.J. Silva</i> 1001 (UEC)	Brazil, Rio de Janeiro	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Deguelia dasycalyx</i>	<i>Deguelia dasycalyx</i> (Harms) A.M.G. Azevedo & R.A. Camargo	GB	<i>Queiroz</i> 14503 (HUEFS)	x	x	KC779548	x
<i>Derris alborubra</i>	<i>Derris alborubra</i> Hemsl.	GB	<i>Y. Sirichamorn</i> YSM 2009-14 (L)	Thailand, Nakhon Nayok province	JX506466	JX506638	JX506524
<i>Derris amoena</i> GB1	<i>Derris amoena</i> (Wall.) Benth.	GB	<i>J.F. Maxwell</i> 8311 (L)	Singapore	JX506458	JX506630	JX506516
<i>Derris amoena</i> GB2	<i>Derris amoena</i> (Wall.) Benth.	GB	<i>A.F.G. Kerr</i> 13700 (L)	Thailand, Satun province	JX506457	JX506629	JX506515
<i>Derris amoena</i> GB3	<i>Derris amoena</i> (Wall.) Benth.	GB	<i>Y. Sirichamorn</i> YSM 2009-20 (L)	Thailand: Surat Thani province	JX506456	JX506628	JX506514
<i>Derris caudatilimba</i>	<i>Derris caudatilimba</i> F.C. How	GB	<i>Hu</i> 1156 (DAV)	China, Yunnan	AF467045	x	x
<i>Derris cumingii</i>	<i>Derris cumingii</i> Benth.	GB	<i>Gaerlan et al.</i> PPI 10368 (L)	Philippines, Luzon	x	JX506618	JX506505
<i>Derris cuneifolia</i>	<i>Derris cuneifolia</i> Benth. [syn. <i>Derris hancei</i>]	GB	<i>Lei</i> 612 (L)	China: Hainan	JX506478	JX506649	JX506535
<i>Derris cuneifolia</i> GB1	<i>Derris cuneifolia</i> Benth. [syn. <i>Derris hancei</i>]	GB	<i>SCBGP521_1</i>	China, Dinghushan National Nature Reserve	KP092716	x	x

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (ITS/matK/trnL-F) and from publication (da Silva <i>et al.</i> (2012))		
					ITS	matK	trnL-F
<i>Derris elegans</i> var. <i>elegans</i>	<i>Derris elegans</i> Graham ex Benth. in Miq. var. <i>elegans</i>	GB	<i>K. Larsen & S. KL. Larsen</i> 32828 (L)	Thailand, Naratiwat province	JX506469	JX506641	x
<i>Derris elliptica</i>	<i>Derris elliptica</i> (Wall.) Adema	GB	x	USA, Michigan State University, cultivated	AF467486	x	x
<i>Derris elliptica</i>	<i>Derris elliptica</i> (Wall.) Adema	GB	<i>Y. Sirichamorn</i> YSM 2009-19 (L)	Thailand, Surat Thani province	x	JX506646	JX506532
<i>Derris elliptica</i>	<i>Derris elliptica</i> (Wall.) Adema	GB	<i>Y. Sirichamorn</i> YSM 2012-01 (SLR)	Thailand, Bangkok (cultivated)	x	x	JX506533
<i>Derris elliptica</i>	<i>Derris elliptica</i> (Wall.) Adema	GB	<i>Kostermans</i> 260 (L)	Thailand, Kanchanaburi province	x	x	JX506534
<i>Derris eriocarpa</i>	<i>Derris eriocarpa</i> F.C. How	GB	<i>Wang Hong</i> 7673 (QSBG)	China, Yunnan	x	JX506625	x
<i>Derris ferruginea</i>	<i>Derris ferruginea</i> Benth.	GB	<i>Y. Sirichamorn</i> YSM 2009-13 (L)	Thailand, Udon Thani province	x	JX506633	JX506519
<i>Derris fordii</i>	<i>Derris fordii</i> Oliv.	P	<i>J.F. Maxwell</i> 96-752 (CAS)	China, Hainan	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Derris glabra</i>	<i>Derris glabra</i> Sirich.	GB	<i>Y. Sirichamorn</i> YSM 2009-23 (L)	Thailand, Songkhla province	JX506463	JX506635	JX506521
<i>Derris laotica</i>	<i>Derris laotica</i> Gagnep.	GB	<i>Magnen et. al.</i> s.n. (P)	Cambodia	JX506473	JX506645	JX506531
<i>Derris laxiflora</i>	<i>Derris laxiflora</i> Benth.	GB	<i>Hu</i> 1081 (DAV)	Taiwan	AF467046	AF142715	x
<i>Derris lianoides</i>	<i>Derris lianoides lianoides</i> Elmer	GB	<i>Ridsdale</i> SMHI 1863 (L)	Philippines, Palawan	JX506482	JX506653	JX506539
<i>Derris lianoides</i> GB2	<i>Derris lianoides lianoides</i> Elmer	GB	<i>Tuba tualang</i> s.n.	x	KJ579433	x	x

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Derris luzoniensis</i>	<i>Derris luzoniensis</i> Adema	GB	<i>Baquiran et al.</i> ISU564 (L)	Philippines, Luzon	JX506483	JX506654	JX506540
<i>Derris marginata</i>	<i>Derris marginata</i> (Roxb.) Benth.	GB	<i>Pierre s.n.</i> (L)	India	x	JX506643	JX506529
<i>Derris montana</i>	<i>Derris montana</i> Benth.	GB	<i>Y. Sirichamorn</i> YSM 2009-21 (L)	Thailand, Songkhla province	JX506479	JX506650	JX506536
<i>Derris monticola</i>	<i>Derris monticola</i> Prain	GB	<i>A.F.G. Kerr</i> 1731 (L)	Thailand, Chiang Mai province	JX506465	JX506637	JX506523
<i>Derris oblongifolia</i>	<i>Derris oblongifolia</i> Merr.	GB	<i>Sulit PNH</i> 21618 (L)	Philippines, Biliran island	JX506481	JX506652	JX506538
<i>Derris piscatoria</i>	<i>Derris piscatoria</i> (Blanco) Sirich.	GB	<i>Sulit PNH</i> 14411 (L)	Philippines, Samar	JX506480	JX506651	JX506537
<i>Derris pseudomarginata</i>	<i>Derris pseudomarginata</i> Sirich.	GB	<i>J.F. Maxwell</i> 76-31 (L)	Thailand, Chon Buri	x	JX506639	JX506525
<i>Derris pubipetala</i>	<i>Derris pubipetala</i> Miq.	GB	<i>J.F. Maxwell</i> 85-370 (L)	Thailand, Pattani province	JX506462	JX506634	JX506520
<i>Derris reticulata</i>	<i>Derris reticulata</i> Craib	GB	<i>Y. Sirichamorn</i> YSM 2009-18 (L)	Thailand, Nakhon Ratchasima province	JX506460	x	JX506518
<i>Derris reticulata</i>	<i>Derris reticulata</i> Craib	GB	<i>Phadungcharoen</i> D002-2006	Thailand, Bangkok	x	AB504375	x
<i>Derris rubrocalyx</i>	<i>Derris rubrocalyx</i> Verdc.	GB	<i>Davis</i> 567 (L)	Indonesia, Irian Jaya	JX506472	JX506644	JX506530
<i>Derris spanogheana</i>	<i>Derris spanogheana</i> Blume ex Miq.	GB	<i>De Vogel</i> 5788 (L)	Indonesia, Sulawesi	JX506464	x	JX506522

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Derris tonkinensis</i>	<i>Derris tonkinensis</i> Gagnep.	GB	<i>Y. Sirichamorn</i> YSM 2009-11 (L)	Thailand, Lampang province	JX506459	JX506631	JX506517
<i>Derris trifoliata</i>	<i>Derris trifoliata</i> Lour.	P	<i>J.H. Beamam et al</i> 9730 (CAS)	Malasia, Borneo	x	x	da Silva <i>et al.</i> (2012)
<i>Derris trifoliata</i> GB	<i>Derris trifoliata</i> Lour.	GB	<i>Y. Sirichamorn</i> YSM 2009-06 (L)	Thailand, Samut Prakan province	JX506470	JX506642	JX506528
<i>Disynstemon paullinioides</i>	<i>Disynstemon paullinioides</i> (Baker) M. Peltier	GB	<i>Phillipson</i> 3077 K)	Madagascar, Toliara	EU729484	GU951670.2	x
<i>Fordia cauliflora</i>	<i>Fordia cauliflora</i> Hemsl.	GB	<i>PS0230MT01</i>	x	GQ434352	HM049511.2	x
<i>Fordia splendidissima</i>	<i>Fordia splendidissima</i> (Blume ex Miq.) Buijsen	GB	<i>Tangah</i> s.n.	Malaysia, Sabah	AF467048	AF142718	x
<i>Hesperothamnus pentaphyllus</i>	<i>Hesperothamnus pentaphyllus</i> (Harms) Harms	P	<i>R. Torres & M.L. Torres</i> 692 (K)	Mexico, Oaxaca	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Kunstleria ridleyi</i> Prain	<i>Kunstleria ridleyi</i> Prain	GB	<i>Ambriansyah et. al.</i> 951 (L)	Indonesia, Berau	x	JX506598	JX506486
<i>Leptoderris brachyptera</i>	<i>Leptoderris brachyptera</i> (Benth.) Dunn	GB	<i>Berolinense</i> 403 (L)	Cameroon, Limbe	JX506444	JX506611	x
<i>Leptoderris brachyptera</i>	<i>Leptoderris brachyptera</i> (Benth.) Dunn	GB	<i>Herbarium Berolinense</i> 403 (L)	Cameroon, Limbe	x	x	JX506498
<i>Leptoderris fasciculata</i>	<i>Leptoderris fasciculata</i> (Benth.) Dunn	GB	<i>Serg.Romyn</i> s.n. (L)	Cameroon, Lolodorf	JX506442	JX506609	JX506496
<i>Leptoderris hypargyrea</i>	<i>Leptoderris hypargyrea</i> Dunn	GB	<i>Zenker</i> 3645 (L)	Cameroon, Bipinde	JX506443	JX506610	JX506497
<i>Lonchocarpus agyrotrichus</i>	<i>Lonchocarpus agyrotrichus</i> Harms	P	<i>M. Sousa</i> 13270 (MEXU)	Mexico, Xicatlacotla	x	da Silva <i>et al.</i> (2012)	x

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Lonchocarpus andrieuxii</i>	<i>Lonchocarpus andrieuxii</i> M. Sousa	P	M. Sousa & G. Andrade 13269 (UEC)	Mexico, Puebla	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus atropurpureus</i>	<i>Lonchocarpus atropurpureus</i> Benth.	P	William A. Haber & E. Bello 60 (MO)	Costa Rica, Puntarenas	x	da Silva <i>et al.</i> (2012)	x
<i>Lonchocarpus benthamianus</i>	<i>Lonchocarpus benthamianus</i> Pittier	P	S.R. Hill 25805 (NY)	Republica, Dominicana, Saint Joseph Parish	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus castilloi</i>	<i>Lonchocarpus castilloi</i> Stand	P	D.J. Macqueen 470 (FHO)	Mexico	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus caudatus</i>	<i>Lonchocarpus caudatus</i> Pittier	P	M.J. German 177 (UEC)	Mexico	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus chiangii</i>	<i>Lonchocarpus chiangii</i> M. Sousa	P	A.H. Willian & E. Bello 1626 (UEC)	Costa Rica, Puntarenas	x	da Silva <i>et al.</i> (2012)	x
<i>Lonchocarpus chiricanus</i>	<i>Lonchocarpus chiricanus</i> Pittier	P	J. Aranda <i>et al.</i> 2263 (NY)	Panama, Prov. Veraguas	x	da Silva <i>et al.</i> (2012)	x
<i>Lonchocarpus comitensis</i>	<i>Lonchocarpus comitensis</i> Pittier	P	C.E. Hughes 418 (FHO)	Honduras, La Cruz	x	da Silva <i>et al.</i> (2012)	x
<i>Lonchocarpus cruentus</i>	<i>Lonchocarpus cruentus</i> Lundell	P	E. Martinez S.16519 (UEC)	Mexico, Oaxaca	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus cultratus</i>	<i>Lonchocarpus cultratus</i> H.C. Lima & A.M.G. Azevedo	P	M.J. Silva 980 (UEC)	Brazil, Espirito Santo	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus dipteroneurus</i>	<i>Lonchocarpus dipteroneurus</i> Pittier	P	H. Pittier 12447 (US)	Venezuela	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus emarginatus</i>	<i>Lonchocarpus emarginatus</i> Pittier	P	I. Trejo <i>et al.</i> 2715 (UEC)	Mexico, Baja	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)

Appendix 2.1 Continued.

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					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Lonchocarpus epigaeus</i>	<i>Lonchocarpus epigaeus</i> M. Sousa	P	<i>F. Medrano et al.</i> 6114 (UEC)	Mexico, Guerrero	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus eriocarinalis</i>	<i>Lonchocarpus eriocarinalis</i> Micheli	P	<i>Rogers Mcvaugh</i> 20812 (NY)	Mexico, Jalisco	x	da Silva <i>et al.</i> (2012)	x
<i>Lonchocarpus eriophyllus</i>	<i>Lonchocarpus eriophyllus</i> Benth.	P	<i>C.S. Nunez & E.M. Martinez</i> 3965 (CAS)	Mexico, Guerrero	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus ferrugineus</i>	<i>Lonchocarpus ferrugineus</i> M. Sousa	P	<i>N. Zamora et al.</i> 2538 (NY)	Costa Rica, Alajuela	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus guatemalensis</i>	<i>Lonchocarpus guatemalensis</i> Benth.	P	<i>E. Martinez S. & M.A. Soto</i> 24226 (MBM)	Mexico, Chiapas	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus hedyosmus</i>	<i>Lonchocarpus hedyosmus</i> Miq.	P	<i>Rusby</i> 1329 (BM)	Bolivia, La Paz	x	da Silva <i>et al.</i> (2012)	x
<i>Lonchocarpus hermanii</i>	<i>Lonchocarpus hermanii</i> M. Sousa	P	<i>T.R. van Devender et al.</i> 97-561 (CAS)	Mexico, Sonora	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus hidalgensis</i>	<i>Lonchocarpus hidalgensis</i> Lundell	P	<i>P. Tenorio L.</i> 19188 (UEC)	Mexico, San Luis Potosi	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus hintonii</i>	<i>Lonchocarpus hintonii</i> Sandwith	P	<i>R. Mcvaugh</i> 20867 (FHO)	Mexico, Jalisco	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus hondurensis</i>	<i>Lonchocarpus hondurensis</i> Benth.	P	<i>F. Ponce</i> 168 (UEC)	Mexico, Rio Tonala	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus huetamoensis</i>	<i>Lonchocarpus huetamoensis</i> M. Sousa & J.C. Soto	P	<i>P. Tenório et al.</i> 19169 (UEC)	Mexico, Michoacan	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus hughesii</i>	<i>Lonchocarpus hughesii</i> M. Sousa	P	<i>C.E. Hughes</i> 1442 (FHO)	Ecuador, Gualaquiza	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)

Appendix 2.1 Continued.

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					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Lonchocarpus imatacensis</i>	<i>Lonchocarpus imatacensis</i> Poppendieck	P	<i>D. Amacuro & C. Blanco</i> 146 (NY)	Venezuela	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus lanceolatus</i>	<i>Lonchocarpus lanceolatus</i> Benth.	P	<i>M. Elorsa</i> C.2209 (NY)	Mexico, Oaxaca	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus lasiotropis</i>	<i>Lonchocarpus lasiotropis</i> F.J. Herm.	P	<i>A. Mendez</i> 6226 (G)	Mexico, Chiapas	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus latifolius</i>	<i>Lonchocarpus latifolius</i> Kunth	P	<i>F.J. Breteler</i> 5156 (MBM)	Venezuela, Monagas	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus lineatus</i>	<i>Lonchocarpus lineatus</i> Pittier	P	<i>I. Cazada</i> 185 (UEC)	Mexico, Oaxaca	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus longipedunculatus</i>	<i>Lonchocarpus longipedunculatus</i> Pittier	P	<i>J.C. Soto Nuñez & S Zárate</i> 1304 (NY)	Mexico, Michoacan	x	da Silva <i>et al.</i> (2012)	x
<i>Lonchocarpus longipedunculatus</i>	<i>Lonchocarpus longipedunculatus</i> Pittier	P	<i>T.S. dos Santos</i> 357 (RB)	Brazil, Bahia	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus longistylus</i>	<i>Lonchocarpus longistylus</i> Pittier	P	<i>Gamerson</i> 23441 (B)	Mexico, Yucatan	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus luteomaculatus</i>	<i>Lonchocarpus luteomaculatus</i> Pittier	P	<i>D. Decana-Nava</i> 86149 (UEC)	Mexico, Michoacan	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus margaritensis</i>	<i>Lonchocarpus margaritensis</i> Pittier	P	<i>I.S. Miranda</i> 563 (IAN)	Brazil, Roraima	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus minimiflorus</i>	<i>Lonchocarpus minimiflorus</i> Donn. Sm	P	<i>M.H. Grayum</i> 12170 (BM)	Costa Rica, Ganacaste	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus molinae</i>	<i>Lonchocarpus molinae</i> Stand	P	<i>F. Morazán & A. Ferrera</i> B. 194 (NY)	Honduras	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus monofoliaris</i>	<i>Lonchocarpus monofoliaris</i> Schery	P	<i>S.A. Cascante et al.</i> 257 (K)	Costa Rica, Limon	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus muehlbergianus</i>	<i>Lonchocarpus muehlbergianus</i> Hass	P	<i>M.J. Silva</i> 959 (UEC)	Brazil, Sao Paulo	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)

Appendix 2.1 Continued.

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					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Lonchocarpus mutans</i>	<i>Lonchocarpus mutans</i> M. Sousa	P	<i>J.M. Aguilar et al.</i> 184 (NY)	Mexico, Sinaloa	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus neurophyllus</i>	<i>Lonchocarpus neurophyllus</i> Urb.	P	<i>R. Garcia & N. Ramirez</i> s.n. (B)	Republica Dominicana, Isla Saona	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus nitidus</i>	<i>Lonchocarpus nitidus</i> (Vogel) Benth.	P	<i>M.J. Silva & R. Camargo</i> 910 (UEC)	Brazil, Rio Grande do Sul	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus nudiflorens</i>	<i>Lonchocarpus nudiflorens</i> Burkart	P	<i>S.M. Faria & A. Pott</i> 955 (RB)	Brazil, Mato Grosso	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus oaxacensis</i>	<i>Lonchocarpus oaxacensis</i> Pittier	P	<i>M. Sousa et al.</i> 9370 (NY)	Mexico, Oaxaca	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus obovatus</i>	<i>Lonchocarpus obovatus</i> Benth.	P	<i>C.E. Hughes</i> 1811 (FHO)	Mexico, Oaxaca	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus oliganthus</i>	<i>Lonchocarpus oliganthus</i> F.J. Herm.	P	<i>R. Foster</i> 2333 (MICH)	Panama, Colon province	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus orotinus</i>	<i>Lonchocarpus orotinus</i> Pittier	P	<i>P. Tenorio L. et al.</i> 3435 (FHO)	Mexico, Oaxaca	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus peninsularis</i>	<i>Lonchocarpus peninsularis</i> (Donn. Sm.) Pittier	P	<i>A.K. Monro et al.</i> 3403 (BM)	El Salvador, La Libertad	x	da Silva <i>et al.</i> (2012)	x
<i>Lonchocarpus phaseolifolius</i>	<i>Lonchocarpus phaseolifolius</i> Benth.	P	<i>D.E. Breedlove</i> 20927 (NY)	Mexico, Chiapas	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus pilosus</i>	<i>Lonchocarpus pilosus</i> M. Sousa	P	<i>W.D. Stevens</i> 23155 (NY)	Nicaragua, Chontales	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus Pittieri</i>	<i>Lonchocarpus Pittieri</i> M. Sousa	P	<i>Magallanes & Lott</i> 3321 (UEC)	Mexico, Michoacan	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)

Appendix 2.1 Continued.

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					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Lonchocarpus pluvialis</i>	<i>Lonchocarpus pluvialis</i> Rusby	P	<i>R.R. Silva & J.S. Velasquez</i> 1312 (UEC)	Brazil, Mato Grosso do Sul	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus punctatus</i>	<i>Lonchocarpus punctatus</i> Kunth	P	<i>G. Davidse</i> 5016 (MO)	Venezuela, Anzoategui	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus purpureus</i>	<i>Lonchocarpus purpureus</i> Pittier	P	<i>R.V. Vilacorta</i> 863 (B)	El Salvador, Dpto. Ahuachapan	x	da Silva <i>et al.</i> (2012)	x
<i>Lonchocarpus pycnophyllus</i>	<i>Lonchocarpus pycnophyllus</i> Urb.	P	<i>W. Greuter & R. Ranki</i> 24974 (B)	Republica Dominicana	x	da Silva <i>et al.</i> (2012)	x
<i>Lonchocarpus retiferus</i>	<i>Lonchocarpus retiferus</i> Stand	P	<i>J.L. Linares</i> 5514 (K)	Honduras, El Paraiso	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus riparius</i>	<i>Lonchocarpus riparius</i> M. Sousa	P	<i>M. Nee</i> 48416 (K)	Bolivia, Santa Cruz	x	da Silva <i>et al.</i> (2012)	x
<i>Lonchocarpus robustus</i>	<i>Lonchocarpus robustus</i> Pittier	P	<i>R.C. Trigos</i> 2904 (K)	Mexico, Vera Cruz	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus rugosus</i> ssp. <i>apricus</i>	<i>Lonchocarpus rugosus</i> ssp. <i>apricus</i> (Lindell) M. Sousa	P	<i>K. Monro et al.</i> 3435 (B)	San Salvador	x	da Silva <i>et al.</i> (2012)	x
<i>Lonchocarpus salvadorensis</i>	<i>Lonchocarpus salvadorensis</i> Pittier	P	<i>C.E. Hughes et al.</i> 1218 (FHO)	Mexico, Chiapas	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus sanctuarii</i>	<i>Lonchocarpus sanctuarii</i> Stand	P	<i>L.O. Williams et al.</i> 25262 (CAS)	Guatemala, Solola	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus santarosanus</i>	<i>Lonchocarpus santarosanus</i> Donn. Sm.	P	<i>R.C. Trigos</i> 3436 (UEC)	Mexico, Vera Cruz	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus schiedeana</i>	<i>Lonchocarpus schiedeana</i> Harms.	P	<i>E. Martinez</i> 19258 (UEC)	Mexico, Chiapas	x	da Silva <i>et al.</i> (2012)	x
<i>Lonchocarpus sericeus</i>	<i>Lonchocarpus sericeus</i> (Poir.) Kunth ex DC.	GB	<i>Fuerte</i> s.n.	Dominican Republic, Barahona	x	da Silva <i>et al.</i> (2012)	x

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (ITS/matK/trnL-F) and from publication (da Silva et al. (2012))		
					ITS	matK	trnL-F
<i>Lonchocarpus sericeus</i>	<i>Lonchocarpus sericeus</i> (Poir.) Kunth ex DC.	P	M.J. Silva 1082 (UEC)	Brazil, Espirito Santo	x	da Silva et al. (2012)	x
<i>Lonchocarpus spectabilis</i>	<i>Lonchocarpus spectabilis</i> F.J. Herm.	P	M. Sousa & J.C. Soto 13277 (FHO)	Mexico, Guerrero	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Lonchocarpus spiciflorus</i>	<i>Lonchocarpus spiciflorus</i> Mart. ex Benth.	P	G.T. Prance et al. 24651 (NY)	Peru, Loreto	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Lonchocarpus torrensis</i>	<i>Lonchocarpus torrensis</i> N. Mattos	P	M.J. Silva & R. Camargo 965 (UEC)	Brazil, Rio Grande do Sul	x	da Silva et al. (2012)	x
<i>Lonchocarpus trifolius</i>	<i>Lonchocarpus trifolius</i> Standl	P	J.J. Hellim & C.E. Hughes 5 (FHO)	Honduras	X	da Silva et al. (2012)	da Silva et al. (2012)
<i>Lonchocarpus unifoliolatus</i>	<i>Lonchocarpus unifoliolatus</i> Benth.	P	G.I. Manriquez et al. 2515 (NY)	Mexico, Veracruz	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Lonchocarpus variabilis</i>	<i>Lonchocarpus variabilis</i> R.R. Silva & A.M.G. Azevedo	P	R.R. Silva & M.V. da Silva 1190 (UEC)	Brazil, Mato Grosso do Sul	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Lonchocarpus xull</i>	<i>Lonchocarpus xull</i> Lundell	P	E. Cabrera et al. 11345 (CAS)	Mexico, Yucatan	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Lonchocarpus yoroensis</i>	<i>Lonchocarpus yoroensis</i> Standl	P	Stevens & Krukoff 9143 (US)	Nicaragua	x	da Silva et al. (2012)	x
<i>Lonchocarpus yucatanensis</i>	<i>Lonchocarpus yucatanensis</i> Pittier	P	E. Madrid et al. 498 (BM)	Mexico, Campeche	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Lonchocarpus acuminatus</i>	<i>Lonchocarpus acuminatus</i> (Schlecht.) M. Sousa	P	M. Sousa 3324 (MICH)	Mexico, Vera Cruz	x	x	da Silva et al. (2012)
<i>Lonchocarpus brachyanthus</i>	<i>Lonchocarpus brachyanthus</i> M. Sousa	GB	R.Torres C.16840	Mexico, Michoacan	KJ411656	x	x
<i>Lonchocarpus costaricensis</i>	<i>Lonchocarpus costaricensis</i> (J.D. Smith) Pittier	P	J. S.nchez 534 (K)	Costa Rica	x	x	da Silva et al. (2012)
<i>Lonchocarpus crassispermus</i>	<i>Lonchocarpus crassispermus</i> Poppend.	P	C. Blanco 382 (MO)	Venezuela, Bolivar	x	x	da Silva et al. (2012)

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Lonchocarpus emarginatus</i> GB	<i>Lonchocarpus emarginatus</i> Pittier	GB	Hughes 1344 (FHO)	Mexico, Oaxaca	AF467052	x	x
<i>Lonchocarpus felipei</i>	<i>Lonchocarpus felipei</i> N. Zamora	GB	BioBot00084	Costa Rica, Area de Conservacion Guanacaste, Sector Santa Rosa, Bosque San Emilio	X	JQ587701	x
<i>Lonchocarpus glaucifolius</i>	<i>Lonchocarpus glaucifolius</i> Urb.	GB	<i>F. Axelrod et al.</i> 205	Puerto Rico	KJ411667	x	x
<i>Lonchocarpus grazioui</i>	<i>Lonchocarpus grazioui</i>	P	<i>M.J. Silva</i> 1077 (UEC)	Brazil, Rio de Janeiro	x	x	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus heptaphyllus</i>	<i>Lonchocarpus heptaphyllus</i> (Poir.) DC.	GB	<i>N. Swensen</i> 261	Puerto Rico	x	HM446705	x
<i>Lonchocarpus hidalgensis</i> GB	<i>Lonchocarpus hidalgensis</i> Lundell	GB	Hughes 1598 (FHO)	Mexico, Queretaro	AF467053	x	x
<i>Lonchocarpus isthmensis</i>	<i>Lonchocarpus isthmensis</i> M. Sousa	P	x		x	x	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus kerberi</i>	<i>Lonchocarpus kerberi</i> Harms	GB	<i>E. Martinez & R. Medina</i> 41616	Mexico, Michoacan	KJ411676	x	x
<i>Lonchocarpus longipedicellatus</i>	<i>Lonchocarpus longipedicellatus</i> Pittier	GB	<i>E. Martinez</i> 40606	Mexico, Guerrero	KJ411678	x	x
<i>Lonchocarpus longipes</i>	<i>Lonchocarpus longipes</i> Urb & Ekm.	P	<i>E.L. Ekman</i> 139183-72		x	x	da Silva <i>et al.</i> (2012)
<i>Lonchocarpus longistylus</i>	<i>Lonchocarpus longistylus</i> Pittier	GB	<i>E. Martinez</i> 31964	Mexico, Campeche	KJ411680	x	x
<i>Lonchocarpus longiuguiculatus</i>	<i>Lonchocarpus longiuguiculatus</i>	P	<i>T.S. dos Santos</i> 357 (RB)	Brazil, Bahia	x	x	da Silva <i>et al.</i> (2012)

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (ITS/matK/trnL-F) and from publication (da Silva et al. (2012))		
					ITS	matK	trnL-F
<i>Lonchocarpus macrocarpus</i>	<i>Lonchocarpus macrocarpus</i> Benth.	P	D.J. Macqueen 585 (FHO)	Costa Rica, Ganacaste	x	x	da Silva et al. (2012)
<i>Lonchocarpus major</i>	<i>Lonchocarpus major</i> M. Sousa	GB	A. Delgado Salinas 2716	Mexico, Michoacan	KJ411682	x	x
<i>Lonchocarpus menezoi</i>	<i>Lonchocarpus menezoi</i>	P	x	x	x	x	da Silva et al. (2012)
<i>Lonchocarpus michelianus</i>	<i>Lonchocarpus michelianus</i> Pittier	P	M. Sousa & L. Rico 1020 (CTES)	Mexico, Oaxaca	x	x	da Silva et al. (2012)
<i>Lonchocarpus michoacanicus</i>	<i>Lonchocarpus michoacanicus</i> M. Sousa	GB	J.C. Soto 15608	Mexico, Michoacan	KJ411684	x	x
<i>Lonchocarpus montevidis</i>	<i>Lonchocarpus montevidis</i> M. Sousa	GB	W. Haber 770	Costa Rica	KJ411686	x	x
<i>Lonchocarpus neei</i>	<i>Lonchocarpus neei</i> M. Sousa	P	G. Israel & C. Vargas 5083 (NY)	Bolivia, Santa Cruz	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Lonchocarpus parviflorus</i>	<i>Lonchocarpus parviflorus</i> Benth.	GB	BioBot00769	Costa Rica, Area de Conservacion Guanacaste, Sector Santa Rosa, Camino A Playa Naranjo	x	JQ587735	x
<i>Lonchocarpus phrebophyllus</i>	<i>Lonchocarpus phrebophyllus</i> Standl. & Steyerem.	P	N. Zamora 2293 (K)	Costa Rica	x	x	da Silva et al. (2012)
<i>Lonchocarpus pycnophyllus</i>	<i>Lonchocarpus pycnophyllus/pycnophyllus</i>	P	W. Greuter & R. Ranki 24974 (B)	Republica Dominicana	x	x	da Silva et al. (2012)

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (ITS/matK/trnL-F) and from publication (da Silva et al. (2012))		
					ITS	matK	trnL-F
<i>Lonchocarpus rugosus</i>	<i>Lonchocarpus rugosus</i> ssp. <i>apiscus</i> (Lindell) M. Sousa	P	<i>E. Martinez et al.</i> 30230 (B)	Mexico, Campeche	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Lonchocarpus santarosanus</i> GB	<i>Lonchocarpus santarosanus</i> Donn. Sm.	GB	<i>Cabrera</i> 1964 (L)	Mexico, Chiapas	x	JX506613	x
<i>Lonchocarpus schubertiae</i>	<i>Lonchocarpus schubertiae</i> M. Sousa	P	<i>M. Sousa & J.C. Soto</i> 13230 (NY)	México, Guerrero	x	x	da Silva et al. (2012)
<i>Lonchocarpus shiedianus</i>	<i>Lonchocarpus shiedianus</i>	P	<i>E. Martinez</i> 19258 (UEC)	Mexico, Chiapas	x	X	da Silva et al. (2012)
<i>Lonchocarpus torrensis</i>	<i>Lonchocarpus torrensis</i> N. Mattos	P	<i>M.J. Silva & R. Camargo</i> 965 (UEC)	Brazil, Rio Grande do Sul	x	x	da Silva et al. (2012)
<i>Millettia dura</i>	<i>Millettia dura</i> Dunn	P	<i>M.J. Silva</i> 830 (UEC)	Brazil, Sao Paulo	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Millettia dura</i> GB	<i>Millettia dura</i> Dunn	GB	<i>Lock</i> 83/124		x	AF142722	x
<i>Millettia extensa</i> GB	<i>Millettia extensa</i> Benth. ex Baker.f.	GB	<i>S. Tagane, K. Fuse, H. Toyama & H. Nagamasu</i>	Thailand, Doi Inthanon, Chiang Mai province	x	LC080901	x
<i>Millettia grandis</i>	<i>Millettia grandis</i> Skeels	GB	<i>Lavin & Lavin</i> s.n.		x	AF142724	x
<i>Millettia grandis</i>	<i>Millettia grandis</i> Skeels	GB	x	x	x	x	AY009137
<i>Millettia ichthyochtona</i>	<i>Millettia ichthyochtona</i> Drake	GB	<i>Lu-Shi Team</i> 1368 (KUN)	China, Yunan	AF467475	x	x
<i>Millettia lasiantha</i> GB	<i>Millettia lasiantha</i> Dunn	GB	<i>Pawek</i> 5926 (UC)	Malawi, Nkhata Bay	AF467476	x	x
<i>Millettia leptobotrya</i>	<i>Millettia leptobotrya</i> Dunn	GB	<i>Hu</i> 1164 (DAV)	China, Yunan	AF467477	AF142725	x
<i>Millettia makondensis</i>	<i>Millettia makondensis</i> Harms	GB	<i>Lotter</i> 1723	Mozambique, Cabo Delgado, 44 km NW of Mocimboa	x	KF147413	x

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Millettia mossambicensis</i>	<i>Millettia mossambicensis</i> J.B.Gillett	GB	OM 2335	Mozambique, de Praia	x	JX517618	x
<i>Millettia pachycarpa</i> GB1	<i>Millettia pachycarpa</i> Benth.	GB	HITBC: <i>Liana Mengsong</i> 189_4_1	x	x	HG004928	x
<i>Millettia pachycarpa</i> GB2	<i>Millettia pachycarpa</i> Benth.	GB	isolate J695	x	x	KR531231	x
<i>Millettia pinnata</i>	<i>Millettia pinnata</i> (L.) Panigrahi	P	Brazil, Rio de Janeiro, cultivated, M.J. Silva 845 (UEC)	x	x	x	da Silva <i>et al.</i> (2012)
<i>Millettia pinnata</i>	<i>Millettia pinnata</i> (L.) Panigrahi	GB	Y. Sirichamorn YSM 2009-25 (L)	Thailand, Surat Thani province	x	JX506616.1	JX506503
<i>Millettia pulchra</i>	<i>Millettia pulchra</i> Kurz	GB	Huang 15567 (TAI)	Taiwan	AF467479	x	x
<i>Millettia pulchra</i> GB	<i>Millettia pulchra</i> Kurz	GB	SCBGP127_2	China, Dinghushan National Nature Reserve		KP093475	x
<i>Millettia richardiana</i>	<i>Millettia (NeoDunnia)</i> <i>richardiana</i>	GB	Schrire 2555 (K)	Madagascar	AF467483	AF142726	x
<i>Millettia thonningii</i> GB	<i>Millettia thonningii</i> Baker	GB	Faden 74/81 (K)	Ghana	AF467481	AF142723	x
<i>Millettia usaramensis</i> <i>ssp. usaramensis</i>	<i>Millettia usaramensis</i> Taub. <i>ssp. usaramensis</i>	GB	Olivier Maurin, Michelle van der Bank & Meg Coates- Palgrave OM2433	Mozambique, Sofala, Catapu, Directly N of the	x	JX905956	x
<i>Millettia xylocarpa</i> GB	<i>Millettia xylocarpa</i> Miq.	GB	S. Tagane, K. Fuse, S. <i>Rueangruea</i> & S. Suddee	Thailand, Bang Krang Camp	x	LC080903	x
<i>Muelleria campestris</i>	<i>Muelleria campestris</i> (Mart. ex Benth.) M.J. Silva & A.M.G. Azevedo	P	M.J. Silva 828 (UEC)	Brazil, Minas Gerais	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (ITS/matK/trnL-F) and from publication (da Silva et al. (2012))		
					ITS	matK	trnL-F
<i>Muelleria denudata</i>	<i>Muelleria denudata</i> (Benth.) M. Sousa	P	<i>R. Spruce</i> 357 (K)	Brazil, Para	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Muelleria fendleri</i>	<i>Muelleria fendleri</i> (Benth.) M.J. Silva & A.M.G. Azevedo (<i>Lonchocarpus fendleri</i>)	P	<i>L. Cardenas & F.F. Leon</i> 3383 (VEN)	Venezuela, Guanacara	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Muelleria filipes</i>	<i>Muelleria filipes</i> (Benth.) M.J. Silva & A.M.G. Azevedo	P	<i>M.J. Silva</i> 822 (UEC)	Brazil, Rio de Janeiro	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Muelleria fluvialis</i>	<i>Muelleria fluvialis</i> (Lindm.) Burkart	P	<i>A. Fuentes</i> 798 (LPB)	Bolivia, Santa Cruz	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Muelleria grazielae</i>	<i>Muelleria grazielae</i> (M.J. Silva & A.M.G. Azevedo) M.J. Silva & A.M.G. Azevedo	P	<i>M.J. Silva & R. Camargo</i> 955 (UEC)	Brazil, Santa Catarina	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Muelleria lutea</i>	<i>Muelleria lutea</i> (Johnston) M.J. Silva & A.M.G. Azevedo [<i>Margaritolobium luteum</i> Harms]	P	<i>A. Sugden</i> 1170 (K)	Venezuela, Cerro Copey	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Muelleria lutescens</i>	<i>Muelleria lutescens</i> (Pittier) M.J. Silva & A.M.G. Azevedo (<i>Lonchocarpus lutescens</i>)	P	<i>H. Pittier</i> 11299 (P)	Venezuela, Guarico	x	x	da Silva et al. (2012)
<i>Muelleria monilis</i>	<i>Muelleria monilis</i> (L.) M.J. Silva & A.M.G. Azevedo	P	<i>F. Encarnacion</i> 26484 (MBM)	Peru, Loreto	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Muelleria montana</i>	<i>Muelleria montana</i> (A.M.G. Azevedo ex M.J. Silva & A.M.G. Azevedo) M.J. Silva & A.M.G. Azevedo [<i>Lonchocarpus montanus</i> A.M.G. Azevedo ex M.J. Silva & A.M.G. Azevedo]	P	<i>M.J. Silva et al.</i> 1133 (UEC)	Brazil, Goiás	x	da Silva et al. (2012)	da Silva et al. (2012)

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (ITS/matK/trnL-F) and from publication (da Silva et al. (2012))		
					ITS	matK	trnL-F
<i>Muelleria obtusa</i>	<i>Muelleria obtusa</i> (Benth.) M.J. Silva & A.M.G. Azevedo	P	M.J. Silva 1118 (UEC)	Brazil, Bahia	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Muelleria sanctaemarthae</i>	<i>Muelleria sanctaemarthae</i> (Pittier) M.J. Silva & A.M.G. Azevedo,	P	H.H. Smith 704 (MICH)	Columbia, Santa Marta	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Muelleria sericea</i>	<i>Muelleria sericea</i> (Micheli) M.J. Silva & A.M.G. Azevedo [<i>Bergeronia sericea</i>]	P	E.M. Zardini 4414 (G)	Paraguai, Dpto. Central	x	x	da Silva et al. (2012)
<i>Muelleria sericea</i>	<i>Muelleria sericea</i> (Micheli) M.J. Silva & A.M.G. Azevedo	P	E.M. Zardini 4414 (G)	Paraguai, Dpto. Central	x	da Silva et al. (2012)	x
<i>Muelleria sericea</i>	<i>Muelleria sericea</i> (Micheli) M.J. Silva & A.M.G. Azevedo	P	M.J. Silva 1082 (UEC)	Brazil, Espirito Santo	x	x	da Silva et al. (2012)
<i>Muelleria virgilioides</i>	<i>Muelleria virgilioides</i> Benth.	P	M.J. Silva 1076 (UEC)	Brazil, Rio de Janeiro	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Mundulea sericea</i>	<i>Mundulea sericea</i> (Willd.) A. Chev.	GB	x	x	x	x	AY009136
<i>Mundulea sericea</i> GB	<i>Mundulea sericea</i> (Willd.) A. Chev.	GB	Schrire 2529 (K)	Madagascar	AF467482	x	x
<i>Mundulea sericea</i> GB	<i>Mundulea sericea</i> (Willd.) A. Chev.	GB	x	x	x	AF142713	x
<i>Mundulea stenophylla</i>	<i>Mundulea stenophylla</i> R. Vig.	GB	x	x	AY009140	x	x
<i>Philenoptera bussei</i>	<i>Philenoptera bussei</i> (Harms) Schrire	P	W.R. Bainbrider 501 (FHO)	x	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Philenoptera cyanescens</i>	<i>Philenoptera cyanescens</i> (Schumach. & Thonn.) Roberty	P	H. Ern et al. 2050 (B)	Togo, Atakpame	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Philenoptera cyanescens</i> 2	<i>Philenoptera cyanescens</i> (Schumach. & Thonn.) Roberty	GB	x	x	AF534802	x	x

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (ITS/matK/trnL-F) and from publication (da Silva et al. (2012))		
					ITS	matK	trnL-F
<i>Philenoptera eriocalyx</i>	<i>Philenoptera eriocalyx</i> (Harms) Schrire	GB	Hu 1090 (DAV)	Zimbabwe	AF467487	AF142720	x
<i>Philenoptera eriocalyx</i>	<i>Philenoptera eriocalyx</i> (Harms) Schrire	P	A. Bogdan 4733 (K)	Kenya, Kapenguria	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Philenoptera katangensis</i>	<i>Philenoptera katangensis</i> (De Wild.) Schrire	P	H. Gamwell 244 (BM)	Zambia	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Philenoptera laxiflora</i>	<i>Philenoptera laxiflora</i> (Guill. & Perr.) Roberty	GB	Hu 1117 (DAV)	Senegal	AF467488	x	x
<i>Philenoptera laxiflora</i>	<i>Philenoptera laxiflora</i> (Guill. & Perr.) Roberty	P	W.J. Eggeling 2373 (BM)	Uganda, Rom Chua	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Philenoptera laxiflora</i> GB	<i>Philenoptera laxiflora</i> (Guill. & Perr.) Roberty	GB	Hu 1126	x	x	AF142721	x
<i>Philenoptera madagascariensis</i>	<i>Philenoptera madagascariensis</i> (Vatke) Schrire	P	F. Barthelat & A.B. Sifory 199 (K)	Madagascar	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Philenoptera nelsii</i>	<i>Philenoptera nelsii</i> (Schinz) Schrire	P	D.B. Fanshawe 5253 (FHO)	x	x	x	da Silva et al. (2012)
<i>Philenoptera violacea</i>	<i>Philenoptera violacea</i> (Klotzsch) Schrire	P	M.J. Silva 823 (UEC)	Brazil, Sao Paulo, Campinas	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Philenoptera violacea</i>	<i>Philenoptera violacea</i> (Klotzsch) Schrire	GB	B & T World Seeds 448908	x	x	x	EU717357
<i>Philenoptera violacea</i> GB	<i>Philenoptera violacea</i> (Klotzsch) Schrire	GB	Busse 530 (L)	Tanzania	JX506439	JX506606	x
<i>Philenoptera bussei</i>	<i>Philenoptera bussei</i> (Harms) Schrire	GB	OM2376	x	x	JX518116	x
<i>Piscidia carthagenensis</i>	<i>Piscidia carthagenensis</i> Jacq.	P	El Oro & G.P. Lewis 2524 (K)	Ecuador	x	da Silva et al. (2012)	da Silva et al. (2012)

Appendix 2.1 Continued.

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					ITS	matK	trnL-F
<i>Piscidia cubensis</i>	<i>Piscidia cubensis</i> Urb.	P	W. Greuter, P. Gonz.lez & R. Rankin 26169 (B)	Cuba, Holguin province	x	da Silva et al. (2012)	x
<i>Piscidia grandifolia</i>	<i>Piscidia grandifolia</i> I.M. Johnst	P	C.E. Hughes et al. 2135 (FHO)	Mexico, Oaxaca	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Piscidia mollis</i>	<i>Piscidia mollis</i> Rose	P	C.E. Hughes et al. 1224 (K)	Mexico, Sonora	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Piscidia mollis</i> GB1	<i>Piscidia mollis</i> Rose	GB	Hu 1117	Mexico, Sonora	KJ411710	x	x
<i>Piscidia piscipula</i>	<i>Piscidia piscipula</i> Sarg.	GB	Lavin & Luckow 5793 (TEX)	x	x	x	AF311379
<i>Piscidia piscipula</i> GB1	<i>Piscidia piscipula</i> Sarg.	GB	Lavin & Luckow 5793A (TEX)	Mexico, Veracruz	AF467490	AF142710	X
<i>Piscidia carthagenensis</i> GB	<i>Piscidia carthagenensis</i> Jacq.	GB	BioBot 1478	x	x	JQ587807	x
<i>Platycyamus regnellii</i>	<i>Platycyamus regnellii</i> Benth.	GB	Lima s.n. (RB)	Brazil	x	x	AF311378
<i>Platycyamus regnellii</i> P	<i>Platycyamus regnellii</i> Benth.	P	M.J. Silva 1106 (UEC)	Brazil, Sao Paulo	x	da Silva et al. (2012)	da Silva et al. (2012)
<i>Platycyamus regnellii</i> GB	<i>Platycyamus regnellii</i> Benth.	GB	Lima s.n.	x	x	AF142709	x
<i>Platysepalum hirsutum</i>	<i>Platysepalum hirsutum</i> (Dunn) Hepper	GB	Adames 720 (K)	x	EU729482	x	x
<i>Pongamiopsis amygdalina</i>	<i>Pongamiopsis amygdalina</i> (Baill.) R. Vig.	GB	Du Puy M575 (K)	Madagascar	AF467494	AF142711	x
<i>Ptychobium biflorum</i> ssp. <i>angolense</i>	<i>Ptychobium biflorum</i> (E. Mey.) Brummitt ssp. <i>angolense</i> (Baker) Brummitt	GB	C. J. Ward 10764 (K)	x	x	JQ669619	x
<i>Requienia obcordata</i>	<i>Tephrosia obcordata</i> Baker [Requienia obcordata (Poir.) DC.]	P	F.N. Hepper 3602 (K)	Senegal, Meckhe	x	da Silva et al. (2012)	da Silva et al. (2012)

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Schefflerodendron usambarensense</i> GB	<i>Schefflerodendron usambarensense</i> Harms	GB		x	EU752495	x	x
<i>Solori cumingii</i>	<i>Solori cumingii</i> (Benth.) Sirich. & Adema	GB	Gaerlan <i>et al.</i> 10368 (L)	Philippines, Luzon	JX506447	x	x
<i>Solori eriocarpa</i>	<i>Solori eriocarpa</i> (F.C. How) Sirich. & Adema	GB	Wang Hong 7673 (QSBG)	China, Yunan	JX506454	x	JX506512
<i>Solori involuta</i>	<i>Solori involuta</i> (Sprague) Sirich. & Adema	GB	Murray, Coveny & Bishop NSW 409439 (L)	Australia, North coast	JX506451	JX506622	JX506509
<i>Solori involuta</i>	<i>Solori involuta</i> (Sprague) Sirich. & Adema	P	A.R. Bean 18104 (K)	Australia, Queensland	x	da Silva <i>et al.</i> (2012)	x
<i>Solori koolgibberah</i>	<i>Solori koolgibberah</i> (F.M. Bailey) Sirch. & Adema	GB	Brass 8205 (L)	Papua New Guinea	JX506453	JX506624	JX506624
<i>Solori microphylla</i>	<i>Solori microphylla</i> (Miq.) Sirich. & Adema	GB	Y. Sirichamorn YSM 2009-16 (L)	Thailand, Chumphon province	JX506448	JX506619	JX506506
<i>Solori philippinensis</i>	<i>Solori philippinensis</i> (Merr.) Sirch. & Adema	GB	Elmer 14373 (L)	Philippines, Sorsogon	JX506455	JX506627	x
<i>Solori pseudoinvoluta</i>	<i>Solori pseudoinvoluta</i> (Verdc.) Sirich. & Adema	GB	Streimann & Kairo N.G.F. 27776 (L)	Papua New Guinea, Marobe	JX506452	JX506623	JX506510
<i>Solori robusta</i>	<i>Solori robusta</i> (Roxb. ex DC.) Sirich. & Adema [<i>Brachypterum robustum</i> (Roxb. ex DC.) Dalzell & A. Gibson]	GB	Hu 1182 (DAV)	x	AF467021	x	x
<i>Solori robusta</i>	<i>Solori robusta</i> (Roxb. ex DC.) Sirich. & Adema	GB	Y. Sirichamorn YSM 2009-09 (L)	Thailand, Lampang province	JX506446	JX506617	JX506504

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Solori scandens</i>	<i>Solori scandens</i> (Roxb.) Sirich. & Adema	GB	<i>Y. Sirichamorn</i> YSM 2009-01 (L)	Thailand, Chon Buri province	JX506450	JX506621	JX506508
<i>Solori submontana</i>	<i>Solori submontana</i> (Verdc.) Sirich. & Adema	GB	<i>Takeuchi et. al.</i> 4349 (L)	Papua New Guinea, Marobe		JX506626	JX506513
<i>Solori thorelii</i>	<i>Solori thorelii</i> (Gagnep.) Sirich. & Adema	GB	<i>Y. Sirichamorn</i> YSM 2009-03 (L)	Thailand, Phrae province	JX506449	JX506620	JX506507
<i>Sylvichadsia grandifolia</i>	<i>Sylvichadsia grandifolia</i> (R. Vig.) Du Puy & Labat	GB	<i>Capuron</i> 24962 SF (K)	x	EU729481	x	x
<i>Tephrosia adunca</i>	<i>Tephrosia adunca</i> Benth.	P	<i>M. J. Silva</i> 1165 (UEC)	Brazil, Minas Gerais		da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Tephrosia candida</i>	<i>Tephrosia candida</i> DC.	GB	<i>Keke</i> 150	x	HE681571	x	x
<i>Tephrosia leiocarpa</i> GB1	<i>Tephrosia leiocarpa</i> A. Gray	GB	x	x	U50753	x	x
<i>Tephrosia florida</i>	<i>Tephrosia florida</i> (F. Dietr.) C.E. Wood	GB	<i>Rider</i> 252 (FLAS)	x	x	KJ773198	X
<i>Tephrosia heckmanniana</i>	<i>Tephrosia heckmanniana</i> Harms	GB	<i>Hu</i> 1127 (DAV)	x	AF467497	AF142712	x
<i>Tephrosia leiocarpa</i> GB2	<i>Tephrosia leiocarpa</i> A. Gray	GB	x	X	U50752	x	x
<i>Tephrosia nubica</i>	<i>Tephrosia nubica</i> (Boiss.) Baker	GB	x	X	KJ004326	x	x
<i>Tephrosia obovata</i>	<i>Tephrosia obovata</i> Merr.	GB	<i>Huang</i> 15568 (TAI)	Taiwan	AF467498	x	x
<i>Tephrosia pogonocalyx</i>	<i>Tephrosia pogonocalyx</i> C.E. Wood	P	<i>O. T.Ilez et al.</i> 12944 (UEC)	Mexico, Tejupilco	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Tephrosia purpurea</i>	<i>Tephrosia purpurea</i> Pers.	GB	<i>isolate</i> C6	x	x	x	KT188583
<i>Tephrosia rufescens</i>	<i>Tephrosia rufescens</i> Benth.	P	<i>J. Mattos</i> 9612 (UEC)	Brazil, Sao Paulo	x	da Silva <i>et al.</i> (2012)	da Silva <i>et al.</i> (2012)
<i>Tephrosia tenella</i> GB1	<i>Tephrosia tenella</i> A. Gray	GB	<i>Jenkins</i> 88-1 (ARIZ)	x	U50755	x	x
<i>Tephrosia tenella</i> GB2	<i>Tephrosia tenella</i> A. Gray	GB	<i>Jenkins</i> 88-1 (ARIZ)	x	U50754	x	x

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Tephrosia villosa</i>	<i>Tephrosia villosa</i> (L.) Pers.	GB	Lavin 6219 (BH)	x	AF467499	x	AF311383
<i>Tephrosia virginiana</i>	<i>Tephrosia virginiana</i> (L.) Pers.	GB	Abbott 23775 (FLAS)	x	x	KJ773199	x
<i>Tephrosia vogelii</i>	<i>Tephrosia vogelii</i> Hook. f.	GB	Gsileshi002-bio_material=K:DNA:MWC40229	x	HE681570	x	x
<i>Tephrosia candida</i>	<i>Tephrosia candida</i> DC.	GB	TCD	x	x	KF545849	x
<i>Tephrosia coccinea</i> GB	<i>Tephrosia coccinea</i> Wall.	GB	TC2	x	x	KF545844	x
<i>Tephrosia jamnagarensis</i>	<i>Tephrosia jamnagarensis</i> Santapau	GB	MSP02	x	x	KC427986	x
<i>Tephrosia nicaraguensis</i>	<i>Tephrosia nicaraguensis</i> Oerst.	GB	BioBot00985	x	x	JQ587880	x
<i>Tephrosia pentaphylla</i>	<i>Tephrosia pentaphylla</i> Sweet	GB	TPe	x	x	KF545843	x
<i>Tephrosia pondoensis</i>	<i>Tephrosia pondoensis</i> (Codd) Schrire	GB	Abbott 9232	x	x	JX517379	x
<i>Tephrosia purpurea</i>	<i>Tephrosia purpurea</i> Pers.	GB	TP4	x	x	KF545850	x
<i>Tephrosia purpurea</i>	<i>Tephrosia purpurea</i> Pers.	GB	MSP03	x	x	KC427987	x
<i>Tephrosia rhodesica</i>	<i>Tephrosia rhodesica</i> Baker.f.	GB	x	x	x	EU717429	x
<i>Tephrosia rhodesica</i>	<i>Tephrosia rhodesica</i> Baker.f.	GB	cultivated at IUGH; no voucher	x	x	x	EU717360
<i>Tephrosia strigosa</i>	<i>Tephrosia strigosa</i> Santapau & Maheshwari	GB	TS2	x	x	KF545847	x
<i>Tephrosia villosa</i>	<i>Tephrosia villosa</i> (L.) Pers.	GB	TV2	x	x	KF545841	x
<i>Tephrosia vogelii</i>	<i>Tephrosia vogelii</i> Hook. f.	GB	TVg	x	x	KF545842	x
<i>Wisteria brachybotrys</i>	<i>Wisteria brachybotrys</i> Siebold & Zucc.	GB	Thimbault, T. Huntington Gardens s.n.	x	KF294873	x	x
<i>Wisteria brachybotrys</i>	<i>Wisteria brachybotrys</i> Siebold & Zucc.	GB	M Chase 22664 (K)	x	x	JQ619956	x
<i>Wisteria brevidentata</i>	<i>Wisteria brevidentata</i> Rehder	GB	H. C. Tang 2349	x	EU424064	x	x

Appendix 2.1 Continued.

Name code in the phylogenetic trees	Full name	Source; GB=Genbank; P= publication but not in Genbank	Voucher specimens and herbarium	Locality	Accession no. from Genbank (<i>ITS/matK/trnL-F</i>) and from publication (da Silva <i>et al.</i> (2012))		
					<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Wisteria floribunda</i>	<i>Wisteria floribunda</i> (Willd.) DC.	GB	Quaryhill Botanical Gardens 2007.074C	x	KF294874	x	x
<i>Wisteria floribunda</i> GB1	<i>Wisteria floribunda</i> (Willd.) DC.	GB	IRGC105690	x	x	NC_027677	x
<i>Wisteria frutescens</i>	<i>Wisteria frutescens</i> (L.) Poir.	GB	ARIZ 196299	x	x	AF142731	x
<i>Wisteria frutescens</i> var. <i>macrostachya</i>	<i>Wisteria frutescens</i> (L.) Poir. var. <i>macrostachya</i> Torr. & A. Gray	GB	S.N. 3592003	x	EU424070	x	x
<i>Wisteria frutescens</i> var. <i>macrostachya</i>	<i>Wisteria frutescens</i> (L.) Poir. var. <i>macrostachya</i> Torr. & A. Gray	GB	<i>J Trusty</i> 81 (AUA)	x	x	JQ619957	x
<i>Wisteria sinensis</i>	<i>Wisteria sinensis</i> (Seems) Sweet	GB	<i>Hu</i> 1125	x	x	AF142732	x
<i>Wisteria villosa</i>	<i>Wisteria villosa</i> Rehder	GB	<i>T.Y. Cheo & L. Yen</i> 219	x	EU424076	x	x

Appendix 2.2 List of species used in this study, collected in the field in Thailand. The locality is given for each species following by the country, district or place and province respectively. Gene markers generated are shown in this study; nuclear: *ITS* and chloroplast *matK* and *trnL-F*, of which x is marked as not amplified. QBG is abbreviated for the Queen Sirikit Botanic Garden Herbarium, Thailand.

Name code in the phylogenetic trees	Full name	Voucher specimens and herbarium	Locality	Gene markers		
				<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Aganope sp.</i>	<i>Aganope sp.</i>	<i>S. Mattapha</i> 1101	Thailand, Pha toop forest park, Nan province	<i>ITS</i>	<i>matK</i>	x
<i>Antheroporum glaucum F1</i>	<i>Antheroporum glaucum</i> Z.Weib	<i>S. Mattapha</i> 1099	Thailand, Khao Sok national park, Surat Thani province	<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Antheroporum pierre</i>	<i>Antheroporum pierre</i> Gagnep.	<i>S. Mattapha</i> s.n.	Thailand, Pran buri, Prachuab Khirikhan province	<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Callera sp.</i>	<i>Callera sp.</i>	<i>S. Mattapha</i> s.n.	Thailand, Km 623-624 Lampang-Tak provinces	x	<i>matK</i>	<i>trnL-F</i>
<i>Callerya atropurpurea F4</i>	<i>Callerya atropurpurea</i> (Wall.) A. Schott	<i>S. Mattapha</i> s.n.	Thailand, Songkla University, Songkhla province	<i>ITS</i>	x	<i>trnL-F</i>
<i>Callerya atropurpurea</i>	<i>Callerya atropurpurea</i> (Wall.) A. Schott	<i>S. Mattapha</i> s.n.	Thailand, Wat Pa Ban Tad, Udon Thani province	<i>ITS</i>	x	<i>trnL-F</i>
<i>Callerya chlorantha F</i>	<i>Callerya chlorantha</i> Mattapha & Sirich.	Phutthai & Y. Sirichamorn 2014-1	Thailand, Kanchanaburi, Sari Yok district	<i>ITS</i>	x	<i>trnL-F</i>
<i>Callerya cinerea</i>	<i>Callerya cinerea</i> (Benth.) Schot	<i>S. Mattapha</i> 1105	Thailand, Doi Phu Ka, Nan province	x	<i>matK</i>	<i>trnL-F</i>
<i>Callerya kityana</i>	<i>Callerya kityana</i> (Craib) Schot	<i>S. Mattapha</i> 1117	Thailand, Chalerm Prakiat district, Nan province	<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Callerya tenasserimensis F</i>	<i>Callerya tenasserimensis</i> Mattapha & Sirich.	Y. Sirichamorn 2015-13	Thailand, Suan Phueng district, Khoa Chon (Khao Chan) waterfall, Ratchaburi province	<i>ITS</i>	x	<i>trnL-F</i>
<i>Craspedolobium unijugum F</i>	<i>Craspedolobium unijugum</i> (Gagnep.) Z. Wei & Pedley	<i>S. Mattapha</i> 1101	Thailand, Khunsthana national park, Nan province	<i>ITS</i>	x	<i>trnL-F</i>
<i>Craspedolobium unijugum</i>	<i>Craspedolobium unijugum</i> (Gagnep.) Z. Wei & Pedley	<i>S. Mattapha</i> 1100	Thailand, Nantaburi national park, Thong Pha Phum district, Kanchanaburi province	x	<i>matK</i>	x
<i>Derris sp.</i>	<i>Derris sp.</i>	<i>S. Mattapha</i> s.n.	Thailand, Doi Phu Ka national park, Nan province	x	<i>matK</i>	x
<i>Derris sp. F1</i>	<i>Derris sp.</i>	<i>S. Mattapha</i> s.n.	Thailand, Doi Phu Ka national park, Nan province	<i>ITS</i>	x	<i>trnL-F</i>
<i>Derris sp.2 F</i>	<i>Derris sp.</i>	<i>S. Mattapha</i> 1102	Thailand, Km 40-42 between Borguea district and Doi Phu Ka national park, Nan province	<i>its</i>	<i>matK</i>	<i>trnL-F</i>

Appendix 2.2 Continued.

Name code in the phylogenetic trees	Full name	Voucher specimens and herbarium	Locality	Gene markers		
<i>Fordia albiflora</i>	<i>Fordia albiflora</i> (Prain) U.A. Dasuki & A.M. Schot	<i>S. Mattapha</i> s.n.	Thailand, Khao Nam Khang national park, Songkhla province	x	x	<i>trnL-F</i>
<i>Millettia acutiflora</i>	<i>Millettia acutiflora</i> Gagnep.	<i>S. Mattapha</i> s.n.	Thailand, Phu Lang Ka, Bueng Kan province	x	x	<i>trnL-F</i>
<i>Millettia brandisiana</i>	<i>Millettia brandisiana</i> Kurz	<i>S. Mattapha</i> 1120	Thailand, Pha Nok Khaw district, Khon Kaen province	<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Millettia caerulea</i>	<i>Millettia caerulea</i> (Graham) Baker	<i>M. Norsaengsri</i> & <i>S. Mattapha</i> 9179 (QBG)	Thailand, Mae Kam Pong waterfall, Chiang Mai province	<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Millettia erythrocalyx</i>	<i>Millettia erythrocalyx</i> Gagnep.	<i>M. Norsaengsri</i> & <i>S. Mattapha</i> s.n. (QBG)	Thailand, Mae Kang district, Chiang Mai province	<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Millettia extensa</i>	<i>Millettia extensa</i> Benth. ex Baker f.	<i>M. Norsaengsri</i> & <i>S. Mattapha</i> 9163 (QBG)	Thailand, Queen Sirikit Botanical Garden, Mae Rim district, Chiang Mai province	<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Millettia glaucescens</i>	<i>Millettia glaucescens</i> Kurz	<i>S. Mattapha</i> s.n.	Thailand, Bok khoranee, Krabi province	<i>ITS</i>		x
<i>Millettia kangensis</i>	<i>Millettia kangensis</i> Craib	<i>M. Norsaengsri</i> & <i>S. Mattapha</i> s.n.	Thailand, Mae Kang district, Chiang Mai province	<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Millettia leucantha</i> var. <i>buteoides</i>	<i>Millettia leucantha</i> Kurz var. <i>buteoides</i> (Gagnep.) Lôt	<i>S. Mattapha</i> 1121	Thailand, between Nam Phong and Kha Sawn Kwang districts, Khon Kaen province	<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Millettia leucantha</i> var. <i>latifolia</i>	<i>Millettia leucantha</i> Kurz var. <i>latifolia</i> (Dunn) Lôt	<i>M. Norsaengsri</i> & <i>S. Mattapha</i> 9165 (QBG)	Thailand, Queen Sirikit Botanical Garden, Mae Rim district, Chiang Mai province	<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Millettia macrostachya</i>	<i>Millettia macrostachya</i> Collett & Hemsl. var. <i>macrostachya</i>	<i>S. Mattapha</i> & <i>M. Norsaengsri</i> s.n. (QBG)	Thailand, The Queen Sirikit Botanical Garden, Mae Rim district, Chiang Mai province	<i>ITS</i>	x	x
<i>Millettia macrostachya</i> var. <i>macrostachya</i>	<i>Millettia macrostachya</i> Collett & Hemsl. var. <i>macrostachya</i>	<i>S. Mattapha</i> & <i>M. Norsaengsri</i> s.n. (QBG)	Thailand, Queen Sirikit Botanical Garden, Mae Rim district, Chiang Mai province	<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Millettia macrostachya</i> var. <i>tecta</i>	<i>Millettia macrostachya</i> var. <i>tecta</i> Craib	<i>M. Norsaengsri</i> & <i>S. Mattapha</i> s.n. (QBG)	Thailand, Mae Kang district, Chiang Mai province	<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Millettia pachycarpa</i>	<i>Millettia pachycarpa</i> Benth.	<i>M. Norsaengsri</i> & <i>S. Mattapha</i> 9177 (QBG)	Thailand, Pong Yaeng hill, Mae Rim district, Chiang Mai province	<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Millettia pachyloba</i>	<i>Millettia pachyloba</i> Drake	<i>S. Mattapha</i> 1122	Thailand, Phu Rue national park, Loei province	<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Millettia peguensis</i>	<i>Millettia peguensis</i> Ali	<i>S. Mattapha</i> s.n.	Thailand, Nam Phong-Kha saun kaeng, Khon Kaen	<i>ITS</i>	<i>matK</i>	<i>trnL-F</i>
<i>Millettia peguensis</i> F1	<i>Millettia peguensis</i> Ali	<i>S. Mattapha</i> 1096	Thailand, Tham Khao Poon temple, Muang district, Kanchanaburi province	<i>ITS</i>	<i>matK</i>	x

Appendix 2.2 Continued.

Name code in the phylogenetic trees	Full name	Voucher specimens and herbarium	Locality	Gene markers		
<i>Millettia peguensis</i>	<i>Millettia peguensis</i> Ali	<i>S. Mattapha</i> 1123	Thailand, Nam Nao national park, Phetchabun province	x	matK	trnL-F
<i>Millettia pegeuensis</i>	<i>Millettia peguensis</i> Ali	<i>S. Mattapha</i> s.n.	Thailand, Nam Phong-Kha saun kaeng district, Khon Kaen province	x	x	trnL-F
<i>Millettia pinnata</i>	<i>Millettia pinnata</i> (L.) Panigrahi	<i>S. Mattapha</i> 1124	Thailand, Pak Bala beach, Stun province	x	matK	trnL-F
<i>Millettia sericea</i> F1	<i>Millettia sericea</i> (Vent.) Wight & Arn. ex Hassk.	<i>S. Mattapha</i> s.n.	Thailand, Pilok district, Kanchanaburi province	ITS	x	x
<i>Millettia sericea</i> F2	<i>Millettia sericea</i> (Vent.) Wight & Arn. ex Hassk.	<i>Y. Sirichamorn</i> YSM 2014-3	Thailand, south of Thailand	ITS	x	trnL-F
<i>Millettia sp. F2</i>	<i>Millettia</i> sp. 2	<i>S. Mattapha</i> s.n.	Thailand, Umphang, Tak province	ITS	x	trnL-F
<i>Millettia sp.3</i>	<i>Millettia</i> sp.3	<i>Y. Sirichamorn</i> YSM 2014-2	Thailand, Huai Yot, Wat Than I-So temple, Trang province	ITS	matK	trnL-F
<i>Millettia sp.4</i>	<i>Millettia</i> sp.4	<i>S. Mattapha</i> 1109	Thailand, Khao Yai national park	ITS	matK	trnL-F
<i>Millettia sp.5</i>	<i>Millettia</i> sp.5	<i>S. Mattapha</i> 1091	Thailand, Khun Paen temple, Muang district, Kanchanaburi province	ITS	matK	trnL-F
<i>Millettia xylocarpa</i>	<i>Millettia xylocarpa</i> Miq.	<i>S. Mattapha</i> 1125	Thailand, Kumpawapi district, Udon Thani province	ITS	matK	trnL-F
<i>Tephrosia coccinea</i>	<i>Tephrosia coccinea</i> Wall.	<i>S. Mattapha</i> 1126	Thailand, Phu Phra Bat historical park, Udon Thani province	ITS	matK	trnL-F
<i>Afgekia filipes</i> F2	<i>Afgekia filipes</i> (Dunn) R. Geesink	obtained from Yotsawate (unpl.)	Thailand, Doi Ang-Khang, Chiang Mai province	ITS	x	trnL-F
<i>Afgekia filipes</i> F4	<i>Afgekia filipes</i> (Dunn) R. Geesink	obtained from Yotsawate (unpl.)	Thailand, Ruesi Valley, Doi Suthep-pui National Park, Chiang Mai province	ITS	x	trnL-F
<i>Afgekia filipes</i> F3	<i>Afgekia filipes</i> (Dunn) R. Geesink	obtained from Yotsawate (unpl.)	Thailand, Doi Suthep-Pui National Park station, Doi Suthep-Pui National Park, Chiang Mai province	ITS	x	trnL-F
<i>Afgekia mahidolae</i> F3	<i>Afgekia mahidolae</i> B.L. Burtt & Chermisrivathana	obtained from Yotsawate (unpl.)	Thailand, Mahidol University, Salaya Campus, Nakhon Pathom province	ITS	x	trnL-F
<i>Afgekia mahidolae</i> F2	<i>Afgekia mahidolae</i> B.L. Burtt & Chermisrivathana	obtained from Yotsawate (unpl.)	Thailand, Sai Yok District, Karnchanaburi province	ITS	x	trnL-F
<i>Afgekia mahidolae</i> F1	<i>Afgekia mahidolae</i> B.L. Burtt & Chermisrivathana	obtained from Yotsawate (unpl.)	Thailand, Sai Yok District, Karnchanaburi province	ITS	x	trnL-F

Appendix 2.2 Continued.

Name code in the phylogenetic trees	Full name	Voucher specimens and herbarium	Locality	Gene markers		
				ITS	x	trnL-F
<i>Afgekia sericea</i> F1	<i>Afgekia sericea</i> Craib	obtained from Yotsawate (unpl.)	Thailand, Hin Ngarm National Park, Thep Sathit District, Chaiyaphum province	ITS	x	trnL-F
<i>Afgekia sericea</i> F2	<i>Afgekia sericea</i> Craib	obtained from Yotsawate (unpl.)	Thailand, Phanom Rung Historical Park, Buri Ram province	ITS	x	trnL-F
<i>Afgekia sericea</i> F3	<i>Afgekia sericea</i> Craib	obtained from Yotsawate (unpl.)	Thailand, Pak Thong Chai District, Nakhon Rachasima province	ITS	x	trnL-F
<i>Afgekia sericea</i> F4	<i>Afgekia sericea</i> Craib	obtained from Yotsawate (unpl.)	Thailand, Sakaerat Environmental Research Station Nakhon Rachasima province	ITS	x	trnL-F

Appendix 2.3 List of species, voucher specimens and herbarium and locality. Herbarium abbreviations follow Thiers (continuously updated), <http://sweetgum.nybg.org/ih/>, given in the parentheses. Species sampled from Leiden herbarium (L) and Paris herbarium (P) are given voucher specimen codes. The locality is given for each species following by the country, place and province respectively. Gene markers generated are shown in this study; nuclear: *ITS* and chloroplast *matK* and *trnL-F*, of which x is marked as not amplified.

Name code in the phylogenetic trees	Full name	Voucher specimens and herbarium	Locality	Gene markers		
				<i>ITS</i>	x	x
<i>Apurimacia boliviana</i> H	<i>Apurimacia boliviana</i> (Britton) Lavin	<i>J. Hudson</i> 1099 (K)	Peru, Cajamarca	<i>ITS</i>	x	x
<i>Apurimacia michellii</i>	<i>Apurimacia michellii</i> (Rusby) Harms	<i>J.R.I. Wood et al.</i> 18729 (K)	Bolivia, Cochabamba	<i>ITS</i>	x	x
<i>Austrosteenisia glabristyla</i> H	<i>Austrosteenisia glabristyla</i> Jessup	<i>D.L. Jones</i> 1807 (K)	Australia, Moreton, Queensland	<i>ITS</i>	x	x
<i>Chadsia couteifolia</i>	<i>Chadsia couteifolia</i> Baillon	<i>D.J. & B.P. Puy</i> M580 (K)	Madagascar, Antsiranana province	<i>ITS</i>	x	x
<i>Chadsia flammea</i> ssp. <i>parviflora</i>	<i>Chadsia flammea</i> Bojer ssp. <i>parviflora</i> Du Puy & Labat	<i>M. Keraudren</i> 395	Madagascar	<i>ITS</i>	x	x
<i>Chadsia grevei</i> H	<i>Chadsia grevei</i> Drake	<i>R. Randriaraivo et al.</i> (1185) (K)	Madagascar, Toliara	<i>ITS</i>	x	x
<i>Chadsia grevei</i> ssp. <i>latifolia</i>	<i>Chadsia grevei</i> Drake ssp. <i>latifolia</i> (R. Viguier) Du Puy & Labat	<i>D.J. & B.P. Puy, P. Ravonjariisoa & P. Phillipson</i> M28 (K)	Madagascar, Toliara	<i>ITS</i>	x	x
<i>Chadsia racemosa</i>	<i>Chadsia racemosa</i> Drake	<i>R. Capuron</i> 23399-SF (K)	Madagascar, Sambirano	<i>ITS</i>	x	x
<i>Dahlstedtia pentaphylla</i>	<i>Dahlstedtia pentaphylla</i> (Taub.) Burkart	<i>G. Hatschbach</i> 42612 (K)	Brazil, Parana	<i>ITS</i>	x	x
<i>Deguelia densiflora</i> H	<i>Deguelia densiflora</i> (Benth.) A.M.G. Azevedo ex Sousa	<i>A.R.A. Gorts-Van Rijn, J. Brandbyge, J.J. de Granville, O. Poncy, H.J.M. Sipman & L.J.W. v.d. Wollenberg</i> 352 (K)	Guyana	<i>ITS</i>	x	x
<i>Deguelia nitidula</i> H	<i>Deguelia nitidula</i> (Benth.) A.M.G. Azevedo & R.A. Camargo	<i>M.M. Arbo, A.M. de Carvalho, M.S. Ferrucci, J.G. Jardim & S.C. de Sant'Ana</i> 7796 (K)	Brazil, Espirito Santo, Espirito Santo	<i>ITS</i>	x	x
<i>Dewevrea bilabiata</i>	<i>Dewevrea bilabiata</i> Micheli	<i>S. Lisowasi</i> 41097 (K)	Copngo, Haut-Zaire	<i>ITS</i>	x	x
<i>Millettia angustidentata</i>	<i>Millettia angustidentata</i> De Wild.	<i>R.M. Harley</i> 9441 (K)	Tanganyika, Mpanda district, Kungwe-Mahali Peninsula	<i>ITS</i>	x	x
<i>Millettia bicolor</i>	<i>Millettia bicolor</i> Dunn	<i>F.J. Breteler</i> 6250 (K)	Gabon, along the road Moanda to Franceville	<i>ITS</i>	x	x

Appendix 2.3 Continued.

Name code in the phylogenetic trees	Full name	Voucher specimens and herbarium	Locality	Gene markers		
				ITS	x	x
<i>Millettia bipindensis</i>	<i>Millettia bipindensis</i> Harms	<i>W. de Wilde</i> 2754 (K)	Cameroon, Riverine forest, bank Nyong river, S.W. of Eseka	ITS	x	x
<i>Millettia diptera</i>	<i>Millettia diptera</i> Gagnep.	<i>N.N. Du, N.Q. Binh, T.T. Bach, R.D. Kok, G. Branley, G. Challen, M. Vorontsova & A. Davis</i> HNK 1102 (K)	Vietnam (Indo-China), Ba Ria-Vung Tau prov., Xuyen Moc distr., Bihh Chau-Phuoc Buu reserved area, around Bung Rieng	ITS	x	x
<i>Millettia drastica</i>	<i>Millettia drastica</i> Welw.	<i>J.-B. Ndjango</i> 566 (K)	Congo, Orientale, Haut-Uele, Asonga Hill	ITS	x	x
<i>Millettia eriocarpa</i>	<i>Millettia eriocarpa</i> Dunn	<i>G.P. Clarke</i> 71 (K)	Tanzania, Chitoo forest reserve, Lindi district	ITS	x	x
<i>Millettia grandis</i> H	<i>Millettia grandis</i> Skeels	<i>Klein et al</i> 689 (K)	Congo	ITS	x	x
<i>Millettia griffoniana</i>	<i>Millettia griffoniana</i> Baill.	<i>G. Jackson</i> 115269 (K)	Nigeria, Jkorodu	ITS	x	x
<i>Millettia lasiantha</i> H	<i>Millettia lasiantha</i> Dunn	<i>W.R.Q. Luke</i> 3201 (K)	Kenya, Kwale district, Shimba hills	ITS	x	x
<i>Millettia laurentii</i>	<i>Millettia laurentii</i> De Wild.	<i>G. Troupin</i> 16315 (K)	Rwanda, Butare, Arboretum Ruhande	ITS	x	x
<i>Millettia leonensis</i>	<i>Millettia leonensis</i> Vatke	<i>X.M. Van der Burght et al.</i> 1565 (K)	Sierra Leone, Tonkolili district, near Sokoia village	ITS	x	x
<i>Millettia macrophylla</i>	<i>Millettia macrophylla</i> Benth.	<i>Watts</i> 1008 (K)	Cameroon, Idenao	ITS	x	x
<i>Millettia makondensis</i>	<i>Millettia makondensis</i> Harms	<i>S. Bidgood, R. Abdallah & K. Vollesen</i> 1336 (K)	Tanzania, Masasi district, Ndanda mission	ITS	x	x
<i>Millettia orientalis</i>	<i>Millettia orientalis</i> Du Puy & Labat	<i>G. McPherson</i> 14456 (K)	Madagascar	ITS	x	x
<i>Millettia panijuga</i>	<i>Millettia paucijuga</i> Harms	<i>J.L. Newman</i> 64 (K)	Tanzania, two miles S. of Dalai	ITS	x	x
<i>Millettia rhodantha</i>	<i>Millettia rhodantha</i> Baill.	<i>J. Moriba, X. Van der Burgt, L. L. Poveda, J. Sessay, T. Kamara & A. K. Kamara</i> 2 (K)	Sierra Leone, North province, Sanda Loko Chiefdom, Laminaia village	ITS	x	x
<i>Millettia rubiginosa</i>	<i>Millettia rubiginosa</i> Wight & Arn.	<i>A.J.G.H. Kostermans</i> 26310 (L; L.2040850)	India, S. India. S. Tamil Nadu, Tinneveli district, E. slopes W. Ghats, road to Walayar cardamon estate, along river.	ITS	matK	x

Appendix 2.3 Continued.

Name code in the phylogenetic trees	Full name	Voucher specimens and herbarium	Locality	Gene markers		
				ITS	x	x
<i>Millettia sanagana</i> H	<i>Millettia sanagana</i> Harms	<i>D. Harris</i> 2607 (K)	Sierra Leone, Tonkolili district	ITS	x	x
<i>Millettia sapinii</i>	<i>Millettia sapinii</i> De Wild.	<i>B. Masens</i> 824 (K)	Congo, Palmeraie	ITS	x	x
<i>Millettia schliebenii</i>	<i>Millettia schliebenii</i> Harms	<i>K. Vollesen</i> 4256 (K)	Tanzania, Kichi hills	ITS	x	x
<i>Millettia simsii</i>	<i>Millettia simsii</i> J.B. Gillett	<i>M.Mbago, O. Kibure & E. Prins</i> FMM 2172 (K)	Tanzania, Lindi region, Noto Plateau	ITS	x	x
<i>Millettia</i> sp.1 H	<i>Millettia</i> sp.	<i>Put</i> 193 (K)	Thailand, Kanchanaburi province	ITS	x	x
<i>Millettia</i> sp.6 H	<i>Millettia</i> sp.	<i>J. & M.S.Clemens</i> 3635 (P; P02753791)	Vietnam, Quang Nam Đà Nang: Mt Ba Na (c.a. 25 km from Tourane)	ITS	x	x
<i>Millettia stuhlmannii</i>	<i>Millettia stuhlmannii</i> Taub.	<i>T. Muller & G.P. Clark</i> 4170 (K)	Mozambique, Cabo Delgado, Quissenga district, Lupangua hill	ITS	x	x
<i>Millettia thonningii</i> H	<i>Millettia thonningii</i> Baker	<i>H. Ern</i> Nr. 3263 (K)	Togo, Pagala station, Bachuferwald Strauch	ITS	x	x
<i>Millettia usaramensis</i> ssp. <i>usaramensis</i>	<i>Millettia usaramensis</i> Taub. ssp. <i>usaramensis</i>	<i>R. Abdallah, E. Mboya & K. Vollesen</i> 96/177 (K)	Tanzania, Mkomazi district, Game Reserve, Uмба river area	ITS	x	x
<i>Millettia warneckeii</i>	<i>Millettia warneckeii</i> Harms	<i>C.C.H. Jongkind & R.D. Noyes</i> 1276 (K)	Ghana, Accra	ITS	x	x
<i>Millettia zechiana</i>	<i>Millettia zechiana</i> Harms	<i>H. Ern</i> 3169 (K)	Togo, Mont Agou	ITS	x	x
<i>Mundulea antanossarum</i>	<i>Mundulea antanossarum</i> Baill.	<i>D.J. & B.P. Du Puy</i> M420 (K)	Madagascar, Toliara (Tulear) province	ITS	x	x
<i>Mundulea laxiflora</i>	<i>Mundulea laxiflora</i> Baker	<i>Dan Turk & J. Randrianasolo</i> 312 (K)	Madagascar, Fianarantsoa, National road 45 SW between Vohiparara and Sahavandronana	ITS	x	x
<i>Philenoptera madagascariensis</i>	<i>Philenoptera madagascariensis</i> (Vatke) Schrire	<i>F. Barthelat & A.B. Sifory</i> 199 (K)	Madagascar	ITS	x	x
<i>Platysepalum chevalieri</i>	<i>Platysepalum chevalieri</i> Harms	<i>Compere</i> 167 (K)	Congo	ITS	x	x
<i>Platysepalum inopinatum</i>	<i>Platysepalum inopinatum</i> Harms	<i>Frontier</i> 2211 (K)	Tanzania, Pande forest, Kinondoni district	ITS	x	x

Appendix 2.3 Continued.

Name code in the phylogenetic trees	Full name	Voucher specimens and herbarium	Locality	Gene markers		
				ITS	x	x
<i>Platysepalum violaceum</i>	<i>Platysepalum violaceum</i> Welw. ex Baker var. <i>vanhouttei</i> (De Wild.) Hauman	<i>Floriber Bujo</i> 3246 (K)	Congo, Orientale, Haut-Uele, Zatusa Hill	ITS	x	x
<i>Ptychlobium plicatum</i>	<i>Ptychlobium plicatum</i> (Oliv.) Harms	<i>J.R.I. Wood</i> 2698 (K)	Yemen, Belou Hadia, Tesel Raynah	ITS	x	x
<i>Pyranthus ambatoana</i>	<i>Pyranthus ambatoana</i> (Baill.) Du Puy & Labat	<i>G. McPherson & H. Van der Werff</i> 16461 (K)	Madagascar, Antananarivo	ITS	x	x
<i>Pyranthus lucens</i>	<i>Pyranthus lucens</i> (R. Vig.) Du Puy & Labat	<i>M.M. Debray</i> 1434 (K)	Madagascar, Namakia village, Ampanantra	ITS	x	x
<i>Pyranthus tullearensis</i>	<i>Pyranthus tullearensis</i> (Baill.) Du Puy & Labat	<i>J.N.-Labat</i> 3647 (K)	Madagascar, Toliara-Sakaraha	ITS	x	x
<i>Requienia obcordata</i>	<i>Requienia obcordata</i> (Lam. ex Poir.) DC.	<i>Eden Foundamon</i> 53 (K)	Nigeria, Zinder Dalu village	ITS	x	x
<i>Requienia sphaerosperma</i>	<i>Requienia sphaerosperma</i> DC.	<i>Rebrown</i> s.n. (K)	Botswana, Ghazi	ITS	x	x
<i>Schefflerodendron usambarense</i> H	<i>Schefflerodendron usambarense</i> Harms	<i>S.R. Semsei</i> 3540 (K)	Kenya	ITS	x	x

Appendix 3.1 Presence or absence of Canavanine in the species sampled for phylogeny reconstruction. The species name in the first column is as it appears in Chapter 3. Presence of Canavanine is indicated P, absence as A. The source whether the specimen sampled is vouchered is indicated in the fourth column. B refers to Bell *et al.* (1978); E refers to Evans *et al.* (1985); F= Fellows *et al.*, 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch; V= vouchered; NV= not vouchered.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch; V=vouchered; NV=not vouchered
<i>Abrus precatorius</i> L.	BMP Grade	A	B
<i>Abrus pulchellus</i> Wall. ex Thwaites ssp. <i>cantoniensis</i> (Hance) VerDC.	BMP Grade	A	Chiang, T-C. <i>et al.</i> (1980) <i>Planta Med.</i> 39: 225; Chiang, T-C. and Chang, H.M. (1982) <i>Planta Med.</i> 46: 52-55; Wong, S-M. <i>et al.</i> (1982) <i>Planta Med.</i> 46: 191-192; Bisby
<i>Aganope gabonica</i> (Baill.) Polhill	BMP Grade	A	E; V
<i>Aganope heptaphylla</i> (L.) Polhill [syn. <i>Derris heptaphylla</i> (L.) Merr.; <i>Derris sinuata</i> Thwaites]	BMP Grade	A	E; V; Bisby; E
<i>Aganope impressa</i> (Dunn) Polhill	BMP Grade	A	E; V; Bisby
<i>Aganope leucobotrya</i> (Dunn) Polhill	BMP Grade	A	E; V
<i>Aganope stuhlmannii</i> (Taub.) Adema [basio. <i>Xerroderris stuhlmannii</i> (Taub.)]	BMP Grade	A	E; V
<i>Aganope thyriflora</i> (Benth.) Polhill [syn. <i>Derris thyriflora</i> (Benth.) Benth.]	BMP Grade	A	E; V; Bisby; E
<i>Antheropoum pierrei</i> Gagnep.	BMP Grade	A	E; V; Bisby
<i>Austrostenisia blackii</i> (F.Muell.) R.Geesink [syn. <i>Kunstleria blackii</i> (F.Muell.) Polhill]	BMP Grade	A	E; V
<i>Craibia brevicaudata</i> ssp. <i>baptistarum</i> (Buttner) J.B.Gillett	BMP Grade	A	E; V; Bisby
<i>Craibia brevicaudata</i> ssp. <i>burtii</i> (Baker.f.) J.B.Gillett	BMP Grade	A	E; V

Appendix 3.1 Continued.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch;V=vouchered; NV=not vouchered
<i>Craspedolobium unijugum</i> (Gagnep.) Z. Wei & Pedley [syn. <i>Craspedolobium schochii</i> Harms]	BMP Grade	P	E; V; Bisby
<i>Dalbergiella nyasae</i> Baker.f.	BMP Grade	A	E; V
<i>Platysepalum regnellii</i> Benth.	BMP Grade	P	E; V; Bisby
<i>Millettia griffoniana</i> Baill.	Clade 1 canavanine	P	E; V; Bisby
<i>Millettia rhodantha</i> Baill.	Clade 1 canavanine	P	E; V; Bisby
<i>Fordia albiflora</i> (Prain) U.A. Dasuki & A.M. Schot [<i>Millettia albiflora</i> Prain]	Clade 1 canavanine clade	P	E; V; Bisby
<i>Leptoderris fasciculata</i> (Benth.) Dunn	Clade 1 canavanine clade	A	E; V; F
<i>Millettia grandis</i> Skeels	Clade 1 canavanine clade	P/A	E; V; Bisby, present
<i>Millettia lasiantha</i> Dunn	Clade 1 canavanine clade	P	E; V; Bisby
<i>Millettia laurentii</i> De Wild.	Clade 1 canavanine clade	P	E; V; F
<i>Millettia leucantha</i> Kurz var. <i>latifolia</i> Dunn PK Loc [syn. <i>Millettia latifolia</i> Dunn; <i>Millettia pendula</i> Benth.]	Clade 1 canavanine clade	P	E; V ; F; Bisby
<i>Philenoptera cyanescens</i> (Schumach. & Thonn.) Roberty [syn. <i>Lonchocarpus cyanescens</i> (Schum. & Thonn.) Benth.]	Clade 1 canavanine clade	P	E; V; F
<i>Philenoptera eriocalyx</i> (Harms) Schrire [basio. <i>Lonchocarpus eriocalyx</i> Harms]	Clade 1 canavanine clade	P	E; V; F; Bisby
<i>Platysepalum chevalieri</i> Harms	Clade 1 canavanine clade	P	E; V; Bisby
<i>Platysepalum violaceum</i> Welw. ex Baker var. <i>vanhouttei</i> (De Wild.) Hauman	Clade 1 canavanine clade	P	E; V B
<i>Platysepalum hirsutum</i> (Dunn) Hepper	Clade 1 canavanine clade	P	E; V; Bisby
<i>Philenoptera bussei</i> (Harms) Schrire [basio. <i>Lonchocarpus bussei</i> Harms]	Clade 1 canavanine clade	P	E; V; F; Bisby
<i>Millettia pachycarpa</i> Kurz	Clade 1 canavanine clade & Clade 2 non canavanine clade	P/A	E; V; Bisby; Hui <i>et al</i> (1973) [Phytochemistry]; Singhal <i>et al.</i> 1980,1981-83 [Phytochemistry]

Appendix 3.1 Continued.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch; V=vouchered; NV=not vouchered
<i>Dahlstedtia araripensis</i> (Benth.) M.J. Silva & A.M.G. Azevedo [syn. <i>Lonchocarpus araripensis</i> Benth.]	Clade 2 non canavanine	A	E; V; Bisby
<i>Muelleria sanctaemarthae</i> (Pittier) M.J. Silva & A.M.G. Azevedo [baio. <i>Lonchocarpus sanctaemarthae</i> Pittier]	Clade 2 non Canavanine	A	E; V; F; Bisby
<i>Dahlstedtia floribunda</i> (Vogel) M.J. Silva & A.M.G. Azevedo [syn. <i>Lonchocarpus subglaucescens</i> Mart. ex Benth.]	Clade 2 non canavanine	A	E; V; Bisby
<i>Dahlstedtia muehlbergiana</i> (Hassl.) M.J. Silva & A.M.G. Azevedo [basio. <i>Lonchocarpus muehlbergianus</i> Hassl.]	Clade 2 non canavanine	A	E; V; Bisby
<i>Dahlstedtia pentaphylla</i> (Taub.) Burkart [basio. <i>Lonchocarpus pentaphyllus</i> Taub.]	Clade 2 non canavanine	A	E; V; Bisby
<i>Dahlstedtia pinnata</i> (Benth.) Malme	Clade 2 non canavanine	A	Bisby; NV; Garcez, F.R. <i>et al</i> (1988) <i>Phytochemistry</i> 27: 1079-1083
<i>Deguelia martynii</i> (A.C. Smith) A.M.G. Azevedo [basio. <i>Lonchocarpus martynii</i> A.C.Sm.]	Clade 2 non canavanine	A	E; V; Bisby
<i>Deguelia rariflora</i> (Mart. ex Benth.) G.P.Lewis & Acev.-Rodr.	Clade 2 non canavanine	A	Bisby; NV; Braz Filho, R. <i>et al</i> (1975) <i>Phytochemistry</i> 14: 261-263
<i>Deguelia scandens</i> Aubl. [syn. <i>Derris guianensis</i> Benth., <i>Derris longifolia</i> Benth., [<i>Derris negrensis</i> Benth., <i>Derris pterocarpa</i> (DC.) Killip, <i>Deguelia negrensis</i> (Benth.) Taub., <i>Lonchocarpus negrensis</i> Benth., <i>Derris amazonica</i> Killip]	Clade 2 non canavanine	P	E; V; Bisby; Vasconcelos, M.N.L. and Maia, J.G.S. (1976) <i>Acta Amazonica</i> 6: 59-61; C.A. 85: 119558h
<i>Deguelia spruceana</i> (Benth.) A.M.G. Azevedo [basio. <i>Lonchocarpus spruceanus</i> Benth.]	Clade 2 non canavanine	A	E V; F; Bisby
<i>Derris amoena</i> (Wall.) Benth.	Clade 2 non canavanine	A	E; V; Bisby

Appendix 3.1 Continued.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch; V=vouchered; NV=not vouchered
<i>Derris cuneifolia</i> Benth. var. <i>cuneifolia</i> [syn. <i>Derris discolor</i> Benth.]	Clade 2 non canavanine	A	E; V; Bisby
<i>Derris elegans</i> Graham ex Benth.	Clade 2 non canavanine	A	E; V; Bisby
<i>Derris elliptica</i> (Wall.) Adema	Clade 2 non canavanine	A	E; V; Bisby
<i>Derris ferruginea</i> (Roxb.) Benth.	Clade 2 non canavanine	A	E; V; Bisby
<i>Derris lianoides</i> Elmer	Clade 2 non canavanine	A	E; V; Bisby
<i>Derris trifoliata</i> Lour.	Clade 2 non canavanine	A	E; V; Bisby
<i>Fordia cauliflora</i> Hemsl.	Clade 2 non canavanine	A	E; V; Bisby
<i>Fordia splendidissima</i> (Miq.) Buijsen [syn. <i>Fordia splendidissima</i> (Miq.) Buijsen ssp. <i>splendidissima</i> ; <i>Fordia filipes</i> Dunn; <i>Fordia coriacea</i> Dunn]	Clade 2 non canavanine	A	E; V; Bisby
<i>Lonchocarpus benthamianus</i> Pittier [syn. <i>Lonchocarpus violaceus</i> Benth. var. <i>violaceus</i>]	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Lonchocarpus dipteroneurus</i> Pittier	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Lonchocarpus emarginatus</i> Pittier	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Lonchocarpus eriocarinalis</i> Micheli	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Lonchocarpus guatemalensis</i> Benth.	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Lonchocarpus guillemineanus</i> (Tul.) Malme [syn. <i>Lonchocarpus neuroscapha</i> Benth.]	Clade 2 non canavanine	A	E; V; F
<i>Lonchocarpus hermannii</i> M.Sousa [syn. <i>Willardia mexicana</i> (S.Watson) Rose]	Clade 2 non canavanine	A	E; V; Bisby
<i>Lonchocarpus lanceolatus</i> Benth.	Clade 2 non canavanine	A	E; V; Bisby
<i>Lonchocarpus latifolius</i> Kunth	Clade 2 non canavanine	A	E; V

Appendix 3.1 Continued.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch;V=vouchered; NV=not vouchered
<i>Lonchocarpus lilloi</i> (Hassler) Burkart	Clade 2 non canavanine	A	E; V; Bisby
<i>Lonchocarpus macrocarpus</i> Benth. [syn. <i>Lonchocarpus ernestii</i> Harms]	Clade 2 non canavanine	A	E; V; Bisby
<i>Lonchocarpus margaritensis</i> Pittier	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Lonchocarpus minimiflorus</i> Donn. Sm	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Lonchocarpus monilis</i> (L.) A.M.G. Azevedo	Clade 2 non canavanine	A	E; V; Bisby
<i>Lonchocarpus nitidus</i> (Vogel) Benth.	Clade 2 non canavanine	A	E; V
<i>Lonchocarpus obovatus</i> Benth.	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Lonchocarpus orotinus</i> Pittier	Clade 2 non canavanine	A	E; V; Bisby
<i>Lonchocarpus parviflorus</i> Benth.	Clade 2 non canavanine	A	E; V; Bisby
<i>Lonchocarpus purpureus</i> Pittier	Clade 2 non canavanine	A	E; V; Bisby
<i>Lonchocarpus rugosus</i> Benth.	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Lonchocarpus salvadorensis</i> Pittier	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Lonchocarpus unifoliolatus</i> Benth.	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Lonchocarpus xuul</i> Lundell	Clade 2 non canavanine	A	E; V; F
<i>Millettia brandisiana</i> Kurz	Clade 2 non canavanine	A	E; V; Bisby
<i>Millettia drastica</i> Welw.	Clade 2 non canavanine	A	E; V; Bisby
<i>Millettia dura</i> Dunn	Clade 2 non canavanine	A	E; V; Bisby
<i>Millettia eriocarpa</i> Dunn	Clade 2 non canavanine	A	E; V; Bisby
<i>Millettia erythrocalyx</i> Gagnep.	Clade 2 non canavanine	A	E; V; Bisby
<i>Millettia extensa</i> Benth. ex Baker.f. [syn. <i>Millettia auriculata</i> Baker]	Clade 2 non canavanine	A	E; V; Bisby
<i>Millettia ichthyochtona</i> Drake	Clade 2 non canavanine	A	E; V; Bisby

Appendix 3.1 Continued.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch;V=vouchered; NV=not vouchered
<i>Millettia macrophylla</i> Benth.	Clade 2 non canavanine	A	E; V; Bisby
<i>Millettia ovalifolia</i> Kurz [<i>Millettia peguensis</i> Ali]	Clade 2 non canavanine	A	Bisby; NV; Gupta and Krishnamurti (1976 & 1977 & 1979) Phytochemisstry
<i>Millettia pinnata</i> (L.) Panigrahi in G. Panigrahi & Amp; S.K. Murti, [syn. <i>Pongamia pinnata</i> (L.) Pierre]	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Millettia pulchra</i> Kurz	Clade 2 non canavanine	A	E; V; Bisby
<i>Millettia rubiginosa</i> Wight & Arn.	Clade 2 non canavanine	A	Bisby; NV; Desai <i>et al.</i> , (1977) [Indian J. Chem., Sect. B15: 291-293]
<i>Millettia sanagana</i> Harms	Clade 2 non canavanine	A	E; V; Bisby
<i>Millettia sericea</i> (Vent.) Wight & Arn. ex Hassk.	Clade 2 non canavanine	A	E; V; Bisby
<i>Millettia stuhlmannii</i> Taub.	Clade 2 non canavanine	P	E; V; F; Bisby
<i>Millettia thonningii</i> Baker	Clade 2 non canavanine	P/A	E, absent; V; Bisby, present
<i>Millettia usaramensis</i> Taub.	Clade 2 non canavanine	A	E; V; Bisby; F
<i>Millettia xylocarpa</i> Miq. [syn. <i>Millettia decipens</i> Prain; <i>Millettia hemsleyana</i> Prain; <i>Millettia pubinervis</i> Kurz]	Clade 2 non canavanine	P/A	E, absent; V; Bisby, present ; F, present
<i>Millettia zechiana</i> Harms	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Muelleria fendleri</i> (Benth.) M.J. Silva & A.M.G Azevedo [basio. <i>Lonchocarpus fendleri</i> Benth.; syn. <i>Lonchocarpus stenurus</i> Pittier]	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Muelleria filipes</i> (Benth.) M.J. Silva & A.M.G. Azevedo [basio. <i>Lonchocarpus filipes</i> Benth.]	Clade 2 non canavanine	A	E; V; Bisby
<i>Muelleria lutescens</i> (Pittier) M.J. Silva & A.M.G. Azevedo[basio. <i>Lonchocarpus lutescens</i> Pittier]	Clade 2 non canavanine	A	E; Bisby

Appendix 3.1 Continued.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch; V=vouchered ; NV=not vouchered
<i>Muelleria moniliformis</i> L.f. [basio. <i>Lonchocarpus monilis</i> (L.) A.M.G.Azevedo]	Clade 2 non canavanine	A	E; V
<i>Muelleria monilis</i> (L.) M.J. Silva & A.M.G. Azevedo [syn. <i>Muelleria frutescens</i> (Aubl.) Standl.; <i>Lonchocarpus monilis</i> (L.) A.M.G.Azevedo]	Clade 2 non canavanine	A	E; V; Bisby; Lyra, D.A. <i>et al.</i> (1979) Gazz. Chim. Ital. 109: 93-94
<i>Muelleria sericea</i> (Micheli) M.J. Silva & A.M.G. Azevedo [syn. <i>Lonchocarpus sericeus</i> (Poir.) Kunth ex DC.]	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Piscidia carthagenensis</i> Jacq. [syn. <i>Piscidia communis</i> (S.F.Blake) Harms]	Clade 2 non canavanine	A	E; V; F; E; Bisby
<i>Piscidia grandifolia</i> (Donn.Sm.) I.M.Johnst.	Clade 2 non canavanine	A	F; NV; Bisby
<i>Piscidia mollis</i> Rose	Clade 2 non canavanine	A	E; V; Bisby
<i>Piscidia piscipula</i> Sarg.	Clade 2 non canavanine	A	E; V; Bisby
<i>Solori involuta</i> (Sprague) Sirch. & Adema [basio. <i>Derris involuta</i> Sprague]	Clade 2 non canavanine	A	E; V; Bisby
<i>Solori microphylla</i> (Miq.) Sirch. & Adema [basio. <i>Derris microphylla</i> Miq.; <i>Derris dalbergioides</i> Baker]	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Solori robusta</i> (Roxb. ex DC.) Sirich. & Adema [syn. <i>Brachypterum robustum</i> (Roxb. ex DC.) Dalzell & A. Gibson]	Clade 2 non canavanine	A	E; V; Bisby
<i>Solori scandens</i> (Roxb.) Sirch. & Adema [basio. <i>Derris scandens</i> Roxb.]	Clade 2 non canavanine	A	E; V; F
<i>Tephrosia candida</i> (Roxb.) DC.	Clade 2 non canavanine	A	E; V; Bisby
<i>Tephrosia heckmanmiana</i> Harms	Clade 2 non canavanine	A	E; V; Bisby
<i>Tephrosia leiocarpa</i> A. Gray	Clade 2 non canavanine	A	Bisby; Gomez-Garibay, F. <i>et al.</i> (1991) [Phytochemistry 30: 3832-3834]
<i>Tephrosia nubica</i> (Boiss.) Baker	Clade 2 non canavanine	A	Bisby; Ammar, N.M. and Jarvis, B.B. (1986) [J. Nat. Prod. 49: 719-720]

Appendix 3.1 Continued

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch; V=vouchered; NV=not vouchered
<i>Tephrosia obovata</i> Merr.	Clade 2 non canavanine	A	Bisby; Chen, Y.-L. <i>et al</i> (1978) [Agric. Biol. Chem 42: 2431-2432]
<i>Tephrosia purpurea</i> (L.) Pers. [syn. <i>Tephrosia piscatoria</i> (Aiton) Pers.; <i>Tephrosia wallichii</i> Fawc. & Rendle]	Clade 2 non canavanine	A	E; V; Bisby
<i>Tephrosia rufescens</i> Benth.	Clade 2 non canavanine	A	E; V; Bisby
<i>Tephrosia uniflora</i> Pers.	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Tephrosia vicioides</i> Schltld. [syn. <i>Tephrosia tenella</i> A.Gray]	Clade 2 non canavanine	A	E; V; Bisby
<i>Tephrosia villosa</i> (L.) Pers.[syn. <i>Tephrosia incana</i> (Roxb.) Sweet]	Clade 2 non canavanine	P/A	E, present; V; Bisby, present
<i>Tephrosia villosa</i> ssp. <i>ehrenbergiana</i> (Schweinf.) Brummitt [syn. <i>Tephrosia ehrenbergiana</i> Schweinf.]	Clade 2 non canavanine	A	E; V; Bisby
<i>Tephrosia vogelii</i> Hook.f.	Clade 2 non canavanine	A	E; V; F; Bisby
<i>Chadsia grevei</i> Drake	Clade 2 non canavanine	A	E; V; Bisby
<i>Afgekia filipes</i> (Dunn) R.Geesink [syn. <i>Padbruggea filipes</i> (Dunn) Craib]	IRLC clade	A	E; V; Bisby
<i>Afgekia sericea</i> Craib	IRLC clade	P	E; V; Bisby
<i>Callery cinerea</i> [syn. <i>Millettia dowardii</i>]	IRLC clade	P	E; V; Bisby
<i>Callerya atropurpurea</i> (Wall.) Schot [syn. <i>Whitfordiodendron atropurpureum</i> ; <i>Millettia atropurpurea</i> (Wall.) Benth.; <i>Padbruggea pubescens</i> Craib]	IRLC clade	P/A	E, absent; V; Bisby, present; T, present
<i>Callerya australis</i> (Endl.) Schot [<i>Millettia australis</i> Endl.]	IRLC clade	P	E; V; Bisby
<i>Callerya cinerea</i> (Benth.) Schot [basio. <i>Millettia cinerea</i> Benth.; syn. <i>Millettia dowardii</i>]	IRLC clade	P	E; V; Bisby; T
<i>Callerya dasyphylla</i> (Miq.) Schot [basio. <i>Padbruggea dasyphylla</i> Miq.]	IRLC clade	A	E; V; Bisby
<i>Callerya dielsiana</i> (Harms) P.K. Lôc ex Z. Wei & Pedley [basio. <i>Millettia dielsiana</i> Harms]	IRLC clade	P	E; V; Bisby; Hui <i>et al</i> 1973; Wang <i>et al</i> 1989 & 1990

Appendix 3.1 Continued.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch;V=vouchered; NV=not vouchered
<i>Callerya eriantha</i> (Benth.) Schot [basio. <i>Millettia eriantha</i> Benth.; syn. <i>Padbruggea eriantha</i> (Benth.) Craib]	IRLC clade	A	E; V; Bisby
<i>Callerya megasperma</i> (F.Muell) Schot [<i>Millettia megasperma</i>]	IRLC clade	P	E; V; Bisby
<i>Callerya nitida</i> (Benth.) R.Geesink [<i>Millettia nitida</i> (Benth.) R.Geesink]	IRLC clade	P	E; V; Bisby; Hui <i>et al</i> (1973) [Phytochemistry]
<i>Callerya nieuwenhuisii</i> (J.J.Sm.) Schot [syn. <i>Whitfordiodendron myrianthum</i> (Dunn) Merr.]	IRLC clade	A	E; V
<i>Callerya reticulata</i> (Benth.) Schot [basio. <i>Millettia reticulata</i> Benth.]	IRLC clade	P	E; V; Bisby
<i>Endosamara racemosa</i> (Roxb.) R.Geesink [syn. <i>Millettia racemosa</i> Roxb.]	IRLC clade	P	E; V; F; Bisby
<i>Wisteria brachybotrys</i> Siebold & Zucc.	IRLC clade	P	E; V; Bisby
<i>Wisteria floribunda</i> (Willd.) DC.	IRLC clade	P	E; V; Bisby
<i>Wisteria frutescens</i> (L.) Poir.	IRLC clade	P	E; V
<i>Wisteria sinensis</i> (Seems) Sweet	IRLC clade	P	E; V; Bisby
<i>Wisteria villosa</i> Rehder	IRLC clade	P	E; V
<i>Aganope polystachya</i> (Benth.) Thoth. & D.N.Das [basio. <i>Derris polystachya</i> Benth.]	not screened in phylogeny	A	E; V; Bisby
<i>Callerya championii</i> (Benth.) X.Y. Zhu [syn. <i>Millettia championii</i> Benth.]	not screened in phylogeny	P	E; V; Bisby
<i>Callerya</i> sp. [<i>Padbruggea</i> sp.]	not screened in phylogeny	A	E; V
<i>Callerya vasta</i> (Kosterm.) Schot [syn. <i>Millettia vasta</i> Kosterm.]	not screened in phylogeny	A	E; V; Bisby
<i>Craibia affinis</i> (De Wild.) De Wild.	not screened in phylogeny	A	E; V; Bisby
<i>Craibia atlantica</i> Dunn	not screened in phylogeny	A	E; V; Bisby
<i>Craibia brownii</i> Dunn	not screened in phylogeny	A	E; V; Bisby
<i>Craibia grandiflora</i> (Micheli) Baker.f.	not screened in phylogeny	A	E; V; Bisby
<i>Craibia laurentii</i> (De Wild.) De Wild.	not screened in phylogeny	A	E; V; Bisby
<i>Craibia zimmermannii</i> (Harms) Dunn	not screened in phylogeny	A	E; V; Bisby
<i>Dalbergiella welwitschii</i> (Baker) Baker.f.	not screened in phylogeny	A	E; V

Appendix 3.1 Continued.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch; V=vouchered; NV=not vouchered
<i>Deguelia rufescens</i> var. <i>urucu</i> (Killip & A.C. mith) A. Tozzi [syn. <i>Lonchocarpus uruzu</i> Killip & A.C. Smith]	not screened in phylogeny	A	E; V; B
<i>Derris benthamii</i> (Thwaites) Thwaites	not screened in phylogeny	A	F; E; V; Bisby
<i>Derris brevipes</i> (Benth.) Baker	not screened in phylogeny	A	Bisby; NV
<i>Derris canarensis</i> (Dalzell) Baker	not screened in phylogeny	A	F; E; V; Bisby
<i>Derris hainesiana</i> Thoth.	not screened in phylogeny	A	Bisby; NV
<i>Derris koolgibberah</i> Bail. ssp. <i>pseudoinvoluta</i> VerDC.	not screened in phylogeny	A	E; V; Bisby
<i>Derris malaccensis</i> Prain	not screened in phylogeny	A	E; V; Bisby
<i>Derris marginata</i> (Roxb.) Benth.	not screened in phylogeny	A	E; V; Bisby
<i>Derris microptera</i> Benth.	not screened in phylogeny	A	E; V; Bisby
<i>Derris</i> sp.1	not screened in phylogeny	A	Bisby; NV
<i>Derris</i> sp.2	not screened in phylogeny	A	Bisby; NV
<i>Hesperothamnus ehrenbergii</i> (Harms) Harms	not screened in phylogeny	A	E; V; Bisby
<i>Leptoderris aurantiaca</i> Dunn	not screened in phylogeny	A	E; V
<i>Leptoderris congolensis</i> (De Wild.) Dunn	not screened in phylogeny	A	E; V
<i>Leptoderris glabrata</i> (Baker) Dunn	not screened in phylogeny	A	E; V
<i>Leptoderris goetzei</i> (Harms) Dunn	not screened in phylogeny	A	E; V
<i>Leptoderris nobilis</i> (Baker) Dunn	not screened in phylogeny	A	F; E; V
<i>Lonchocarpus atropurpureus</i> Benth.	not screened in phylogeny	A	F; E; V
<i>Lonchocarpus capassa</i> Rolfe	not screened in phylogeny	P	E; V; F; Bisby
<i>Lonchocarpus castilloi</i> Standl.	not screened in phylogeny	A	E; V; F; Bisby

Appendix 3.1 Continued.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch;V=vouchered; NV=not vouchered
<i>Lonchocarpus constaricensis</i> (Donn.Sm.) Pittier	not screened in phylogeny	A	F; NV
<i>Lonchocarpus constrictus</i> Pittier	not screened in phylogeny	A	E; V; Bisby
<i>Lonchocarpus costaricensis</i> (Donn.Sm.) Pittier	not screened in phylogeny	A	E; V; F; Bisby
<i>Lonchocarpus densiflorus</i> Benth.	not screened in phylogeny	A	Bisby; NV
<i>Lonchocarpus discolor</i> Huber	not screened in phylogeny	A	F; NV
<i>Lonchocarpus domingensis</i> (Pers.) DC.	not screened in phylogeny	A	E; V; Bisby
<i>Lonchocarpus erocarinalis</i> Micheli	not screened in phylogeny	A	F; NV
<i>Lonchocarpus floribundus</i> Benth.	not screened in phylogeny	A	E; V; Bisby
<i>Lonchocarpus glabrescens</i> Benth.	not screened in phylogeny	A	E; V; F; Bisby
<i>Lonchocarpus guillemineanus</i> (Tul.) Malme	not screened in phylogeny	A	F; E; V; Bisby
<i>Lonchocarpus hondurensis</i> Benth.	not screened in phylogeny	A	F; E; V; Bisby
<i>Lonchocarpus laxiflorus</i> Guill. & Perr.	not screened in phylogeny	P	F; E; V; Bisby
<i>Lonchocarpus leucanthus</i> Burkart	not screened in phylogeny	A	E; V
<i>Lonchocarpus nelsii</i> (Schinz) Heering & Grimme	not screened in phylogeny	P	E; V; F; Bisby
<i>Lonchocarpus nitidulus</i> Benth.	not screened in phylogeny	A	E; V; Bisby
<i>Lonchocarpus oliganthus</i> F.J.Herm.	not screened in phylogeny	A	F; E; V
<i>Lonchocarpus peninsularis</i> (Donn.Sm.) Pittier	not screened in phylogeny	A	E; V; F; Bisby
<i>Lonchocarpus</i> sp.2	not screened in phylogeny	P	B
<i>Lonchocarpus spiciflorus</i> Benth.	not screened in phylogeny	A	F; E; V; Bisby
<i>Lonchocarpus sutherlandii</i> (Harv.) Dunn	not screened in phylogeny	P	E; V; Bisby
<i>Lonchocarpus velutinus</i> Benth.	not screened in phylogeny	A	F; E; V; Bisby
<i>Lonchocarpus violaceus</i> (Jacq.) DC.	not screened in phylogeny	A	F; NV
<i>Millettia aboensis</i> (Hook.f.) Baker	not screened in phylogeny	A	E; V; Bisby

Appendix 3.1 Continued.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch;V=vouchered; NV=not vouchered
<i>Millettia barteri</i> (Benth.) Dunn	not screened in phylogeny	A	E; V; Bisby
<i>Millettia bussei</i> Harms	not screened in phylogeny	P/A	F; E, absent; V; Bisby, present
<i>Millettia chrysophylla</i> Dunn	not screened in phylogeny	P	E; V; Bisby
<i>Millettia dinklagei</i> Harms	not screened in phylogeny	P	E; V; Bisby
<i>Millettia eetveldeana</i> (Micheli) Hauman	not screened in phylogeny	A	E; V; Bisby
<i>Millettia elongatistyla</i> J.B.Gillett	not screened in phylogeny	A	E; V; Bisby
<i>Millettia ferruginea</i> (Hochst.) Baker ssp. <i>darassana</i> (Cuf.) J.B. Gillett	not screened in phylogeny	A	Bisby; NV
<i>Millettia ferruginea</i> (Hochst.) Baker ssp. <i>ferruginea</i>	not screened in phylogeny	A	E; V; Bisby; Dage <i>et al.</i> , 1989 & 1990 [Phytochemistry 28,1989; Phytochemistry 29 1990]
<i>Millettia hylobia</i> Hauman	not screened in phylogeny	P	E; V; Bisby
<i>Millettia impressa</i> Harms	not screened in phylogeny	A	E; V; Bisby
<i>Millettia irvinei</i> Hutch. & Dalziel	not screened in phylogeny	P	E; V; Bisby
<i>Millettia japonica</i> (Siebold & Zucc.) A. Gray [basion. <i>Wisteria japonica</i> Siebold & Zucc.]	not screened in phylogeny	P	E; V; Bisby
<i>Millettia lucens</i> (Scott-Elliott) Dunn	not screened in phylogeny	P	E; V; Bisby
<i>Millettia micans</i> Taub.	not screened in phylogeny	A	E; V; Bisby
<i>Millettia mossambicensis</i> J.B.Gillett	not screened in phylogeny	A	E; V; Bisby
<i>Millettia oblata</i> Dunn ssp. <i>intermedia</i> J.B. Gillett	not screened in phylogeny	A	E; V; Bisby
<i>Millettia pallens</i> Stapf	not screened in phylogeny	A	E; V; Bisby
<i>Millettia piscidia</i> (Roxb.) Wight	not screened in phylogeny	A	E; V; Bisby
<i>Millettia puguensis</i> J.B.Gillett	not screened in phylogeny	P	E; V; Bisby
<i>Millettia solomonensis</i> VerDC.	not screened in phylogeny	A	E; V; F; Bisby

Appendix 3.1 Continued.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch;V=vouchered; NV=not vouchered
<i>Millettia</i> sp.3	not screened in phylogeny	A	Bisby
<i>Millettia splendens</i> Harms	not screened in phylogeny	A	E; V; Bisby
<i>Millettia urophylloides</i> De Wild.	not screened in phylogeny	P	E; V; Bisby
<i>Millettia versicolor</i> Baker	not screened in phylogeny	A	E; V; Bisby
<i>Mundulea sericea</i> (Willd.) A.Chev. ssp. <i>madagascariensis</i> Du Puy & Labat [syn. <i>Mundulea telfairii</i>]	not screened in phylogeny	A	E; V; F; Bisby
<i>Mundulea</i> sp.1	not screened in phylogeny	P	Bisby
<i>Piscidia grandifolia</i> (Donn.Sm.) I.M.Johnst. var. <i>glabrescens</i> Sandwith	not screened in phylogeny	A	E; V; Bisby
<i>Poecilanthe amazonica</i> (Ducke) Ducke	not screened in phylogeny	A	E; V
<i>Sarcodum scandens</i> Lour.	not screened in phylogeny	P	E; V; Bisby
<i>Spatholobus harmandii</i> Gagnep.	not screened in phylogeny	A	E; V
<i>Tephrosia abbottiae</i> C. Wood	not screened in phylogeny	A	Bisby
<i>Tephrosia acaciifolia</i> Baker	not screened in phylogeny	A	E; V
<i>Tephrosia aequilata</i> Baker	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia apollinea</i> (Delile) DC.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia bidwillii</i> Benth.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia bracteolata</i> Guill. & Perr. var. <i>bracteolata</i>	not screened in phylogeny	A	E; V; Bisby; Khalid, S.A. and Waterman, P.G. (1981) [Phytochemistry 20: 1719-1720]
<i>Tephrosia bracteolata</i> var. <i>strigulosa</i> Brumm.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia brandegei</i> (Standl.) L.Riley	not screened in phylogeny	A	E; V
<i>Tephrosia burchellii</i> Burtt Davy	not screened in phylogeny	A	E; V; Bisby

Appendix 3.1 Continued.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch;V=vouchered; NV=not vouchered
<i>Tephrosia cephalantha</i> var. <i>decumbens</i> Baker [syn. <i>Tephrosia cephalantha</i> Baker var. <i>decumbens</i>]	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia cinerea</i> (L.) Pers.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia deflexa</i> Baker	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia disperma</i> Baker	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia dregeana</i> E.Mey.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia elata</i> Deflers[syn. <i>Tephrosia elata</i> Deflers var. <i>elata</i>]	not screened in phylogeny	A	E; V; Bisby; Lwande, W. <i>et al.</i> (1985) [J. Nat. rod. 48: 1004-1005]; Bisbyentley, M.D. <i>et al.</i> , (1987) Insect Sci. Its Appl 8: 85-88; CA 108: 128914s
<i>Tephrosia elata</i> var. <i>tomentella</i> Brumm.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia elegans</i> Schum.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia elongata</i> E.Mey.	not screened in phylogeny	A	E; V; Bisby; Smallberger, T.M. <i>et al</i> (1975) Tetrahedron 31: 2297-2301
<i>Tephrosia emeroides</i> A.Rich.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia eriocarpa</i> Benth.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia falciformis</i> Ramasw.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia flammea</i> Benth.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia flexuosa</i> G.Don	not screened in phylogeny	A	E; V
<i>Tephrosia forbesii</i> Baker	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia forbesii</i> Baker ssp. <i>interior</i> Brumm.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia fulvinervis</i> A. Ruch.	not screened in phylogeny	A	Bisby, NV
<i>Tephrosia glomeruliflora</i> Meissner	not screened in phylogeny	A	E; V; Bisby

Appendix 3.1 Continued.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch; V=vouchered; NV=not vouchered
<i>Tephrosia grandiflora</i> (Aiton) Pers.	not screened in phylogeny	P/A	E, absent; V; Bisby, present
<i>Tephrosia hildebrandtii</i> Vatke	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia holstii</i> Taub.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia hookeriana</i> Wight & Arn.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia interrupta</i> Engl. [syn. <i>Tephrosia interrupta</i> Engl. ssp. <i>interrupta</i>]	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia kazibensis</i> Cronquist	not screened in phylogeny	A	E; V
<i>Tephrosia lepida</i> Baker.f.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia letestui</i> Tisser.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia leucantha</i> Kunth	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia lindherimeri</i> A.Gray	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia linearis</i> (Willd.) Pers.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia longipes</i> Meissner	not screened in phylogeny	A	E; V
<i>Tephrosia lupinifolia</i> DC.	not screened in phylogeny	A	Bisby; NV
<i>Tephrosia luzonensis</i> J. Vogel	not screened in phylogeny	A	E; Bisby
<i>Tephrosia macrocarpa</i> Benth.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia madrensis</i> Seemann	not screened in phylogeny	A	Bisby; NV; Gomez-Garibay, F. <i>et al.</i> (1991) [Phytochemistry 22: 1305-1306]
<i>Tephrosia maxima</i> (L.) Pers.	not screened in phylogeny	A	Bisby; NV
<i>Tephrosia micrantha</i> J.B. Gillett.	not screened in phylogeny	A	E; V; B
<i>Tephrosia montana</i> Brummitt	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia mossiensis</i> A.Chev.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia multifolia</i> Rose	not screened in phylogeny	A	E; V; Bisby

Appendix 3.1 Continued.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch;V=vouchered; NV=not vouchered
<i>Tephrosia multijuga</i> R.G. Young [syn. <i>T. woodii</i>]	not screened in phylogeny	A	Bisby; Vleggar, R. <i>et al.</i> (1975) [Tetradedron 31: 2571-2573]; Dominguez, X.A. <i>et al.</i> (1983) [Phytochemistry 22: 2047-2049]
<i>Tephrosia nana</i> A. Chev. [syn. <i>Tephrosia barbiger</i> Baker]	not screened in phylogeny	A	Bisby; NV
<i>Tephrosia nitens</i> Seem.	not screened in phylogeny	A	E; V; Bisby; Gomez, F. <i>et al.</i> (1984) [Chem. Ind. (London): 632]
<i>Tephrosia noctiflora</i> Baker	not screened in phylogeny	A	E; V; Forgacs, P. <i>et al.</i> (1980) [Phytochemistry 19: 1225-1226]; Bisby
<i>Tephrosia nyikensis</i> Baker	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia oblongata</i> Benth.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia paniculata</i> Baker	not screened in phylogeny	A	F; NV; Bisby
<i>Tephrosia pentaphylla</i> (Roxb.) G.Don	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia platycarpa</i> Guill. & Perrottet	not screened in phylogeny	A	Bisby; NV; Hayman, A.R. and Gray, D.O. (1987) [Phytochemistry 26: 839-841 & 3247-3248]
<i>Tephrosia polystachya</i> E.Mey.	not screened in phylogeny	A	E; V; Bisby; Vleggar, R. <i>et al.</i> (1978) [S. Afr. J. Chem. 31: 47-50; CA 91: 5128m]
<i>Tephrosia praecana</i> Brummitt	not screened in phylogeny	A	E; V; Bisby; Camele, G <i>et al.</i> (1980) [Phytochemistry 19: 707-709]
<i>Tephrosia procumbens</i> (Ham.) Benth.	not screened in phylogeny	A	E; V
<i>Tephrosia pumila</i> (Lam.) Pers.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia pumila</i> (Lam.) Pers. [syn. <i>Tephrosia dichotoma</i> Desv.]	not screened in phylogeny	A	E; V

Appendix 3.1 Continued.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch; V=vouchered; NV=not vouchered
<i>Tephrosia punctata</i> J.B.Gillett	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia purpurea</i> ssp. <i>leptostachya</i> (DC.) Brumm. [syn. <i>Tephrosia leptostachya</i> DC.]	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia quercetorum</i> C. Wood	not screened in phylogeny	A	Bisby; NV; Gomez-Garibay, F. <i>et al.</i> (1988) [Phytochemistry 27: 2971-2973]
<i>Tephrosia radicans</i> Baker	not screened in phylogeny	A	E; V
<i>Tephrosia reptans</i> Baker	not screened in phylogeny	A	E; V; Bisby; Keen, N.T. <i>et al.</i> (1989) [Biochem. Syst. Ecol. 17: 395-398]
<i>Tephrosia reticulata</i> Benth.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia rhodantha</i> Brandegees	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia rhodesica</i> Baker.f	not screened in phylogeny	A	F; E; V; Bisby
<i>Tephrosia richardisae</i> J.B.Gillett	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia Rosea</i> Benth.	not screened in phylogeny	A	E; V; Bisby; Ingham, J.L. and Markham, K.R. (1982) [Phytochemistry 21: 2969-2972]
<i>Tephrosia semiglabra</i> Sond.	not screened in phylogeny	A	E; V; Bisby; Smalberger, T.M. <i>et al.</i> (1973) [Tetrahedron 29: 3099-3104]
<i>Tephrosia senna</i> Kunth [syn. <i>Tephrosia cathartica</i> (Sesse & Moc.) Urb.]	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia senticosa</i> (L.) Pers.	not screened in phylogeny	A	E; V
<i>Tephrosia sinapou</i> (Buc'hoz) A.Chev. [syn. <i>Tephrosia toxicaria</i> (Sw.) Pers.]	not screened in phylogeny	A	E; V; F; Bisby
<i>Tephrosia</i> sp.1	not screened in phylogeny	A	Bisby; NV
<i>Tephrosia spinosa</i> (L.f.) Pers.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia stormsii</i> De Wild.	not screened in phylogeny	A	F; E; V; Bisby

Appendix 3.1 Continued.

Species	Clade	Canavaine; A refers to absent; B refers to present; / refers to polymorphic	References; B refers to Bell <i>et al.</i> (1978); E refers to Evans <i>et al.</i> (1985); F= Fellows <i>et al.</i> , 1978; Bisby refers to Bisby & Harborne (1994); T= Tschiersch;V=vouchered; NV=not vouchered
<i>Tephrosia strigosa</i> (Dalzell) Santapau & Maheshw.	not screened in phylogeny	A	Bisby; NV
<i>Tephrosia subtriflora</i> Baker	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia supina</i> Domin	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia tanganyikensis</i> De Wild.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia tinctoria</i> Pers.	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia vestita</i> Vogel	not screened in phylogeny	A	E; V; Bisby
<i>Tephrosia virginiana</i> (L.) Pers.	not screened in phylogeny	A	E; V; Bisby; Ingham, J.L. and Markham, K.R. (1982) [Phytochemistry 21: 2969-2972]
<i>Tephrosia watsoniana</i> (Standl.) J.F.Macbr.	not screened in phylogeny	P	Bisby; NV
<i>Tephrosia zoutpansbergensis</i> Bremek.	not screened in phylogeny	A	E; V; F; Bisby

Appendix 3.2 Lists all the genera surveyed by Bell *et al.* (1978), following Legumes of the World (2005), for which there is data about canavanine. Number in the bracket refers to number of phylogenetically sampled taxa.

Species sampled in phylogeny	Presence/absence of Canavanine/ number of species screened; A refers to absent; B refers to present	Phylogenetic placement following Legumes of the World (2005)
<i>Cajanus</i> DC.	A/2	Phaseoleae <i>s.str.</i> ; core Phaseoleae
<i>Calopogonium</i> Desv.	P/5	Phaseoleae <i>s.str.</i> ; core Phaseoleae
<i>Abrus</i> Adans.	A/2(1)	Millettoid <i>s.l.</i> ; Abreae
<i>Adenocarpus</i> DC.	A/4	Genisteeae
<i>Adenodolichos</i> Harms	P/A/2	Phaseoleae <i>s.str.</i> ; Cajaninae
<i>Adesmia</i> DC.	A/3	Dalbergieae
<i>Aeschynomene</i> L.	A/2	Dalbergieae
<i>Alhagi</i> Gagnebin	P/2	IRLC; Hedysareae
<i>Alysicarpus</i> Desv.	P/A/4	Phaseoleae <i>s.l.</i> ; Desmodideae
<i>Amicia</i> Kunth	A/1	Dalbergieae
<i>Ammodendron</i> Fisch. ex DC.	A/1	Genistoid; Sophoreae <i>s.str.</i>
<i>Amorpha</i> L.	A/3	Amorpheae; Amorphoid
<i>Amphicarpa</i> (<i>Amphicarpa</i>) Elliott ex Nutt.	A/3	Phaseoleae <i>s.str.</i> ; Glycininae
<i>Amphimas</i> Pierre ex Harms	A/2	Robinoid; Sesbanieae
<i>Amphithalea</i> Eckl. & Zeyh.	A/1	Genistoid; Podalyrieae
<i>Anagyris</i> L.	A/2	Genistoid; Thermopsidae
<i>Anarthrophyllum</i> Benth.	A/3	Genistoid; Genisteeae
<i>Andira</i> Lam.	A/1	Dalbergioid <i>s.l.</i>
<i>Angylocalyx</i> Taub.	A/1	Sophoreae <i>p.p.</i> 1
<i>Anthyllis</i> L.	P/3	Robinoid; Loteae
<i>Aotus</i> Sm.	P/2	Mirbelioid <i>s.l.</i> ; Mirbelieae; 5-Nucleate
<i>Apios</i> Fabr.	P/A/2	Phaseoleae <i>s.l.</i> ; Desmodioid <i>s.l.</i>
<i>Apoplanesia</i> C.Presl	A/1	Amorpheae; Amorphoid
<i>Arachis</i> L.	A/1	Dalbergieae
<i>Argyrolobium</i> Eckl. & Zeyh.	A/5	Genistoid; Genisteeae
<i>Aspalathus</i> L.	A/6	Genistoid; Crotalarieae
<i>Astragalus</i> L.	P/A/48	IRLC; Astragaleae <i>s.str.</i>
<i>Ateleia</i> (Moç. & Sessé ex DC.) Benth.	A/1	Swartzieae <i>s.str.</i>
<i>Atylosia</i> Wight & Arn.= <i>Cajanus</i>	A/6	Phaseoleae; Cajaninae
<i>Baphia</i> Afzel. ex Lodd.	A/1	Baphioid; Sophoreae <i>p.p.</i> 8
<i>Baptisia</i> Vent.	A/2	Genistoid; Thermopsidae
<i>Bolusanthus</i> Harms	A/1	Genistoid; Sophoreae <i>s.str.</i>
<i>Bolusia</i> Benth.	A/1	Genistoid; Crotalarieae
<i>Bossiaea</i> Vent.	P/A/8	Mirbelioid <i>s.l.</i> ; Bossiaeeae
<i>Brachysema</i> R.Br. ex W.T.Aiton= <i>Gastrolobium</i>	A/3	Mirbelieae; 5-Nucleate
<i>Brongniartia</i> Kunth	A/2	Brongniartieae; New World
<i>Burtonia</i> R.Br. ex W.T.Aiton= <i>Gompholobium</i>	P/A/2	Mirbelieae; Giant Antipodals
<i>Butea</i> Roxb. ex Willd.	A/1	Phaseoleae <i>s.l.</i> ; Phaseoleae <i>s.str.</i>
<i>Cadia</i> Forssk.	A/1	Genistoid; Podalyrieae
<i>Calicotome</i> Link	A/2	Genisteeae; Cytisinae
<i>Calophaca</i> Fisch. ex DC.	P/1	IRLC; Hedysareae
<i>Calpurnia</i> E.Mey.	A/2	Genistoid; Podalyrieae
<i>Camoensia</i> Welw. ex Benth.	A/1	Genistoid; Sophoreae <i>s.str.</i>
<i>Camptosema</i> Hook. & Arn.	P/1	Millettoid <i>s.str.</i> ; Diocleinae
<i>Campylotropis</i> Bunge	P/1	Phaseoleae <i>s.l.</i> ; Desmodideae

Appendix 3.2 Continued.

Species sampled in phylogeny	Presence/absence of Canavanine/ number of species screened; A refers to absent; B refers to present	Phylogenetic placement following Legumes of the World (2005)
<i>Canavalia</i> DC.	P/8	Millettoid <i>s.str.</i> ; Diocleinae
<i>Caragana</i> Fabr.	P/11	IRLC; Hedysareae
<i>Carmichaelia</i> R.Br.	P/3	IRLC; Astragaleae <i>s.str.</i>
<i>Castanospermum</i> A.Cunn. ex Hook.	A/1	Sophoreae <i>p.p</i> 1
<i>Centrolobium</i> Mart. ex Benth.	A/1	50kb; Dalbergieae
<i>Centrosema</i> (DC.) Benth.	P/6	Phaseoleae <i>s.l.</i> ; Clitoriinae
<i>Chaetocalyx</i> DC.	A/1	50kb; Dalbergieae
<i>Chesneya</i> Lindl. ex Endl.	P/1	IRLC; Astragaleae <i>s.l.</i>
<i>Chordospartium</i> Cheeseman= <i>Carmichaelia</i>	P/1	IRLC; Astragaleae <i>s.str.</i>
<i>Chorizema</i> Labill.	A/4	Mirbelieae; 5-Nucleate
<i>Christia</i> Moench	A/1	Phaseoleae <i>s.l.</i> ; Desmodieae
<i>Chrysoscias</i> E.Mey.	A/1	Phaseoleae; Cajaninae
<i>Cicer</i> L.	A/1	Faboid (Vicioid) Cicereae
<i>Clathrotropis</i> (Benth.) Harms	A/1	Genistoid; Sophoreae <i>p.p.6</i>
<i>Cleobulia</i> Mart. ex Benth.	A/1	Millettoid <i>s.str.</i> ; Diocleinae
<i>Clianthus</i> Sol. ex Lindl.	P/2	IRLC; Astragaleae <i>s.str.</i>
<i>Clitoria</i> L.	A/7	Phaseoleae <i>s.l.</i> ; Clitoriinae
<i>Collaea</i> DC.	P/2	Millettoid <i>s.str.</i> ; Diocleinae
<i>Cologania</i> Kunth	A/3	Phaseoleae <i>s.str.</i> ; Glycininae
<i>Colutea</i> L.	P/6	IRLC; Astragaleae <i>s.str.</i>
<i>Corallospartium</i> J.B.Armstr.= <i>Carmichaelia</i>	P/1	IRLC; Astragaleae <i>s.str.</i>
<i>Coronilla</i> L.	P/5	Robinoid; Loteae
<i>Coursetia</i> DC.	P/2	Robinoid; Robinieae
<i>Craibia</i> Harms & Dunn	A/2	Millettoid <i>s.l.</i> ; Basal-Mill-Phas
<i>Crotalaria</i> L.	A/31	Genistoid; Crotalarieae
<i>Cruddasia</i> Prain	A/1	Phaseoleae <i>s.l.</i> ; Ophrestinae
<i>Cyamopsis</i> DC.	P/A/1	Millettoid <i>s.l.</i> ; Indigofereae
<i>Cyclocarpa</i> Afzel. ex Urb.	A/1	50kb; Dalbergieae
<i>Cyclopia</i> Vent.	A/2	Genistoid; Podalyrieae
<i>Cymbosema</i> Benth.	P/1	Millettoid <i>s.str.</i> ; Diocleinae
<i>Cytisus</i> Desf.	A/15	Genisteeae; Cytisinae
<i>Dalbergia</i> L.f.	A/5(2)	50kb; Dalbergieae
<i>Dalea</i> Lucanus	A/5	Amorpheae; Daleoid
<i>Daviesia</i> Sm.	P/7	Mirbelieae; Giant Antipodals
<i>Decorsea</i> R.Vig.	A/4	Phaseoleae <i>s.l.</i> ; Phaseoleae <i>s.str.</i>
<i>Derris</i> Lour.	P/13	Core Millettieae; Non-canavanine
<i>Desmodium</i> Desv.	A/1	Phaseoleae <i>s.l.</i> ; Desmodieae
<i>Dichilus</i> DC.	A/1	Genistoid; Genisteeae
<i>Dillwynia</i> Sm.	P/4	Mirbelieae; 5-Nucleate
<i>Dioclea</i> Kunth	P/A/7	Millettoid <i>s.str.</i> ; Diocleinae
<i>Diploctropis</i> Benth.	A/1	50kb; Genistoid
<i>Dipogon</i> Liebm.	A/1	Phaseoleae <i>s.str.</i> ; Phaseolinae
<i>Dipteryx</i> Schreb.	A/1	Aldinoid; Dipterygeae
<i>Dolichos</i> L.	A/10	Phaseoleae <i>s.str.</i> ; Phaseolinae
<i>Dorycnium</i> Mill.	P/4	Robinoid; Loteae
<i>Drepanocarpus</i> G.Mey.= <i>Machaerium</i> Pers.	A/1	50kb; Dalbergieae
<i>Dumasia</i> DC.	A/3	Phaseoleae <i>s.str.</i> ; Glycininae
<i>Dunbaria</i> Wight & Arn.	A/2	Phaseoleae <i>s.str.</i> ; Cajaninae

Appendix 3.2 Continued.

Species sampled in phylogeny	Presence/absence of Canavanine/ number of species screened; A refers to absent; B refers to present	Phylogenetic placement following Legumes of the World (2005)
<i>Dysolobium</i> (Benth.) Prain	A/2	Phaseoleae <i>s.l.</i> ; Phaseoleae <i>s.str.</i>
<i>Ebenus</i> L.	A/1	IRLC; Hedysareae
<i>Eminia</i> Taub.	A/2	Phaseoleae <i>s.str.</i> ; Glycininae
<i>Endomallus</i> Gagnep.= <i>Cajanus</i>	A/1	Phaseoleae <i>s.str.</i> ; core Phaseoleae
<i>Erythrina</i> L.	A/15	Phaseoleae; Phaseoleae <i>s.str.</i>
<i>Euchresta</i> Benn.	A/1	Genistoid; Sophoreae <i>s.str.</i>
<i>Eutaxia</i> R.Br. ex W.T.Aiton	P/1	Mirbelieae; 5-Nucleate
<i>Fagelia</i> Neck. ex DC.= <i>Bolusafrax</i> Kuntze	A/1	Phaseoleae <i>s.str.</i> ; Cajaninae
<i>Flemingia</i> Roxb. ex W.T.Aiton	A/7	Phaseoleae <i>s.str.</i> ; Cajaninae
<i>Galactia</i> P.Browne	P/9	Millettoid <i>s.str.</i> ; Diocleinae
<i>Galega</i> L.	P/1	Faboid (Vicioid); Galegeae
<i>Gastrolobium</i> R.Br. ex W.T.Aiton	A/3	Mirbelieae; 5-Nucleate
<i>Genista</i> L.	A/9	Genisteeae; Genistinae
<i>Geoffroea</i> Jacq.	A/1	50kb; Dalbergieae
<i>Gliricidia</i> Kunth	P/1	Robinoid; Robinieae
<i>Glycine</i> Willd.	A/8	Phaseoleae <i>s.str.</i> ; Glycininae
<i>Glycyrrhiza</i> L.	P/2	IRLC; Glycyrrhiza
<i>Gompholobium</i> Sm.	P/4	Mirbelieae; Giant Antipodals
<i>Gonocytisus</i> Spach	A/2	Genisteeae; Genistinae
<i>Goodia</i> Salisb.	P/2	Mirbelioid <i>s.l.</i> ; Bossiaeeae
<i>Halimodendron</i> Fisch. ex DC.	P/1	IRLC; Hedysareae
<i>Hardenbergia</i> Benth.	P/2	Phaseoleae
<i>Harpalyce</i> Moç. & Sessé ex DC.	A/2	Brongniartieae; New World
<i>Hedysarum</i> L.	P/10	IRLC; Hedysareae
<i>Hippocrepis</i> L.	P/A/3	Robinoid; Loteae
<i>Hovea</i> R.Br. ex W.T.Aiton	A/3	Brongniartieae; Australia
<i>Humularia</i> P.A.Duvign.	A/1	50kb; Dalbergieae
<i>Hymenocarpus</i> Savi	P/1	Robinoid; Loteae
<i>Hypocalyptus</i> Thunb.	P/3	Mirbelioid <i>s.l.</i> ; Hypocalypteeae
<i>Indigofera</i> L.	P/A/24	Millettoid <i>s.l.</i> ; Indigofereae
<i>Inocarpus</i> J.R.Forst. & G.Forst.	A/1	50kb; Dalbergieae
<i>Isotropis</i> Benth.	P/1	Mirbelieae; Giant Antipodals
<i>Jacksonia</i> R.Br. ex Sm.	P/A/7	Mirbelieae; 5-Nucleate
<i>Kennedia</i> Vent.	P/9	Desmodioid <i>s.l.</i> ; Kennediinae
<i>Lablab</i> Adans.	A/1	Phaseoleae <i>s.str.</i> ; Phaseolinae
<i>Laburnum</i> Fabr.	A/2	Genisteeae; Cytisinae
<i>Lamprolobium</i> Benth.	A/1	Brongniartieae; Australia
<i>Lathyrus</i> L.	A/11	Faboid (Vicioid); Fabeae
<i>Lebeckia</i> Thunb.	A/4	Genistoid; Crotalarieae
<i>Lens</i> Mill.	A/2	Faboid (Vicioid); Fabeae
<i>Leptoderris</i> Dunn	A/2	Millettoid <i>s.str.</i> ; Basal Millettoid
<i>Lepedeza</i> Michx.	P/A/16	Phaseoleae <i>s.l.</i> ; Desmodieae
<i>Lessertia</i> DC.	P/1	IRLC; Astragaleae <i>s.str.</i>
<i>Lonchocarpus</i> Kunth	P/A/16	Core Millettieae; Non-canavanine
<i>Lotononis</i> (DC.) Eckl. & Zeyh.	A/5	Genistoid; Crotalarieae
<i>Lotus</i> L.	P/18	Robinoid; Loteae
<i>Lupinus</i> L.	A/11	Genistoid; Genisteeae
<i>Maackia</i> Rupr. & Maxim.	P/1	Genistoid; Sophoreae <i>s.str.</i>

Appendix 3.2 Continued.

Species sampled in phylogeny	Presence/absence of Canavanine/ number of species screened; A refers to absent; B refers to present	Phylogenetic placement following Legumes of the World (2005)
<i>Machaerium</i> Pers.	A/1	50kb; Dalbergieae
<i>Macropsychanthus</i> Harms	P/1	Millettoid <i>s.str.</i> ; Diocleinae
<i>Macroptilium</i> (Benth.) Urb.	A/4	Phaseoleae <i>s.str.</i> ; Phaseolinae
<i>Macrotyloma</i> (Wight & Arn.) VerDC.	A/5	Phaseoleae <i>s.str.</i> ; Phaseolinae
<i>Mastersia</i> Benth.	P/1	Phaseoleae <i>s.l.</i> ; Desmodioid <i>s.l.</i>
<i>Medicago</i> L.	P/11	Faboid (Vicioid); Trifolieae <i>s.l.</i>
<i>Melilotus</i> Mill.	P/A/5	Faboid (Vicioid); Trifolieae <i>s.l.</i>
<i>Melolobium</i> Eckl. & Zeyh.	A/1	Genistoid; Genisteeae
<i>Millettia</i> Wight Arn. (incl. <i>Callerya</i> Endl. & <i>Endosamara</i> R.Geesink)	P/A/16	Millettoid <i>s.str.</i> ; Core Millettieae
<i>Mirbelia</i> Sm.	P/A/3	Mirbelieae; 5-Nucleate
<i>Mucuna</i> Adans	A/11	Phaseoleae <i>s.l.</i> ; Desmodioid <i>s.l.</i>
<i>Muelleranthus</i> Hutch.	P/1	Mirbelioid <i>s.l.</i> ; Bossiaeeae
<i>Mundulea</i> (DC.) Benth.	A/2	Core Millettieae; Non-canavanine
<i>Myroxyton</i> L.f.	A/1	Aldinoid; Sophoreae <i>p.p.</i> 2
<i>Neonotonia</i> J.A.Lackey	P/1	Phaseoleae; Glycininae
<i>Neorautanenia</i> Schinz	A/2	Phaseoleae <i>s.str.</i> ; Glycininae
<i>Nesphostylis</i> VerDC.	A/1	Phaseoleae <i>s.str.</i> ; Phaseolinae
<i>Nissolia</i> Jacq.	A/1	50kb; Dalbergieae
<i>Notospartium</i> Hook.f.= <i>Carmichaelia</i> R.Br.	P/1	IRLC; Astragaleae <i>s.str.</i>
<i>Olneya</i> A.Gray	P/1	Robinoid; Robinieae
<i>Onobrychis</i> Mill.	A/8	IRLC; Hedysareae
<i>Ononis</i> L.	P/8	Faboid (Vicioid); Trifolieae <i>s.l.</i>
<i>Ophrestia</i> H.M.L.Forbes	A/4	Phaseoleae <i>s.l.</i> ; Ophrestinae
<i>Ormocarpum</i> P.Beauv.	A/1	50kb; Dalbergieae
<i>Ormosia</i> Jacks.	A/9	Genistoid; Sophoreae <i>p.p.</i> 6
<i>Ornithopus</i> L.	P/4	Robinoid; Loteae
<i>Otoptera</i> DC.	A/1	Phaseoleae <i>s.l.</i> ; Phaseoleae <i>s.str.</i>
<i>Oxylobium</i> Andrews	P/A/4	Mirbelieae; 5-Nucleate
<i>Oxytropis</i> DC.	P/A/3	IRLC; Astragaleae <i>s.str.</i>
<i>Pachyrhizus</i> Rich. ex DC.	P/A/4	Phaseoleae <i>s.str.</i> ; Glycininae
<i>Padbruggea</i> Miq.= <i>Callerya</i> Endl.	A/1	IRLC; Wisterieae
<i>Paracalyx</i> Ali	A/2	Phaseoleae <i>s.str.</i> ; Cajaninae
<i>Pearsonia</i> Dummer	A/1	Genistoid; Crotalarieae
<i>Periandra</i> Mart. ex Benth.	A/1	Phaseoleae <i>s.l.</i> ; Clitoriinae
<i>Pericopsis</i> Thwaites	A/1	Amorpheae; Daleoid
<i>Petalostemon</i> Michx.= <i>Dalea</i>	A/1	Amorpheae; Daleoid
<i>Phaseolus</i> L.	P/A/16	Phaseoleae <i>s.str.</i> ; Phaseolinae
<i>Phyllota</i> (DC.) Benth.	A/1	Mirbelieae; 5-Nucleate
<i>Physostigma</i> Balf.	A/2	Phaseoleae <i>s.str.</i> ; Phaseolinae
<i>Pickeringia</i> Nutt. ex Torr. & A.Gray	A/1	Sophoreae <i>p.p.</i> 3
<i>Piptanthus</i> Sweet	A/3	Genistoid; Thermopsidae
<i>Piscidia</i> L.	A/2	Core Millettieae; Non-canavanine
<i>Pisum</i> L.	A/1	Faboid (Vicioid); Fabeae
<i>Platygyamus</i> Benth.	A/1	Millettoid <i>s.l.</i> ; Basal-Mill-Phas
<i>Platylobium</i> Sm.	P/A/3	Mirbelioid <i>s.l.</i> ; Bossiaeeae
<i>Podalyria</i> Willd.	A/5	Genistoid; Podalyrieae
<i>Podocytisus</i> Boiss. & Heldr.	A/1	Genisteeae; Cytisinae

Appendix 3.2 Continued.

Species sampled in phylogeny	Presence/absence of Canavanine/ number of species screened; A refers to absent; B refers to present	Phylogenetic placement following Legumes of the World (2005)
<i>Poecilanthe</i> Benth.	A/2	Brongniartieae; New World
<i>Pongamia</i> Vent.= <i>Millettia</i>	A/1	Millettoid <i>s.str.</i> ; Core Millettieae
<i>Priestleya</i> DC.= <i>Xiphotheca</i> Eckl. & Zeyh.	A/1	Genistoid; Podalyrieae
<i>Pseudarthria</i> Wight & Arn.	P/1	Phaseoleae <i>s.l.</i> ; Desmodideae
<i>Pseudeminia</i> VerDC.	A/1	Phaseoleae; Glycininae
<i>Pseudoeriosema</i> Hauman	A/2	Phaseoleae <i>s.l.</i> ; Ophrestinae
<i>Pseudovigna</i> (Harms) VerDC.	A/1	Phaseoleae <i>s.str.</i> ; Glycininae
<i>Psophocarpus</i> Neck. ex DC.	A/3	Phaseoleae <i>s.l.</i> ; Phaseoleae <i>s.str.</i>
<i>Psoralea</i> L.	A/6	Phaseoleae <i>s.str.</i> ; Psoraleeae
<i>Pterocarpus</i> Jacq.	A/7	Dalbergieae
<i>Ptychosema</i> Benth.	P/1	Mirbelioid <i>s.l.</i> ; Bossiaeeae
<i>Pueraria</i> DC.	P/A/7	Phaseoleae <i>s.str.</i> ; Glycininae
<i>Pultenaea</i> Sm.	P/A/6	Mirbelieae; 5-Nucleate
<i>Rafnia</i> Thunb.	A/2	Genistoid; Crotalarieae
<i>Ramirezella</i> Rose	A/1	Phaseoleae <i>s.str.</i> ; Phaseolinae
<i>Retama</i> Raf.	A/3	Genisteeae; Genistinae
<i>Rhynchosia</i> Lour.	A/15	Phaseoleae <i>s.str.</i> ; Cajaninae
<i>Robinia</i> L.	P/4	Robinioid; Robinieae
<i>Robynsiophyton</i> R.Wilczek	P/1	Genistoid; Crotalarieae
<i>Rothia</i> Pers.	A/2	Genistoid; Crotalarieae
<i>Sabinea</i> DC.= <i>Poitea</i> Vent.	P/1	Robinieae; Gliricidia
<i>Sarcodum</i> Lour.	P/1	IRLC; Wisterieae
<i>Scorpiurus</i> L.	P/3	Robinioid; Loteae
<i>Securigera</i> DC.	P/1	Robinioid; Loteae
<i>Sesbania</i> Adans.	P/15	Robnioid; Sesbanieae
<i>Shuteria</i> Wight & Arn.	P/1	Phaseoleae <i>s.l.</i> ; Desmodioid
<i>Sinodolichos</i> VerDC.	A/1	Phaseoleae <i>s.str.</i> ; Glycininae
<i>Smirnowia</i> Bunge	P/1	IRLC; Astragaleae <i>s.str.</i>
<i>Sophora</i> L.	A/6	Genistoid; Sophoreae <i>s.str.</i>
<i>Spartium</i> L.	A/1	Genisteeae; Genistinae
<i>Spathionema</i> Taub.	A/1	Phaseoleae <i>s.str.</i> ; Phaseolinae
<i>Spatholobus</i> Hassk.	P/1	Phaseoleae <i>s.l.</i> ; Phaseoleae <i>s.str.</i>
<i>Sphaerolobium</i> Sm.	P/A/24	Mirbelieae; Giant Antipodals
<i>Sphenostylis</i> E.Mey	P/1	Phaseoleae <i>s.str.</i> ; Phaseolinae
<i>Stizolobium</i> P.Browne= <i>Mucuna</i>	A/3	Phaseoleae <i>s.l.</i> ; Desmodioid <i>s.l.</i>
<i>Strongylodon</i> Vogel	P/3	Phaseoleae <i>s.l.</i> ; Phaseoleae <i>s.str.</i>
<i>Strophostyles</i> Elliott	A/3	Phaseoleae <i>s.str.</i> ; Phaseolinae
<i>Stylosanthes</i> Sw.	A/2	50kb; Dalbergieae
<i>Sutherlandia</i> R.Br. ex W.T.Aiton	P/1	IRLC; Astragaleae <i>s.str.</i>
<i>Swainsona</i> Salisb.	P/A/8	IRLC; Astragaleae <i>s.str.</i>
<i>Templetonia</i> R.Br. ex W.T.Aiton	A/3	Brongniartieae; Australia
<i>Tephrosia</i> Pers.	P/A/19	Core Millettieae; Non-canavanine
<i>Teramnus</i> P.Browne	A/4	Phaseoleae <i>s.str.</i> ; Glycininae
<i>Tetragonolobus</i> Scop.	P/2	Robinioid; Loteae
<i>Thermopsis</i> R.Br. ex W.T.Aiton	A/4	Genistoid; Thermopsidae
<i>Tipuana</i> (Benth.) Benth.	A/1	50kb; Dalbergieae
<i>Trifolium</i> L.	P/10	Faboid (Vicioid); Trifolieae <i>s.str.</i>
<i>Trigonella</i> L.	P/A/6	Faboid (Vicioid); Trifolieae <i>s.l.</i>

Appendix 3.2 Continued.

Species sampled in phylogeny	Presence/absence of Canavanine/ number of species screened; A refers to absent; B refers to present	Phylogenetic placement following Legumes of the World (2005)
<i>Ulex</i> L.	A/1	Genisteae; Genistinae
<i>Uraria</i> Desv.	P/1	Phaseoleae; Desmodieae
<i>Vatovaea</i> Chiov.	A/1	Phaseoleae; Phaseolinae
<i>Vicia</i> L.	P/A/44	Faboid (Vicioid); Fabeae
<i>Vigna</i> Savi	A/28	Phaseoleae <i>s.str.</i> ; Phaseolinae
<i>Virgilia</i> Poir.	A/2	Genistoid; Podalyrieae
<i>Voandzeia</i> Thouars= <i>Vigna</i>	A/1	Phaseoleae <i>s.str.</i> ; Phaseolinae
<i>Whitfordiodendron</i> Elmer= <i>Callerya</i>	A/2	IRLC; Wisterieae
<i>Wiborgia</i> Thunb.	A/1	Genistoid; Crotalarieae
<i>Wisteria</i> Nutt.	P/2	IRLC; Wisterieae
<i>Xanthocercis</i> Baill.	A/1	Sophoreae <i>p.p.</i> 1
<i>Xeroderris</i> Roberty	A/1	Millettoid <i>s.l.</i> ; Basal-Mill-Phas
<i>Zornia</i> J.F.Gmel.	A/3	50kb; Dalbergieae

Appendix 4.1 List of species used in this study. Codes of *Derris elliptica* coded namely C, K1 &ST are abbreviated here following from Sirichamorn *et al.* (2014). Voucher specimens indicate collector(s), collection number, herbarium where a specimen deposited is abbreviated in parentheses (abbreviation follows Index herbariorum: <http://sweetgum.nybg.org/science/ih/>), country and location. Accession numbers for each gene is obtained from Genbank (<http://www.ncbi.nlm.nih.gov/>).

Species from Sirichamorn <i>et al.</i> (2014)	Voucher specimens	ITS/5.8s	trnK-matK	trnL-F
<i>Derris alborubra</i> Hemsl.	Y.Sirichamorn YSM 2009-14 (L), Thailand: Nakhon Nayok province	JX506466	JX506638	JX506524
<i>Derris amoena</i> Benth. (code name in this study as <i>Derris amoena1</i>)	Y.Sirichamorn YSM 2009-20 (L), Thailand: Surat Thani province	JX506456	JX506628	JX506514
<i>Derris amoena</i> Benth. (code name in this study as <i>Derris amoena2</i>)	Kerr 13700 (L), Thailand: Satun province	JX506457	JX506629	JX506515
<i>Derris amoena</i> Benth. (code name in this study as <i>Derris amoena3</i>)	Maxwell 83-11 (L), Singapore	JX506458	JX506630	JX506516
<i>Derris constricta</i> Mattapha & Hawkins	S.Mattapha 1102, Thailand Km 40-42 between Bo klua district and Doi Phu Ka national park, Nan province	This study	This study	This study
<i>Derris cuneifolia</i> Benth.	Lei 612 (L), China: Hainan	JX506478	JX506649	JX506535
<i>Derris elegans</i> Benth. var. <i>elegans</i>	K. & S. Larsen KL 32828 (L), Thailand: Narathiwat province	JX506469	JX506641	JX506527
<i>Derris elliptica</i> (Wall.) Benth. (code name in this study as <i>Derris ellipticaC</i>)	Y.Sirichamorn YSM 2012-01, Thailand: Bangkok (cultivated) in Suan Luang Rama IX Park and Botanic Garden (abbreviated SLR in Sirichamorn <i>et al.</i> 2014),	JX506475	JX506647	JX506533
<i>Derris elliptica</i> (Wall.) Benth. (code name in this study as <i>Derris ellipticaK1</i>)	Kostermans 260 (L), Thailand: Kanchanaburi province	JX506477	JX506648	JX506534
<i>Derris elliptica</i> (Wall.) Benth. (code name in this study as <i>Derris ellipticaST</i>)	Y.Sirichamorn YSM 2009-19 (L), Thailand: Surat Thani province	JX506474	JX506646	JX506532
<i>Derris ferruginea</i> (Roxb.) Benth.	Y.Sirichamorn YSM 2009-13 (L), Thailand: Udon Thani province	JX506461	JX506633	JX506519
<i>Derris glabra</i> Sirich.	Y.Sirichamorn YSM 2009-23 (L), Thailand: Songkhla province	JX506463	JX506635	JX506521
<i>Derris laotica</i> Gagnep.	Magnen, Gourgand and Châtillon s.n. (P), Cambodia	JX506473	JX506645	JX506531
<i>Derris laxiflora</i> Benth.	Hu 1081, Taiwan	x	AF142715	x
<i>Derris lianoides</i> Elmer	Ridsdale SMHI 1863 (L), Philippines: Palawan,	JX506482	JX506653	JX506539
<i>Derris lithocarpa</i> (Benth.) Mattapha & Hawkins (formerly <i>Milletia pachycarpa</i> Benth.)	M.Norsaengsri & S. Mattapha 9177 (QBG), Thailand: Pong Yang, Chiang Mai province	This study	This study	This study
<i>Derris luzoniensis</i> (Adema) Sirich.	Baquiran & al. ISU564 (L), Philippines: Luzon	x	JX506654	JX506540

Appendix 4.1 Continued.

Species from Sirichamorn <i>et al.</i> (2014)	Voucher specimens	ITS/5.8s	trnK-matK	trnL-F
<i>Derris luzoniensis</i> (Adema) Sirich.	<i>Baquiran et al.</i> ISU564 (L)	JX506483	x	x
<i>Derris marginata</i> (Roxb.) Benth.	<i>Pierre</i> s.n. (L), India	JX506471	JX506643	JX506529
<i>Derris montana</i> Benth.	<i>Y.Sirichamorn</i> YSM 2009-21 (L), Thailand: Songkhla province	JX506479	JX506650	JX506536
<i>Derris monticola</i> (Kurz) Prain	<i>Kerr</i> 1731 (L), Thailand: Chiang Mai province	JX506465	JX506637	JX506523
<i>Derris oblongifolia</i> Merr.	<i>Sulit</i> PNH 21618 (L), Philippines: Biliran island	JX506481	JX506652	JX506538
<i>Derris piscatoria</i> (Blanco) Sirich.	<i>Sulit</i> PNH 14411 (L), Philippines: Samar	JX506480	JX506651	JX506537
<i>Derris pseudomarginata</i> Sirich.	<i>Maxwell</i> 76-31 (L), Thailand: Chon Buri province	JX506467	JX506639	JX506525
<i>Derris pubipetala</i> Miq.	<i>Maxwell</i> 85-370 (L), Thailand: Pattani province	JX506462	JX506634	JX506520
<i>Derris reticulata</i> Craib	<i>Y.Sirichamorn</i> YSM 2009-18 (L), Thailand: Nakhon Ratchasima province	JX506460	JX506632	JX506518
<i>Derris rubrocalyx</i> Verdc.	<i>Davis</i> 567 (L), Indonesia: Irian Jaya	JX506472	JX506644	JX506530
<i>Derris</i> sp.	<i>Maxwell</i> 50-75 (L), Thailand: Nakhon Sawan province	JX506468	JX506640	JX506526
<i>Derris spanogheana</i> Blume ex Miq.	<i>De Vogel</i> 5788 (L), Indonesia: Sulawesi	JX506464	JX506636	JX506522
<i>Derris tonkinensis</i> Gagnep.	<i>Y.Sirichamorn</i> YSM 2009-11 (L), Thailand: Lampang province	JX506459	JX506631	JX506517
<i>Derris trifoliata</i> Lour.	<i>Y.Sirichamorn</i> YSM 2009-06 (L), Thailand: Samut Prakan province	JX506470	JX506642	JX506528
<i>Fordia cauliflora</i> Hemsl.	<i>voucher</i> PS0230MT01, unknown	GQ434352	HM049511	x
<i>Fordia splendidissima</i> (Blume ex Miq.) Buijsen	<i>Tangah</i> s.n., Malaysia: Sabah	AF467048	AF142718	x
<i>Millettia glaucescens</i> Kurz	<i>S. Mattapha</i> s.n., Thailand, Bok khoranee national park, Krabi province	This study	x	x
<i>Solori cumingii</i> (Benth.) Sirich. & Adema	<i>Gaerlan & al.</i> PPI 10368 (L), Philippines: Luzon	JX506447	JX506618	JX506505
<i>Solori eriocarpa</i> (F.C.How) Sirich. & Adema	<i>Wang Hong</i> 7673 (QBG), China: Yunnan	JX506454	JX506625	JX506512
<i>Solori involuta</i> (Sprague) Sirich. & Adema	<i>Murray, Coveny & Bishop</i> s.n., sheet no. NSW 409439 (L), Australia: North coast,	JX506451	JX506622	JX506509
<i>Solori koolgibbearah</i> (F.M.Bailey) Sirich. & Adema	<i>Brass</i> 8205 (L), Papua New Guinea: Sturt Island,	JX506453	JX506624	JX506511
<i>Solori microphylla</i> (Miq.) Sirich. & Adema	<i>Y.Sirichamorn</i> YSM 2009-16 (L), Thailand: Chumphon	JX506448	JX506619	JX506506
<i>Solori philippinensis</i> (Merr.) Sirich. & Adema	<i>Elmer</i> 14373 (L), Philippines: Sorsogon,	JX506455	JX506627	x
<i>Solori pseudoinvoluta</i> (Verdc.) Sirich. & Adema	<i>Streimann & Kairo</i> NGF 27776 (L), Papua New Guinea: Morobe,	JX506452	JX506623	JX506510
<i>Solori robusta</i> (Roxb. ex DC.) Sirich. & Adema	<i>Y.Sirichamorn</i> YSM 2009-09 (L), Thailand: Lampang province	JX506446	JX506617	JX506504
<i>Solori scandens</i> (Roxb.) Sirich. & Adema	<i>Y.Sirichamorn</i> YSM 2009-01 (L), Thailand: Chon Buri province	JX506450	JX506621	JX506508

Appendix 4.1 Continued.

Species from Sirichamorn <i>et al.</i> (2014)	Voucher specimens	<i>ITS/5.8s</i>	<i>trnK-matK</i>	<i>trnL-F</i>
<i>Solori submontana</i> (Verdc.) Sirich. & Adema	<i>Takeuchi & al.</i> 4349 (L), Papua New Guinea: Morobe	x	JX506626	JX506513
<i>Solori thorelii</i> (Gagnep.) Sirich. & Adema	<i>Y.Sirichamorn</i> YSM 2009-03 (L), Thailand: Phrae province	JX506449	JX506620	JX506507