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Aglaia fellii W.E.Cooper & Joyce (Meliaceae), a new species for Cape York Peninsula

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Abstract

Aglaia fellii W.E.Cooper & Joyce (Meliaceae) is described from restricted areas of rainforest on Cape York Peninsula, Queensland, Australia. Given the unusual morphological features of the species, including solitary flowers and fruits, a molecular phylogenetic analysis was conducted to confirm its placement within *Aglaia* prior to formal description. All Australian *Aglaia* species and eight Australian representatives of closely allied Meliaceae genera were sampled, and 353 nuclear loci were sequenced. Maximum likelihood analysis of these loci retrieved *A. fellii* as nested within *Aglaia*, most closely related to *A. cooperae* and *A. monticola*. This validates its assignment to *Aglaia*, making it the only *Aglaia* species with mostly solitary flowers (rarely 3- or 4-flowered) and solitary fruits. A full taxonomic description of *Aglaia fellii* and notes on its habitat are provided.

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Introduction

In July 2018, botanist David Fell collected a specimen (DGF IRRS284 BRI) of an unknown Meliaceae at Steve Irwin Wildlife Reserve (SIWR), Cape York Peninsula, Queensland, Australia. Further material was later collected in a different area of SIWR and on Bramwell Station (*c.* 14 km to the east) in 2020. The specimens exhibit many characters typical of *Aglaia* Lour. (Meliaceae), a genus of 126 species in Indomalesia, Australia and the Western Pacific (Pannell 2013; Joyce *et al.* 2023a), with twelve species occurring in Australia (Cooper & Forster 2021). *Aglaia* species are small to large trees, generally characterised by imparipinnate leaves (with a few trifoliolate or simple-leaved species), an indumentum of compound hairs (including stellate scales, peltate scales and stellate hairs), and small flowers arranged in axillary panicles on which up to several hundred fruits are borne (Pannell 1992).

While the specimens are consistent with *Aglaia* in having an indumentum of peltate scales and compound leaves, they also exhibit characters unusual or previously unknown in the genus such as solitary, trimerous flowers, a small tree habit, and small trifoliolate leaves. We conducted a morphological assessment and molecular phylogenetic analysis to resolve the relationships of this novelty and inform an appropriate taxonomic status and generic placement. The results confirm the entity is distinct and phylogenetically nested within *Aglaia*, and

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we therefore describe it as *Aglaia fellii* W.E.Cooper & Joyce.

Methods

Molecular analysis

Fifteen *Aglaia* samples were obtained for this analysis, including three individuals from across the range of the putative novelty and one sample from each accepted Australian species (Table 1). To test the hypothesis of relationship to *Aglaia*, Australian representatives of *Chisocheton*, *Prasoxylon*, *Dysoxylum*, *Epicharis* and *Didymocheton* (following the revised taxonomy of Holzmeyer *et al.* 2021) were also sampled. Together with *Aglaia*, these genera have been placed within the 'GA clade' of Meliaceae (Koenen *et al.* 2015; Holzmeyer *et al.* 2021; Joyce *et al*. 2023b). *Vavaea amicorum* Benth. was used as the outgroup based on the phylogenetic results of Koenen *et al.* (2015). Leaf material was field-collected and dried on silica gel for all taxa except *Aglaia brownii* Pannell, *Chisocheton longistipitatus* (F.M.Bailey) L.S.Sm., *Didymocheton mollis* (Miq.) Holzmeyer & Hauenschild and *Epicharis parasitica* (Osbeck) Mabb., for which herbarium material was used.

Genomic DNA was extracted from 40 mg of dried leaf material using the CTAB protocol of Doyle and Doyle (1987). The protocol was modified at the isopropanol precipitation step, with samples left to precipitate at -20℃ over 24 hours. DNA was eluted to a final volume of 60 µl, and quality and quantity were ascertained using a NanoDrop 1000 Spectrophotometer (Thermo Fisher Scientific, Massachusetts, USA) and Quantus Fluorometer (Promega Corporation, Wisconsin, USA).

DNA samples were fragmented enzymatically and libraries were prepared using the NEBNext Ultra II FS Library Prep Kit (New England Biolabs, Ipswich, MA, USA), following the manufacturer's instructions with inserts of approximately 350 bp. Capture pools were 12–16 plex. Pooled libraries were enriched using the Angiosperms353 probe kit (Johnson *et al.* 2019) by hybridising at 65°C with the Arbor Biosciences MyBaits Expert Plant Angiosperms353 v1 bait set with V5 chemistry (Cat. # 308108.v5) following the manufacturer's instructions. Sequencing was performed on a NovaSeq 6000 (Illumina Inc., San Diego, USA) at the Australian Genome Research Facility (Melbourne) with v1.5 chemistry and 150bp paired-end reads.

Sequence reads for 23 samples were obtained. Trimmomatic (Bolger *et al.* 2014) was used to remove adapter sequences, poor quality base calls and poor quality reads with the settings: illuminaclip 2:30:10, leading 30, trailing 30, sliding window 4:2:30 and minimum length 36. Exon sequences were assembled using the HybPiper v2 pipeline for the amino acid translation of nucleotide data using BLASTx (Johnson *et al.* 2016). Trimmed reads were mapped against the Meliaceae subset of the mega target file of McLay *et al.* (2021). The HybPiper exon output was then processed through HybPhaser v2 (Nauheimer *et al.* 2021), to generate consensus sequences and identify single nucleotide polymorphisms (SNPs). Summary statistics for all samples and loci were generated, and the dataset was optimised by removing loci with >80% missing samples, <55% target sequence length recovery, and outlying heterozygosity (> 1.5x the inter-quartile range for heterozygosity). In the final dataset, an average of 334 loci were retrieved with a mean target recovery of 90.29%.

HybPhaser consensus sequences (i.e. sequences including ambiguity codes) were aligned using MAFFT with the -auto flag to automatically select alignment strategy (Katoh and Standley 2013). Sites with >75% missing data were removed from the alignment using the -clean option in Phyutility (Smith and Dunn 2008), and exon alignments concatenated with AMAS (Borowiec 2016). A maximum likelihood tree was estimated from the clean alignment in IQ-TREE, with the appropriate substitution model and partitioning scheme for the alignment chosen using ModelFinder Plus option –MFP+MERGE (Lanfear *et al.* 2012; Nguyen *et al.* 2015; Kalyaanamoorthy *et al.* 2017; Hoang *et al.* 2018). Support was estimated using 1000 ultrafast bootstrap replicates in IQ-TREE.

Morphological study

Morphology was assessed through examination of herbarium material from BRI and CNS, as well as field observations. All specimens cited were seen by WEC or EMJ. Measurements of floral parts and fruits are based on material preserved in 70% ethanol as well as fresh material from the field.

Results

Molecular Analysis

The concatenated alignment of 353 loci comprised 257557 bp and 18056 parsimony-informative sites with 7.32% gaps or ambiguities. IQ-TREE identified the best partition scheme and merged the alignment into 19 partitions (LnL = -832664.736, df=235), all of which were allocated an optimal substitution model with the ModelFinder function of IQ-TREE. After 102 tree search iterations IQ-TREE produced a consensus tree with a log-likelihood of -832640.20 (Figure 1).

All sampled *Aglaia* species were retrieved as monophyletic with maximum support. Previous studies have indicated that *Aglaia* may not be monophyletic—section *Neoaglaia* does not group with the rest of the genus (Grudinski *et al.* 2014; Koenen *et al.* 2015)—but representatives of *Neoaglaia* do not occur in Australia and so were not included in the present analysis. Our results support the monophyly of sections *Amoora* and *Aglaia*. The topology of *Aglaia* is also in broad agreement with previous phylogenetic studies on the genus, with *A. spectabilis*, *A. meridionalis* and *A. australiensis* retrieved as sister to the rest of the Australian species in section *Amoora*, and *A. silvestris* and *A. argentea* retrieved in the

Table 1. Samples included in the phylogenetic analysis of Australian *Aglaia* and related species to test the generic assignment of *Aglaia fellii.*

Species	Collector name & no.	Source	Herbarium accession	SRA accession
Aglaia argentea	Cooper, W. WWC 2348	Silica	FHO 00123761K	SRR21798429
Aglaia australiensis	Forster 27615	Silica	AQ 0607797	SRR21798428
Aglaia brownii	Champion, I.G. 2158	Herbarium	CNS 148263	SRR21798417
Aglaia cooperae	Cooper, W. WWC 2029	Silica	CNS 129530	SRR21798413
Aglaia elaeagnoidea	Ford, A. 5776	Silica	CNS 134440	SRR21798412
Aglaia euryanthera	Cooper, W. WWC 2780	Silica	CNS 151035	SRR21798411
Aglaia fellii	Cooper, W. WWC 2716	Silica	CNS 152652	SRR21798408
Aglaia fellii	Cooper, W. WWC 2764	Silica	CNS 152654	SRR21798410
Aglaia fellii	Cooper, W. WWC 2769	Silica	CNS 152653	SRR21798409
Aglaia ferruginea	Costion, C. 1328	Silica	CNS 131156	SRR21798407
Aglaia meridionalis	Cooper, W. WWC 2780	Silica	FHO 00123764N	SRR21798427
Aglaia monticola	Cooper, W. WWC 2378	Silica	CNS 144556	SRR21798426
Aglaia sapindina	Cooper, W. WWC 2388	Silica	CNS 144561	SRR21798425
Aglaia silvestris	Cooper, W. WWC 2342	Silica	FHO 00123760J	SRR21798424
Aglaia spectabilis	Cooper, W. WWC 2354	Silica	FHO 00123763M	SRR21798423
Chisocheton longistipitatus	Ford, A. 4730	Herbarium	QRS 128685	SRR21798422
Didymocheton gaudichaudianus	Cooper, W. WWC 2347	Silica	FHO 00140604F	SRR21798421
Didymocheton mollis	Dowe, J.L. 1348	Herbarium	CNS 146676	SRR21798420
Didymocheton rufus	Cooper, W. WWC 2402	Silica	CNS 146421	SRR21798419
Dysoxylum oppositifolium	Cooper, W. WWC 2781	Silica	CNS 151036	SRR21798418
Epicharis parasitica	Costion, C. 2140	Herbarium	CNS134828	SRR21798416
Prasoxylon alliaceum	Costion, C. 3017	Silica	CNS 135374	SRR21798415
Vavaea amicorum	Cooper, W. WWC 2786	Silica	CNS 151039	SRR21798414

same clade of section *Aglaia* (Grudinski *et al.* 2014). However, the relationships of *A. elaeagnoidea*, *A. brownii*, *A. sapindina*, *A. ferruginea* and *A. cooperae* differ from Grudinski *et al.* (2014). This is likely due to a difference in the amount of data used to reconstruct relationships; Grudinski *et al.* (2014) used one locus (ITS) and reported weak to moderate bootstrap support for most species relationships, while we used 334 loci and received maximum support for most relationships. A difference in sampling and in species concepts may also play a role in the differences in relationships. For example, *A. elaeagnoidea* has recently been recircumscribed by Joyce *et al.* (2023), and *A. monticola* was recently split from *A. brassii* by Cooper & Forster (2021). Future studies including comprehensive sampling with many loci should be conducted to corroborate the relationships retrieved in our analysis.

Discussion

Our analysis retrieved all samples of the putative novelty as a clade nested within *Aglaia* section *Aglaia*, most closely related to *A. monticola* and *A. cooperae* (relationships among these three are not resolved with support). Thus we describe the new taxon herein as *Aglaia fellii* W.E.Cooper & Joyce. The addition of *Aglaia fellii* brings the total number of *Aglaia* species in Australia to 13 (Cooper & Forster 2021), of which six are endemic: *A. australiensis* Pannell, *A. cooperae* Pannell, *A. fellii*, *A. ferruginea* C.T.White & W.D.Francis, *A. meridionalis* Pannell and *A. monticola* W.E.Cooper & P.I.Forst. The description of *A. fellii* brings the total number of accepted species in *Aglaia* to 127.

Aglaia fellii is the only species of *Aglaia* with solitary flowers and fruits (Pannell 1992). The number of petals in *A. fellii* is also noteworthy; although flowers with three petals are common in sections *Amoora* and *Neoaglaia*, the species of section *Aglaia* usually have (4)5–6(7) petals (Pannell 1992). Genus-wide sampling of *Aglaia* in future phylogenetic studies (including extra-Australian species) should be conducted to determine the closest relative of *A. fellii,* to infer its biogeographic history, and to investigate the evolution of its exceptional morphological traits.

Taxonomy

Aglaia fellii W.E.Cooper & Joyce *sp. nov.*

Type: Australia, Queensland. Cook District: Steve Irwin Wildlife Reserve, 4 June 2022, *W. Cooper 2854* & *T. Hawkes* (holo: CNS 152656 [2 sheets CNS + spirit], iso: 6 sheets to BRI, CANB, K, L, MO, M).

Diagnosis. Similar to *Aglaia cooperae* Pannell but differs in the trifoliolate leaves (v. 5–7 leaflets); leaflets obovate (v. elliptical); leaflets chartaceous (v. coriaceous); inflorescence to 7 mm long (v. 25–30 mm long); flower diameter *c*. 2 mm (v. 2.5–3 mm); petals glabrous (v. densely clothed in scales); staminal tube glabrous (v. clothed in scales); fruit obovoid and *c*. 15 mm long (v. subglobose and 17–25 mm long).

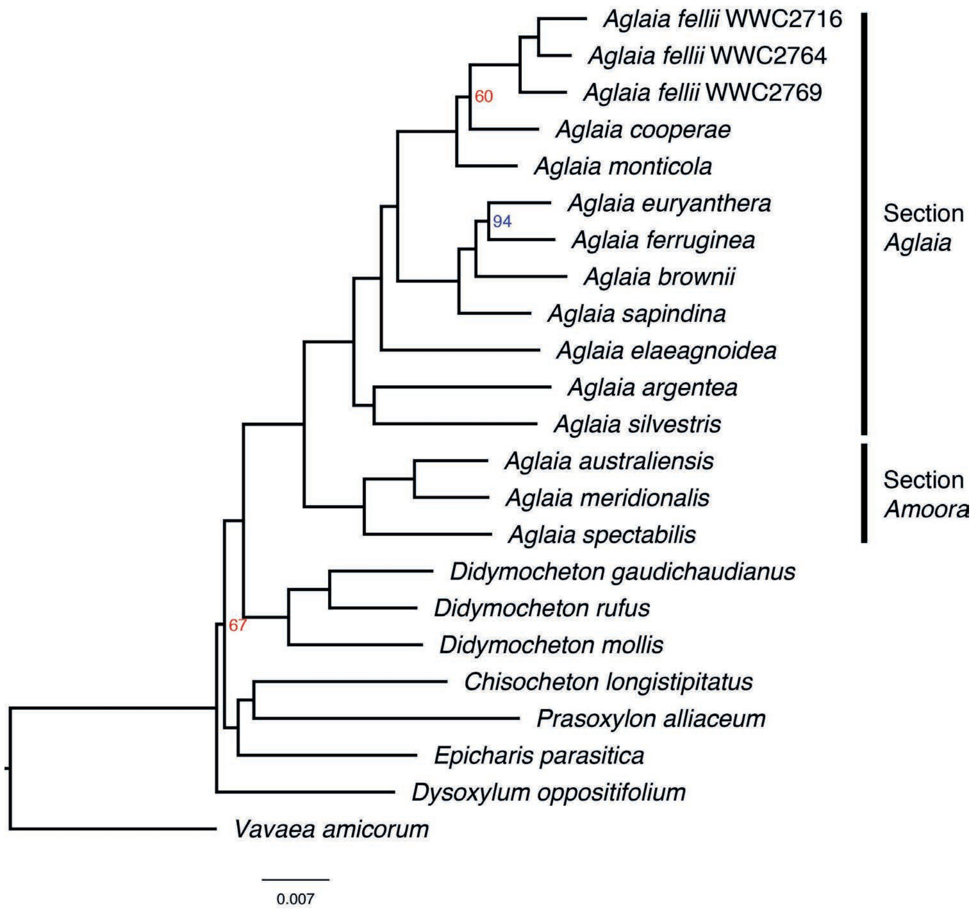

Figure 1. Phylogenetic relationships of all Australian *Aglaia* species and Australian representatives of closely allied genera based on maximum likelihood analysis of 353 nuclear genes. Bootstrap values for moderately (blue) and weakly (red) supported nodes are shown; nodes without values received maximum support.

Small tree to *c*. 7 m high, trunk diameter at breast height to 30 cm; bark grey, tessellated, flaky; branches glabrous; twigs densely tuberculate; newer twigs, petioles, petiolules, peduncles, pedicels, leaflets, bracts, sepals and fruit clothed in rusty peltate scales with fimbriate margins. **Leaves** compound, alternate; petiole 5–10 mm long; **leaflets** 3; lateral petiolules 1.5–3 mm long, pulvinus at base; terminal petiolules 2–3 mm long with a pulvinus at base; petiolules and pulvinulus grooved adaxially; lamina discolorous, obovate, 20–55 mm long, 10–17 mm wide, chartaceous; base decurrent; apex bluntly acute or obtuse; margin entire; abaxially and adaxially clothed in scales which are denser along primary vein, dehisced scales leave a pitted surface; venation brochidodromous; primary veins raised on both sides; secondary veins 8–12 pairs, slightly raised on both surfaces; tertiary venation reticulate. **Inflorescence** axillary or ramiflorous, mostly an erect solitary flower or occasionally a 3- or 4-flowered raceme to 7 mm long; peduncle *c*. 2.5 mm long; bracts solitary at base or up to 4 set partway along pedicels, *c*. 0.5 mm long and wide, triangular, base truncate, apex acute; pedicels 1.25–4 mm long. **Flower** fragrance not detected, diameter *c*. 2 mm; calyx cupular with 5 sepals, lobes broadly ovate, *c*. 1 mm long; petals 3 (rarely 4), *c*. 2 mm long and 1.5 mm wide, hooded at apex, concave, glabrous, green to brown with cream margins; staminal tube globose, *c*. 1.5 mm long, aperture diameter *c*. 0.25 mm; anthers oblate, inserted at apex, *c*. 0.1 mm long and 0.5 mm wide; ovary obovoid, *c*. 1.25–2 mm high and 0.6 mm wide, glabrous, stigma 5-lobed, apex often 3-cornered; ovules 2 or 3. **Fruiting** peduncle *c*. 2.5 mm long; **pedicel** *c*. 2.5 mm long; bracts persistent at pedicel base; sepals persistent at apex and densely scaly. **Fruit** a 2- or 3-locular drupe, obovoid, *c*. 15 mm long, 13–13.5 mm wide, densely clothed in small, rusty peltate scales with fimbriate margins; 5-lobed stigma *c*. 1.2 mm long and persistent at apex; seeds 2 or 3, *c*. 10 mm long and 7 mm wide, testa brown; aril not seen.

Other specimens examined. Moaning Scrub, Steve Irwin Wildlife Reserve, Nov 2020, *Cooper 2716, Fell, Hawkes, Jensen & Venables* (CNS); Moaning Scrub, Steve Irwin Wildlife Reserve, June 2021, *Cooper 2764, Fell & Jensen* (CNS); Moaning Scrub, Steve Irwin Wildlife Reserve, June 2022, *Cooper 2853 & Hawkes* (CNS); Near gravel pit, Bramwell, June 2021, *Cooper 2768, Fell & Jensen* (CNS); Near gravel pit, Bramwell, Nov 2021, *Cooper 2817, Addicott & Zich* (CNS); Steve Irwin Wildlife Reserve, July 2018, *Fell DGF IRRS284, Cook, Cook & Davidson* (BRI).

Figure 2. *Aglaia fellii* showing tessellated flaky bark. (*Cooper 2854 & Hawkes*, CNS). Photo W. Cooper.

Phenology. Both flowers and fruits have been recorded in June.

Distribution & habitat. Aglaia fellii is endemic to rainforest patches on Steve Irwin Wildlife Reserve and Bramwell Station on Cape York Peninsula, north Queensland, where it is currently known to occur at three sites at

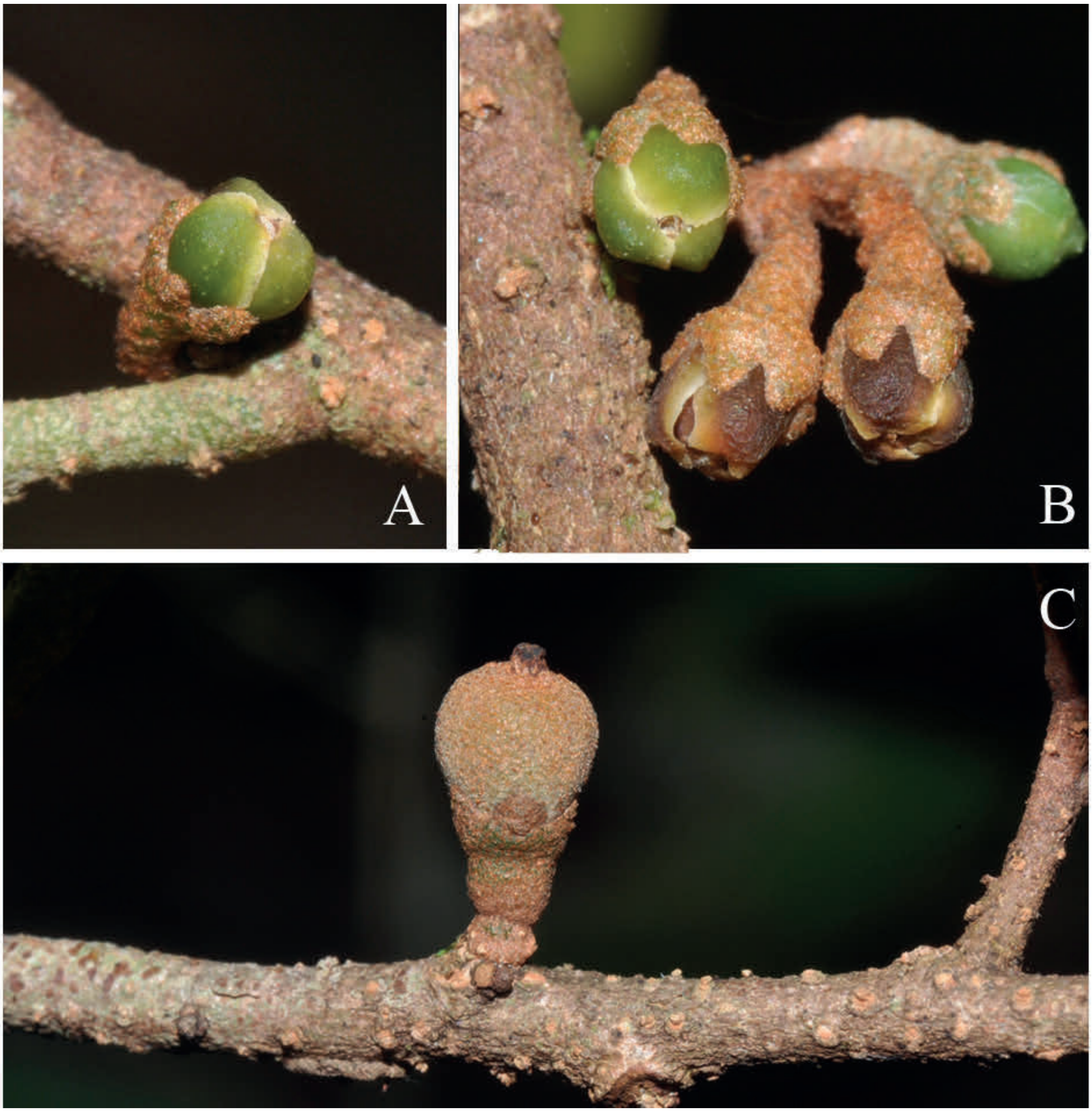

Figure 3. *Aglaia fellii* showing A. a typical solitary-flowered inflorescence (*Cooper 2853 & Hawkes*, CNS). B. a 4-flowered inflorescence with petals aging from green to brown (*Cooper 2853 & Hawkes*, CNS). C. immature fruit. (*Cooper 2854 & Hawkes*, CNS). Photos T. Hawkes.

altitudes between 80–110 m. These forests are broadly consistent with Qld Regional Ecosystem 3.5.4 - Semi-deciduous notophyll vine forest on northern plateaus on red earth soils on remnant lateritic surfaces (Queensland Herbarium 2021).

Aglaia fellii is an understorey tree that occurs beneath a closed canopy typically dominated by *Stenocarpus verticis* Foreman, *Welchiodendron longivalve* (F.Muell.) Peter G.Wilson & J.T.Waterh and *Dinosperma erythrococcum* (F.Muell.)T.G.Hartley. Other co-occurring species include *Acacia fleckeri* Pedley, *Acacia polystachya* A.Cunn. ex Benth., *Aglaia elaeagnoidea* (A.Juss.) Benth., *Aidia racemosa* (Cav.) Tirveng., *Ailanthus tripyhsa* (Dennst.) Alston, *Arytera bifoliolata* S.T.Reynolds, *Brachychiton velutinosus* Kosterm., *Canarium australianum* F.Muell., *Celtis philippensis* Blanco, *Celtis timorensis* Span., *Cordia dichotoma* G.Forst., *Denhamia peninsularis* J.J.Halford & Jessup, *Dimorphocalyx australiensis* C.T.White, *Drypetes deplanchei* (Brongn. & Gris) Merr., *Falcataria toona* (F.M.Bailey) Gill.K.Br., D.J.Murphy & Ladiges, *Garuga floribunda* Decne., *Gossia floribunda* (A.J.Scott) N.Snow & Guymer, *Gyrocarpus americanus* Jacq., *Margaritaria dubium-traceyi* Airy Shaw & B.Hyland, *Medicosma riparia* (Proven) T.G.Hartley, *Meiogyne cylindriocarpa* (Burck) Heusden, *Miliusa traceyi* Jessup, *Mimusops elengi* L., *Rhodamnia australis* A.J.Scott and *Sersalisia sericea* (Aiton) R.Br.

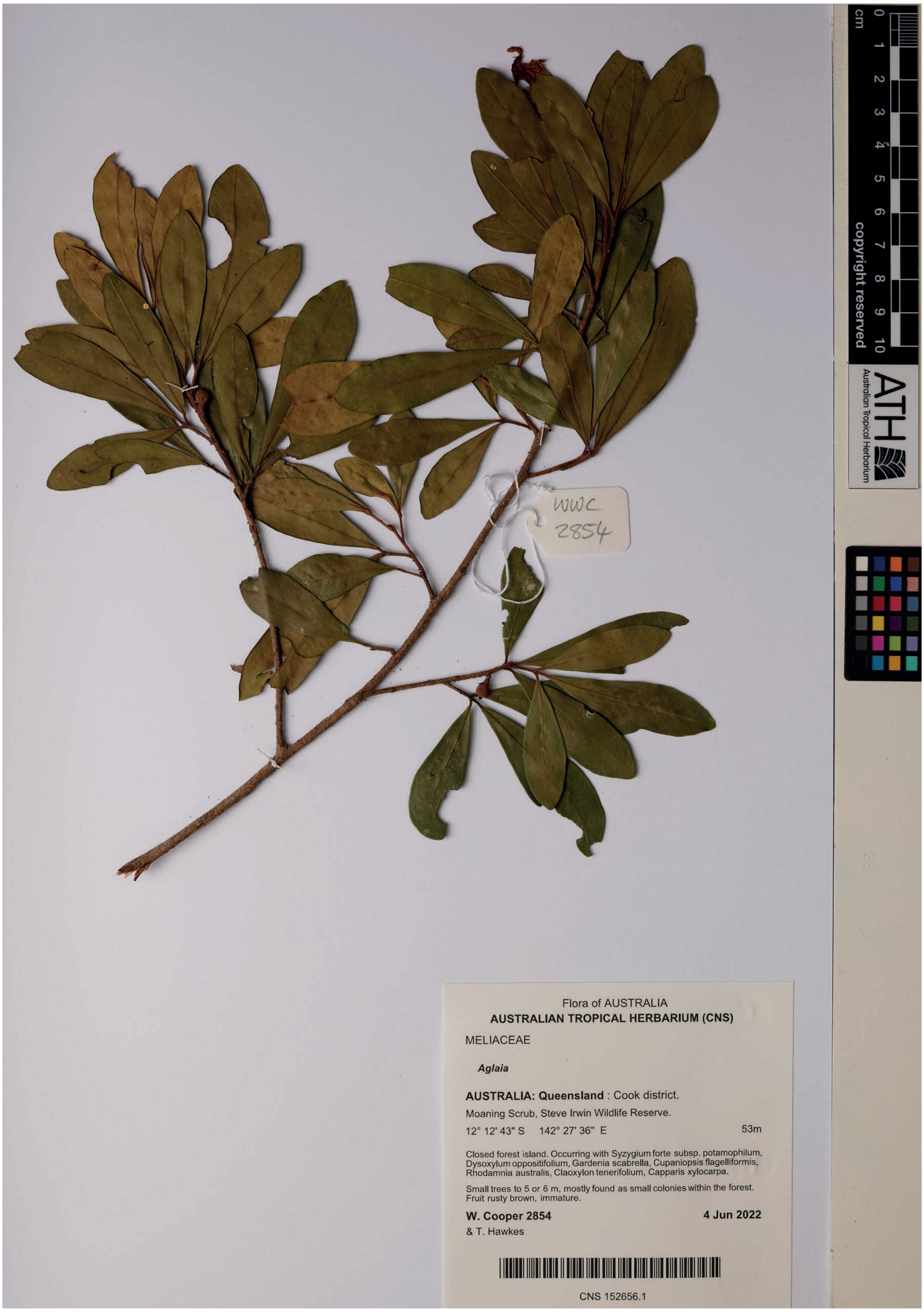

Figure 4. *Aglaia fellii* Type specimen (*W.Cooper 2854 & Hawkes* CNS).

Aglaia fellii is only known from within three well separated patches of rainforest on residual lateritic (or bauxitic) low plateaus and rises with well-drained red earth soils. Similar patches are scattered between the Wenlock and Jackson rivers with another concentration between the Wenlock and Mission rivers (Stanton and Fell 2005) where the species may also occur.

Conservation status. Aglaia fellii is known from three small stands of 10–30 individuals each. Two of these stands are conserved in the private Steve Irwin Wildlife Reserve. The greatest threat to the rainforest habitat of *Aglaia fellii* is the impact of fire. One population occurs close to the southern margin of a rainforest patch where past fire incursion is evident. Tropical cyclones cause catastrophic damage and accumulation of debris that increases the flammability of rainforests; the increased likelihood of such extreme stochastic weather events with climate change means that *A. fellii* populations are particularly sensitive to these sorts of events in the future.

Based on known locations, the extent of occurrence of *A. fellii* is estimated to be 78 km^2 and area of occupancy is 12 km^2 (calculated with GeoCat; Bachman *et al.* 2011). As such, *Aglaia fellii* is eligible for nomination as Endangered [EN B1ab(i, ii, iii, iv)+B2ab(i, ii, iii, iv)] according to Queensland's nomination procedure based on the IUCN Red List Categories and Criteria (IUCN 2012).

Etymology. The specific epithet honours David G. Fell (1962–), a botanist who has made outstanding contributions to knowledge of the flora of Cape York Peninsula, and who made the first collection of this taxon and recognised its novelty.

Notes. In many *Aglaia* species, male and female flowers cannot be easily distinguished morphologically (Pannell 1992:32). Floral segments of *A. fellii* seen by the first author, whether they be vestigial or functional (ovaries, stigmas, anthers and ovules) all appear similar and therefore the sexuality of *A. fellii* cannot be ascertained at present. All fruit observed have been solitary.

Aglaia fellii is most similar to *A. cooperae* Pannell and *A. monticola* W.E.Cooper & P.I.Forst., but is distinguished from both by its trifoliolate leaves and usually solitary flowers (or much-reduced inflorescences). Flowers of *A. fellii* and *A. cooperae* usually have three petals (rarely four) unlike other species in section *Aglaia* which always have five or six. These two species occur in disjunct areas on Cape York Peninsula and both are only known from small populations.

Disclosures

We have no conflicts of interest.

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