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The *Bruguiera* (Rhizophoraceae) Species in the Mangroves of Singapore, Especially on the New Record and the Rediscovery

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ABSTRACT: We reported here the new record of *Bruguiera hainesii* C. G. Rogers, and the rediscovery of an extinct species, *Bruguiera sexangula* (Lour.) Poir., in the mangroves of Singapore. To simplify the process of identifying all the five *Bruguiera* species in Singapore, a colour plate illustrating the calyx structures (across different development stages) and diagnostic features of the five *Bruguiera* species were provided. A diagnostic key to the five *Bruguiera* species was also provided, with updated descriptions for the two species. As it was difficult to identify the different *Bruguiera* species solely on the basis of vegetative structures, we therefore suggest that the series or numbers of colleters (finger-like glandular structures inside the base of stipules) could be an aid for identifying members of Rhizophoraceae especially in the absence of reproductive structures.

KEY WORDS: Mangroves, Rhizophoraceae, Singapore, colleters, *Bruguiera hainesii*, *Bruguiera sexangula*.

INTRODUCTION

Bruguiera is the largest genus in the Rhizophoraceae (Hou, 1958; Tomlinson, 1986; Hogarth, 1999; Saenger, 2002; Sheue, 2003) and all six described *Bruguiera* species belong to the "Indo-Malayan" group of mangroves, which extend from East Africa to Australia and the West Pacific. With the exception of *Bruguiera exaristata* which is found in Northern Australia and Southern New Guinea (Hou, 1958), the remaining five *Bruguiera* species could be found in Malaysia (Watson, 1928; Wyatt-Smith, 1953; Kochummen, 1989) while four *Bruguiera* species were previously recorded in Singapore (Keng, 1990; Turner and Yong, 1999). Based on flower size and the pollinating agent, various authors (Tomlinson, 1986; Noske, 1993) generally divided *Bruguiera* into two groups. *Brugueria* species with large, recurved flowers (*B. gymnorhiza*, *B. sexangula*, *B. exaristata*, *B. hainesii*) are considered to be bird-pollinated, while the remaining two species (*B. cylindrica*, *B. parviflora*) with comparatively smaller and erect flowers are probably insect-pollinated.

A recent mangrove article by Ong (2003) highlighted the perennial problem of identifying the five *Bruguiera* species in Malayan mangroves and especially with dried herbarium samples. Such identification problems associated with the genus *Bruguiera* are not unexpected as the earlier botanists, such as Watson (1928), Symington (1940) and Wyatt-Smith (1953) have encountered similar difficulties. In Singapore, information about *B. sexangula* is very limited, and there is no known record of *B. hainesii* from any Singaporean

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mangroves (Ng and Sivasothi, 1999). In Keng's Concise Flora of Singapore (1990), only the calyx, seedling features and the former localities of *B. sexangula* were provided. According to the Singapore's Red Data Book (Ng and Wee, 1994), *B. sexangula* is considered to be an extinct mangrove species as it has never been sighted in the wild for the last 50 years.

In this article, we attempt to describe these two *Bruguiera* species in Singapore with more botanical description, and with some brief notes on its habitat and local distribution. A botanical key based on both vegetative and fertile characters is provided to distinguish the five species of *Bruguiera* present in Singapore. Hopefully, this botanical key and the colour plate will assist others in identifying the five *Bruguiera* species in Singapore, and probably in Malaysia. The possibilities of using colleters (inside the base of the stipule) (Sheue, 2003; Sheue *et al*., 2003b) in identifying morphological similar members of *Bruguiera* are also discussed.

The five species of *Bruguiera* in Singapore could be distinguished based on the following morphological characters by key and Figs. 1 & 2.

Key to the species of *Bruguiera* in Singapore

1. Flowers solitary; petals more than 12 mm long; calyx lobes 10-14(16)
   2. Calyx tube mostly red to pink; each apex of petal lobe with 3(4) extended bristles 2-3 mm long; hypocotyl 15-25 cm long; colleters inside the stipule 12-14 series ..... *B. gymnorhiza* (tumu merah)
   2. Calyx tube mostly yellow; each apex of petal lobe without or with 1-2 bristles less than 1.2 mm long; hypocotyl 6-8 cm long; colleters inside the stipule 3-5 series ..... *B. sexangula* (tumu putih)
1. Flowers 2-8; petals less than 8 mm long; calyx lobes 7-10(11)
   3. Calyx lobes less than 2.5 mm long; petal less than 2 mm long; leaves elongate-elliptic, L/W ratio 2.5~3.0 …..…….. *B. parviflora* (lenggadai)
   3. Calyx lobes more than 5 mm long; petal more than 3 mm long; leaves elliptic to elliptic oblong, L/W ratio 2~2.5
      4. Calyx tube yellow-green, smooth; calyx lobes 8, reflexed in fruit; leaf veins 7-8, drying greenish ……..……..…….....…… *B. cylindrica* (berus)
      4. Calyx tube variable from pink-red to greenish, slightly ridged nearer to lobes; calyx lobes (9)10(11), patent at right angles in fruit; leaf veins 9-11, drying brownish ..…… *B. hainesii* (berus mata buaya)

1. ***Bruguiera hainesii*** C. G. Rogers, Kew Bull. 225. 1919; D. Hou, Flora Malesiana, ser. 1, 5: 468. 1958. (The species is named after Haines). Figs. 3A-3C

Bruguiera eriopetala auct. non Wight & Arnott: Watson, Mangrove Forests of the Malay Peninsula, Malayan Forest Records 6: 35. 1928. pro part. & quoad figure 13.

Trees up to 15 m tall, with knee roots, bark brown to grey. Leaves elliptic to elliptic-oblong, 9-13 × 4-6 cm, acute at both ends; lateral veins 10-11 pairs, visible to obscure; petioles 2.5-3.8 cm; stipules green to yellow-green, 3.5-4.2 cm long before dropping, colleters 12-15 rows inside the base of the stipule. Inflorescence simple diachasium (cymose), 2-3 flowered, at the upper 3 (2) nodes of shoot. Peduncles 7-13 mm long; pedicles 6-8 mm long, green to yellow-green. Calyx lobes 10(-11), as long as tube, yellow-green to slightly pink or red, tube 1-1.2 cm long, 5 mm in diameter, slightly ridged near calyx lobes (ridges become prominent when dry). Petals 7-8 mm long, bifid, densely covered with transparent hairs along the outer margins from the base to the apex; lobes 1/3 as long as the petal, each with 2-3 bristles at the apex 2.5-3 mm long, slightly pilose at the upper part of the lobes, sinus bristle exceeding the petal apex, 3-4 mm long. Stamens twice the number of petals, a pair embraced by a petal; anthers linear, 5-6 mm long. Ovary inferior, adnate to 1/3 lower part of

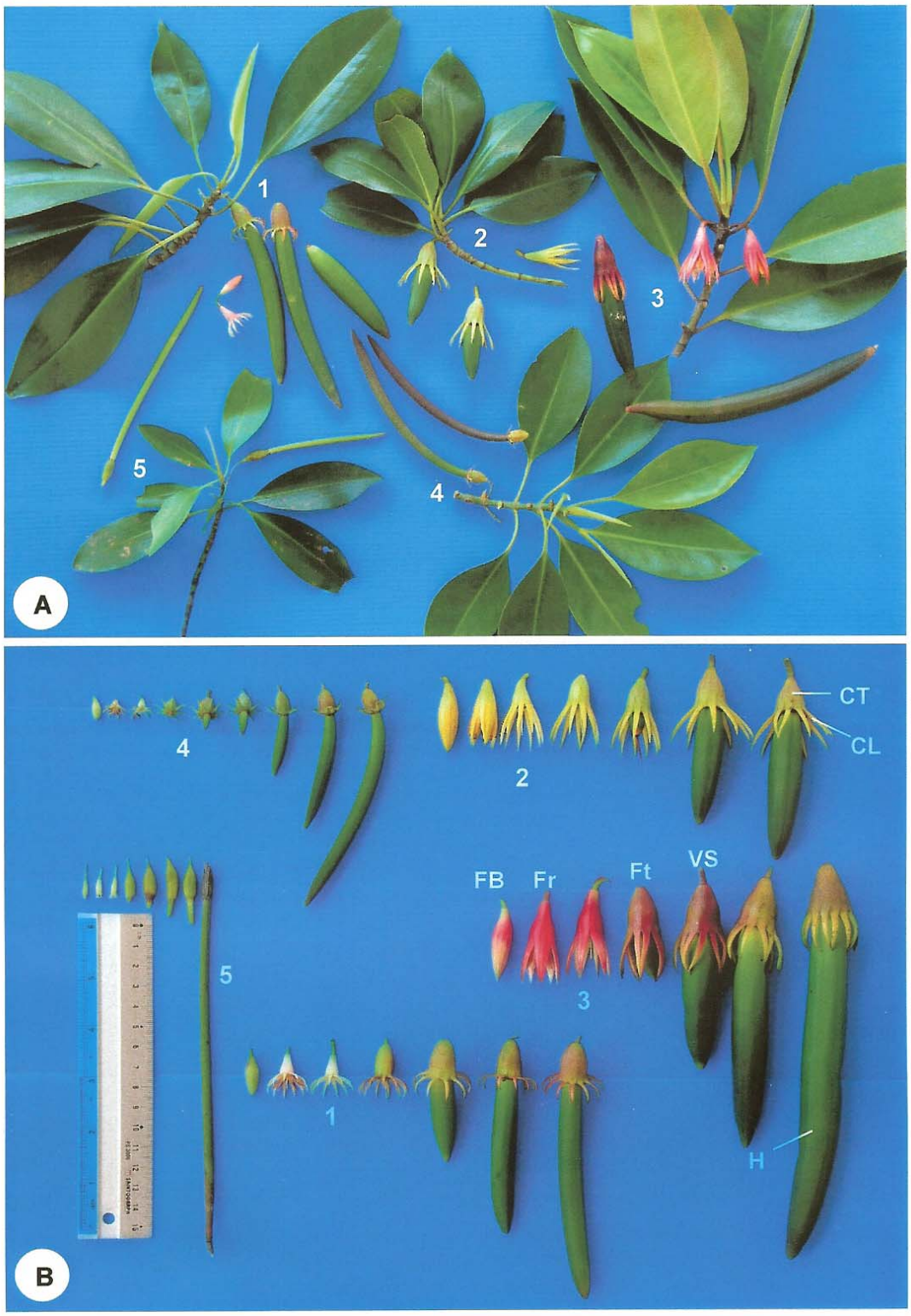

Fig. 1. The five species of *Bruguiera* in Singapore. A: Branchlets with flowers or viviparous seedlings. B: Reproductive organs, from flower bud to fruit and viviparous seedling, at the different stages. 1: *B. hainesii*. 2: *B. sexangula*. 3: *B. gymnorhiza*. 4: *B. cylindrica*. 5: *B. parviflora*. CL: calyx lobe, CT: calyx tube, FB: flower bud, Fr: flower, Ft: fruit, H: hypocotyl, VS: viviparous seedling.

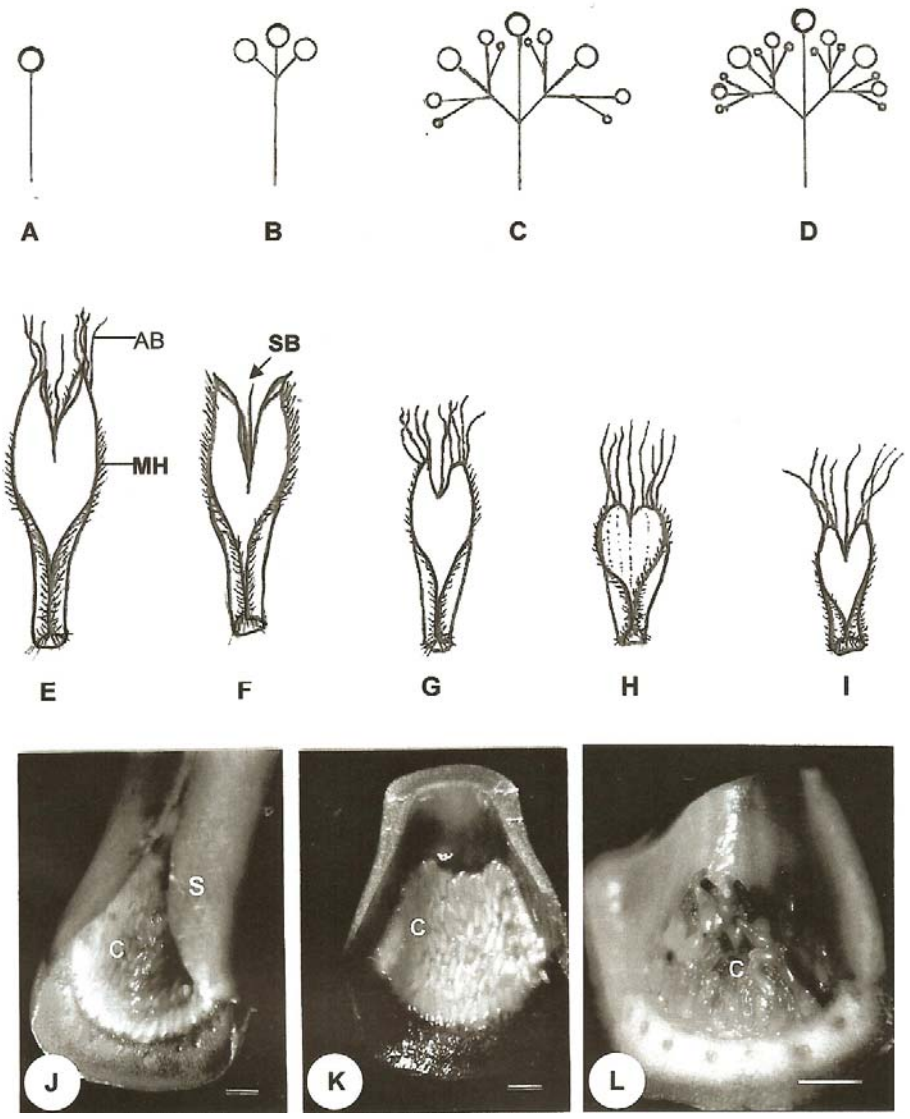

Fig. 2. Some diagnostic characters of *Bruguiera* in Singapore. A-D: Inflorescence. A: Solitary in *B. gymnorhiza* and *B. sexangula*. B: Simple diachasium in *B. cylindrica* and *B. hainesii*. C and D: Compound diachasium and its derived form in *B. parviflora*. E-I: petal morphology, bifid with marginal hairs, apex bristles and sinus bristle. E: *B. gymnorhiza*. F: *B. sexangula*. G: *B. hainesii*. H: *B. cylindrica*. I: *B. parviflora*. J-L: Finger-like colleters inside the base of stipule, part of stipule tissue removed in K and L. J and K: *B. gymnorhiza* with 12-14 series colleters. L: *B. sexangula* with 3-5 series colleters. AB: Apex bristle, C: colleter, S: stipule, SB: sinus bristle, MH: marginal hair. All scale bars = 1 mm in J-L.

the calyx tube, 2-3 celled, each cell with 2 ovules; style filiform, 1.2 cm long, stigma obscurely 2-3 lobed. Calyx lobes patent in flower and patent at right angle in fruit. Hypocotyl cigar-shaped or slightly clavate, up to 22 cm × 1-1.2 cm.

Specimens examined: SINGAPORE: Sungei Loyang: *J. W. H. Yong JY-2003-LOY-1* (SINU); Sungei Jelutong, Pulau Ubin: *J. W. H. Yong JY-2003-2* (SINU), *Ali Ibrahim et al. GW22* (SING). MALAYSIA: Selanger: *C. F. Symington 51661* (SING), *K. M. Kochummen FRI 2354* (SING); Perak, Taiping: *H. N. Ridley FMS 3* (SING).

Notes: The species is a new record in Singapore. According to Hou (1958), *B. hainesii* produces hypocotyls of not more than 9 cm in length. However, based on our observations in Singapore, *B. hainesii* hypocotyls could attain 22 cm in length.

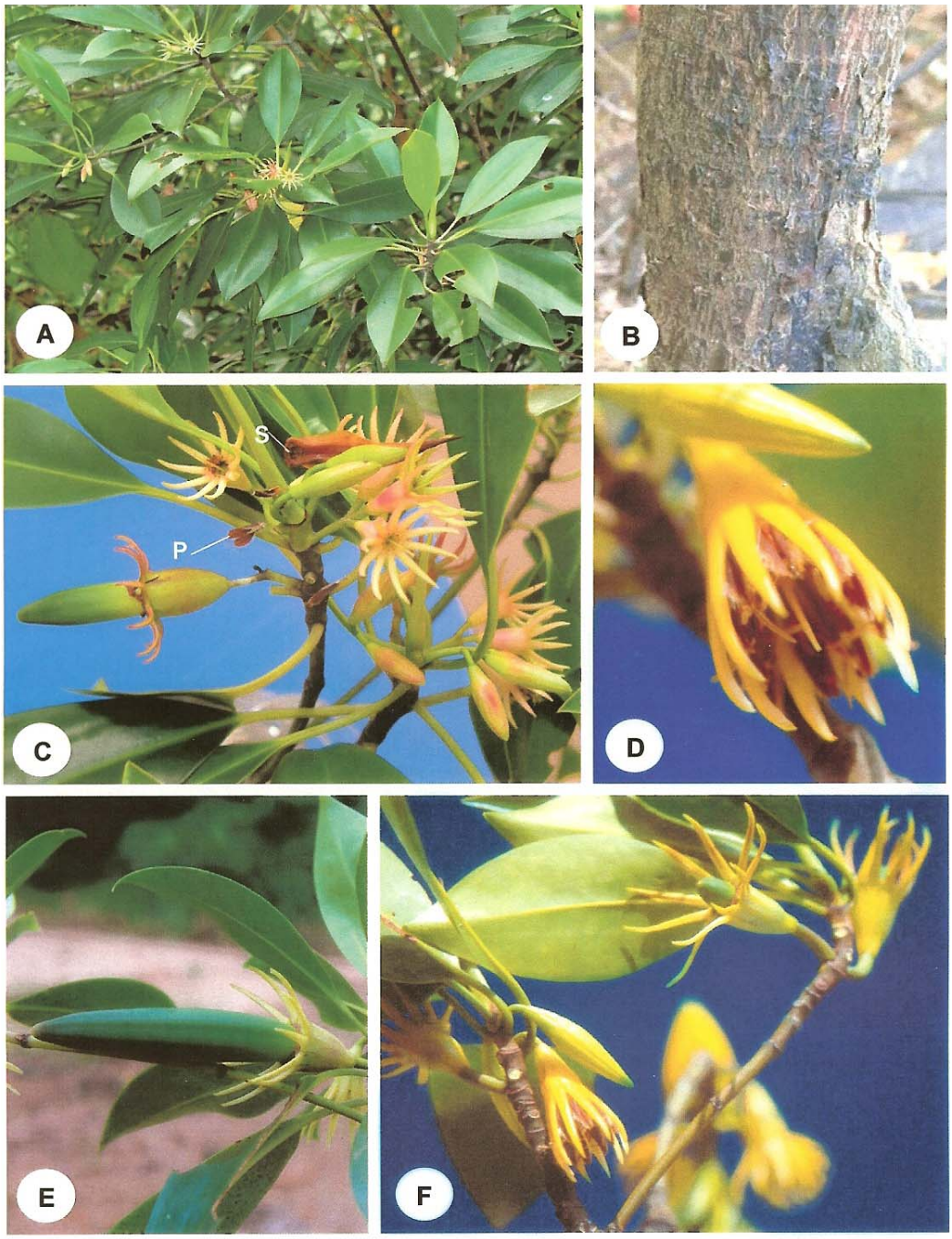

Fig. 3. The new record of *Bruguiera hainesii* (A-C), and the rediscovery of an extinct species, *Bruguiera sexangula* (D-F), in the mangroves of Singapore. P: petal, S: stipule. A: Shoots of *B. hainesii*. B: Bark of *B. hainesii*. C: The calyx colour is variable and ranges from pink-red to greenish, calyx lobes are patent at right angles in the fruiting stage of *B. hainesii*. Note the stipule with colleters inside, three-flowered inflorescence and bifid petal. D: A solitary flower of *B. sexangula* with yellow calyx. E: A viviparous seedling of *B. sexangula*. F: A shoot of *B. sexangula*.

2. ***Bruguiera sexangula*** (Lour.) Poir., Lam. Enc. Meth. Bot. Suppl. **4**: 262. 1816; D. Hou, Flora Malesiana, ser. 1, **5**: 463. 1958. (Latin, *sex* = six, *angulus* = angle; the ridged hypocotyls) Figs. 3D-3F

Rhizophora sexangula Lour., Fl. Cochinch. 297. 1790.
Bruguiera eriopetala Wight & Arn. in Arn., Ann. Nat. Hist. **1**: 368. 1838.

Trees up to 7 m, with knee roots, bark grey. Leaves elliptic to elliptic-oblong, 6.8-11 × 2.2-4.2 cm, acute at both ends; lateral veins 10-11 pairs, visible to obscure; petioles 1.5-3.0 cm; stipules green to yellow-green, 3.5-4 cm long before dropping, colleters 3-4 rows inside the base of the stipule. Flower solitary, at the upper 3 (2) nodes of shoot. Pedicles 6-10 mm long, yellow or yellow-green. Calyx lobes 10-12(13), 1.3-1.8 cm long, yellow, tube 1.3-1.5 cm long, distinctly ridged outside. Petals 1.5 cm long, bifid, densely covered with transparent hairs on the outer margins from the base to the apex; lobes half the length of the petal, each without or with 1(-3) short bristle(s) less than 1 mm long or so and not or hardly exceeding the tip, sinus bristle shorter than the lobe, 4-5 mm long. Stamens twice the number of petals, a pair embraced by a petal; anthers linear, 5-6 mm long. Ovary inferior, adnate to one third lower part of the calyx tube, 3-4 celled, each cell with 2 ovules; style filiform, 2.0-2.3 cm long, stigma obscurely 3-4 lobed. Hypocotyl 6-8 cm × 1.5 cm, slightly ridged, with narrow blunt end.

Specimens examined: SINGAPORE: Kampung Permatang, Pulau Tekong: *J. W. H. Yong JY-2003-PT-1* (SINU), Tg. Pasir Laba: *J. Sinclair SFN 40175* (SING). MALAYSIA: Johore: *C. R. Sheue & J. W. H. Yong M52, M53* (SYSU), *I. M. Turner & J. W. H. Yong PT 96-643* (SING); Selangor, Port Klang: *C. F. Symington 51663* (SING); Selangor, Pulau Lumut: *J. Wyatt-Smith KEP Field no. 85212* (SING); Terengganu, Kuala Terengganu: *R. E. Holtum SFN 17681* (SING).

Note: The species is a re-discovery from extinction for Singapore.

DISCUSSIONS

Four species of *Bruguiera* were previously recorded in Singapore (Keng, 1990; Turner and Yong, 1999), namely, *B. cylindrica*, *B. gymnorhiza*, *B. parviflora*, and *B. sexangula*. Among all the *Bruguiera* species, *B. hainesii* is the least known species, with a reputedly extensive distribution extending from Myanmar to Papua New Guinea (Hou, 1958; Tomlinson, 1986). This species does not occur in Australia, and its current presence in Papua New Guinea is still unclear. In Malaysia, Watson (1928) and Kochummen (1989) noted that *B. hainesii* is the rarest of the five *Bruguiera* species and normally found on the inland ("back mangrove") side of the mangroves. Thus, the occurrence of only two known *B. hainesii* trees in Singapore is not unexpected. Since the island of Singapore is separated from the Malay Peninsula by a narrow Johore Straits, the flora of Singapore naturally is an extension of that of the southern part of the Malay Peninsula (Keng, 1990).

In June 2003, the second author found two individual trees (ca. 8 m and 15 m tall) at Sungei Loyang (Singapore) and Sungei Jelutong (Pulau Ubin), respectively. The trees produced inflorescence with three flowers, calyx with mostly 10 (and rarely 11) lobes which are patent at right angle in fruit, and calyx tube with smooth surfaces. The combination of these characters clearly suggested that the two trees are different from the four known *Bruguiera* species, and represented an additional one species to the flora of Singapore. Based on the earlier reports and descriptions about *B. hainesii* in Malaysia (Symington, 1940; Wyatt-Smith, 1953; Kochummen, 1989), the authors came to realize that the unknown species in Singapore were very similar to *B. hainesii*. It is noteworthy that the two Singaporean *B. hainesii* trees are not found in the typical back mangrove environment as reported earlier by Watson (1928) and Kochummen (1989). Such an anomaly may be attributed to the higher degree of anthropogenic disturbance experienced by mangrove trees in urban Singapore (Ng and Sivasothi, 1999; Turner and Yong, 1999).

In 1953, based on the earlier works of Watson (1928) and Symington (1940), Wyatt-Smith (1953) made a detailed morphological comparison of the vegetative as well as the reproductive structures for the five *Bruguiera* species in the Malay Peninsula. His contribution (Wyatt-Smith, 1953) highlighted the salient differences among the five species, and Hou (1958) probably followed the Wyatt-Smith's approach towards classifying *Bruguiera*. Thus, on the basis of the descriptions provided by Wyatt-Smith (1953) and Kochummen (1989), the authors concluded that the unknown *Bruguiera* species in Singapore is *B. hainesii*.

Bruguiera sexangula is widely distributed from India (Banerjee *et al*., 1989; Naskar and Mandal, 1999), Sri Lanka (Abeysinghe *et al*., 2000; Jayatissa *et al*., 2002), South East Asia (throughout Thailand and Malaysia), to New Britain, East New Guinea, and Australia (Hou, 1958). It is also found in the Philippines (Pimavera *et al*., 2004) and China (Ko, 1983). In addition, it was also introduced to Hawaii where the species has adapted well in the region (Hou, 1958). It was pointed out that seven mangrove species have been lost in Singapore during the past years (Turner and Yong, 1999). *B. sexangula* is one of the extinct species (since it has not been sighted in the wild for the last 50 years), previously found naturally at Bakau, Kranji, Jurong, and Tanjong Pasir Laba in Singapore (Keng, 1990; Turner and Yong, 1999). In Pulau Tekong (Singapore), *B. sexangula* trees grow mainly in the back mangrove (the landward zone) where there is less frequent tidal inundation and often in association with *B. gymnorhiza*, *Sonneratia ovata*, *Lumnitzera littorea* and *Rapanea porteriana*.

From our field observations, the calyx colours of *B. sexangula* are either yellow or yellow-green, and similar to those found in India and Australia (Banerjee *et al*., 1989; Naskar and Mandal, 1999; P. Saenger, personal communication). According to Hou (1958), it may vary from yellow-brown to reddish, but never bright red in colour. However, it was reported that the calyx colour of *B. sexangula* was bright red in species found in China (Ko, 1983). Watson (1928) mentioned that "the color of calyx is by no means infallible, since both yellow *B. gymnorhiza* and bright scarlet *B. eriopetala* (currently *B. sexangula*) have been collected." Therefore, it will be interesting to investigate further the colour variation of *B. sexangula* along its global distribution range and the factor(s) affecting calyx colour formation (Sheue, 2003).

As discussed by the various botanists (Watson, 1928; Symington, 1940; Wyatt-Smith, 1953), it was difficult to identify the different *Bruguiera* species solely on the basis of vegetative structures: for example, between *B. gymnorhiza* and *B. sexangula*. The leaves of *B. sexangula* are usually more yellow-green and with shorter petioles than those of *B. gymnorhiza*. But such generalizations are invalid when there are other dominant prevailing ecological factors (e.g. sun versus shade leaves, nutrient limitation, etc.) present in the habitats affecting foliar development and morphology. Nevertheless, our recent works have offered a potential solution to resolving the identification of *Bruguiera*, and also for the other members of Rhizophoraceae, on the basis of an unexplored vegetative character: colleters inside a stipule (Sheue, 2003; Sheue *et al*. 2003a, b).

All members of the Rhizophoraceae have large and conspicuous interpetiolar, glabrous and caducous stipules on both the vegetative and reproductive shoots (Hou, 1958). They enclosed tightly the young leaves and inflorescences (before dropping). Generally, several to hundreds of aggregated colleters could be found at the adaxial base of stipules in all members of Rhizophoraceae (Sheue, 2003). The finger-like colleters are a type of glandular structure (Fahn, 1990) with a central axis of slender and elongated cells surrounded by a palisade-like epidermis (Lersten and Curtis, 1974; Sheue, 2003).

It was reported that the series or numbers of colleters could be an aid for identifying members of Rhizophoraceae especially in the absence of reproductive structures (Sheue, 2003; Sheue *et al*. 2003a, b). For the two morphologically similar *Bruguiera* species, *B. gymnorhiza* and *B. sexangula*, we suggest that the series or numbers of colleters inside the stipules could be a useful character for identifying vegetative materials (see Key). Recently, we also found that the number of colleters inside the bracteoles is also different for the two *Kandelia* species (Sheue *et al*., 2003b).

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新加坡紅茄苳屬的紅樹林植物及其新紀錄和再發現種

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摘　　要

本研究報導新加坡所產的紅茄苳屬紅樹林植物現況，包括一新紀錄種－*Bruguiera hainesii* 和一滅絕後再發現種－*Bruguiera sexangula*，共計有五種紅茄苳屬之紅樹林植物。除了說明此五種植物的鑑別特徵，提供彩色圖片以便於鑑定及分辨外，文中並首次嘗試以位於托葉內的指狀腺體 (colleter) 特徵成功地辨別出本屬外部形態極為相近的種類。另提供本屬植物的檢索表及此新紀錄種和再發現種的植物描述與相關資訊更新。

關鍵詞: 紅樹林、紅茄苳屬、新加坡、指狀腺體、*Bruguiera hainesii*、*Bruguiera sexangula*。

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