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BOTANICAL DISCOVERIES OF GUNUNG SARUT, TERENGGANU

Syahida-Emiza S (syahida@frim.gov.my), Sam YY, Aliaa-Athirah AM, Imin K, Siti-Munirah MY, Ahmad Firdaus Z, Nor-Ezzawanis AT, Wan Syafiq WP & Angan A.

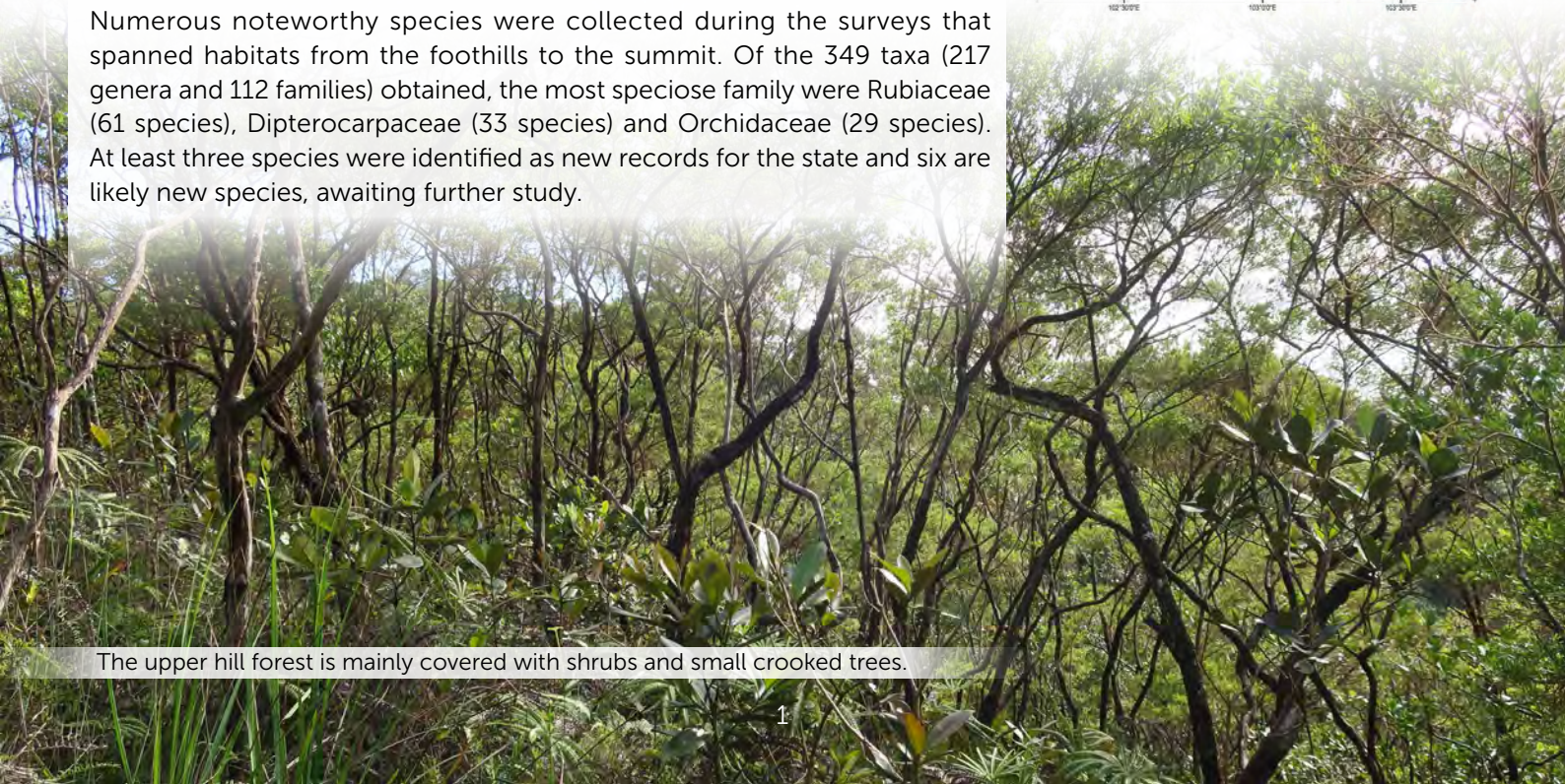
Introduction

Gunung Sarut is a mountain located in Hulu Nerus Forest Reserve (5.33° N, 102.72° E), in the Setiu District of Terengganu, Malaysia. Rising 1,229 m above sea level (asl), Gunung Sarut is the highest mountain in the district.

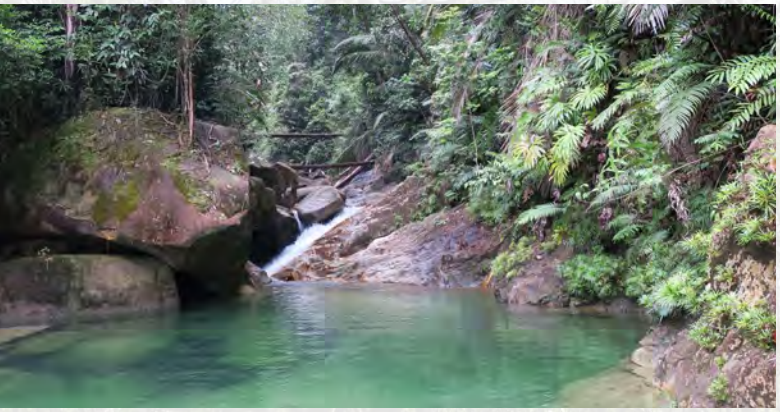
The mountain is part of the Terengganu Hills which run along the interior of Terengganu, sandwiched between the Tahan Range on its west and the coastline to its east. The forest in this mountain range harbours extraordinarily rich flora and high endemism, so much so that the region is recognised as one of the plant diversity centres (Davis et al, 1995) and an evolutionary hotspot (Tan et al, 2020). Yet, many areas remain poorly known or unexplored such as Gunung Sarut. Our expeditions in year 2019 and 2020 were the first systematic botanical surveys to document the flora of Gunung Sarut.

The track begins at Lata Payung amenity forest, a recreation area famous for its beautiful sparkling green river. The most popular site is the Blue Pool because of its beautiful emerald green water that mystically turns blue after a heavy downpour. Hiking is popular here and the hike to the summit takes 5–6 hours. Many hikers however, prefer to spend a two days' visit to enjoy its natural beauty.

Numerous noteworthy species were collected during the surveys that spanned habitats from the foothills to the summit. Of the 349 taxa (217 genera and 112 families) obtained, the most speciose family were Rubiaceae (61 species), Dipterocarpaceae (33 species) and Orchidaceae (29 species). At least three species were identified as new records for the state and six are likely new species, awaiting further study.



The upper hill forest is mainly covered with shrubs and small crooked trees.



Pristine and emerald green water at Blue Pool.

Forest types and vegetation

Gunung Sarut comprises lowland, hill, and upper hill dipterocarp forests and lower montane forest. At 250 m asl, the landscape is undulating and consists of large boulders that can be seen along the trail to the Blue Pool. The lowland and upper hill dipterocarp forests are dominated by emergent trees with large buttresses, mainly members of the family Dipterocarpaceae such as *Anisoptera curtisii*, *Dipterocarpus crinitus, Hopea nervosa* and *Shorea macroptera*. Several lowland non-dipterocarp tree species included *Agathis borneensis* (Araucariaceae), *Calophyllum soulattri* (Guttiferae), *Canarium patentinervium* (Burseraceae), *Monocarpia marginalis* and *Goniothalamus macrophyllus* (Annonaceae).

The understorey layer was occupied by treelets, small bushes and palms. Palmae such as *Pinanga malaiana*, *P. disticha* and *Licuala* spp. were abundant along the trail. The magnificent palm *Johannesteijsmannia altifrons* grew luxuriantly from the lowland to upper hill forest, up to c. 700 m asl. Treelets and shrubs such as *Ardisia* spp. and *Ficus* spp. which are important fruit trees to birds and primates were common here.

On shady slopes and rocky areas in the valley, where conditions are ideal for many shade-tolerant herbaceous plants, *Argostemma elatostemma* (Rubiaceae), *Begonia sinuata* (Begoniaceae), *Camptandra parvula* (Zingiberaceae), *Sauvagesia serrata* (Ochnaceae) and *Sundamomum hastilabium* (Zingiberaceae, a new record for Terengganu) were encountered. On the ground, mycoheterotrophic species such as *Burmannia* spp., *Thismia* spp., *Gymnosiphon* sp. and *Didymoplexis pallens* grow amongst the leaf litter and could be easily missed as the sizes are small. In stream vicinities, ferns and lycophytes that flourish included *Cephalomanes javanicum, Dipteris lobbiana, Pronephrium rubicundum, Sellaginella cuprea, S. intermedia* and *Tapeinidium pinnatum*. Also found was *Globba tembatensis,* a Terengganu endemic, which has the affinity for steep slopes and damp forest floor. The plants are scattered on boulders and hill slopes along rocky streams from the lowland to hills.

The terrain to the upper hill forest was a rocky and steep slope. Along the ridge, tree species encountered were dipterocarps (e.g. *Dipterocarpus fagineus* and *Shorea bracteolata*), *Gluta malayana* (Anacardiaceae), *Tabernaemontana polyneura* (Apocynaceae) and *Schima wallichii* (Theaceae). Among these, *Dipterocarpus eurynchus* was the most prominent as it reached about 40 m in height and 50 cm in diameter. The understorey layer was dense with small trees such as *Gomphandra quadrifida* (Stemonuraceae), *Psychotria calocarpa* and *Lasianthus attenuatus* (Rubiaceae). The pitcher plant, *Nepenthes ampullaria* and terrestrial orchid, *Bromheadia finlaysoniana* were common on the ridge, while *Codonoboea crinita* and *Labisia pumila* inhabited the slopes. *Lindsaea divergens* is a tufted fern that grew along the trail after 600 m asl up to the lower montane forest. Interestingly, we also discovered old and new elephant dung on the ridge trail at the upper hill forest. This was phenomenal as elephants were not known to roam at such high elevation. According to our local guide Dome Nikong, the site is an important route for elephants to enter the Kenyir forest in the south.

View of the Gunung Sarut mountain from Petuang (photo by Dome Nikong).

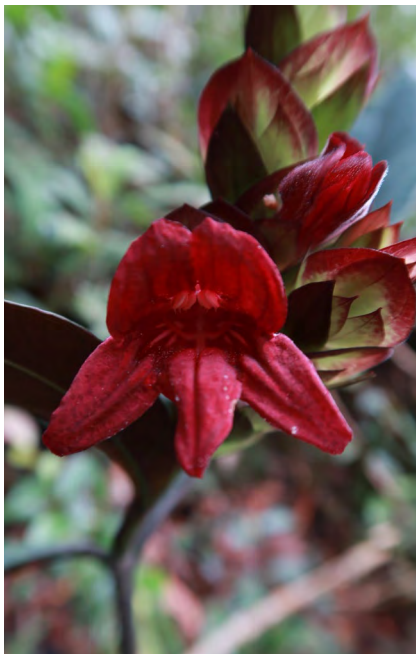
Gunung Sarut has an amazing diversity of pitcher plants.

Reaching 900 m asl, tall emergent trees were notably infrequent and trees grew about 10–15 m high. The floral composition gradually changed to upper hill forest species such as *Dacrydium elatum* (Podocarpaceae), *Leptospermum javanicum* (Myrtaceae), *Tristaniopsis merguensis* (Myrtaceae), and *Syzygium* species. Ferns such as *Dipteris conjugata*, *Matonia pectinata* and *Taenitis dimorpha* were common in clearings and on mountain ridges, while *Cheiropleuria bicuspis* occupied shady slope on the ridges. At a ridge close to Camp Bonsai, a species endemic to Peninsular Malaysia, *Chroesthes longifolia* (Acanthaceae) with notable deep red corolla, was found. A terrestrial pandan, *Pandanus yvanii* and a sedge, *Mapania* sp. were found near a small river below the base camp.

On the path ascending to the summit, trees established here had twisted trunks with small to pole sized diameter due to the strong wind. The dwarf shrub *Baeckea frutescens* (known as Cucur atap) was common, while the ericaceous species that we had expected more were rare. Only one species of *Vaccinium* was flowering in the area. Pitcher plants were well-represented, of which *Nepenthes kuchingensis*, *N. ampullaria*, *N. gracilis* and three newly described species namely *N. domei*, *N. latiffiana* and *N.* x *setiuensis* were discovered near the summit. These three new species are hyper-endemic to Setiu.

Species confined to montane forest such as *Dianella javanica* (Xanthorrhoeaceae) and *Gahnia baniensis* (Cyperaceae) were dominant in mildly disturbed and open areas found at the summit. Pitcher plants, orchids, gesneriads and ferns were fairly abundant here. At the peak and its surrounding area,

Hydnophytum formicarum, epiphyte of plants-ant at the summit of Gunung Sarut. Close-up: the plant and flower.



Chroesthes longifolia is widely distributed from lowland to upper montane forest.

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Unveiling the Beautiful Gesneriads of Sarut Forest, Terengganu

Sam Yen Yen (samyen@frim.gov.my) and Aliaa Athirah Adam Malek

Gesneriads are members of the Gesneriaceae, the African violet family which is well known for many economically important ornamental plants such as African violets, flame violets, gloxinias and the lipstick vine.

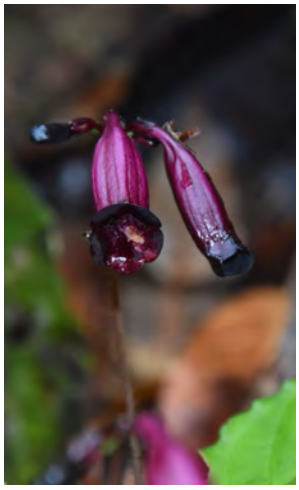
In Malaysia, the gesneriads is one of the most diverse herbaceous groups with an estimated 400 species representing about 10% of the global total. Their flowers are one of the cheeriest to grace our rainforests. Many are aesthetically appealing with great potential for the ornamental plant trade.

At Gunung Sarut, we discovered a great variety of gesneriads thriving in the shady, cool and damp forest understorey. From the foothills to mountain tops, the steep terrain, rocky bedrock and many tributaries in the pristine forest of Sarut provide lots of niches for a diverse group of gesneriads. It was common to find the plants growing on crevices of outcropping rocks, steep earth slopes, vertical stream banks, uphill side of a logging road and tree roots above soil surface. These substrates often have litter gaps which are ideal microsites for the gesneriads' tiny seeds and seedlings to establish as their roots are unable to penetrate thick litter.

At the entrance to Lata Payung, the gateway to Gunung Sarut, two beautiful gesneriads immediately greeted us as we stepped on the footpath leading to the hanging bridge across Sungai Payung Anak. Both *Codonoboea*

There are many rocky streams with crystal clear water in Sarut forest. Rock faces are a haven to many herbaceous plants such as gesneriads, ferns and even bigger ones like pandans and gingers.

Codonoboea leiophylla grows on surfaces free of leaf litter such as steep earth slopes. Inset: dainty bell-shaped flower.



Large boulders in valley is the favourite spot for *Ridleyandra kiewii* subsp. *magnifica*, bearing stunning deep purple flowers.

Codonoboea rugosa blossoms gregariously to attract pollinators (photo: Siti Munirah MY); the strongly veined leaf surface with distinct rectangle wrinkle is characteristic of *C. rugosa* (inset).

Unlike most gesneriads with conspicuous inflorescences and rosette leaves, the flower of *Cyrtandra wallichii* is hidden at the leaf axil and its leaves are distinctly paired.

The whole of *Loxocarpus incanus* var. *sekayuensis* is covered with whitish hairs which turn silvery when dry. Its flower is very tiny, measuring less than 1 cm in size. (Photo: Syahida Emiza S)

Codonoboea sp. 1 is easily distinguished from other gesneriads by its paired leaves, smooth glossy leaf surfaces and pure white flowers.

Codonoboea sp. 2 is very rare, we found only one plant at the base of a huge boulder at the summit.

Codonoboea sp. 3 is common in the valley in upper hill forest. The leaf surface glitters when hit by sunlight at a certain angle.

leiophylla and *Ridleyandra kiewii* subsp. *magnifica* clung to the steep cut slopes beside the walking path, growing sympatrically with many ferns such as *Blechnopsis finlaysoniana*, *Cyathea alternans*, *Cyathea mollucana*, *Diplazium crenatoserratum* and *Selaginella stipulata*. When not in flower, they could be easily overlooked by passers-by.

Coincidently, both *Codonoboea leiophylla* and *Ridleyandra kiewii* subsp. *magnifica* are endemic to the forest of northwest Terengganu and the adjacent forest of southeast Kelantan. *Codonoboea leiophylla* spreads from the lowland to upper hill forests at about 900 m altitude, often growing in large numbers in suitable conditions. Its pale violet flowers are prominently raised on long slender stalks above the basal clustering leaves. On the contrary, *Ridleyandra kiewii* subsp. *magnifica* is confined to the forest at low elevations. Together with *Codonoboea rugosa*, *Cyrtandra wallichii* and *Loxocarpus incanus* var. *sekayuensis*, these four are found in stream valleys where they occupy different niches. *Codonoboea rugosa* and *Cyrtandra wallichii* grow on humus-rich soil above streams or on peat accumulated on the top of big boulders, and are usually exposed to rather long hours of light shade. Both species are herbaceous with stout woody stems that can grow to one metre tall. Kiew (2009) observed such plants are slow growing and live for a very long time, possibly up to 20 years!

Ridleyandra kiewii subsp. *magnifica* is a shade-loving plant. It grows on the deep shaded slopes of stream banks or lodges onto the mossy surface of rocks lining the streams.

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Loxocarpus sp. 1 is only found at the summit where the plants nearly carpeted the whole boulder.

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Its stunning deep purple flowers are held high above the leaves, visible even from afar.

Loxocarpus incanus var. *sekayuensis* is another lovely gesneriad found in the lowlands on granite rocks near streams. The plants are very small, hardly exceeding 10 cm in height. Their small seeds often germinate in the crevices, and the plants later produce extensive roots to firmly secure the plant onto rock face.

As we ascended the upper hill and lower montane forests, we noticed the lowland gesneriads gradually disappeared and different species manifested. We encountered five species during our survey of the forest surrounding Camp Bonsai and the summit, and they turn out to be new species and also endemic to Terengganu! The authors are in the midst of describing and naming these new species.

The flora of Terengganu is highly diverse and unique (Davis et al, 1995; Kiew & Lim, 2019). Recent botanical surveys in Terengganu have led to the discovery of many new species and markedly increased our knowledge of the rich flora of Terengganu. However, many areas remain botanically unexplored, especially mountains of the interior, which are part of the poorly known East Coast. More surveys are needed here to document the rich natural heritage for conservation purposes.

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we encountered at least four species of *Codonoboea* and one *Loxocarpus* flowering. Several fern species including *Cheiropleuria bicuspis* and *Matonia pectinata*, and lycophytes such as *Lycopodiella cernua* and *Selaginella alutacia* were dominant at the peak. The ground was covered with lichens and mosses where *Selaginella intermedia* var. *dolichocentrus*, a montane lycophyte, was encountered and recorded for the first time in Terengganu. Some common epiphytes species such as *Oreogrammitis adspersa, Pachycentria glauca* subsp. *maingayi* and plant-ant-nest, *Hydnophytum formicarum* (Rubiaceae) were seen on tree branches.

Conclusion

The botanical exploration promised interesting and surprising discoveries of several new species and records. Gunung Sarut is highly diverse with preliminary identification of 349 taxa comprising at least 39 species endemic to Peninsular Malaysia. For example, *Ridleyandra kiewii* subsp. *magnifica* is a rare Peninsular Malaysian endemic which is Endangered (MyBis, 2021) while *Loxocarpus incanus* var. *sekayuensis* is hyper endemic to Terengganu. The survival of these species may be threatened if their habitats are destroyed, for example by the impact of tourism activities and indiscriminate forest clearance without proper planning. Therefore, it is important to educate the community and create biodiversity awareness to prevent biodiversity loss.

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A Glimpse of the Trees Along the Trail of Gunung Sarut

Ahmad-Firdaus Z (ahmadfirdaus@frim.gov.my), Imin K, Syahida-Emiza S, Wan-Mohamad-Syafiq WP & Siti-Munirah MY

During the expedition to Gunung Sarut, Hulu Nerus Forest Reserve, a total of 232 tree species belonging to 110 genera and 57 families were collected. Along the trails from Lata Payung to the summit of Gunung Sarut, tree species belonging to the Rubiaceae family were the most abundant with a total of 35 species, followed by Dipterocarpaceae (33 species), Myrtaceae (15 species), Phyllanthaceae (11 species) and Guttiferae and Lauraceae (12 species). Annonaceae, Euphorbiaceae, Polygalaceae and Ebenaceae were also discovered along the expedition routes. Thirty-one taxa (or 13.4%) of the total tree species recorded at Gunung Sarut are endemic to Peninsular Malaysia. Rubiaceae and Guttiferae had the most endemics with five and four species respectively. Some of the interesting and endemic species are highlighted here.

We checked the conservation status of some tree species collected from this expedition and 48 species are listed in the Malaysia Red List. One species is Critically Endangered (i.e. *Memecylon lancifolium*), seven are Vulnerable, nine are Near Threatened and 31 are Least Concern (Yong et. al., 2021).

Gunung Sarut has a high diversity of flora and good species composition in various forest types. It is home to many species endemic to the region and those on the verge of extinction. Although this short expedition was not sufficient to produce a complete tree checklist, observations on the flora and the current state of vegetation provided a good understanding of the plant ecology at Gunung Sarut. Additional large-scale surveys are required to collect comprehensive data on tree diversity for biodiversity conservation efforts.

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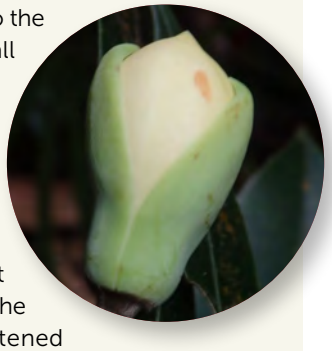
Litsea penangiana is a new record for Terengganu. Locally known as 'Medang asam', it is a small tree found on lightly shaded areas in the upper hill forest. The species name is derived from the state of Penang. The leaves are leathery and whitish below, and are used to treat hysteria, madness and insomnia (Quattrocchi, 2016). The fruit is ovoid with a cup-shaped stem and sits in the leaf axil. Endemic to Peninsular Malaysia, this species was previously described from the hill and montane forests in Kedah, Penang, Kelantan and Pahang. Its conservation status is Endangered (De Kok, 2021).

Tabernaemontana polyneura (Apocynaceae) is endemic to Peninsular Malaysia. It is a small tree found in the upper hill forests. The species name is derived from the Greek words 'polys' meaning many and 'neuron' meaning nerve, referring to the leaves having many nerves. When cut, the stem produces white milky sap. The fruit sits hanging in pairs from the terminal leaves, is crescent-shaped, turns orange-red when ripe and is filled with many seeds. The conservation status is Least Concern (Middleton, 2011).

Barringtonia chaniana, locally known as 'Putat', is a small tree with obovoid fruits that turn reddish or light brown when ripe. The flower has pink stamens and pale green sepals. The species is named after Chan Yee Chong, a field botanist of Kepong Herbarium who first discovered the species. The species normally occurs in lowland forests, but has also been found on ridges in upper hill forest at Gunung Sarut. The conservation status is Near Threatened (Prance, 2012).



Magnolia liliifera (Magnoliaceae) is commonly known as 'Egg Magnolia', referring to the egg-shaped flower buds. This small tree is found on the lightly shaded slopes in the upper hill forest and the species name is derived from the Latin word 'lilifera' meaning lily, referring to the lily-like flowers. *Magnolia liliifera* has fragrant flowers and is suitable as an ornamental plant in recreational parks and gardens. The conservation status is Near Threatened (Nooteboom, 2012).

Thismia in Hulu Nerus Forest Reserve

By Siti Munirah Mat Yunoh (sitimunirah@frim.gov.my) & Dome Nikong

***Thismia* Griff. is a genus belonging to the family Thismiaceae. *Thismia* is a small mycoheterotrophic herb that has a close relationship with fungi (Coelho et al., 2021) and has no chlorophyll. *Thismia* species also have a variety of complex floral structures, and information on the reproductive strategies is still very scarce. The distribution range extends from tropical and subtropical Asia to temperate Australia and (mostly) tropical America (Shepeleva et al., 2020). Currently, there are about 89 species, of which about 35 have been recorded in Malaysia, and 26 (74%) of them are endemic.**

Thismia spp. are notable angiosperms (flowering plants) for their distinctive flowers which have a wide range of structure. The main flower component is usually shaped like a lantern, earning the genus name "fairy lantern". The entire flower colour scheme can be varied and appealing.

At present nine species are known in Terengganu, i.e., *Thismia alba* Holttum ex Jonker, *T. aseroe* Becc., *T. domei* Siti-Munirah, *T. javanica* J. J. Sm., *T. terengganuensis* Siti-Munirah (Siti-Munirah & Dome, 2019), *T. arachnites* Ridl and *T. ornata* Dančák, Hroneš & Sochor (unpublished data, reported Facebook Dome Nikong, 2020), *T. latiffiana* Siti-Munirah & Dome (unpublished data) and *T. sitimeriamiae* Siti-Munirah, Dome & Thorogood (Siti-Munirah *et al.,* 2021).

At Hulu Nerus Forest Reserve (FR), a *Thismia* plant was first noticed and photographed in 2015 by the second author while doing his research on orchids. Active searching for *Thismia* began in 2018, and numerous plants have been seen and photographed since then. However, there was no proper botanical study until recently.

During the botanical expedition at the Hulu Nerus FR, which covered Gunung Sarut, Lata Payung and Lata Papan, five species of *Thismia* were collected and documented. After a thorough survey and taxonomic study, these were identified as *T. aseroe* which is widely distributed in many states of Peninsular Malaysia, *T. latiffiana* and *T. sitimeriamiae,* the two newly described species, and *Thismia* sp1 and *Thismia* sp2, another two new taxa that are being reviewed.

Based on our recent studies, including field observations and documentation, we concluded that most *Thismia* individuals in the Hulu Nerus FR were found in certain types of microhabitats. They were found on rotting logs, rotting leaves on the ground and on sandy soil patches. These habitats were near river, in the shade of a large rock, or along a hiking trail with naturally littered ground from fallen leaves.

We found that *T. latiffiana* and *T. sitimeriamiae* visible only in wet seasons, and *Thismia* sp1 visible in both wet and dry seasons, but were most abundant in the wet season. We also found that some species were widespread while some were found only in certain areas. For example, *Thismia* sp1 was the most widespread species in the Hulu Nerus FR, found from Lata Papan to Gunung Sarut and up to 300 meters above sea level. It was also recorded in the Tembat FR, based on herbarium collection. *Thismia* sp1 is intriguing because of its highly variable colour pattern and the length of its tepal appendages.

For *Thismia* sp2, there were only a few populations discovered at Lata Payung. It was not as common as *Thismia* sp1, but was more common than *T. latiffiana* and *T. sitimeriamiae*. However, *Thismia* sp2 could be easily overlooked because its brown colour camouflage among dry and decayed leaves.

Thismia latiffiana and *T. sitimeriamiae*, the two newly proposed species, were extremely rare, with just a few specimens found in each population. Only two and four individuals of *T. latiffiana* and *T. sitimeriamiae*, respectively, were observed during population visits every few months for more than a year from December 2019 to June 2021. Long-term efforts and observations

to find additional populations within the Hulu Nerus FR or at other locations so far have been unsuccessful. To date, both species are only known from the type locality (Lata Payung), implying that both are endemic to Terengganu.

For *T. aseroe*, it was found at Lata Papan. Its bright yellow colour is similar to *Thismia alba*, which also looks like a star on the ground. *Thismia aseroe* is common in several states in Peninsular Malaysia and was first discovered in Singapore in 1865 by the Italian botanist Odoardo Beccari.

In summary, the documentation of *Thismia* species in Hulu Nerus FR has contributed to the number of flowering species listed for Hulu Nerus FR and also for the state of Terengganu. Our results showed that Hulu Nerus FR is currently home to five species of *Thismia*. In addition, this study demonstrated the importance of collaboration between scientists and local people in scientific work. It is a challenge for scientists who are usually based far from the original site/forest to visit the forest regularly. Since the occurrence of *Thismia* spp. is unpredictable, collaboration with locals is important to get ground support, including collecting information and monitoring for long-term scientific data. At the same time, scientists can educate the locals about the importance of plant diversity.

Much biological information on *Thismia* is still lacking, for example their phenology, pollinators, and phylogenetic relationships within the *Thismia* group itself. Understanding their biological details and ecology will undoubtedly contribute to better forest and conservation management and all other related issues in the future.

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Spying on the private life of the Tortoise Shell Begonia *(Begonia kingiana)*

Chan Yoke Mui (yokemui@frim.gov.my) & Tan Kok Kiat

This ornamental 'fortune tortoise' can be a symbol of good luck and longevity (Photo: Yap Kok Sun).

***Begonia kingiana* is named after Sir George King, the Superintendent of the Royal Botanic Garden in Calcutta, India from 1871 to 1898 (Kiew, 2005). It is endemic to Peninsular Malaysia, and confined to limestone areas. The conservation status of this species is Endangered (FRIM, unpublished data).**

The common name comes from this variegated form which resembles a tortoise shell (Kiew, 2005).

Begonia kingiana is a creeping herbaceous member of the Begoniaceae family that can grow up to 6 cm long. The leaves vary from green to blackish in colour with visible veins on the upper surface. The colour of the flowers is quite variable, ranging from pale pink to pink, greenish pink, light green, pale green to bright red (Tan, 2013). The striking colours of the flowers and the captivating shell-like patterns of the leaves make this species a good candidate for an ornamental, but this has yet to be exploited. In Asia, the tortoise symbolises good luck and longevity, and in the future *B. kingiana* could perhaps be marketed and popularised as a 'fortune tortoise' plant that brings good blessings to its owner.

To understand the floral behaviour and sexual biology of *B. kingiana*, we studied the plants collected from Langkawi and Kelantan which are being grown at FRIM's nursery. Eight plants flowered during the observation periods from January to August in 2011, in September 2012 and from June to August 2014. A total of 13 inflorescences were recorded: one of the plants produced 3 inflorescences, another produced 4 inflorescences and the rest produced only 1 inflorescence per plant. The species is monoecious (i.e., bearing both male and female flowers on the same plant) but with unisexual flowers (i.e., either male or female only). The inflorescence is normally bisexual but unisexual inflorescences bearing only male flowers do occur, as shown in this study (Table 1).

Table 1. Floral behaviour of *B. kingiana*

	Parameters	Days
1	Male bud development to first anthesis, mean (range)	12 (9-15)
2	Anthesis duration within flower, mean (range)	3 (1-7)
3*	Anthesis duration within inflorescence, week	1 – 6*
4	Female bud development, mean (range)	15 (7-32)
5	Female receptivity, mean (range)	5 (3-6)
		Number or ratio
6	Male buds observed	161
7	Male buds per inflorescence, mean	16
8	Male flowers observed	69
9	Female buds observed	20
10	Female buds per inflorescence, mean	2
11	Female flowers observed	13
12	Male to female sex ratio, mean	10.9
	Unisexual (male only) inflorescence, %	15

**Parameter 3 in weeks.*

The floral phase of an inflorescence from bud to the end of flowering took at least 4 weeks. In general, male flowers always develop and flower first before the female; this is known as protandry. In an inflorescence, male bud development required an average of 12 days before reaching the first anthesis or becoming fully open and functional (Table 1). The duration of development in some male buds could not be ascertained because of missing observations in the early bud stage. Male flowers have been observed to open in the morning from 6–8 a.m. and then closing or closing slightly after 3 p.m. in the evening (Fig. 1, C–E). A male flower usually opened for 3 days before dropping off. The period between first anthesis of the male flower until production of the female bud took at least 9 days.

On the other hand, the time taken for a female bud to develop into flower is slightly longer, about 15 days on average. Not all female buds developed into flowers; some were prematurely aborted. Similar to the male flowers, three female flowers were observed to open in the early morning, closing later in the evening. Female flower receptivity lasted 3–6 days.

It was interesting to find that within an inflorescence of *B. kingiana*, the overlap between male anthesis and female receptivity period of between 2–7 days was quite common; this occurred in 6 out of 8 plants. Non-overlapping or a temporal gap between anthesis and receptivity was observed in only 2 inflorescences. Hence, geitonogamy or selfing, which is the fertilisation of a flower by pollen from another flower on the same plant, is possible in this species. In one particular plant where both male and female flowers were open, the female flower was hand-pollinated with pollen from the male flowers. After the tepals of the female flower had dropped off (end of receptivity), the ovary remained intact for 9 days before abscission. Thus, fruit failed to set. For the rest of the plants, no pollination took place in the absence of assisted pollination and insect pollinators such as stingless bees or honey bees. So the female flowers were eventually aborted a few days after the end of receptivity.

Fig. 1 Floral development. (A) Male phase with first anthesis (Day 1) starting in the morning around 8 a.m. on 21st June 2011. (B) The male flower abscised 3 days later, leaving a scar as indicated by the orange arrow. A female bud was observed on Day 10 (green arrow). (C) Male flowers opened in the morning, and (D) started closing in the afternoon. (E) One of the male flowers closed completely in the evening on the same day. The flowers opened again the next morning. (F) On Day 28, the female flower started to open in the afternoon.

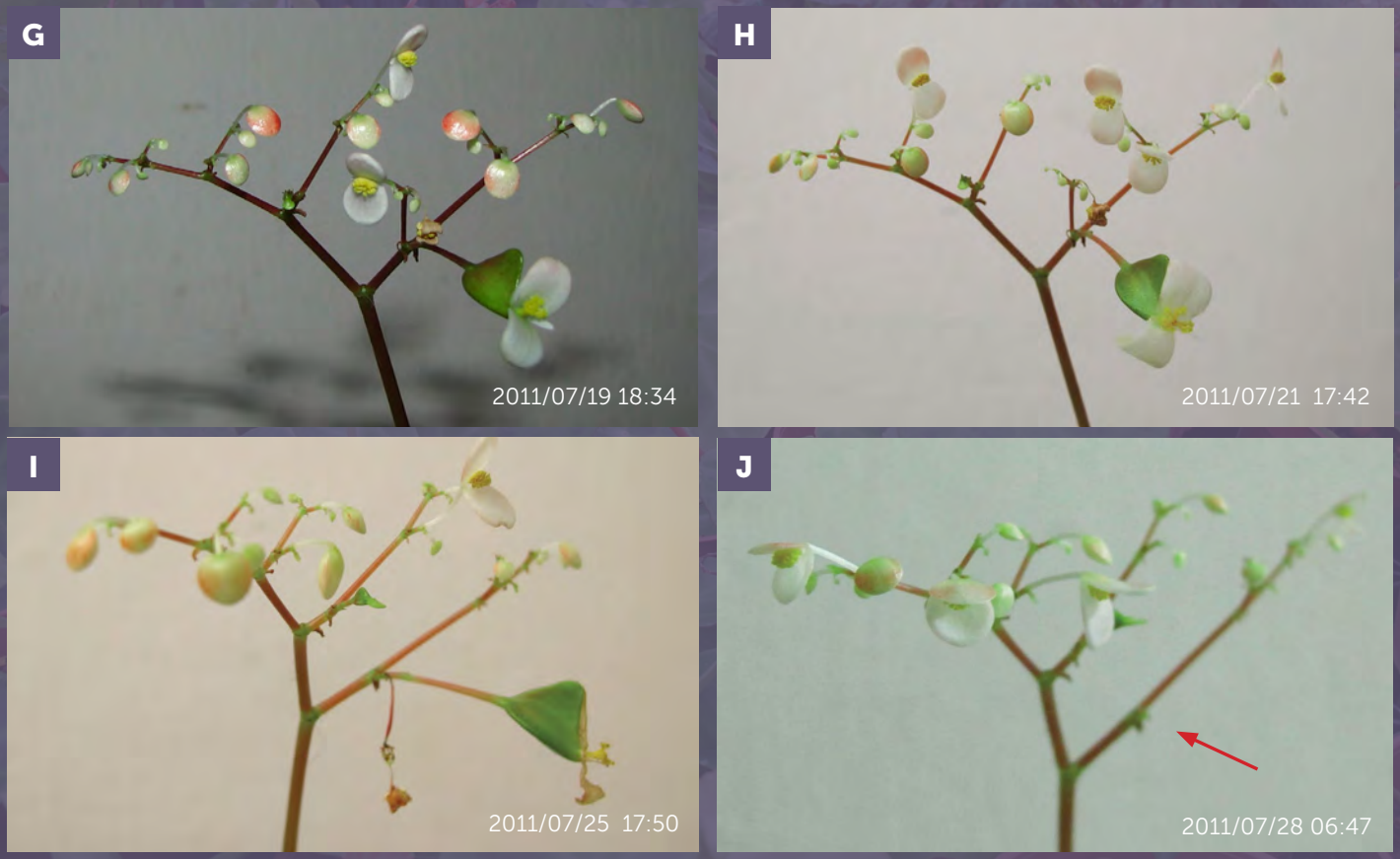

Fig. 1 (G) This female flower was fully open the next day together with 2 other male flowers. (F-H) Overlapping between male anthesis and female receptivity occurred for 5 days before (I) the female flower dropped its tepals after flowering for 7 days and (J) abscised 3 days later.

The mean sex ratio of male to female flowers was 10.9 with high numbers of male flowers produced compared to female flowers. There are some theories which may explain this. According to the sex allocation theory, the cost of production and development of fruit is much more expensive in female than in male flowers (Charnov, 1982). Gender specialisation in *Begonia* facilitates the unusual pollination strategy, in which the male flowers produce pollen reward to attract pollinators whereas the female flowers do not produce any rewards or nectar but attract pollinators by mimicking the male flowers (Chan & Chua, 2007). Thus, the floral sex ratio is under frequency-dependent selection; male-biased inflorescences will have less seed produced, while female-biased inflorescences are less attractive to pollinators.

In conclusion, both male and female floral development in *B. kingiana* takes about 2 weeks before flowering. *Begonia kingiana* exhibits protandrous flowering where male flowers open first, usually in the early morning, followed by female flowers a few weeks later. There may or may not be a temporal gap between anthesis and receptivity within an inflorescence.

This study enabled us to predict the timing for possible assisted pollination for selective or improved breeding and propagation purposes. We assume that for these purposes, it would be best to hand pollinate female flowers within the first 3 days of their opening with fresh pollen from male flowers aged less than 2 days.

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52109 Kepong, Selangor.
(Attn: Dr. Chan Yoke Mui, yokemui@frim.gov.my or Ms. Ong Su Ping, ongsuping@frim.gov.my)

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