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RESEARCH ARTICLE

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The status of *Cecropia* (*Urticaceae*) introductions in Malesia: addressing the confusion

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Key words

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Abstract As part of the great global movement of plants in the 18th and 19th centuries, many valuable and commercial plants were sent from the Neotropics to Europe as seeds or as live specimens. *Cecropia* (*Urticaceae*) was in cultivation in England in 1789, yet species delimitation was not well-understood until much later, long after subsequent introductions to other tropical regions where alien populations are now invasive. The earliest record of *Cecropia* being cultivated in Malesia is based on material of *C. peltata* thought to have been sent from the Royal Botanic Gardens Kew to 's Lands Plantentuin (Buitenzorg) in Jawa, Indonesia, sometime between 1862 and early 1868. In 1902, *C. peltata* was first cultivated in the botanical gardens of Singapore and introduced to Peninsular Malaysia in 1954. The source of these latter introductions is uncertain. Many researchers have assumed that *C. peltata* is the only species of *Cecropia* introduced in Indonesia, Malaysia and Singapore. We confirm that *C. peltata* is naturalised in Singapore and is invasive on the island of Jawa, Indonesia, and in Peninsular Malaysia. However, a second introduced species, *C. pachystachya*, has also been discovered as invasive in both Jawa and Singapore. There is no evidence for the third previously introduced species, *C. palmata*, being extant in Malesia.

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INTRODUCTION

In the late 18th and early 19th centuries, colonial botanic gardens were pioneering and enthusiastic parties in the global movement of a great diversity of plants within and between continents (Alpern 2008). The Kew Gardens in London (now Royal Botanic Gardens Kew) and the Bogor Botanic Gardens (Indonesia) were part of this trading network, importing many plants from Africa and the Neotropics. Many of these early plant introductions into botanical gardens have subsequently become significant invasion problems (for recent references on this issue, see Dawson et al. 2008, Hulme 2011). *Cecropia peltata* L. is listed by the 'Invasive Species Specialist Group' as one of the 100 worst invasive alien species globally (Lowe et al. 2004). During the period of early global plant movements for *Cecropia* (i.e. up to 1840), only three species were recognised – *C. peltata* L., *C. palmata* Willd. and *C. concolor* Willd. Furthermore, the former two names were applied widely to a range of *Cecropia* material.

By the time the diversity and circumscription of species in *Cecropia* was becoming better understood in the 20th century (e.g. Snethlage 1923), many herbaria and botanic gardens already had all or many of their collections identified using the earlier, broader and/or poorly defined species concepts. Frequently, these misidentifications or these older species concepts were not corrected by reference to the modern species concepts of *Cecropia*. The identification of cultivated material was further compounded because the provenance of much of the material was unclear. Even with the extensive revision of the genus by Berg & Franco-Rosselli (2005), their regional approach to the construction of species identification keys makes it difficult to identify introduced plants of unknown provenance.

Prior to the recent taxonomic account of *Cecropia* (Berg & Franco-Rosselli 2005), this genus had often been poorly understood and misrepresented in the literature due to a lack of understanding of taxonomic and biological variation in this genus. Sixty-one species of *Cecropia* are currently recognised, with native ranges from southern Mexico to northern Argentina (with two species in the Antilles) and a wide variety of habitats. It is now becoming clear that within the genus there is also considerable variation in life history traits (Berg & Franco-Rosselli 2005). For example, there is a high degree of specialisation within *Cecropia* to certain regeneration and establishment niches, as well as distinct types of habitats, such as those only occurring in montane areas or lowland tropical rainforest habitats (Berg & Franco-Rosselli 2005, Webber et al. 2011). Furthermore, some species, for example those within the '*C. peltata* Group' (*sensu* Berg & Franco-Rosselli 2005), are differentiated into ecotypes, ecospecies or ecological subspecies (Berg & Franco-Rosselli 2005).

Depending on the context, such as time since introduction and abiotic suitability of the environment, and assuming that life history traits remain relevant in alien populations, some species and/or ecological variants of *Cecropia* are more likely to naturalise successfully or become invasive. For those managing these invasive populations, recent literature that treats multiple species or the entire genus as a single entity (e.g. Csurhes 2008, Panetta et al. 2011) is likely to be an over-simplified summary, leading to potential problems with any proposed control program.

A fundamental goal of invasion ecology (Dawson et al. 2009, Pyšek & Richardson 2007) is to understand why some species become invasive after introduction to new areas, while others fail to naturalise. The success of tropical species becoming naturalised has been attributed, in part, to longer residence

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time, faster growth rate, fewer seeds per fruit, smaller seed mass and shade tolerance (Dawson et al. 2009). These characteristics are found in varying combinations in the diverse introduction history and life history traits of *Cecropia* species and their introductions worldwide. Moreover, although the fruits of all *Cecropia* species are one-seeded achenes, the infructescence functions as a multi-seeded 'compound fruit' consisting of many small seeds, a trait typical of invasive species (Dawson et al. 2009). Some *Cecropia* species can be regarded as being more or less classically 'weedy' in disturbed habitats, such as *C. pachystachya* Trécul and *C. peltata*. However, not all *Cecropia* species or alien populations can be considered of equal risk to naturalise and become invasive.

Against this historical background of scientific uncertainty and confusion and the frequent incorrect identification of *Cecropia* species in current literature (e.g. Hulme 2011), we aim to provide a clarification of the introduction history and current status of *Cecropia* in Indonesia, Singapore and Malaysia. Since the earliest movements of *Cecropia* out of the Neotropics were into European botanic gardens and from there to other parts of the world, we first seek to clarify some of these earliest introductions in an effort to assist in the identification at the specific or infraspecific level of re-distributed *Cecropia* material, and to work towards our ultimate goal of identifying the provenance of all introduced *Cecropia*. We also present the diagnostic features for field identification of introduced species of *Cecropia* occurring in Malesia.

MATERIALS AND METHODS

In this work, we follow the recent generic revision of Berg & Franco-Rosselli (2005) in which 61 species of *Cecropia* are recognised. Due to dioecy and the variation in characters, their revision does not contain a single identification key, but rather a series of keys grouped by countries, regions or by species-groups. Although their monograph represents a significant advance on previous generic revisions, the keys make it particularly challenging to identify species of *Cecropia* outside their native range. To assist in the identification of the three *Cecropia* species found in Malesia, the main features distinguishing *C. pachystachya*, *C. palmata* (not regarded as currently extant in Malesia) and *C. peltata* are listed in Table 1. Unfortunately, at least in plants occurring in Malesia, some of the more useful character-states for species-level determinations overlap, making it difficult to identify these introduced plants with certainty.

To document *Cecropia* introduction pathways and source information on known and possible new populations, three strategies were utilised. Firstly, herbarium specimens were critically examined in collections held at Herbarium Bogoriense, Indonesia (BO), Royal Botanic Gardens Kew, United Kingdom (K), Forest Research Institute Malaysia (KEP), Kebun Raya Bogor, Indonesia (KRB), Nationaal Herbarium Nederland, Leiden, The Netherlands (L) and Botanic Gardens Singapore (SING). We have revised the determinations if required. Selected herbarium specimens examined and their determinations are provided. Secondly, the official records of plant collections cultivated at KRB were examined in detail. These records include: Kartu mati – index cards recording the death of cultivated collections (here referred to as 'dead cards'); Kartu kebun – index cards registering the living cultivated accessions (here referred to as 'living cards'), and Buku kebun – botanic garden registration books (here referred to as 'garden book'). The records of plant material received (accessions) for cultivation at KRB are frequently divided into two or more accession identifiers (e.g. VII.G.81 and VII.G.81a). However, it is important to remember that these two identifiers only represent the receipt of one accession. Thirdly, we consulted literature and sought clarification from experts on the status of species of *Cecropia* in local or regional floras.

To determine the extent and current invasion status of *Cecropia* plants and populations in Malesia, we used two approaches. Firstly, during 2009–2011, informal surveys were conducted in the vicinity of Bogor, extending from Cibodas (in the south) to Jakarta (in the north) to confirm the current status of *Cecropia* introductions in Jawa Barat (West Java). A survey of the Lawang region of Jawa Timur (East Java) was undertaken in 2011 to try and locate any plants of *Cecropia* that may have persisted since their introduction in the early 1900s. Secondly, we approached local organisations and experts to obtain information on local populations of *Cecropia* that we were not able to directly inspect. In this case, species-level identifications were confirmed by either voucher specimens or detailed photos (particularly for plants occurring in Malaysia). We followed the native/alien framework of Webber & Scott (2011) to define the terms alien and native, and the invasion framework of Blackburn et al. (2011) to define the terms casual, naturalised and invasive. Voucher specimens of representative populations surveyed were lodged at BO, KRB and the National Herbarium of New South Wales, Australia (NSW).

Table 1 Diagnostic macro-morphological features distinguishing *Cecropia pachystachya*, *C. palmata* and *C. peltata*.

Characters	*C. pachystachya*	*C. palmata*	*C. peltata*
Stipules	caducous	semi-persistent	caducous
Stipule length	(80–)100–200 mm	70–150 mm	30–100(–120) mm
Leaf median lobe shape	narrowly obovate to obovate, rarely broadly so	obovate to elliptic, oblong or ovate	oblong to elliptic
Leaf median lobe margin	often with secondary lobing (at least in juvenile leaves)	with secondary lobing	entire, secondary lobing absent
Leaf lobe incisions[a]	(0.5–)0.7–0.9	0.5–0.8	0.5–0.7
Trichilia	present, well-developed	present	present or absent
Hairs of trichilia	distinctly long white hairs usually present	with both short white to brownish hairs	only short white hairs
Arachnoid hairs	present, dense (on stipules and frequently on petiole)	present	absent or only sparse
Spathe	3–18 cm long, white to pale green	10–17 cm long, white or sometimes reddish	2.5–7 cm long, pinkish, greenish or whitish
Peduncle length of female inflorescence	(20–)40–150	200–400 mm	30–100(–160) mm
Number of spikes in male inflorescence	5–20	4–6(–11)	(10–)15–25(–60)

[a] Degree of leaf incision (lobing) is here expressed as the ratio of length of lobe to radial length of lamina, as measured from point of insertion of petiole to apex of lobe.

RESULTS AND DISCUSSION

Cecropia out of the Neotropics

Cecropia peltata was first recorded as cultivated at the Royal Botanic Gardens Kew, England, in 1789 (Aiton 1789). This Kew material was introduced into England from Jamaica in 1778 by Thomas Clark (Aiton 1789), a nurseryman with a reasonably large nursery of plants (Harvey 1978) in Keswick, Cumberland. Therefore, we can assume that *C. peltata* was in cultivation in England for up to 11 years prior to it being received at Kew. There was a further introduction in 1793. On the 5th February 1793, H.M.S. Providence, commanded by Captain William Bligh, and accompanied by Lieutenant Nathaniel Portlock on H.M.S. Assistant, arrived in Port Royal harbour, Jamaica (Powell 1977) after gathering botanical specimens from the Pacific. Some plants were left at the Botanic Garden in Saint Vincent, Saint Vincent and Grenadines, West Indies (23 January 1793), with an additional '465 pots and 2 tubs containing botanic plants' (Powell 1977: 399) received from the superintendent of the Botanic Garden, Dr Alexander Anderson, for 'His Majesty's Gardens at Kew' (Powell 1977: 399). However, Anderson's list of plants sent from St Vincent (Anderson 28 Jan. 1793) does not include species of *Cecropia*. Therefore, if the early specimens were collected from Jamaica, then we can deduce confidently that they were *C. peltata* (the only *Cecropia* species native to the island). However, at least some of the 48 plants provided by Anderson were of South American provenance. Whether or not specimens of *Cecropia* were included is unclear from the apparently incomplete lists provided by James Wiles (as cited in Powell 1977).

Dr Arthur Broughton, physician of Kingston, Jamaica, cared for the Saint Vincent material while it was held in Jamaica (Powell 1977). When the surviving collections were despatched for England (arriving 7 Aug. 1793), the living plant collections were supplemented with several hundred rooted plants and seeds collected from Jamaica by Broughton (Appendix B, Plants sent to Kew Gardens, 1, in Broughton's List, as cited in Powell 1977: 416–424). *Cecropia peltata* is listed as being included (Powell 1977: 418) and because *C. peltata* is the only *Cecropia* species native to Jamaica, we can be reasonably confident of the identification (assuming Broughton had collected his Jamaican material from native sources outside the Botanical Gardens). However, for the overall shipment that left on H.M.S. Providence, there is no definitive proof that these early shipments consisted entirely of *C. peltata* (in its current circumscription). This uncertainty results from the inclusion of the additional plants of South American provenance (which may have included *Cecropia*) and because we were unable to find any extant herbarium specimens that could be directly traced to this early material. Therefore, there is some uncertainty about the provenance and identity of early *Cecropia* material arriving in England, which therefore also applies to plants and seeds subsequently distributed throughout Europe or re-directed globally.

Cecropia peltata in Indonesia

Cecropia peltata was probably first introduced to Kebun Raya Bogor (KRB) as seeds, from plants grown at the Royal Botanic Gardens, Kew (K). The exact date of introduction to KRB is not recorded. The earliest known collection from the cultivated material growing at KRB ('ex horto bogoriensi') was made by *Teijsmann s.n.* in 1868 (recorded as received by K in May 1868; K576063; 'Recd 5/68'), and listed as *Cecropia schiedeana* Klotzsch (here regarded as a synonym of *C. peltata*). Johannes Elias Teijsmann (Teysmann) was Curator of the Buitenzorg Botanic Gardens (now KRB) at the time of this collection (Van Welzen 2006+). A review of the records of plants exported from K, listed in the 'Outwards goods' ledgers, reveal no listings of *Cecropia* being sent to Indonesia prior to 1862. Therefore, the first *Cecropia* material sent from K to KRB for cultivation must have been after 1861 and prior to 1868. A second herbarium collection (*Anonymous s.n.,* BO; originally determined as *C. schiediana*; = *C. peltata*) of an individual plant in cultivation at KRB (VII.G.113a) was made in 1896 ("Datum van inzameling 5 May 1896; zijn dit bloemen? een ?? vorm[?] van bloem of vrucht heb ik nog nimmer[?] gezien" ["Date of collection 5 May 1896, are these flowers? a ?? form/shape[?] of flower or fruit I have never seen [before]"] – note: hand-writing difficult to decipher. It is not known whether the above *Teijsmann* collection is from the same plant or from a different one to that of the latter *Anonymous* collection. The KRB cultivation identifier 'VII.G.113a' is recorded as a cutting ('tj') from 'VII.G.113' (Botanische Tuin 1904-05). The individual VII.G.113 was recorded as originating from Mexico and was present at KRB in 1875 and 1892, but appears to be absent in 1897 (finally recorded as dead by Sept. 1949). Based on our assessment of herbarium specimens of these individuals, the two plants are probably different. VII.G.113 appears more likely to be *C. pachystachya* because of the narrowly obovate leaf lobes and long bracts, whereas the plant VII.G.113a represents *C. peltata*. This can be explained in various ways. It may be that the herbarium collections for these two accession numbers have been mixed with others, there may have been an error in the registration process at KRB such that 'VII.G.113a' was not a cutting from 'VII.G.113', or the supposed cutting 'VII.G.113a' died without being noticed, and was subsequently replaced in the garden bed by a naturalised plant of *C. peltata*. Another explanation of this apparent anomaly is that the leaf shape of *C. peltata* in Jawa may be more variable and, at least, sometimes more similar to that of *C. pachystachya* than previously thought.

The next earliest known collection of *Cecropia* from material cultivated at KRB was gathered from a male plant (VII.G.117) that was recorded as dead on 12 May 1896 (*Anonymous s.n.*, KRB). The origin of this material, hence its relationship with other material at KRB is unknown. Furthermore, there is some confusion concerning this record because the herbarium voucher is *C. peltata*, whereas the extant cultivated plant with this same accession identifier (namely, VII.G.117) is *Artocarpus incisus* (Thunb.) L.f. (*Moraceae*; Table 2). The most likely explanation is that after the death of the *C. peltata* plant, a plant of *A. incisus* occupied the same garden bed.

Later accessions cultivated at KRB are recorded as received from three other sources (Table 2). These accessions are listed as *C. peltata*; however, we have not been able to confirm these identifications and thus the true identity of these plants remains unknown. Firstly, seeds from 'Vilmorin-Andrieux, Paris', date of receipt not recorded, provenance 'American Tropics' were received prior to 1897 (no longer extant). Vilmorin was founded as a plant and seed boutique in 1742 by seed expert Claude Geoffroy and her husband Pierre Andrieux, the chief seed supplier and botanist to King Louis XV (Victory Seed Company 1998). In 1774, their daughter married botany enthusiast Philippe-Victoire Levêque de Vilmorin (1746–1804) and they created the Vilmorin-Andrieux House, which later became 'Vilmorin-Andrieux and Company' under the leadership of their son, Philippe André de Vilmorin (1776–1862) (Victory Seed Company 1998). Philippe-Victoire de Vilmorin began importing trees and exotic plants into Europe in 1766 for food, fodder and ornamentation. Secondly, material (accessions VII.G.51 and VII.G.51a) was received from Paris Botanic Gardens, France (Afk. ['Afkomst' = source] Hort. Parys, Frankryk' presumably Jardin des Plantes, Paris), date of receipt not recorded but provenance listed as "Amerika, Brazilie". These accessions were both recorded as dead in 1952 and 1935, respectively

(Table 2). Thirdly, seed was received from 'C. Jinaradasa, Madras, India' in 1940 and planted in 1943 at KRB (accessions VII.G.81 and VII.G.81a). Both individuals were recorded as dead in 1990 and 1949, respectively (Table 2). Curuppumullage Jinarajadasa was associated with the Adyar group of the Theosophical Society (Jinarajadasa 1921, Mojzesz 2005) and was interested in transferring plants from one part of the world to another and in conducting naturalisation experiments (Shearman 1975). Although the provenance of these seeds is not recorded, *Cecropia* individuals (the species cannot be confirmed) are still cultivated in the extensive gardens of the headquarters of this Society in Chennai (previously known as Madras; K. Satapathy, pers. comm.).

Apart from the horticultural interest in *C. peltata*, this species, along with many others, was more recently investigated in Indonesia as a potential new source of timber (Rachman & Balfas 1987) and grown in experimental gardens in Dramaga (Bogor) and Pasir Hantap (Sukabumi), Jawa Barat. The source of the seeds for these two experimental gardens is unknown, but it possibly was KRB.

No living plants of *C. peltata* of confirmed provenance are currently cultivated in KRB. However, this species does occur in these gardens as spontaneous re-introductions from naturalised populations in the surrounding area. These *C. peltata* populations may have originally escaped from Kebun Raya Bogor, Dramaga and/or Pasir Hantap (Sukabumi). Likewise, self-maintaining populations now found in the Dramaga area are possibly derived from the nearby original introductions. *Cecropia peltata* frequently forms dense stands along river banks and drainage channels, in abandoned lots, cemeteries and sometimes on the margin of house gardens. Over the last 114 years, based on our surveys and herbarium vouchers (see Selected specimens), our observations suggest that *C. peltata* has spread 35–40 km from the Bogor region towards Jakarta. Such a rate combined with high fecundity in this alien range suggests that *C. peltata* can be viewed as invasive in Jawa Barat. Although *C. pachystachya* (discussed below) is also invasive in Jawa Barat, *C. peltata* appears to be the more common species of the two.

Plants that appear morphologically intermediate between *C. peltata* and *C. pachystachya* are frequently found in Jawa Barat. Whether or not these plants are of hybrid origin is not yet clear. The absence of trichilia has previously been emphasised as a useful diagnostic characteristic for introduced species of *Cecropia* (Putz & Holbrook 1988, Berg & Franco-Rosselli 2005). This advice may be due to the fact that *C. peltata* from Jamaica, which often has no trichilia or only vestigial ones, is a commonly introduced species (e.g. Cameroon; B. Webber & C. Born, unpublished results; McKey 1988). While the absence of trichilia (in combination with other key characters) is a useful

Table 2 Plants of *Cecropia* (*Urticaceae*) grown at Kebun Raya Bogor, Indonesia (KRB), based on Botanische Tuin (Botanic Garden book) records, index cards recording the death of cultivated collections, and herbarium specimens held at KRB. The identity of the plant material received is listed, when that name is regarded as incorrect, the corrected name is provided in parentheses. Note: identities of the following herbarium vouched or living records can be verified with certainty: VII.G.106 & 106a (because it was source material for VII.G.197 & 197a and the latter has an herbarium voucher), VII.G.112 & 112a, VII.G.113 & 113a, VII.G.117 and VII.G.197 & 197a. The identity of the other accessions cannot be verified.

Plant Accession	Plant Name	Source	Origin	Received	Planted	Death	Information Source
VII.G.51 &51a	*C. peltata*	Paris Botanic Garden[a], France	Brazil			[1952, 1935], resp.	dead card
VII.G.81 & 81a	*C. peltata*	Jinarajadasa, Madras (now Chennai), India 'No.28' (seed)	West Indies	15 Nov. 1940	16 Mar. 1943[b]	22 Apr. 1990, [Sept. 1949], resp.	garden book & dead card[c]
VII.G.106 & 106a	*C. adenopus* (= *C. pachystachya*)	Buysman[d], Lawang (seeds[e])	Argentina	18 Apr. 1918	8 May 1921	19 June 1990, 8 Aug. 2005, resp.	garden book & dead card
VII.G.112& 112a	*C. palmata*	Hortus Kew no. 12	Brazil	1904		[Sept. 1949, 1971], resp.	garden book & dead card
VII.G.113 & 113a	*C. schiedeana* (113 possibly = *C. pachystachya*; 113a = *C. peltata*)	Anonymous s.n.	Mexico		Alive 1875[f]	[after 1896; re-confirmed dead Sept. 1949]	herbarium specimen (KRB) & dead card[g]
VII.G.117	*Cecropia* sp. (= *C. peltata*)	Anonymous s.n.			Alive 1875[h]	12 May 1896[i]	herbarium specimen (KRB)[j]
VII.G.197 & 197a	*C. adenopus* (= *C. pachystachya*)	VII.G.106a (cuttings)	Argentina		12 Oct. 1993	still alive	herbarium specimen (KRB) & garden book
VIII.B.162 & 162a	*Cecropia* sp.[k]	casuals or naturalised[l]		Prior to 23 Feb. 1960[m]		23 Jan. 1961, [5 ?month 1965][n], resp.	dead card[o]
XI.B.V.12 & 12a[p]	*C. peltata*	Vilmorin- Andrieux, Paris, France (seeds)	American Tropics	After 1897[q]			garden book; year of the book not recorded[r]

[a] Le Jardin des Plantes, Paris.
[b] Recorded as 16 Mar. 2603 (using Japanese Imperial Year; later changed to 16 Mar. 1943 for Gregorian Calendar).
[c] In 1990, accession VII.G.81 – plant recorded as fallen.
[d] "… the late Mr. Buysman, who conducted a private plant-introduction garden for many years at Lawang, Java, … (Taylor 1921)".
[e] Seeds were received by KRB. However, cuttings of VII.G.106a were taken and recorded as accessions VII.G.197 & 197a.
[f] Recorded in the 1875 Botanische Tuin (Botanic Garden book) and still alive in 1896 (KRB Herbarium collection label "Datum van inzameling: 5-5-[18]96").
[g] No records on the current garden books. However, this accession listed in the 1875 Botanische Tuin although it does not provide any further details on the collection, just the name. No records in the current garden books.
[h] In the 1875 Botanische Tuin VII.G.117 listed as *Artocarpus incisus* (*Moraceae*).
[i] Based on herbarium record, referring to *C. peltata*.
[j] No dead card; no records in current or old garden books.
[k] Identity of plant not recorded and no voucher material at KRB.
[l] Provenance of tree unknown because already growing in garden, hence naturalised.
[m] Registered on 23 Feb. 1960.
[n] Month of death not recorded.
[o] No details because tree already established in garden (registered on 23 Feb. 1960).
[p] Accession XI.B.V.12a has a cross sign indicating plant already dead (without date) at time of registration.
[q] Information from an old green garden book (year of book not recorded).
[r] This plant not listed in the 1897 garden book (Botanische Tuin X. A- XVIII.D.IV 1897 -), therefore this collection cannot be the first living material in the garden because collections VII.G.113 & VII.G.117 were already recorded as dead in 1896.

discriminatory character for distinguishing some species of *Cecropia* in Malesia, the presence of trichilia does not rule out an identification as *C. peltata* (Table 1).

Cecropia peltata in Singapore and Peninsular Malaysia

Seeds of *Cecropia peltata* were introduced to Singapore Botanic Gardens in '1902' and these seeds were sourced from 'B.G.' [Botanic Gardens in Kingstown, St Vincent] (Anonymous without date). The seeds were "successfully germinated and grown in the gardens and produced seed freely; seedlings appear in many parts of the Gardens" (Anonymous without date). The number of plants growing in the Singapore Botanic Gardens is currently restricted by active removal of seedlings (Benito Tan 2010, pers. comm.); however, apart from streetscape beautification, plants of this species are not controlled outside the Gardens. Naturalised plants determined as *C. peltata* have been recorded as occurring in Tyersall Avenue (Lok et al. 2010) and Mandai Road, Singapore, outside the Botanic Gardens, but this restricted distribution suggests that *C. peltata* should not be considered invasive in Singapore at this stage.

The collection of *C. peltata* by *Nur s.n.* (SING) from New Tamil Lines, Singapore lacks trichilia but has a leaf lamina with an obovate median lobe, similar but slightly broader than those of *C. pachystachya* (whose introduction is discussed below); also apex acuminate (acumen 6–12 mm long); and hairs on the adaxial surface are appressed, antrorse (hairs are not present on *C. pachystachya*). Based on these somewhat intermediate morphological characteristics of this collection and other naturalised plants seen, there is a strong possibility of hybridisation between *C. pachystachya* and *C. peltata* in Singapore.

Material described as *C. peltata* was introduced into Selangor (Peninsular Malaysia) as part of plantation trials in Kepong (in May 1954, with further planting in July, October and December 1954 and April 1955), Selayang Tin Tailings (planted November 1956, February 1957, December 1958, December 1959 and January 1961) and Sungai Buloh Forest Reserve (planted December 1954; Selvaraj & Muhammad 1980). Plants in the region of Kepong and Selayang Tin Tailings are probably no longer extant because of clearing and conversion to residential housing. However, individuals originating from the plantation trials of *C. peltata* along the road surrounding the Sungai Buloh Forest Reserve have naturalised and are now spread along the highway at least 10 km from the source plantings at Kepong (Saw Leng Guan 2011, pers. comm.). Putz & Holbrook (1988) reported that by 1982 plants were observed as far as 0.6 and 10.4 km from their original introduction site and are common in nearby plantations. We interpret this spread rate and fecundity to indicate that these populations are invasive in Peninsular Malaysia.

The source of the *Cecropia* material planted in Peninsular Malaysia is reported to be seed from KRB with an original provenance of 'Brazilia' (K. Soemarna pers. comm. in Putz & Holbrook 1988). However, neither the source nor the provenance could be confirmed because some of the early garden records of KRB have been lost and no information is available in the extant records. Assuming only one *Cecropia* species was introduced and that the currently existing populations in the region (for which herbarium specimens exist; see Selected specimens) are derived from this source, then it appears that the original identification as *C. peltata* was accurate. It follows that if the recorded provenance is correct, then the material must have been sourced from either the Roaima or Pára regions of northern Brazil (refer Berg & Franco-Rosselli 2005; Fig. 18.3). Since all native neotropical mainland populations of *C. peltata* have trichilia (Berg & Franco-Rosselli 2005), the provenance of the Malaysian plants does not accord with the observations of Putz & Holbrook (1988), who describe 20 % (n = 100) of surveyed *Cecropia* trees in Peninsular Malaysia as either lacking trichilia or with vestigial trichilia. Therefore, we hypothesise that inaccurate provenance information, rather than ubiquitous mortality for every individual without trichilia in mainland native populations (Putz & Holbrook 1988), may explain this observed discrepancy.

Cecropia pachystachya in Indonesia and Singapore

There appears to have been only one introduction of *C. pachystachya* to Indonesia. It was first planted at KRB on 8 May 1921, and recorded as *C. adenopus* (here regarded as a synonym of *C. pachystachya*). The plant material was received from M. Buysman of Lawang (Jawa Timur) on 16 April 1918 (Table 2: accession 'VII.G.106'), with provenance recorded as Argentina; further information is not available. This individual was recorded as dead on 19 June 1990. A second planting of seeds (VII.G.106a), planted at the same time as VII.G.106, was recorded as dead on 8 Aug. 2005 (Table 2). Cuttings from accession VII.G.106a were planted in KRB on 12 October 1993 and are still living as VII.G.197 and VII.G.197a (Table 2). Maarten Buysman (1856–June 1919) initially worked in a plant nursery near Lawang that was owned by J.P. Mousset (Van Welzen 2006+). Although native plants were cultivated in this nursery, it also functioned as a plant-introduction nursery (Taylor 1922). At least by 1913, he was employed by the proprietor of Hotel Nongkodjadjar [Nongkojajar] (Gunung Tengger) and continued to cultivate plants, as well as receive and exchange seeds in his spare time (Buysman 1913, Taylor 1922, Van Welzen 2006+). The hotel was destroyed by Japanese bombing during World War II and nothing of the hotel garden or nursery survives today. In 2009–2011 we made an effort to visit all the possible plant nursery sites that may have cultivated *C. pachystachya*. In the Lawang area, the sites have now been converted to general farm land, one to an agricultural school, and another to the testing and development of crop species. None of the visited sites appear to have retained any remnants of the old garden. In the Nongkojajar area there was one other nursery during that time, but it was not visited because it specialised in food crop species. We have concluded that in Jawa Timur none of the original cultivated plants of *C. pachystachya* appears to exist anymore and they do not appear to persist as casual or naturalised populations.

In Jawa Barat, the distribution of naturalised plants of this species is incompletely known, but it has been positively identified in Cibinong; Jalan Bogor–Cilebut–Bojong Gede; Jalan Cibatok, towards Gunung Salak Endah; and Curug Cihurang, Gunung Bunder, Gunung Salak Endah (selected voucher collections cited below), at distances of up to 10 km from Kebun Raya Bogor. In these locations, self-sustaining populations occupy similar habitats to those of *C. peltata*, namely most frequently along banks of rivers and drainage channels and in abandoned areas. On basis of this distribution, it is likely that these naturalised plants originate from KRB and the material introduced by Buysman. Recently, individuals of *C. pachystachya* have also been found naturalised in the region of Bandung (C.C. Berg, Jan. 2011, pers. comm.). Van der Pijl (1955) reports on *Cecropia* specimens growing in the botanic gardens in Bandung as well as Bogor, although no information on the origins or species-level identification of the latter material was found. These observations suggest that the Bandung plants may have originated from cultivated plants present in 1955. A high fecundity and broad distribution, particularly in more disturbed habitats, indicates that *C. pachystachya* can be viewed as invasive in Jawa Barat.

A study of herbarium voucher material previously determined as *C. peltata* held at SING in 2010 (by BJC and JTH) revealed that *C. pachystachya* was also present in Singapore (Lok et al. 2010). Although this species is widely naturalised throughout

Singapore (Lok et al. 2010) and is here considered invasive, the date and source of introduction of *C. pachystachya* is unknown. The earliest herbarium collection of *C. pachystachya* cultivated at the Singapore Botanic Gardens (ex Brazil) was collected by Marlali in December 1957 (*SING124136*). This pre-dates the introduction and plantings at the Singapore Zoo in 1992 for feeding sloths, which Lok et al. (2010) hypothesised as being the initial introduction event.

Cecropia palmata in Indonesia

Cecropia palmata was introduced into Indonesia from material grown at the Royal Botanic Gardens Kew (accession: *Hortus Kew 12*) (Table 2), and planted (probably as seed) at Kebun Raya Bogor in 1904. The provenance of this material was recorded as Brazil (Table 2: accession VII.G.112 & 112a). Both collections were recorded as dead in 1949 and 1971, respectively (Table 2). This species is no longer extant in the gardens and no other material of *C. palmata* is known to be in cultivation or persisting as casual or naturalised populations in Indonesia.

CONCLUSIONS

Our study has documented two species of *Cecropia*, namely, *C. pachystachya* and *C. peltata* that are both currently naturalised and invasive in Malesia with putative evidence of naturalised hybrids between these two species in some areas. Although *C. palmata* was also introduced into Indonesia, it does not appear to be extant. Management of invasive alien plants, particularly those from poorly known genera with species having very variable life histories, is often only efficient and effective if the species involved are correctly identified. Only then, control strategies such as biocontrol, eradication and containment, can be tailored to the particular life history traits of the taxa concerned while taking into account other influential components (e.g. time since introduction and suitability of abiotic factors). In their native range, both *C. pachystachya* and *C. peltata* are most frequently found as 'classical' pioneers and colonisers of large canopy gaps. Although this may mean that intact primary forests may be somewhat resilient to invasion from these particular *Cecropia* species, the increasing prevalence of logged and otherwise disturbed native forests in Malesia means that management for their control should remain a high priority.

A thorough understanding of the often complex introduction history of alien plants not only assists with distinguishing the different species involved and with recognition of potential hybrids, it may also provide clues as to the provenance and likely genetic diversity imported into the alien environment. Within Malesia, it may be that past introductions with unconfirmed identities persist today in as yet unidentified populations. Given that the gross morphology of some individual *Cecropia* plants appears to be atypical in their Malesian habitats compared to their appearance in native Neotropical populations, a thorough comparative study of the morphological features of these species, both in natural and alien environments, is required. Furthermore, the documentation of multiple species introduced on multiple occasions, as well as putative evidence for hybridisation, suggests that a complementary molecular approach is also required for a more complete understanding of *Cecropia* invasions in Malesia and elsewhere in the world.

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Selected specimens.

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Cecropia peltata: Indonesia, Jawa Barat, *Buysman s.n.* (KRB), Kebun Raya Bogor, Garden Bed VII.G.106 & 106a, cultivated Lawang [Nongkojajar] (ex Argentina), 16 Apr. 1918; *Conn 5632 & Hadiah* (KRB, NSW), Jalan Bogor–Cilebut–Bojong Gede, 19 Apr. 2011; *Conn 5642 & Hadiah* (KRB, NSW), Sungai Ciapus, Kampung Ciherang, near Jalan Raya Darmaga, 22 Apr. 2011 (KRB, NSW). – Malaysia, Selangor, *Mat Asri FRI25549* (K576061), Kota Tinggi Forest Reserve, at road side, near Norwaygen-Malaysia Quarters, 30 Jan. 1980. – Singapore, *Ng SING2008-411* (*SING113787*, *SING113788*), Mandai Road, 7 Oct. 2008; *Marlali 70* (*SING124136*), Singapore Botanic Gardens (cultivated ex Brazil), 15 Dec. 1959.

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