

CHAPTER 3

RESULTS

3.1 Specimen collection

A total of 72 taxa were collected and identified to species level. In general, 21 species including a recently described species by Lim, CK (2007), *Alpinia suriana*, were recorded. Specimens which were successfully identified to species level were *Alpinia aquatica*, *Alpinia capitellata*, *Alpinia* cf. *assimilis*, *Alpinia conchigera*, *Alpinia galanga*, *Alpinia javanica*, *Alpinia javanica* var. *colorata*, *Alpinia latilabris*, *Alpinia macrostephana*, *Alpinia malaccensis* var. *nobilis*, *Alpinia murdochii*, *Alpinia mutica*, *Alpinia oxymitra*, *Alpinia pahangensis*, *Alpinia petiolata*, *Alpinia rafflesiana*, *Alpinia scabra*, *Alpinia suriana*, *Alpinia vitellina*, *Alpinia vitellina* var. *cannifolia* and *Alpinia zerumbet*. Generally all *Alpinia* species collection belongs under section *Alpinia* or section *Allughas* (in accordance to Smith's classification, Smith 1990).

Table 3.1 List of species collected

Species (n)	Collection date	Specimen ID	Location/Coordinates	Type of Forest/ Topography
<i>A. aquatica</i> (Retz.) Roscoe (3)	19/6/2008	N9	Rimba Ilmu, UM (Kuala Lumpur)	Conservatory/ Lowland
	10/11/2010	N149	Hutan Simpan Menchali, Rompin (Pahang)	Secondary forest (disturbed)/ Lowland
	19/6/2008	N263	Rimba Ilmu, UM (Kuala Lumpur)	Conservatory / Lowland
<i>A. capitellata</i> Jack. (3)	5/2/2012	N200	Suriana Gardens, Balik Pulau (Penang)	Conservatory / Lowland
	5/2/2012	N201	Suriana Gardens, Balik Pulau (Penang)	Conservatory / Lowland
	5/2/2012	N202	Suriana Gardens, Balik Pulau (Penang)	Conservatory / Lowland
<i>A. cf. assimilis</i> Ridl. (3)	3/8/2009	N140	Suriana Gardens, Balik Pulau (Penang)	Conservatory / Lowland
	3/8/2009	N230	Suriana Gardens, Balik Pulau (Penang)	Conservatory / Lowland
	3/8/2009	N231	Suriana Gardens, Balik Pulau (Penang)	Conservatory / Lowland
<i>A. conchigera</i> Griff. (3)	19/6/2008	N3	Rimba Ilmu, UM (Kuala Lumpur)	Conservatory / Lowland
	18/11/2008	N43	Kerian (Perak)	Oil-palm plantation (disturbed) / Lowland
	19/11/2008	N46	Penang Botanic Gardens (Penang)	Conservatory / Lowland
<i>A. galanga</i> (L.) Willd. (4)	27/6/2008	N5	Rimba Ilmu, UM (Kuala Lumpur)	Conservatory / Lowland
	16/12/2008	N58	Tasik Chini, Pekan (Pahang)	Secondary forest (reserved) / Lowland
	2/8/2009	N129	Hutan Lipur Ulu Licin, Beruas (Perak)	Secondary forest (reserved) / Lowland
	23/4/2009	N101	Hutan Simpan Sungai Nipah, Kemaman (Terengganu)	Secondary forest (reserved) / Lowland
<i>A. javanica</i> Blume (6)	19/9/2008	N24	Hutan Simpan Berembun, Jelebu (Negeri Sembilan)	Primary forest (reserved)/ Midland
	21/8/2008	N25	Fraser's Hill (Pahang)	Primary forest (reserved)/ Midland
	26/11/2008	N36	Rimba Ilmu, UM (Kuala Lumpur)	Conservatory / Lowland/ Midland
	23/4/2009	N100	Hutan Sungai Nipah, Kemaman (Terengganu)	Secondary forest (disturbed) / Midland
	5/2/2012	N206	Suriana Gardens, Balik Pulau (Penang)	Conservatory/ Midland
	10/8/2006	FRI50213	Endau-Rompin, Mersing (Johor)	Secondary forest (disturbed) / Midland

Table 3.1 (continued)

Species (n)	Collection date	Specimen ID	Location/Coordinates	Type of Forest/ Topography
<i>A. javanica</i> var. <i>colorata</i> Ridl. (3)	25/11/2011	N87	Piah Forest Reserve, Lasah (Perak)	Secondary forest (reserved)/ Midland
	18/6/2009	N127	Hutan Lipur Ulu Licin, Beruas (Perak)	Secondary forest (reserved)/ Midland
	3/8/2009	N133	Suriana Gardens, Balik Pulau (Penang)	Conservatory/ Midland
<i>A. latilabris</i> Ridl. (4)	19/6/2008	N2	Rimba Ilmu, UM (Kuala Lumpur)	Conservatory / Lowland
	19/11/2008	N44	Penang Botanic Gardens (Penang)	Conservatory / Lowland
	16/4/2009	N82	FRIM, Kepong (Selangor)	Conservatory / Lowland
	3/8/2009	N137	Suriana Gardens, Balik Pulau (Penang)	Conservatory / Lowland
<i>A. macrostephana</i> (Baker) Ridl. (3)	3/8/2009	N134	Suriana Gardens, Balik Pulau (Penang)	Conservatory/ Midland
	5/2/2012	N224	Suriana Gardens, Balik Pulau (Penang)	Conservatory/ Midland
	5/2/2012	N225	Suriana Gardens, Balik Pulau (Penang)	Conservatory/ Midland
<i>A. malaccensis</i> var. <i>nobilis</i> (Ridl.) I. M. Turner (4)	20/11/2008	N50	Simpang Pulai, Cameron Highlands (Pahang)	Secondary forest (disturbed)/ Lowland
	16/4/2009	N83	FRIM, Kepong (Selangor)	Conservatory / Lowland
	3/8/2009	N141	Suriana Gardens, Balik Pulau (Penang)	Conservatory / Lowland
<i>A. murdochii</i> Ridl. (3)	11/11/2008	N33	Genting Highlands (Pahang)	Primary forest (reserved)/ Highland
	2/12/2008	N53	Fraser's Hill (Pahang)	Primary forest (reserved)/ Highland
	23/8/2012	N300	Genting Highlands (Pahang)	Primary forest (reserved)/ Highland
<i>A. mutica</i> Roxb. (5)	16/12/2008	N60	Tasik Chini, Pekan (Pahang)	Rubber-estate plantation (disturbed) / Lowland
	16/4/2009	N84	FRIM, Kepong (Selangor)	Conservatory / Lowland
	19/6/2009	N128	Kerian (Perak)	Oil-palm plantation (disturbed) / Lowland
	5/2/2012	N236	Suriana Gardens, Balik Pulau (Penang)	Conservatory / Lowland
	11/12/2012	N267	Rimba Ilmu, UM (Kuala Lumpur)	Conservatory / Lowland
<i>A. oxymitra</i> K. Schum. (3)	13/1/2009	N71	Suriana Gardens, Balik Pulau (Penang)	Conservatory/ Midland
	16/4/2009	N81	FRIM, Kepong (Selangor)	Conservatory / Lowland
	29/4/2008	N86	Rimba Ilmu, UM (Kuala Lumpur)	Conservatory/ Midland

Table 3.1 (continued)

Species (n)	Collection date	Specimen ID	Location/Coordinates	Type of Forest/ Topography
<i>A. pahangensis</i> Ridl. (3)	16/12/2008	N56	Tasik Chini, Pekan (Pahang)	Secondary forest (disturbed) / Lowland
	20/1/2012	N248	Tasik Chini, Pekan (Pahang)	Secondary forest (disturbed) / Lowland
	20/1/2012	N249	Tasik Chini, Pekan (Pahang)	Secondary forest (disturbed) / Lowland
<i>A. petiolata</i> (Bak.) Holtt. (3)	21/8/2008	N26	Fraser's Hill (Pahang)	Primary forest (reserved)/ Highland
	4/9/2008	N264	Fraser's Hill (Pahang)	Primary forest (reserved)/ Highland
	7/5/2009	N109	Genting Highlands (Pahang)	Primary forest (reserved)/ Highland
<i>A. rafflesiana</i> Wall. ex Baker (5)	3/1/2009	N65	Hutan Simpan Berembun, Jelebu (Negeri Sembilan)	Primary forest (reserved)/ Midland
	7/5/2009	N112	Gunung Bunga Buah, Genting Highlands (Pahang)	Primary forest (reserved)/ Highland
	16/6/2009	N124	Hutan Lipur Ulu Kenas, Kuala Kangsar (Perak)	Secondary forest (reserved)/ Midland
	15/11/2005	FRI50145	Hutan Simpan Gunung Panti, Kota Tinggi (Johor)	Primary forest (reserved)/ Highland
	6/12/2006	FRI50237	Hutan Simpan Ulu Sedili, Pontian (Johor)	Secondary forest (reserved)/ Midland
<i>A. scabra</i> (Blume) Naves (3)	5/9/2008	N29	Fraser's Hill (Pahang)	Primary forest (reserved)/ Highland
	11/11/2008	N31	Genting Highlands (Pahang)	Primary forest (reserved)/ Highland
	23/8/2012	N301	Genting Highlands (Pahang)	Primary forest (reserved)/ Highland
<i>A. suriana</i> Lim (3)	3/8/2009	N131	Suriana Gardens, Balik Pulau (Penang)	Conservatory / Lowland
	5/2/2012	N227	Suriana Gardens, Balik Pulau (Penang)	Conservatory / Lowland
	5/2/2012	N228	Suriana Gardens, Balik Pulau (Penang)	Conservatory / Lowland
<i>A. vitellina</i> (Lindl.) Ridl. (3)	19/11/2008	N49	Penang Botanic Gardens (Penang)	Conservatory / Lowland
	3/1/2009	N66	Hutan Simpan Berembun, Jelebu (Negeri Sembilan)	Primary forest (reserved)/ Midland
	3/8/2009	N144	Suriana Gardens, Balik Pulau (Penang)	Conservatory / Lowland
<i>A. vitellina</i> var. <i>cannifolia</i> (Ridl.) Holtt. (3)	5/2/2012	N245	Suriana Gardens, Balik Pulau (Penang)	Conservatory / Lowland
	5/2/2012	N246	Suriana Gardens, Balik Pulau (Penang)	Conservatory / Lowland
	5/2/2012	N247	Suriana Gardens, Balik Pulau (Penang)	Conservatory / Lowland
<i>A. zerumbet</i> (Pers.) B.L. Burtt & R.M. Sm. (3)	27/6/2008	N6	Rimba Ilmu, UM (Kuala Lumpur)	Conservatory / Lowland
	13/1/2009	N73	Putrajaya Botanic Garden (Putrajaya)	Conservatory / Lowland
	11/12/2013	N265	Rimba Ilmu, UM (Kuala Lumpur)	Conservatory / Lowland



Figure 3.1 Map of *Alpinia* collection from 21 locations in Peninsular Malaysia. Dotted arrow lines represent collections from recorded herbarium location, while the straight lines represent new locations. ‘x’ marks the location where samples were not found. sp represents: species, and sm represents: samples

3.1.1 Brief species description

1. *Alpinia aquatica* (Retz.) Roscoe

Alpinia aquatica (Retz.) Roscoe, Trans. Linn. Soc. London 8 (1807) 346. – Basionym:

Heritiera aquatic Retz., Observ. Bot. (1791) 18. – Type: *J.G. König s.n.*, specimen lost.

Hellenia melanocarpa Teijsm. & Binn., Natuurk. Tijdschr. Ned. –Indië 24 (1862) 328.

– *Alpinia melanocarpa* (Teijsm. & Binn.) Ridl., J. Straits Branch Roy. Asiat. Soc. 32 (1899) 163. – *Languas melanocarpa* (Teijsm. & Binn.) Burkill, Gard. Bull. Straits Settle. 6 (1930) 260. – Type: *J. E. Teijsmann s. n.* (BO).

Alpinia fraseriana Oliv., Hooker's Icon. Pl. 16 (1887) t. 1567. – *Languas fraseriana*

(Oliv.) Merr., Univ. Calif. Publ. Bot. 15 (1929) 33. – Type: *F. W. Burbidgea s. n.* (syn FI!), *M. Fraser s. n.* (syn K).

Alpinia rosella Ridl., J. Straits Branch Roy. Asiat. Soc. 32 (1899) 164. – Lectotype:

G.F. Hose 16 (K, designated by Turner, 2000), Brunei.

Alpinia exostylis K. Schum., Pflanzenr. IV, 46 (1904) 314. – *Languas exostylis* (K.

Schum.) Merr., Univ. Calif. Publ. Bot. 15 (1929) 34. – Type: *P. W. Korthals s.n.*

Alpinia cornucervi Ridl., J. Straits Branch Roy. Asiat. Soc. 46 (1906) 243. – *Languas*

cornucervi (Ridl.) Merr., Univ. Calif. Publ. Bot. 15 (1929) 34. – Type: *J.Hewitt s.n.* (holo K), Sarawak.

Alpinia rubella Ridl. in Winkler, Bot. Jahrb. Syst. 44 (1910) 529. – *Languas rubella*

(Ridl.) Merr., Univ. Calif. Publ. Bot. 15 (1929) 35. – Type: *H. J. P. Winkler 3095* (holo WRSL), Kalimantan.

Alpinia quadriloba Ridl., Bull. Misc. Inform. (1926) 90. – Type: *C. B. Kloss 14527*

(holo K, iso SING!), Pulau Siberut.

Distribution – Sumatra, Peninsular Malaysia, Sarawak, Brunei, Sabah, Kalimantan,

Java.

(continued) *Alpinia aquatica* (Retz.) Roscoe

Family: Zingiberaceae

Genus: *Alpinia*

Clumps



Single plant



Infructescence



(continued) *Alpinia aquatica* (Retz.) Roscoe

Morphological description: **Rhizome** 1 cm or thicker. **Stems** about 2 metre tall. Leafy shoots very close together forming tight clumps. Glabrous sheaths. **Leaves** to 30 cm length by 5 cm width, apex shortly acuminate, base broad and abruptly cuneate, glabrous with tooth-like thorn along the leaf margin, petiole 5-10 mm long. **Bracts** small, deciduous. **Inflorescence** 15 cm long, with short cincinni (~1.5cm), glabrous. **Calyx** about 0.9 cm long, glabrous, corolla tube 1.2 cm, white; dorsal lobe light pink. **Lip** broadly obovate, 1.5 cm long, narrow base, labellum split almost to the base light pink with purplish pink at the base. **Staminodes** triangular. **Filament** creamy white, slender, 0.5 cm long; **anther** crested, white, 0.4 cm long. **Infructescence** erect, up to 15 cm long. **Fruit** green when unripe, round, diameter about 0.5 cm.

Habitat distribution: Seen on sandy beaches of South of Peninsular Malaysia, near the sea.

Medicinal properties: Unknown

Remarks: Although in 1950, Holttum recorded that the species is common and abundant in southern Peninsular Malaysia and East Coast, recent findings only found a number of samples due to the vast development of the areas.

2. *Alpinia capitellata* Jack.

Alpinia capitellata Jack., Descriptions of Malayan plants 2 (1822) 4 – *Languas capitellata* (Jack) Merr., Univ. Calif. Publ. Bot. 15 (1929) 33. – Type: *W. Jack s. n.* specimen lost.

Alpinia grandiceps Ridl., J. Straits Branch Roy. Asiat. Soc. 50 (1908) 148. – *Languas grandiceps* (Ridl.) Merr., Univ. Calif. Publ. Bot. 15 (1929) 34. – Type: *J. Hewitt s.n.* (November 1907) (holo K, iso SAR!), Kuching.

Distribution – Sumatra, Sarawak, Sabah

(continued) *Alpinia capitellata* Jack.

Family: Zingiberaceae

Genus: *Alpinia*

Clumps



Inflorescence



Flower



(continued) *Alpinia capitellata* Jack.

Morphological description: **Stems** about 2-3 metre tall. **Leaves** to 90 cm length by 15 cm width, apex caudate, base unequally cuneate, distinctly ribbed, petiole to 10 cm long. **Inflorescence** drooping, short and condensed covered by very large brownish red sheaths and bracts. **Bracts** wide and broad, up to 8cm wide and 7cm long. **Flower** compact on cincinnus. **Calyx** about 2 cm long, red, corolla tube shorter than calyx yellowish red; dorsal lobe yellowish white with distinct red on the hood, 3.0 cm length to 1.7 cm width; lateral lobes smaller, hooded, colour similar with dorsal lobe, 2.0 cm length to 1.5 cm width. **Lip** broadly obovate, 5 cm long, basal part funnel shaped red with yellowish orange, the distal part spread to a broad wrinkled whitish edge throughout the margin. **Staminodes** red, irregularly shaped about 8mm long. **Filament** creamy white, 1.5 cm long; **anther** non-crested, yellowish cream, 1cm long to 0.8 cm width. **Fruit** not seen.

Habitat distribution: Shaded area; cultivated in the conservatory.

Medicinal properties: Unknown

Remarks: This species closely resembles floral characteristics of *A.javanica* var *colorata*. Attempts were made to collect the plant in the recorded herbarium locality (Gunung Tunggul, Perak). However, due to the conversion of agricultural plantation of palm oil in the area, it is possible that the species had been destroyed; and the collection obtained were only seen in Suriana Garden, Penang.

3. *Alpinia cf. assimilis* Ridl.

Alpinia assimilis Ridl., J. Straits Branch Roy. Asiat. Soc. 32 (1899) 166. – *Catimbium assimile* (Ridl.) Holttum, Gard. Bull. Singapore 13 (1950) 152. – Lectotype: *C. curtis* 2766 (SING!, designated by Turner, 2000), Penang.

Distribution – Peninsular Malaysia.

Family: Zingiberaceae

Genus: *Alpinia*

Clumps



Infructescence



(continued) *Alpinia cf. assimilis* Ridl.

Morphological description: Stems up to 2.0 metre tall. Leaves to 57 cm long and 9 cm width, apex caudate, base cuneate, glabrous, petiole to 5 cm long. Flower not seen. Inflorescence up to 15 cm long. Fruits red orange, spherical, sparsely hairy, about 2.5 cm in diameter.

Habitat distribution: Shaded area; cultivated in the conservatory.

Medicinal properties: Unknown

Remarks: *Alpinia cf. assimilis* is a close resemblance to *Alpinia latilabris* yet differ in its smaller vegetative size. It may be possible that this species is a hybrid between *Alpinia mutica* and *Alpinia latilabris* since its morphological characteristics of inflorescence are rather in between. Attempts were made to collect the plant in the recorded herbarium locality (Pekan, Pahang). However, due to the conversion of agricultural plantation of rubber estate in the area it is possible that the species had been destroyed; and the collection obtained were only seen in Suriana Garden, originally collected from Air Itam, Penang. In addition, since the flowers of the cultivated plant were not seen to verify its characteristics of *Alpinia assimilis*, hence for the purpose of this study it is identified as *Alpinia cf. assimilis* instead of *Alpinia assimilis*.

4. *Alpinia conchigera* Griff.

Alpinia conchigera Griff., Not. pl. asiat. 3 (1851) 424. – *Languas conchigera* (Griff.)

Burkill, Bull. Misc. Inform. (1930) 37. – Type: *W. Griffith 5700* (holo K), Peninsular
Malaysia.

Alpinia laosensis Gagnep., Bull. Soc. Bot. France 53 (1906) 133. – Type: *Pavie s. n.*

(holo P!), Laos.

Distribution – Thailand, Peninsular Malaysia.

(continued) *Alpinia conchigera* Griff.

Family: Zingiberaceae

Genus: *Alpinia*

Clumps



Inflorescence



Infructescence



(continued) *Alpinia conchigera* Griff.

Morphological description: **Stems** about 180 cm, closely grown together in clumps. **Leaves** to 26 cm length by 7 cm, glabrous, apex shortly acuminate, base cuneate, petiole short, up to 5 mm long. **Inflorescence** erect, up to 25 cm long, with many cincinni, usually 3-5 flowers on each cincinni. Stalk of cincinni short, 3 mm long; pedicel 5 mm long, primary bracts brown, small, usually unseen, secondary bracts funnel shaped, up to 6 mm long. **Calyx** pale green, 3 mm long, apex broadly 3-lobed, corolla tube 6 mm long, longer than calyx, whitish green; dorsal corolla lobe cream, hooded, up to 9 mm long by 4 mm width; lateral corolla lobe cream, hooded, up to 7 mm by 3 mm long. **Lip** obovate, strongly concave, 5 mm long, base yellowish with 4-5 red streaks on each side, labellum median longitudinal with irregularly wrinkled surface. Staminode red, 2mm long x 1 mm width, quadrate-like. Filament slender, curved, cream, up to 5 mm long; anther non crested yellowish cream, 3 mm to 2 mm width. **Infructescence** about the size of inflorescence. **Fruits** spherical, 8mm in diameter, green when young, red or orange when mature, glabrous, persistent calyx at the apex.

Habitat distribution: Common in shaded areas, around the village areas on damp soils.

Medicinal properties: Anti-fungal, post-partum medicine.

Remarks: The rhizomes and fruits when crushed are strongly aromatic. Holttum mentioned that this species is quite peculiar due to its small flowers unlike other *Alpinia*.

5. *Alpinia galanga* (L.) Willd.

Alpinia galanga (L.) Willd., Willd. Sp. Pl. 1 (1797) 12. – Basionym: *Maranta galanga*

L., Sp. Pl., ed. 2,1(1762) 3. – *Languas galanga* (L.) Stuntz, U. S. D. A. Bur. Pl. Industr. Bull. 261 (1912) 21. – Type: Herb. Amboin. 5: 143, t. 63 (1747).

Heritiera alba Retz., Observ. Bot. 6 (1791) 18. – *Alpinia alba* (Retz.) Roscoe, Trans.

Linn. Soc. London 8 (1807) 346. – Type: *J.G. König s.n.*, specimen lost.

Alpinia pyramidata Blume, Enum. Pl. Javae (1827) 58. – *Languas pyramidata* (Blume)

Merr., Enum. Philipp. Fl. pl. 1 (1923) 233. – Type: *C.L. von Blume s.n.* (holo L!), Java.

Alpinia carnea Griff., Not. pl. asiat. 3 (1851) 420. – Type: Material not located.

Alpinia viridiflora Griff., Not. pl. asiat. 3 (1851) 423. – Type: Material not located.

Alpinia rheedii Wight, Icon. Pl. Ind. Orient. 6 (1853) 19, t. 2026. – Type: Material not located.

Alpinia zingiberina Hook. F., Bot. Mag. (1887) t. 6944. – Type: Material not located.

Alpinia bifida Warb., Bot. Jahrb. Syst. 13 (1891) 275. - Type: Material not located.

Distribution – Peninsular Malaysia, Singapore, Sabah, Kalimantan, Phillipines.

(continued) *Alpinia galanga* (L.) Willd.

Family: Zingiberaceae

Genus: *Alpinia*

Clumps



Inflorescence



Flower



(continued) *Alpinia galanga* (L.) Willd.

Morphological description: **Stems** up to 2.5 m tall. **Leaves** about 50 cm length to 8 cm width., glabrous with a few short hairs at the apex of leaf, apex acute, base cuneate; petiole about 0.7 cm, hairy ; ligule up to 0.7 cm long. **Inflorescence** erect, peduncle from 7 cm or more. Rachis up to 25 cm long, light green, contains numerous cincinni each bearing 3 to 5 flowers Primary bracts variable and deciduous light cream to green Stalk of cincinni up to 1.0 cm long Secondary bracts about 1.0 cm long, narrow and enclosed the bud when young, white Pedicel about 0.5 cm, pale green Calyx creamy green, 1.2 cm, Corolla tube about the size of calyx, Dorsal lobe about 0.8 cm long with 0.3 cm wide, white, hooded. **Lip** about 2.5 cm long, white with pink lines at each side of midrib, Lateral lobe narrow at the tip, the edges are irregularly toothed, Staminode at the base of labellum, broad, red Filament about 1.4 cm long, narrow; Anther 0.9 cm long, yellow without crest. **Fruit** green when unripe, yellowish green to red when ripe, smooth, about 1.0 cm in diameter, Stylodes short and irregularly lobed with rounded apices.

Habitat distribution: Very common, cultivated in village areas throughout Peninsular Malaysia. Usually grown in clumps.

Medicinal properties: The rhizomes were used as spice in traditional Malay dishes, as well in traditional medicine.

Remarks: This species is commonly used in Malaysian traditional culinary dishes.

6. *Alpinia javanica* Blume

Alpinia javanica Blume, Enum. pl. Javae (1827) 59. – *Languas javanica* (Blume)

Burkill, Bull. Misc. Inform. (1935) 318. – Type: *H. Kuhl & J.C. van Hasselt s.n.*
(holo L!), Java.

Alpinia blumei D. Dietr., Syn. pl. 1 (1839) 13. – Type: Material not located.

Alpinia involucrate Griff., Not. pl. asiat. 3 (1851) 422. – Type: Material not located.

Alpinia campanaria Ridl., J. Straits Branch Roy. Asiat. Soc. 86 (1922) 308. – Type:

H.N. Ridley s.n. (20 December 1920) (holo K), Peninsular Malaysia.

Distribution – Thailand, Peninsular Malaysia, Java, Moluccas.

(continued) *Alpinia javanica* Blume

Family: Zingiberaceae

Genus: *Alpinia*

Clumps



Inflorescence and Flower



Inflorescence and Flower



Inflorescence and Flower



(continued) *Alpinia javanica* Blume

Morphological description: **Stems** up to 3 metre tall. **Leaves** about 90 cm length to 15 cm width, distinctly ribbed, apex shortly caudate, base cuneate; petiole up to 10 cm long; ligule 2.5 cm long. **Inflorescence** erect or drooping, about 25 cm long; primary bracts broad, brown, attached to the base; rachis bears about 12 cincinni with 3-6 flowers on each cincinni; secondary bracts 2-3 cm, cup-shaped, sparsely hairy; calyx white, glabrous, 2.0 cm long by 1.5 cm width; dorsal lobe up to 3 cm long by 1.7 cm width, cream-yellow with strongly hooded white apex; lateral lobe smaller, 1.2 cm x 1.2 cm less hooded; yellowish white at the base. **Lip** broadly obovate, 5 cm width to 3.5 cm long, base funnel shaped with wrinkled broad white margin, basal part orange yellowish with red spots and stripes; staminodes red, irregular, 8 to 10 mm long. Filament white, 1.3 cm long; anther yellowish cream with a few red spots, 1.0 cm by 1.0 cm width, non-crested. **Fruits** not seen.

Habitat distribution: Seen in the primary and secondary forests, sometimes at the hillside area.

Medicinal properties: Unknown

Remarks: The size of the inflorescence and flowers are distinctly variable. Although previously recorded as common in lowlands, in open places at many localities, recently such populations are not observed probably due to habitat destruction. This species can only be seen in several areas; which were disturbed by the immense logging and agricultural plantations.

7. *Alpinia javanica* var. *colorata* Ridl.

Alpinia javanica var. *colorata* Ridl., Fl. Malay Penins. 4 (1924) 283. – Lectotype: *H. N.*

Ridley 9697 (K, designated by Turner, 2000), Perak.

Distribution – Peninsular Malaysia.

Family: Zingiberaceae

Genus: *Alpinia*

Clumps



Inflorescence and Flower



(continued) *Alpinia javanica* var. *colorata* Ridl.

Morphological description: **Stems** up to 3 metre tall. **Leaves** 70-90 cm length by 10-15 cm width, distinctly ribbed, velvety, apex shortly caudate, base cuneate; petiole up to 13 cm long; ligule 2.5 cm long. **Inflorescence** somewhat drooping, 10-25 cm long; primary bracts broad, rose-red to brown, attached to the base; secondary bracts rose-red to brown, 2-3 cm, cup-shaped, sparsely hairy; calyx rose red, glabrous, 2.5 cm long by 1.5 cm width; dorsal lobe up to 3 cm long by 1.7 cm width, yellowish red with strongly hooded red apex; lateral lobe smaller, 1.2 cm x 1.2 cm less hooded; yellowish red with white at the base. **Lip** broadly obovate, 4-5 cm width to 3.5 cm long, base funnel shaped with wrinkled broad white margin, basal part orange maroon; staminodes red, irregular, 8 to 10 mm long. Filament cream, 2.0 cm long; anther cream, 1.0 cm by 1.0 cm width, non-crested. **Fruits** not seen.

Habitat distribution: Shaded, humid areas, near waterfall or river

Medicinal properties: Unknown

Remarks: This species is a variation of *Alpinia javanica* and its vegetative structures are closely similar. The striking difference is its floral characteristics; yet somehow it looks fairly comparable to *Alpinia capitellata*.

8. *Alpinia latilabris* Ridl.

Alpinia latilabris Ridl., J. Straits Branch Roy. Asiat. Soc. 32 (1899) 168. – *Catimbium latilabre* (Ridl.) Holttum, Gard. Bull. Singapore 13 (1950) 153. – Lectotype: *H. N. Ridley s.n. (August 1891)* (SING, designated by Turner, 2000), Pahang.

Alpinia hookeriana Valetton, Bull. Inst. Bot. Buitenzorg 20 (1904) 81. – *Languas hookeriana* (Valetton) Merr., Univ. Calif. Publ. Bot. 15 (1929) 34. – Type: *T. Valetton s.n.* (holo BO, iso P!), Bogor (cultivated in Hortus Bogoriensis).

Alpinia sericea Ridl., J. Linn. Soc., Bot. 42 (1914) 163. – *Languas sericea* (Ridl.) Merr., Univ. Calif. Publ. Bot. 15 (1929) 35. – Type: *L.S. Gibbs 3025* (holo BM), Sabah.

Distribution – Peninsular Malaysia, Singapore, Sabah.

(continued) *Alpinia latilabris* Ridl.

Family: Zingiberaceae

Genus: *Alpinia*

Clumps



Inflorescence and Flower



Infructescence



(continued) *Alpinia latilabris* Ridl.

Morphological description: **Stems** up to 3.5 metres tall. **Leaves** 45-70 cm length by 10-15 cm width, hairy, apex caudate, base narrowly cuneate, petiole up to 3.0 cm, ligule up to 1.5cm long. **Inflorescence** up to 30 cm long, rachis bears 20-25 cincinni, each 1-3 flowers; secondary bracts up to 3.5 cm long, white with red flush on the apex completely enveloping buds, hairy; calyx white, pink at the apex, 2.5 cm long by 2.0 cm width; corolla tube white, 1.0 cm long; dorsal lobe up to 3.5 cm length by 1.5 cm width, creamy white; lateral lobe smaller than dorsal about 3.2 cm by 1.5 cm, creamy white. **Lip** 4.5 cm long by 3.5 cm wide, broadly ovate and strongly concave with slight 3-lobed, wrinkled margin, yellow with maroon lines and spots towards the base; staminode thin, 3 mm, maroon. Filament cream with pink at base, 1.5 cm long; anther yellowish cream with a flush of pink, 1.2 cm by 1.0 cm width, non-crested. **Fruits** sparsely hairy, green, 2.5cm to 3.0 cm.

Habitat distribution: In open areas, lowlands.

Medicinal properties: Unknown

Remarks: *Alpinia latilabris* is allied to *Alpinia mutica* and closely allied to *Alpinia malaccensis* var. *nobilis*. Attempts were made to collect at the recorded herbarium localities (Pulau Rumpit and Pulau Datoh, Pahang). However, due to the conversion of agricultural plantation of rubber estate in the area it is possible that the species had been destroyed. This specimen was from Rimba Ilmu Botanic Garden.

9. *Alpinia macrostephana* (Baker) Ridl.

Alpinia macrostephana (Baker) Ridl., J. Straits Branch Roy. Asiat. Soc. 32 (1899) 175.

– Basionym: *Amomum macrostephanum* Baker, Fl. Brit. India 6 (1892) 243. –

Cenolophon macrostephanum (Baker) Holttum, Gard. Bull. Singapore 13 (1950)

135. – Type: *H.H. Kunstler 1905* (iso SING).

Distribution – Peninsular Malaysia.

Family: Zingiberaceae

Genus: *Alpinia*

Clumps



Single plant



Inflorescence and Flower



(continued) *Alpinia macrostephana* (Baker) Ridl.

Morphological description: Stems up to 2.5 metre tall. Leaves wavy, glabrous, 60 cm length by 10 cm width, apex shortly caudate, base very unequally cordate, petiole up to 13 cm long, slender; ligule about 1.5 cm long. **Inflorescence** erect, up to 10 cm long, rachis bears 1 flower per cincinnus; calyx pale green, 2.0 cm long by 1.0 cm wide, glabrous; corolla tube about the same size as calyx,; dorsal lobe hooded, yellow, 2.0 cm long by 1.3 cm width; lateral lobe hooded, yellow, 2.0 cm long by 1.0 cm width. **Lip** 2.5 cm long by 3.0 cm width, strongly wrinkled on the yellow margin, yellow with orange dots and lines at the base and lines spreading to the apex; staminode thin, 4 mm, adaxial yellow and abaxial orange. Filament 2.0 cm long, yellow; anther 5 mm long by 3 mm wide, yellow, crested. **Fruits** not seen.

Habitat distribution: Shaded area; cultivated in the conservatory.

Medicinal properties: Unknown

Remarks: This species has distinct vegetative features unlike other *Alpinias*. One of the most striking features is the wavy glabrous leaves. While it has been recorded to be found in Larut, Perak; the vast development in the area has made it impossible to be found at neither the location nor its surrounding area. However, this species was collected from Suriana Garden, Penang.

10. *Alpinia malaccensis* var. *nobilis* (Ridl.) I. M. Turner

Alpinia malaccensis var. *nobilis* (Ridl.) I. M. Turner, Novon 6 (1996) 223. – Basionym:

Alpinia nobilis Ridl., J. Straits Branch Roy. Asiat. Soc. 32 (1899) 169. – *Catimbium*

malaccense var. *nobilis* (Ridl.) Holttum, Gard. Bull. Singapore 13 (1950) 155. –

Lectotype: *H.N. Ridley 4617* (K, designated by Smith, 1990), Singapore.

Distribution – Singapore.

(continued) *Alpinia malaccensis* var. *nobilis* (Ridl.) I. M. Turner

Family: Zingiberaceae

Genus: *Alpinia*

Single plant



Inflorescence



Infructescence



(continued) *Alpinia malaccensis* var. *nobilis* (Ridl.) I. M. Turner

Morphological description: **Stems** 2-4 metre tall. **Leaves** densely hairy, up to 100 cm length by 25 cm width, apex acuminate, base narrowly cuneate, petiole 3-5 cm long; ligule hairy, up to 2.5 cm long. **Inflorescence** erect, up to 35 cm long; rachis bears 60 or more flowers; secondary bracts hairy, white with red tip at apex, 4.2 cm by 4 cm wide, sparsely hairy; calyx 3.2 cm long by 2.5 cm wide, white with reddish pink at apex; corolla tube white, 1.2-1.5 cm long; dorsal lobe white, 4.0-4.2 cm by 2.5 cm width, densely pubescent; lateral lobe white, smaller than dorsal lobe, 3.0-3.5 cm by 1.5 cm wide, densely pubescent. **Lip** obovate, 6.0-6.5 cm long by 5.5 cm width, apex distinctly 3-lobed, inner part deep red spotted with yellow, yellowish mottled with red stripes along the wrinkled margin. Filament 2.0-2.3 cm by 0.5 cm wide, cream speckled with pink; anther 1.2 cm long by 0.5 cm wide, yellow, not crested; staminode horn-like, 5 mm by 2 mm, red. **Infructescence** as long as inflorescence; fruits 2-4 cm in diameter, green when unripe, densely hairy.

Habitat distribution: In lowlands, edges of forests.

Medicinal properties: Unknown

Remarks: The locality of this species is currently undergoing vast logging and development of land. However, this species were also cultivated in several conservatory units.

11. *Alpinia murdochii* Ridl.

Alpinia murdochii Ridl., J. Straits Branch Roy. Asiat. Soc. 44 (1905) 196. – Lectotype:

A.M. Burn- Murdoch s.n. (February 1904) (K, designated by Holttum, 1950),
Selangor.

Distribution – Peninsular Malaysia.

Family: Zingiberaceae

Genus: *Alpinia*

Inflorescence



Flower



Infructescence



(continued) *Alpinia murdochii* Ridl.

Morphological description: **Stems** up to 2.0 meter tall. **Leaves** glabrous, up to 30 cm long by 7 cm width, oblanceolate, apex caudate (cauda 2-4cm long); base truncate, petiole 1-3 cm long; ligule up to 1.1 cm. **Inflorescence** erect, up to 15 cm, rachis bears up to 25 cincinni, each 1-3 flowers per cincinnus; primary bracts thin, brown, about 1.5 cm long by 0.7 cm width; secondary bracts cream, thin; calyx hairy, up to 1.5 cm long by 4mm wide, cream; corolla tube white, about the same size as calyx; dorsal lobe sparsely hairy, white, hooded, pointed at apex, 2.5 cm long by 1.0 cm width; lateral lobe sparsely hairy, white, hooded, 2.0 cm long by 0.8 cm wide. **Lip** broadly obovate 3-lobed, 2 cm length by 2cm width, white with maroon lines from base to apex and maroon smears at the sides of lip, white around the margin. Filament 1.5 cm long, white with maroon at base; anther 0.8 cm long by 0.4 cm wide, cream yellow with maroon smear, crested. **Infructescence** about the size of inflorescence; fruits globose, green when unripe, diameter about 2.0 cm.

Habitat distribution: In shaded areas of primary forests, highlands.

Medicinal properties: Unknown

Remarks: *Alpinia murdochii* and *Alpinia pahangensis* flowers looked strikingly similar although they are found in noticeably different altitudinal sites.

12. *Alpinia mutica* Roxb.

Alpinia mutica Roxb., *Asiat. Res.* 11 (1810) 354. – *Renealmia mutica* (Roxb.) Salisb., *Trans. Hort. Soc. London* 1 (1812) 280. – *Languas mutica* (Roxb.) Merr., *Univ. Calif. Publ. Bot.* 15 (1929) 35. – *Catimbium muticum* (Roxb.) Holttum, *Gard. Bull. Singapore* 13 (1950) 150. – Type: *Icones Roxburghianae 1929* (CAL).

Alpinia laxiflora Gagnep., *Bull. Soc. Bot. France* 48 (1901) LXXXXVIII. – *Languas laxiflora* (Gagnep.) Merr., *Univ. Calif. Publ. Bot.* 15 (1929) 34. – Type: *Talmy 233* (syn P), *E. Lefèvre 209* (syn P), *C. Thorel 121* (syn P).

Alpinia korthalsii K. Schum., *Pflanzenr.* IV, 46 (1904) 327. – *Languas korthalsii* (K. Schum.) Merr., *Univ. Calif. Publ. Bot.* 15 (1929) 34. – Type: *O. Beccaru 3557* (syn F!), *P.W. Korthals s.n.* (syn L!), *J. Montley 234* (syn K).

Distribution – Peninsular Malaysia, Singapore, Borneo, Kalimantan, Java, Sulawesi.

(continued) *Alpinia mutica* Roxb.

Family: Zingiberaceae

Genus: *Alpinia*

Clumps



Inflorescence and flower



Infructescence



(continued) *Alpinia mutica* Roxb.

Morphological description: Stems up to 2.0 metre tall. Leaves glabrous, 55 cm by 8 cm, apex caudate (cauda up to 3 cm long), base narrowly cuneate; petiole up to 3.0 cm long; ligule up to 1.0 cm. **Inflorescence** erect, up to 15 cm, rachis bears about 12 cincinni (2-3 flowers per cincinni); secondary bracts white, 1.0 cm long by 0.5 cm wide; calyx white, 2.0 cm by 0.5 cm wide, sparsely hairy; corolla tube shorter than calyx 1.5 cm by 0.4 cm wide, white; dorsal lobe white, hooded, 3.8 cm long by 2.8 cm wide, sparsely hairy; lateral lobe white, hooded, 3.5 cm by 1.7 cm, sparsely hairy. **Lip** broadly obovate, 3.5 long by 3.0 cm wide, basal concave with maroon spots and lines, apex yellow throughout the wrinkled margin. Filament 1.5 cm long, cream; anther yellow, 1.2 cm long, not crested. **Infructescence** about the size of inflorescence; fruits 2-3 cm in diameter, green when unripe, sparsely hairy with persistent calyx at the apex.

Habitat distribution: Commonly found in semi-shaded areas, usually in villages by ditches and streams.

Medicinal properties: Rhizomes were used to treat flatulence and the fruits to reduce swelling.

Remarks: Although *Alpinia mutica* can be found in several states, increasing land developments that were seen at the localities will be a threat to this species.

13. *Alpinia oxymitra* K. Schum.

Alpinia oxymitra K. Schum., Bot. Tidsskr. 24(3) (1902) 268. – *Cenolophon oxymitrum* (K. Schum.) Holttum, Gard. Bull. Singapore 13 (1950) 134. – Type: *J. Schmidt*. 798 (holo C, iso K!), Ko Chang.

Alpinia comosa Ridl., nom. illeg., J Straits Branch Roy. Asiat. Soc. 32 (1899) 170, non Jacq., 1791. – Lectotype: *H.N. Ridley 4443* (K, designated by Holttum, 1950, isolecto SING!), Kedah.

Alpinia macrocarpa Gagnep., Bull. Soc. Bot. France 53 (1906) 136. – Type: *Anon. s.n.* (May 1866) (syn P), *Anon. s.n.* (8 January 1864) (syn P), *Anon. s.n.* (1 April 1874) (syn P), *Anon. s.n.* (May 1870) (syn P), *J. B. L. Pierre s.n.* (April 1870) (syn P), *P. Hahn s.n.* (29 February 1896) (syn P), *A. Godefroy-Lebeuf 769* (syn P).

Distribution – Thailand, Peninsular Malaysia.

(continued) *Alpinia oxymitra* K. Schum.

Family: Zingiberaceae

Genus: *Alpinia*

Clumps



Single plant



Inflorescence and flower



(continued) *Alpinia oxymitra* K. Schum.

Morphological description: **Stems** up to 3 metre tall. **Leaves** glabrous, 45 cm by 5 cm width, apex caudate (cauda up to 4.0 cm long), base cuneate; petiole short (2-5 mm) or sessile; ligule 0.5-1.0 cm long by 1.0 cm wide. **Inflorescence** erect, up to 17 cm long, rachis bearing numerous compactly arranged single flowers that overlap each other when in bud; bracts 1.4 cm long, densely hairy, dorsally prolonged upwards into a pointed hood; calyx whitish cream, 1.2 cm ; corolla tube 1.5 mm long; dorsal lobe 1.6 cm long by 0.6 cm width, creamy green, hooded; lateral lobe 1.3 cm by 0.4 cm, creamy green, hooded. **Lip** broadly obovate, cream with yellow and red smear at the base, wrinkled around the margin. Filament 1.0 cm long, cream; anther 0.5 cm long by 0.3 cm width, cream, crested; staminode fan shaped, 0.5 cm. **Fruits** narrowly ellipsoid, longitudinally ribbed, greenish brown, 5 cm long by 1.5 cm wide, densely hairy with persistent calyx.

Habitat distribution: Cultivated in several conservatories, by the shaded hillside.

Medicinal properties: Unknown

Remarks: Previous recorded localities (Kedah Peak, Kelantan) are recently being developed into recreational area; hence, might threaten the population of this species. However, several conservatories have successfully cultivated *Alpinia oxymitra*.

14. *Alpinia pahangensis* Ridl.

Alpinia pahangensis Ridl., J. Fed. Malay States Mus. 10 (1920) 154. – *Languas pahangensis* (Ridl.) M.R. Hend., Gard. Bull. Straits Settlem. 7 (1933) 125. – Type: *I.H.N. Evans s.n. (July 1917)* (holo K, iso E!), Pahang.

Alpinia burkillii M.R. Hend., Gard. Bull. Straits Settlem. 4 (1927) 55. – Type: *I.H. Burkill 4980* (syn SING!), *I.H. Burkill & M. Haniff 17310* (syn SING!), *I.H. Burkill & M. Haniff 17461* (syn SING!).

Distribution – Peninsular Malaysia.

(continued) *Alpinia pahangensis* Ridl.

Family: Zingiberaceae

Genus: *Alpinia*

Clumps



Inflorescence and flower



Infructescence



(continued) *Alpinia pahangensis* Ridl.

Morphological description: **Stems** up to 3.0 metre tall. **Leaves** sparsely hairy, 74 cm long by 13.0 cm width; apex caudate (cauda up to 3 cm); base unequally cuneate; petiole 5 cm; ligule bilobed, 1.5 cm. **Inflorescence** erect, up to 30 cm long; rachis bears 20-25 cincinni with 2-5 flowers each; secondary bracts 2-3 cm, cream, thin; calyx 2.5 cm, cream, sparsely hairy; corolla tube shorter than calyx; dorsal lobe 2.5 cm long by 1.0 cm width, cream, hooded with strongly concave apex; lateral lobe narrower, 2.5 cm long by 0.7 cm width, cream, hooded. **Lip** trilobed, white with two maroon patches on both sides, deep maroon lines spreading at the median towards apex, white throughout the slight concave margin. Filament 1.6 cm, cream; anther 1.3 cm by 0.5 cm wide, cream with maroon patches, crested; staminode dark maroon, 0.2 cm by 0.2 cm. **Inflorescence** shorter than inflorescence, fruits green, sparsely hairy, diameter about 2.5 cm with persistent dried calyx on the apex.

Habitat distribution: In open or semi shaded areas in the lowlands.

Medicinal properties: Unknown

Remarks: The localities of *Alpinia pahangensis* (restricted to the state of Pahang) are currently undergoing vast logging and increasing land developments; therefore may threaten the population of this species. Several attempts were made to replant the species in conservatory garden; unfortunately it doesn't seem to acclimatise well outside Pahang.

15. *Alpinia petiolata* (Bak.) Holtt.

Alpinia petiolata Baker, Fl. Brit. India 6 (1892) 255. – *Cenolophon petiolatum* (Baker) Holttum, Gard. Bull. Singapore 13 (1950) 136. – Type: *H.H. Kunstler 6357* (iso L!, P!, SING).

Distribution – Peninsular Malaysia.

Family: Zingiberaceae

Genus: *Alpinia*

Single plant



Leaves and petioles



Inflorescence and flower



(continued) *Alpinia petiolata* (Bak.) Holtt.

Morphological description: Stems up to 1.5 metre. Leaves glabrous, 50 cm by 10 cm width; apex shortly caudate; base gradually narrowed; petiole up to 15 cm, slender; ligule 1.5 cm. **Inflorescence** drooping, slender, up to 20 cm long, sheaths brown, 15 cm long, rachis bears single flowers up to 10 mm apart; bracts 1.0 cm long; calyx white flushed with pink, 2.5 cm long by 0.6 cm wide; corolla tube shorter than calyx, white; dorsal lobe creamy white, 2.5 cm long by 1.0 cm wide, concave; lateral lobe narrower, 2.5 cm by 0.8 cm wide, creamy white, concave. Lip obovate, 4.5 cm long by 3.5 cm wide, cream with maroon and yellow lines spreading from base towards apex, thicker lines on median, white wrinkled margin. Filament 1.5 cm long, white ; anther 1.3 cm, cream with pink towards apex, crested (crescent-shaped). **Fruits** not seen.

Habitat distribution: At shaded highland areas.

Medicinal properties: Unknown

Remarks: This species were only seen in Pahang, particularly Fraser's Hill. Other recorded areas in Perak, Selangor and Negeri Sembilan were not found.

16. *Alpinia rafflesiana* Wall. ex Baker

Alpinia rafflesiana Wall. ex Baker, Hooker's Icon. Pl. 20 (1891) t. 1963. – *Languas rafflesiana* (Wall. ex Baker) Burkill, Bull. Misc. Inform. (1935) 318. – Type: *N. Wallich* 6575 (holo K).

Alpinia aurantiaca Wall. ex Baker, nom. nud., Fl. Brit. India 6 (1892) 255.

Alpinia aurantiaca Ridl., J. Fed. Malay States Mus. 4(1) (1909) 78. – Lectotype: *H.N. Ridley* 13896 (K, designated by Turner, 2000), Pahang.

Distribution – Peninsular Malaysia.

(continued) *Alpinia rafflesiana* Wall. ex Baker

Family: Zingiberaceae

Genus: *Alpinia*

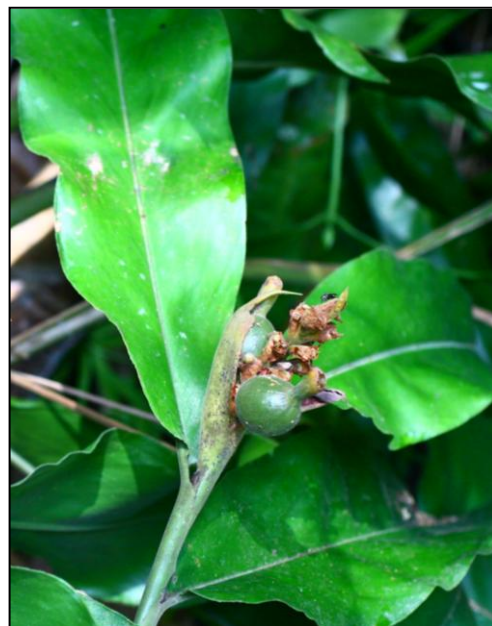
Clumps



Inflorescence and flower



Infructescence



(continued) *Alpinia rafflesiana* Wall. ex Baker

Morphological description: **Stems** up to 1.6 metre tall. Leaves hairy, 55 cm long by 9 cm wide; apex caudate (cauda up to 5 cm) ; base cuneate; petiole up to 3.5 cm; ligule 2.0 cm, swollen. **Inflorescence** erect, short and stout up to 7 cm; primary bracts up to 1.5 cm long, orange-red; secondary bracts 1.2 cm long, maroon, sparsely hairy; rachis bears many short cincinni; calyx maroon red, 1.5 cm long, sparsely hairy; corolla tube 1.6 cm long, orange, slightly hairy; dorsal lobe strongly hooded, yellow with dark maroon on the apex; lateral lobe, 4 cm long by 1.6 cm wide, yellow orange, hooded. **Lip** obovate, orange red with orange lines spreading from base towards the apex, orange yellow wrinkled margin; staminode triangular, 0.3 cm long, maroon. Filament 1.3cm long, yellow with maroon at the base; anther yellow orange, crested, 1.0 cm long by 0.6 cm wide. **Fruits** green, 2 cm diameter, sparsely hairy with persistent calyx at the apex.

Habitat distribution: Semi shaded areas in low to mid-lands

Medicinal properties: Unknown

Remarks: *Alpinia rafflesiana* was recorded as common in Peninsular Malaysia but now it has become rare. The compact orange-red inflorescence is distinctive.

17. *Alpinia scabra* (Blume) Näves

Alpinia scabra (Blume) Näves, Nov. app. (1880) 226. – Basionym: *Hellenia scabra* Blume, Enum. pl. Javae (1827) 60. – *Languas scabra* (Blume) Burkill, Gard. Bull. Straits Settlem. 6 (1930) 260. – Type: *H. Kuhl & J.C. van Hasselt s.n. (September)* (holo L!), Hariang.

Distribution – Java.

Family: Zingiberaceae

Genus: *Alpinia*

Clumps



Inflorescence and flower



Infructescence



(continued) *Alpinia scabra* (Blume) Naves

Morphological description: **Stems** up to 3.0 metre tall. Leaves glabrous with stiff hairs at the margin, 50 cm long by 9 cm width; apex acuminate; base cuneate; petiole 1.0 cm long; ligule 1.0 cm long. **Inflorescence** erect, up to 45 cm; rachis bears short cincinni (up to 6 flowers per cincinni); calyx 0.6 cm, cream white, sparsely hairy; corolla tube 0.8 cm long, creamy green; dorsal lobe 1.0 cm long by 0.4 cm wide, creamy green, hooded; lateral lobe same size as dorsal, hooded, creamy green. **Lip** shorter than corolla tube, creamy white, cleft to the base, 0.6 cm by 0.3 cm wide. Filament slender, 1.0 cm long, cream with green at apex; anther 0.5 cm by 0.2 cm wide, crested, yellowish cream. **Infructescence** red, up to 30 cm long, fruits green when unripe; blue-black on ripening, diameter 0.5 cm.

Habitat distribution: Usually in highland areas at the border of waterfall or streams.

Medicinal properties: Unknown

Remarks: *Alpinia scabra* flowers closely resembles *Alpinia galanga*, a lowland, commonly cultivated species in Peninsular Malaysia. However, other than its flowers, the location, fruits and vegetative structures are strikingly dissimilar.

18. Alpinia suriana Lim

Alpinia suriana Lim

Distribution – Peninsular Malaysia.

Family: Zingiberaceae

Genus: *Alpinia*

Clumps



Inflorescence and flower



Infructescence



(continued) *Alpinia suriana* Lim

Morphological description: **Stems** up to 1.5 metre tall. Leaves densely hairy, 60 cm long by 11.5 cm width; apex acuminate-caudate; base cuneate or obtuse; petiole up to 5.0 cm long; ligule 2.0 cm long, reddish. **Inflorescence** erect, up to 10 cm; primary bracts hairy, hooded, 6.0 cm by 2.0 cm width; rachis bears 10-15 cincinni (3-4 flowers per cincinni); calyx 1.3 cm, pink with white base, hairy; corolla tube a little shorter than calyx, yellow; dorsal lobe 2.3 cm long by 1.2 cm wide, yellow, apex reddish, hooded; lateral lobe 2.0 cm by 1.0 cm wide, hooded, yellow with reddish apex. **Lip** broadly obovate, 3.0 cm by 3.5 cm wide, crenulate edge, yellow with red stripes at the middle from base to tri-lobed apex. Filament 0.7 cm long, yellow; anther 1 cm long, non-crested, yellow, short-hairy. **Infructescence** up to 9 cm long, fruits green when unripe, sparsely hairy, diameter 1.5 cm.

Habitat distribution: Cultivated in conservatory, shaded area. Originally collected from Sungai Tekam Forest Reserve, Pahang

Medicinal properties: Unknown

Remarks: This new species might be closely related to *Alpinia rafflesiana* as their flowers are relatively similar in shape and colour. It differs from *Alpinia rafflesiana* by its non-crested anther.

19. *Alpinia vitellina* (Lindl.) Ridl.

Alpinia vitellina (Lindl.) Ridl., J. Straits Branch Roy. Asiat. Soc. 32 (1899) 173. –

Basionym: *Amomum vitellinum* Lindl., J. Hort. Soc. London 2 (1847) 245. –

Cenolophon vitellinum (Lindl.) Horan., Prodr. Monogr. Scitam. (1862) 36. –

Cardamomum vitellinum (Lindl.) Kuntze, Revis. gen. pl. 2 (1891) 687. – *Languas*

vitellina (Lindl.) Alston, Handb. fl. Ceylon 6 (1931) 282. – Type: *J. Lindley s.n.*

(holo K), Penang.

Alpinia wrayi King ex Baker, Fl. Brit. India 6 (1892) 254. – Type: *H.H. Kunstler s.n.*

(K).

Distribution – Peninsular Malaysia.

(continued) *Alpinia vitellina* (Lindl.) Ridl.

Family: Zingiberaceae

Genus: *Alpinia*

Clumps



Single plant



Infructescence



(*continued*) *Alpinia vitellina* (Lindl.) Ridl.

Morphological description: **Stems** up to 1.5 metre tall. **Leaves** 40 cm long by 11cm wide, slightly wrinkled, glabrous and shiny; apex acuminate; base cuneate; petiole slender, up to 15 cm; ligule 1.7 cm. Inflorescence not seen. **Infructescence** up to 20 cm, hairy, fruits green when unripe, narrowly ellipsoid, 3.5 cm by 1.0 cm, sparsely hairy with persistent calyx at apex.

Habitat distribution: At shaded areas, hillside (low to midland) near lake streams

Medicinal properties: Unknown

Remarks: The vegetative characteristics of *Alpinia vitellina* are highly variable. Only fruits were observed even though numerous field work were done at the localities. While it has been recorded in Penang, Johor and Selangor; the vast development at these areas has made it impossible to be found at neither the location nor its surrounding areas. This specimen was encountered in Negeri Sembilan forest reserve and cultivated in Suriana Garden, Penang.

20. *Alpinia vitellina* var. *cannifolia* (Ridl.) Holtt.

Alpinia vitellina var. *cannifolia* (Ridl.) Holtt., Novon 6 (1996) 223. – Basionym: *Alpinia cannifolia* Ridl., J. Straits Branch Roy. Asiat. Soc. 32 (1899) 174. – *Languas cannifolia* (Ridl.) Burkill, Bull. Misc. Inform. (1935) 318. – Lectotype: *H.N. Ridley s.n.* (K, designated by Smith, 1990, isolecto SING!), Selangor.

Distribution – Peninsular Malaysia.

Family: Zingiberaceae

Genus: *Alpinia*

Clumps



Single plant



(continued)*Alpinia vitellina* var. *cannifolia* (Ridl.) Holtt.

Morphological description: **Stems** up to 1.5 metre tall. **Leaves** 40 cm long by 15 cm wide, slightly wrinkled, glabrous and shiny; apex acuminate; base cuneate; petiole slender, up to 8 cm; ligule 2.0 cm. **Flowers** not seen. **Fruits** not seen.

Habitat distribution: Cultivated in conservatory, semi-shaded area

Medicinal properties: Unknown

Remarks: The vegetative characteristics of *Alpinia vitellina* var. *cannifolia* closely resemble *Alpinia vitellina*. The localities of this species are currently undergoing vast development of land. However, this species was also cultivated in Suriana Garden, Penang.

21. *Alpinia zerumbet* (Pers.) B.L. Burtt & R.M. Sm.

Alpinia zerumbet (Pers.) B.L. Burtt & R.M. Sm., Notes Roy. Bot. Gard. Edinburgh 31 (1972) 204. – Basionym: *Zerumbet speciosum* J.C. Wendl., Sert. hannov. 1 (1978) 3, t. 19. – *Costus zerumber* Pers., nom. nov., Syn. pl. 1 (1805) 3. – *Alpinia speciosa* (J.C. Wendl.) K. Schum., nom. illeg., Fl. Kais. Wilh. Land (1889) 29. – *Languas speciosa* (J.C. Wendl.) Small, Fl. s.e. U.S. 2 (1913) 307. – *Catimbium speciosum* (J.C. Wendl.) Holttum, Gard. Bull. Singapore 13 (1950) 152 – Type: *J.C. Wendland s.n.* (GOET).

Alpinia schumanniana Valeton, Bull. Inst. Bot. Buitenzorg 20 (1904) 84. – *Languas schumanniana* (Valeton) Sasaki, Trans. Nat. Hist. Soc. Taiwan 14 (1924) 23. – Type: *T.valeton s.n.* (holo BO), 55 Taiwan.

Alpinia fimbriata Gagnep., Bull. Soc. France 51 (1905) 447. – Type: *Anon s.n.* (HB XI B4) (BO)

Alpinia flavitalis Hayata, Ic. pl. formos. 5 (1915) 227. – Type: Material not located.

Distribution – Peninsular Malaysia.

(continued) *Alpinia zerumbet* (Pers.) B.L. Burtt & R.M. Sm.

Family: Zingiberaceae

Genus: *Alpinia*

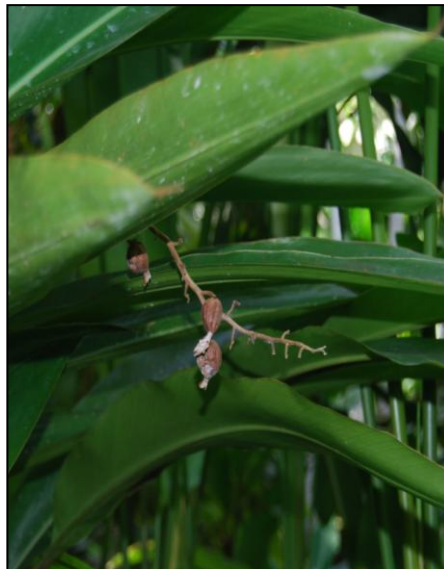
Clumps



Inflorescence and flower



Infructescence



(*continued*) *Alpinia zerumbet* (Pers.) B.L. Burtt & R.M. Sm.

Morphological description: **Stems** up to 2.0 metre tall. **Leaves** sparsely hairy at the margin, 60 cm long by 10 cm wide, apex shortly acuminate, base narrowly cuneate; petiole 2.5 cm; ligule 1.2 cm, hairy. **Inflorescence** usually decurved or drooping, up to 25 cm; rachis bears about 35 cincinni with 2 flowers each; secondary bracts 2.5 cm long by 1.5 cm wide, white with pink at apex; calyx 2.0 cm long, white with pink at apex; corolla tube shorter than calyx; dorsal lobe 2.5 cm long by 1.0 cm wide, white with pink at apex, hooded; lateral lobe narrower, 2.5 cm long by 0.6 cm wide, white with pink at apex, hooded. **Lip** obovate, 3.5 cm long by 3.0 cm wide, deeply lobed, inner part deep red spotted with yellow, yellow mottled with red stripes along the wrinkled margin. **Fruits** orange when ripe, diameter 2.0 cm, sparsely hairy.

Habitat distribution: Grown in clumps at low elevated areas.

Medicinal properties: Unknown

Remarks: This species is introduced as an ornamental in Peninsular Malaysia, originated from North-East India, Burma and Indo-China. Worldwide, *Alpinia zerumbet* is commonly cultivated in botanical gardens and other recreational parks.

3.2. Sequence variation analysis

DNA sequencing of ITS and *matK* was done for 20 and 18 species respectively, where two species, *Alpinia petiolata* and *Alpinia latilabris* failed to be amplified for *matK* region and *Alpinia javanica*, *Alpinia mutica* and *Alpinia rafflesiana* were represented by more sequences to denote the various sampling location they were collected from, since they were commonly found in Peninsular Malaysia. Direct sequencing successfully generated the entire internal transcribed spacer region (ITS) of a total number of 72 taxa of *Alpinia* species from Peninsular Malaysia while partial sequence of maturase K (*matK*) gene produced 52 taxa of *Alpinia* species (Table 3.2). All generated sequences were used to construct ITS and *matK* phylogenetic trees.

Table 3.2 List of species and the generated sequences of internal transcribed spacer region (ITS) and maturase K (*matK*) with their corresponding Genbank accession number (*pending*).

Species	Location	Specimen code	GenBank accession number	
			ITS	<i>matK</i>
<i>Alpinia aquatica</i>	Rimba Ilmu, UM (Kuala Lumpur)	N9	KJ507884	KJ507831
	Hutan Simpan Menchali, Rompin (Pahang)	N149	KJ507882	KJ507830
	Rimba Ilmu, UM (Kuala Lumpur)	N263	KJ507883	KJ507832
<i>Alpinia assimilis</i>	Suriana Gardens, Balik Pulau (Penang)	N140	KJ507885	
	Suriana Gardens, Balik Pulau (Penang)	N230	KJ507886	
	Suriana Gardens, Balik Pulau (Penang)	N231	KJ507887	KJ507853
<i>Alpinia capitellata</i>	Suriana Gardens, Balik Pulau (Penang)	N200	KJ507888	KJ507842

Table 3.2 (continued)

Species	Location	Specimen code	GenBank accession number	
			ITS	matK
	Suriana Gardens, Balik Pulau (Penang)	N201	KJ507889	KJ507843
	Suriana Gardens, Balik Pulau (Penang)	N202	KJ507890	KJ507844
<i>Alpinia conchigera</i>	Rimba Ilmu, UM (Kuala Lumpur)	N3	KJ507891	KJ507836
	Kerian (Perak)	N43	KJ507892	KJ507838
	Penang Botanic Gardens (Penang)	N46	KJ507893	KJ507837
<i>Alpinia galanga</i>	Rimba Ilmu, UM (Kuala Lumpur)	N5	KJ507896	KJ507840
	Tasik Chini, Pekan (Pahang)	N58	KJ507897	KJ507841
	Hutan Lipur Ulu Licin, Beruas (Perak)	N101	KJ507894	KJ507839
	Hutan Simpan Sungai Nipah, Kemaman (Terengganu)	N129	KJ507895	
<i>Alpinia javanica</i>	Hutan Simpan Berembun, Jelebu (Negeri Sembilan)	N24	KJ507904	KJ507865
	Fraser's Hill (Pahang)	N25	KJ507905	KJ507864
	Rimba Ilmu, UM (Kuala Lumpur)	N36	KJ507906	KJ507866
	Hutan Sungai Nipah, Kemaman (Terengganu)	N100	KJ507901	KJ507867
	Suriana Gardens, Balik Pulau (Penang)	N206	KJ507902	KJ507868
	Endau-Rompin, Mersing (Johor)	FRI50213	KJ507903	KJ507869
<i>Alpinia javanica</i> var. <i>colorata</i>	Piah Forest Reserve, Lasah (Perak)	N87	KJ507900	KJ507833
	Hutan Lipur Ulu Licin, Beruas (Perak)	N127	KJ507898	KJ507834
	Suriana Gardens, Balik Pulau (Penang)	N133	KJ507899	KJ507835
<i>Alpinia latilabris</i>	Rimba Ilmu, UM (Kuala Lumpur)	N2	KJ507908	
	Penang Botanic Gardens (Penang)	N44	KJ507909	

Table 3.2 (continued)

Species	Location	Specimen code	GenBank accession number	
			ITS	matK
	FRIM, Kepong (Selangor)	N82	KJ507907	
	Suriana Gardens, Balik Pulau (Penang)	N137	KJ507910	
<i>Alpinia macrostephana</i>	Suriana Gardens, Balik Pulau (Penang)	N134	KJ507911	KJ507861
	Suriana Gardens, Balik Pulau (Penang)	N224	KJ507912	
	Suriana Gardens, Balik Pulau (Penang)	N225	KJ507913	
<i>Alpinia malaccensis</i> <i>var. nobilis</i>	Simpang Pulai, Cameron Highlands (Pahang)	N50	KJ507915	KJ507851
	FRIM, Kepong (Selangor)	N83	KJ507916	KJ507852
	Suriana Gardens, Balik Pulau (Penang)	N141	KJ507914	
<i>Alpinia murdochii</i>	Genting Highlands (Pahang)	N33	KJ507918	KJ507845
	Fraser's Hill (Pahang)	N53	KJ507919	KJ507846
	Genting Highlands (Pahang)	N300	KJ507917	
<i>Alpinia mutica</i>	Tasik Chini, Pekan (Pahang)	N60	KJ507923	KJ507854
	FRIM, Kepong (Selangor)	N84	KJ507924	
	Kerian (Perak)	N128	KJ507920	KJ507855
	Suriana Gardens, Balik Pulau (Penang)	N236	KJ507921	KJ507856
	Rimba Ilmu, UM (Kuala Lumpur)	N267	KJ507922	KJ507857
<i>Alpinia oxymitra</i>	Suriana Gardens, Balik Pulau (Penang)	N71	KJ507925	KJ507858
	FRIM, Kepong (Selangor)	N81	KJ507926	KJ507859
	Rimba Ilmu, UM (Kuala Lumpur)	N86	KJ507927	KJ507860
<i>Alpinia pahangensis</i>	Tasik Chini, Pekan (Pahang)	N56	KJ507930	KJ507870

Table 3.2 (continued)

Species	Location	Specimen code	GenBank accession number	
			ITS	matK
	Tasik Chini, Pekan (Pahang)	N248	KJ507928	KJ507871
	Tasik Chini, Pekan (Pahang)	N249	KJ507929	KJ507872
<i>Alpinia petiolata</i>	Fraser's Hill (Pahang)	N26	KJ507932	
	Genting Highlands (Pahang)	N109	KJ507931	
	Fraser's Hill (Pahang)	N264	KJ507933	
<i>Alpinia rafflesiana</i>	Hutan Simpan Berembun, Jelebu (Negeri Sembilan)	N65	KJ507938	KJ507881
	Gunung Bunga Buah, Genting Highlands (Pahang)	N112	KJ507934	KJ507877
	Hutan Lipur Ulu Kenas, Kuala Kangsar (Perak)	N124	KJ507935	KJ507880
	Hutan Simpan Gunung Panti, Kota Tinggi (Johor)	FRI50145	KJ507936	KJ507878
	Hutan Simpan Ulu Sedili, Pontian (Johor)	FRI50237	KJ507937	KJ507879
<i>Alpinia scabra</i>	Fraser's Hill (Pahang)	N29	KJ507939	KJ507847
	Genting Highlands (Pahang)	N31	KJ507941	
	Genting Highlands (Pahang)	N301	KJ507940	KJ507848
<i>Alpinia suriana</i>	Suriana Gardens, Balik Pulau (Penang)	N131	KJ507942	KJ507873
	Suriana Gardens, Balik Pulau (Penang)	N227	KJ507943	
	Suriana Gardens, Balik Pulau (Penang)	N228	KJ507944	KJ507874
<i>Alpinia vitellina</i>	Penang Botanic Gardens (Penang)	N49	KJ507949	
	Hutan Simpan Berembun, Jelebu (Negeri Sembilan)	N66	KJ507950	KJ507876
	Suriana Gardens, Balik Pulau (Penang)	N144	KJ507948	KJ507875

Table 3.2 (continued)

Species	Location	Specimen code	GenBank accession number	
			ITS	matK
<i>Alpinia vitellina</i> var. <i>cannifolia</i>	Suriana Gardens, Balik Pulau (Penang)	N245	KJ507945	KJ507862
	Suriana Gardens, Balik Pulau (Penang)	N246	KJ507946	KJ507863
	Suriana Gardens, Balik Pulau (Penang)	N247	KJ507947	
<i>Alpinia zerumbet</i>	Rimba Ilmu, UM (Kuala Lumpur)	N6	KJ507952	KJ507850
	Putrajaya	N73	KJ507953	KJ507849
	Rimba Ilmu, UM (Kuala Lumpur)	N265	KJ507951	
Total sequence			72	52

3.2.1 Molecular characterization of ITS sequences

The alignments consisted of 104 taxa, inclusive of 72 taxa of *Alpinia* species from Peninsular Malaysia and 32 reference sequences of Genbank, which include *Alpinia* species and outgroup taxa from subfamily Riedelieae (Table 2.1). The total alignment length of ITS1-5.8S-ITS2 region for *Alpinia* species in Peninsular Malaysia is 621bp or 621 sites (unaligned raw sequences ranged from 620 bp to 689 bp). ITS 1 spacer had total aligned length of 190 bp with a mean GC content of 55.3%, the 5.8S region had an aligned length of 166 bp and GC content of 51%, and the ITS 2 aligned length was 248 bp with GC content of 58.4%.

Of these nucleotide sites, 459 were invariant across all taxa, and 152 (24.5%) were parsimony informative (Table 3.3) found largely at ITS 1 region (Figure 3.2). An average number of nucleotide frequencies in percentage across the entire alignment are as follows: T: 24.6, C: 24.0, A: 20.1 and G: 31.4 (Table 3.4). All ITS sequences showed average base composition of T and C (~24%), and high amount of Guanine content (31.4%). The rate of transition for ITS sequences is higher than the transversional sites (Table 3.6).

3.2.2 Molecular characterization of *matK* sequences

Partial sequence of *matK* gene was obtained from direct sequencing. natKf and natKr primer (primer set 1) produced longer sequence length (unaligned raw sequence ranged from 1100 bp to 1362 bp) than 3f and 1r primer (primer set 2) pair (unaligned raw sequence ranged from 865 bp to 892 bp). Trimmed aligned sequences for data set of both primers consisted of 52 taxa of *Alpinia* species from Peninsular Malaysia, and 30 reference sequences of *Alpinia* species and outgroup taxa from subfamily Riedelieae (Table 2.1).

Combined alignments of *Alpinia* species from Peninsular Malaysia produced a total aligned length of 866 bp with a mean GC content of 30.1%.

matK gene region are more conserved compared to ITS region, where only 49 bp (5.7%) were parsimony informative (Table 3.3), which are mostly found at 200-400 position (Figure 3.2). An average number of nucleotide frequencies in percentage across the entire alignment are as follows: T: 38.7, C: 15.1, A: 31.3 and G: 15.0 (Table 3.5). Base composition of G and C for *matK* sequences is quite similar and the amount of Thymine is higher than other nucleotides (38.7%). The rate of transition and transversion for *matK* sequences is similar in the first codon, and biased towards transitions for second and third codon (Table 3.6).

Table 3.3: Frequencies and proportion of variable and parsimony-informative sites found in ITS and *matK* sequences.

ITS	Total variable 162/621 = 26.1%	Parsimony-informative 152/621 = 24.5%
ITS1	66/190	65/190
5.8S	16/166	14/166
ITS2	78/248	73/248
<i>matK</i>	Total variable 53/866 = 6.1%	Parsimony-informative 49/866=4.9%

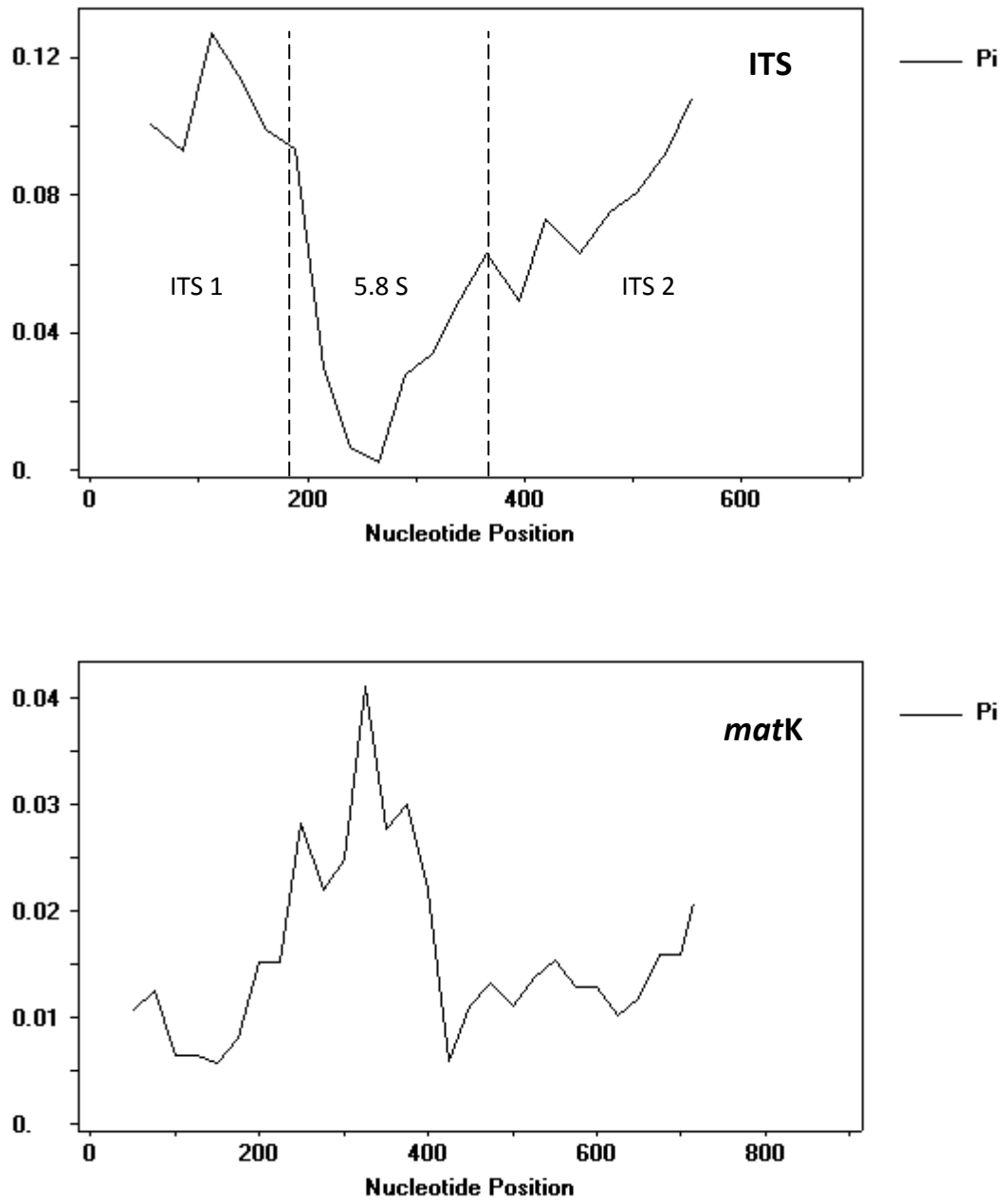


Figure 3.2: Comparison of the distribution and levels of variability (parsimony-informative sites, Pi) between internal transcribed spacer region (ITS) and maturase K gene (*matK*).

Table 3.4 Composition of nucleotides and their percentage (%) in ITS sequences.

Species	Number of samples (n)	ITS region (621 bp)			
		T	C	A	G
<i>A. aquatica</i>	3	23.2	24.7	19.5	32.6
<i>A. capitellata</i>	3	24.7	23.7	19.9	31.7
<i>A. cf. assimilis</i>	3	23.5	25.4	20.8	30.3
<i>A. conchigera</i>	3	23.6	25.2	21	30.2
<i>A. galanga</i>	4	24.8	23.7	21.2	30.4
<i>A. javanica</i>	6	25	23.3	19.6	32.1
<i>A. javanica. var. colorata</i>	3	24.9	23.3	19.2	32.6
<i>A. latilabris</i>	4	24.6	23.7	19.4	32.3
<i>A. macrostephana</i>	3	25	23.9	19.6	31.5
<i>A. malaccensis. var. nobilis</i>	3	24.5	23.8	19.2	32.5
<i>A. murdochii</i>	3	25.4	23.1	20.6	30.9
<i>A. mutica</i>	5	24.2	24.7	20.6	30.5
<i>A. oxymitra</i>	3	25.4	23.1	20.6	30.9
<i>A. pahangensis</i>	3	23.5	25.4	20.5	30.7
<i>A. petiolata</i>	3	25	23.3	19.7	32
<i>A. rafflesiana</i>	5	25.6	22.5	20.2	31.6
<i>A. scabra</i>	3	25.8	22.3	20.5	31.4
<i>A. suriana</i>	3	25.2	23.3	19.5	31.9
<i>A. vitellina. var. cannifolia</i>	3	25.2	23.3	19.6	31.9
<i>A. vitellina</i>	3	23.5	25.4	20.5	30.7
<i>A. zerumbet</i>	3	25	23.3	20.5	31.2
Average		24.6	24.0	20.1	31.4

Table 3.5 Composition of nucleotides and their percentage (%) in *matK* sequences.

Species	Number of samples (n)	matK region (866 bp)															
		First codon				Second codon				Third codon							
		T	C	A	G	T	C	A	G	T	C	A	G	T	C	A	G
<i>A.aquatica</i>	3	33.9	21.1	30.8	14.2	34.6	16.6	32.9	15.9	46.5	8.3	29.5	15.6	38.3	15.4	31.1	15.2
<i>A.capitellata</i>	3	34.3	20.9	31.0	13.8	36.0	15.2	32.5	16.3	46.3	8.7	30.8	14.2	38.8	14.9	31.4	14.8
<i>A.cf.assimilis</i>	1	33.6	21.8	30.1	14.5	34.9	16.3	33.2	15.6	45.8	8.7	30.2	15.3	38.1	15.6	31.2	15.1
<i>A.conchigera</i>	3	33.5	21.9	29.9	14.7	36.7	14.8	32.9	15.6	46.4	8.7	30.2	14.6	38.9	15.1	31.0	15.0
<i>A.galanga</i>	3	33.7	21.9	30.1	14.3	35.8	15.1	33.0	16.1	46.2	8.7	30.6	14.6	38.5	15.2	31.2	15.0
<i>A.javanica</i>	6	34.6	20.5	31.4	13.5	35.6	15.3	32.5	16.6	46.5	8.7	30.4	14.4	38.9	14.8	31.4	14.8
<i>A.javanica.var.colorata</i>	4	34.3	20.6	31.3	13.8	36.0	15.2	32.5	16.3	46.5	8.7	30.4	14.4	38.9	14.9	31.4	14.8
<i>A.macrostephana</i>	1	33.6	21.1	30.8	14.5	34.9	16.3	32.9	15.9	45.5	8.7	30.6	15.3	38.0	15.4	31.4	15.2
<i>A.malaccensis.var.nobilis</i>	2	33.9	21.5	30.4	14.2	34.9	16.1	33.4	15.6	45.8	8.7	30.2	15.3	38.2	15.4	31.4	15.0
<i>A.murdochii</i>	2	34.6	20.8	31.1	13.5	36.0	14.9	32.5	16.6	46.9	8.3	30.2	14.6	39.1	14.7	31.3	14.9
<i>A.mutica</i>	4	34.3	21.5	30.1	14.2	34.9	16.3	32.9	15.9	45.8	8.7	30.2	15.3	38.3	15.5	31.1	15.1
<i>A.oxymitra</i>	3	33.9	21.5	30.5	14.1	34.9	16.3	32.8	16.1	46.3	8.7	30.0	14.9	38.4	15.5	31.1	15.0
<i>A.pahangensis</i>	3	34.3	20.8	31.1	13.8	36.0	15.2	32.5	16.3	47.2	8.3	30.2	14.2	39.1	14.8	31.3	14.8
<i>A.rafflesiana</i>	5	34.3	20.8	31.1	13.8	36.0	15.2	32.5	16.3	46.9	8.3	30.2	14.6	39.0	14.8	31.3	14.9
<i>A.scabra</i>	2	33.9	20.8	31.5	13.8	36.0	15.2	32.9	15.9	47.2	8.3	30.7	13.7	39.0	14.8	31.7	14.5
<i>A.suriana</i>	2	34.3	20.8	31.1	13.8	36.0	15.2	32.5	16.3	46.9	8.3	30.2	14.6	39.0	14.8	31.3	14.9
<i>A.vitellina</i>	2	34.3	21.3	30.6	13.8	34.6	16.3	32.9	16.3	46.5	8.0	30.2	15.3	38.5	15.2	31.2	15.1
<i>A.vitellina.var.cannifolia</i>	2	33.9	21.1	31.0	14.0	34.8	16.3	32.9	16.1	46.2	8.3	30.2	15.3	38.3	15.2	31.4	15.1
<i>A.zerumbet</i>	1	34.3	21.5	30.4	13.8	34.6	16.3	32.9	16.3	46.2	8.3	30.2	15.3	38.3	15.4	31.2	15.1
Average		34.1	21.1	30.8	14.0	35.5	15.6	32.7	16.2	46.5	8.5	30.3	14.7	38.7	15.1	31.3	15.0

Table 3.6 Base frequencies found in ITS and *matK* sequences.

	ii	si	sv	R	TT	TC	TA	TG	CT	CC	CA	CG	AT	AC	AA	AG	GT	GC	GA	GG	Total
ITS	174.7	10.33	3	7.49	42.67	3	0.67	0.33	3	41.67	0	0.67	0.67	0	35	2.33	0.33	0.67	2.33	55.67	188.63
<i>matK</i>																					
1st codon	284	2	2	1.42	97	1	0	0	0	60	0	0	0	1	87	1	0	0	1	40	287.54
2nd codon	284	3	1	2.5	101	1	0	0	1	44	0	0	0	0	93	1	0	0	0	46	287.54
3rd codon	279	6	2	3.68	131	2	0	0	2	22	0	0	0	0	85	1	0	0	1	41	286.54
Avg	847	11	4	2.53	329	3	0	1	3	126	1	0	1	1	266	2	1	0	2	126	861.62

*All frequencies are averages over all taxa. ii – identical pairs; si – transitional pairs; sv – transversional pairs; R – si/sv.

3.3 Phylogenetic relationships of *Alpinia* species based on ITS and *matK*

A total of 72 ITS sequences generated in this study were aligned with reference and outgroup sequences obtained from Genbank, whereas for *matK*, 52 generated sequences were aligned with Genbank reference sequences (Table 3.2 and Table 2.1).

3.3.1 Model of evolution

jModeltest 2.0 result of Aikake Information Criterion (AIC) suggested the Tamura-Nei evolutionary model of equal frequency of base nucleotide with invariable and gamma distribution (TrNef+I+G; I=0.2550; G=0.96000) for ITS sequences, whereas for partial *matK* sequences, the program jModeltest 2.0 suggested the transition model with invariable and gamma distribution (TIM1+I+G; I=0.5860; G=0.9270).

Base frequencies (A, C, G, and T) for ITS were equal with incorporated rate matrix for the substitution model in BI analysis: [A-C] = 1.0000; [A-G] = 5.3110; [A-T] = 1.0000; [C-G] = 1.0000; [C-T] = 7.9116; [G-T] = 1.0000. Unequal base frequencies were observed in *matK* with 0.3126, 0.1536, 0.1572, and 0.3766 for A, C, G, and T respectively. The incorporated rate matrix for CR were [A-C] = 1.0000; [A-G] = 2.0392; [A-T] = 0.2125; [C-G] = 0.2125; [C-T] = 1.3280; [G-T] = 1.0000.

3.3.2 Phylogenetic trees

All phylogenetic tree building methods, Neighbour Joining (NJ), Maximum Parsimony (MP), Bayesian inference (BI), generally produce similar ITS tree topologies (Appendix 5.0), although Bayesian analysis produced the most resolved ITS phylogenetic tree. Therefore, the phylogenetic relationships were based on Bayesian analysis with the inclusion of bootstrap values of NJ and MP results in the phylogram.

However for partial *matK* sequences, although Bayesian method resolved most of the taxa relationship, Neighbour Joining analysis produced a more defined phylogram. Therefore the phylogram was based on the Neighbour Joining tree with the inclusion of MP bootstrap values and BI posterior probabilities.

The ITS phylogram of *Alpinia* species is rooted with the outgroup species of Riedelieae (Figure 3.3) and form a polytomy tree coherent with six major clades of Kress *et al.* (2005a) - (Clade I- the *Fax* clade, Clade II – the *Galanga* clade, Clade III – the *Carolinensis* clade, Clade IV- the *Zerumbet* clade, Clade V – the *Eubractea* clade, Clade VI- the *Rafflesiana* clade), although there is a notable expansion of Kress *et al.* 2005 original Clade IV and Clade VI. The new subclades are designated as subclades IVb and VIb, to differentiate from Kress's original Clade IV and Clade VI (indicated here as subclade IVa and VIa, respectively (Fig. 3.3). All clade branches are well supported with over 0.90 posterior probabilities for BI, and over 90% bootstrap values for MP and NJ analysis.

Most reference sequences from Genbank formed Clade I, III and V. Clade I consist of *A. fax* and *A. abundiflora* with average sequence divergence of 6.3% (± 1.4). Clade III comprise of *A. boia* and *A. eremochlamys* with average sequence divergence of 2.5% (± 0.8). Clade V which includes *A. modesta*, *A. vittata*, *A. arctiflora* and *A. pinetorum* showed the highest amount of intra-species divergence among all clades

(6.9% \pm 1.0). The highest inter-species variation between the clades were observed between Clade I and Clade V with 26.4% (\pm 3.7) and the lowest inter-species variation were seen between Clade VIa and Clade VIb with 2.8% (\pm 0.6) (Table 3.7).

Table 3.7 ITS sequence divergence (%) within/between clades.

Clade	I	II	III	IV a	IV b	V	VI a	VI b
I	6.3							
II	14.7	1.2						
III	14.2	14.7	2.5					
IV a	15.3	13.5	13.2	4.4				
IV b	15.7	12.5	13.0	11.2	5.9			
V	26.4	22.1	21.8	20.6	20.1	6.9		
VI a	14.7	10.3	12.1	11.6	10.7	20.3	0.3	
VI b	13.9	10.1	11.3	11.4	10.1	19.0	2.8	1.7

The *Alpinia* species from Peninsular Malaysia were grouped within Clade II, Clade IV (subclades IVa and IVb) and Clade VI (subclades VIa and VIb). Clade II comprises of well supported relationship between *A. conchigera* and *A. galanga* with inter-species divergence of 1.7% and average sequence divergence of 1.2% (\pm 0.3). Although a single reference sequence of *A. aquatica* from Genbank unexpectedly clusters together with subclade II, the association was not strongly supported. Most of the *A. aquatica* sequences of Peninsular Malaysia belong to subclade IVa which also includes *A. mutica*, *A. malaccensis* var. *nobilis*, *A. latilabris* A. cf. *assimilis* and *A. zerumbet* where the inter-species sequence divergence range from 0.5% to 10.5%. The novel subclade IVb encompasses *A. macrostephana*, *A. oxymitra*, *A. petiolata*, *A. vitellina* and *A. vitellina* var. *cannifolia* whereby its average intra-sequence divergence is 5.9% (\pm 0.8) and inter-species divergence ranging from 0.0% to 3.3%. The inter-

sequence divergence of subclades IVa and IVb is 11.2% (± 1.2) (Figure 3.3). The highest amount of intra-species variation was detected in *A. latilabris* and *A. oxymitra* of 1.8% (± 0.5) while variations in other species were ranging from 0.0% to 1.3%.

The *Rafflesiana* clade has two subclades, subclade VIa that comprises of *A. capitellata*, *A. javanica*, *A. javanica* var. *colorata*, and reference sequence of *A. rafflesiana*; and subclade VIb that consists of *A. suriana*, *A. murdochii*, *A. pahangensis*, *A. rafflesiana* and *A. scabra*. It appears that *A. scabra* is the most basal species within Clade VI. The average intra-sequence divergences for subclades VIa and VIb are 6.3% (± 0.1) and 1.7% (± 0.3) respectively, while the average inter-sequence divergence is 2.8% (± 0.6). Result from all phylogenetic trees exhibit high posterior probabilities and strong bootstrap support of closely related clustering between subclade VIa and new subclade VIb. Inter-species variation of subclade VIa ranged from 0.2% to 0.3% while inter-species divergence in subclade VIb produced a wider range between 0.2% to 4.4%.

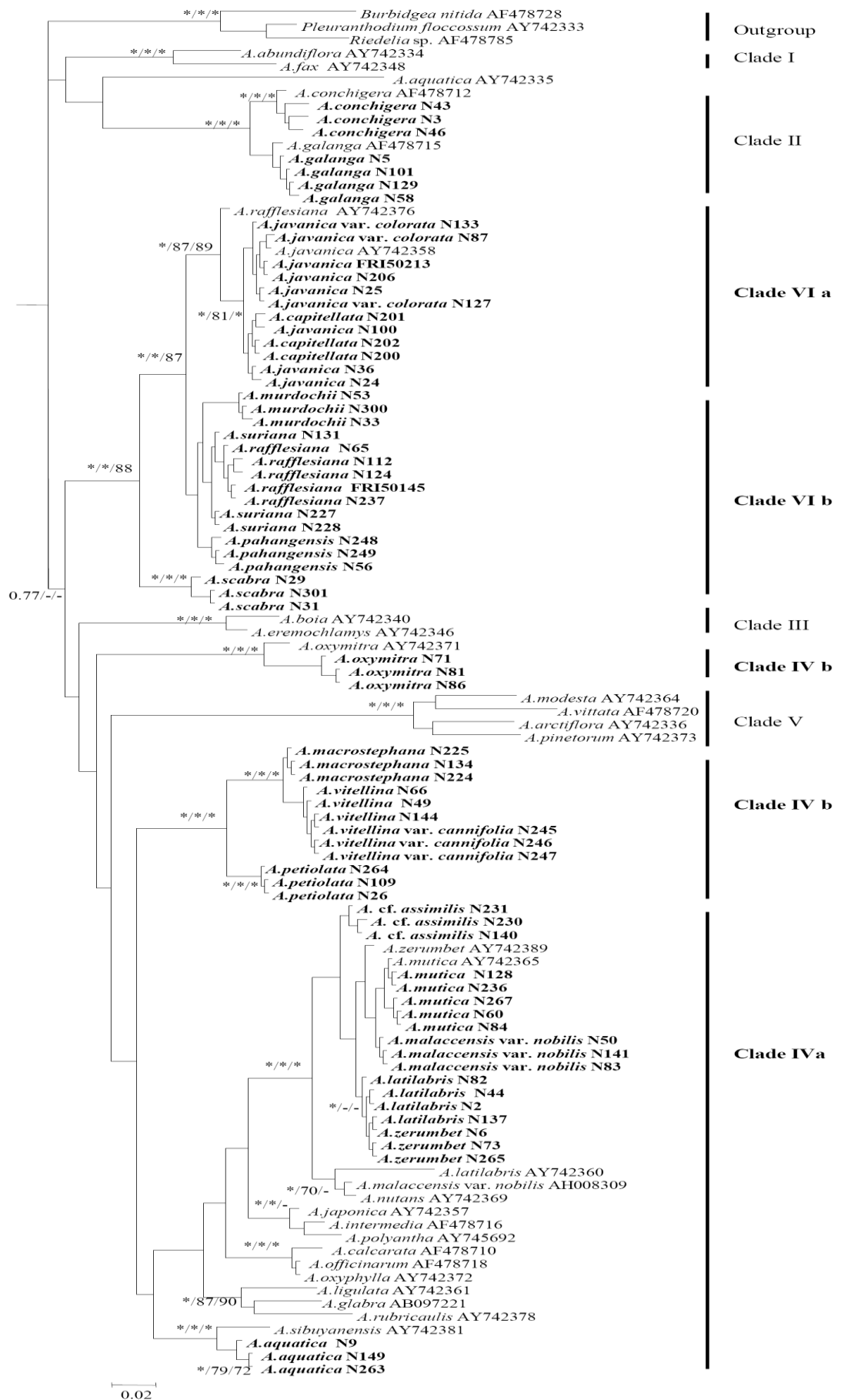


Figure 3.3 Bayesian phylogram of 38 species of *Alpinia* showing six clades (I-VI) as inferred from internal transcribed spacer region (ITS). Species name in bold indicates samples from Peninsular Malaysia. Statistical support of BI/MP/NJ are shown at the branch node, with value higher than 0.90 is indicated by asterisk (*).

Similarly, the rooted *matK* phylogenetic tree of *Alpinia* species showed a similar consistent topology to the ITS phylogram (Figure 3.4) which also formed a polytomy tree between the six major clades following Kress *et al.* (2005a), including the newly expanded Clade IV and Clade VI as mentioned earlier. *Alpinia* of Peninsular Malaysia showed a different clustering pattern within the clades. Several clades are well supported with over 0.90 posterior probabilities (Clade I, Clade II, Clade V, subclade VIa, subclade VIb) while others (Clade III, subclade IVa, subclade IVb) exhibit strong or low support only in BI inference and/or moderate to low bootstrap support for MP and NJ analysis.

Clade I, III and V consists of reference sequences from Genbank, where the average sequence divergence for Clade I is 0.3% (± 0.2) and Clade V is 0.8% (± 0.2). Clade III contain only one species (*A. eremochlamys* AY742404), and *A. boia* was not included because no available *matK* sequence in Genbank was found for the species. Highest amount of inter-sequence divergence was observed between both Clade III and subclade VIa and Clade III with subclade VIb (3.9% ± 0.7) and the lowest inter-sequence variation was seen between subclade IVa and subclade IVb (1.3% ± 0.2).

Clade II contains similar taxa in ITS analyses where *A. conchigera* and *A. galanga* are well supported with an average intra-sequence divergence of 0.4% (± 0.1). Clade IV interestingly appears to produce a weak separation between the clustering of previous reference sequences (in subclade IVa) and the new Peninsular Malaysian taxa (in subclade IVb). Subclade IVb includes *A. aquatica*, *A. cf. assimilis*, *A. malaccensis* var. *nobilis*, *A. macrostephana*, *A. mutica*, *A. oxymitra*, *A. vitellina* and *A. vitellina* var. *cannifolia* (Figure 3.4). The inter-sequence divergence of subclade IVa and subclade IVb is 1.3% (± 0.2). In subclade IVb, variation among the species ranged from 0.3% to 1.1% with intra-species divergence of 0.7% (± 0.2) (Table 3.8).

Table 3.8 *matK* sequence divergence (%) within/between clades.

Clade	I	II	III	IV a	IV b	V	VI a	VI b
I	0.3							
II	2.4	0.4						
III	3.5	3.6	0.0					
IV a	2.9	2.8	3.3	1.3				
IV b	2.7	2.4	3.2	1.3	0.7			
V	2.4	2.5	3.0	2.1	2.1	0.8		
VI a	2.8	2.2	3.9	3.3	3.0	2.9	1.7	
VI b	3.0	2.8	3.9	3.2	2.6	2.9	3.1	0.7

Similarly in the *Rafflesiana* clade, a weak separation between Malaysian and previous Genbank sequences was also observed in the *matK* phylogram. Subclade VIa comprises of reference sequences of *A. javanica*, *A. rafflesiana* and *A. aquatica*, while subclade VIb contain new added Peninsular Malaysian species namely *A. capitellata*, *A. javanica*, *A. javanica* var. *colorata*, *A. murdochii*, *A. pahangensis*, *A. rafflesiana*, *A. scabra* and *A. suriana*. Although *A. scabra* is genetically distinct as indicated by its basal position and long branch length, with an average sequence divergence of 0.1% (± 0.1), this species belongs to Clade VI. Inter-species variation of subclade VIb ranged from 0.0% to 2.2%.

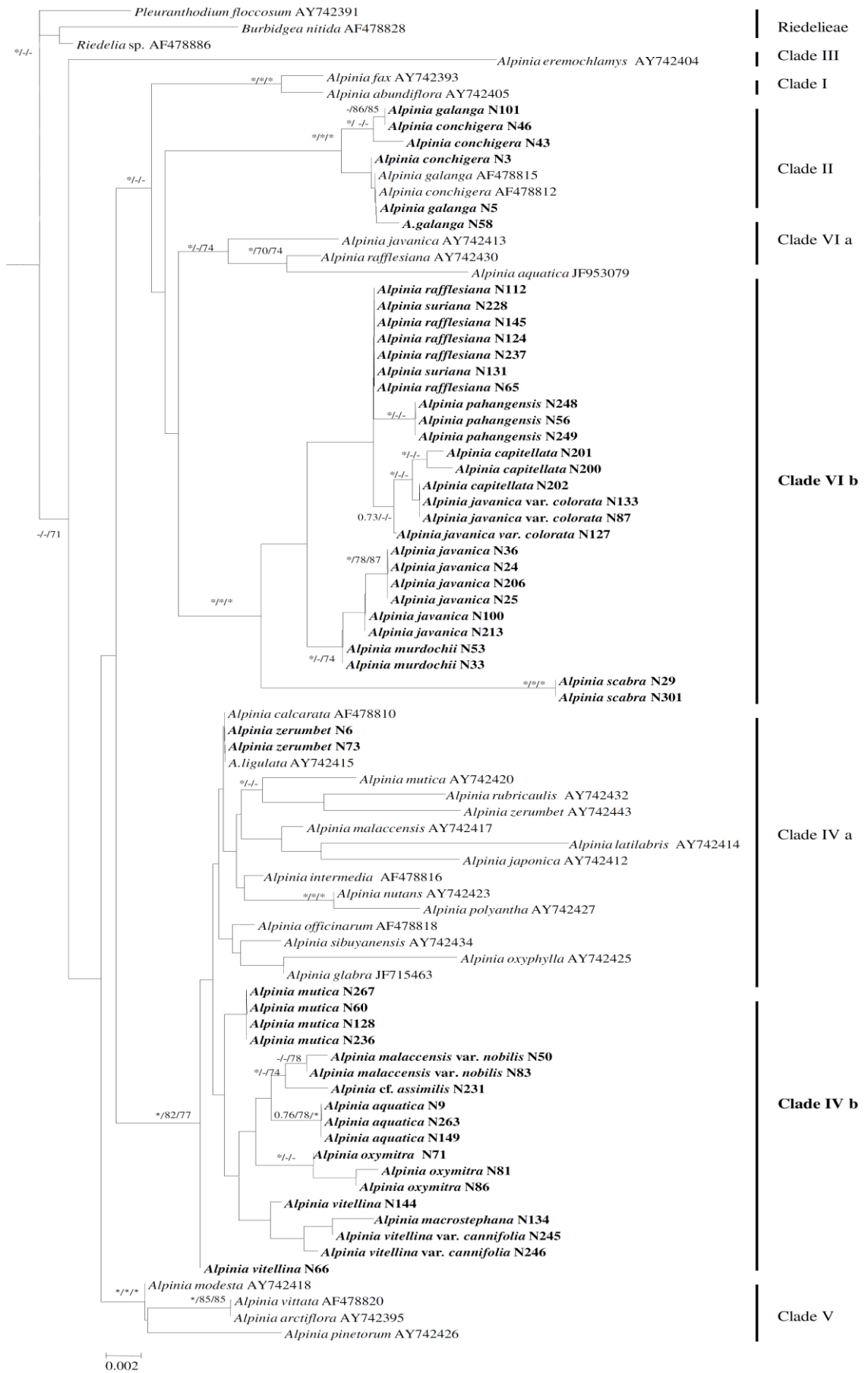


Figure 3.4 Neighbour-Joining phylogram of 35 species of *Alpinia* showing six clades (I-VI) as inferred from maturase K gene (*matK*). Species name in bold indicates samples from Peninsular Malaysia. Statistical support of BI/MP/NJ are shown at the branch node, with value higher than 0.90 is indicated by asterisk (*).