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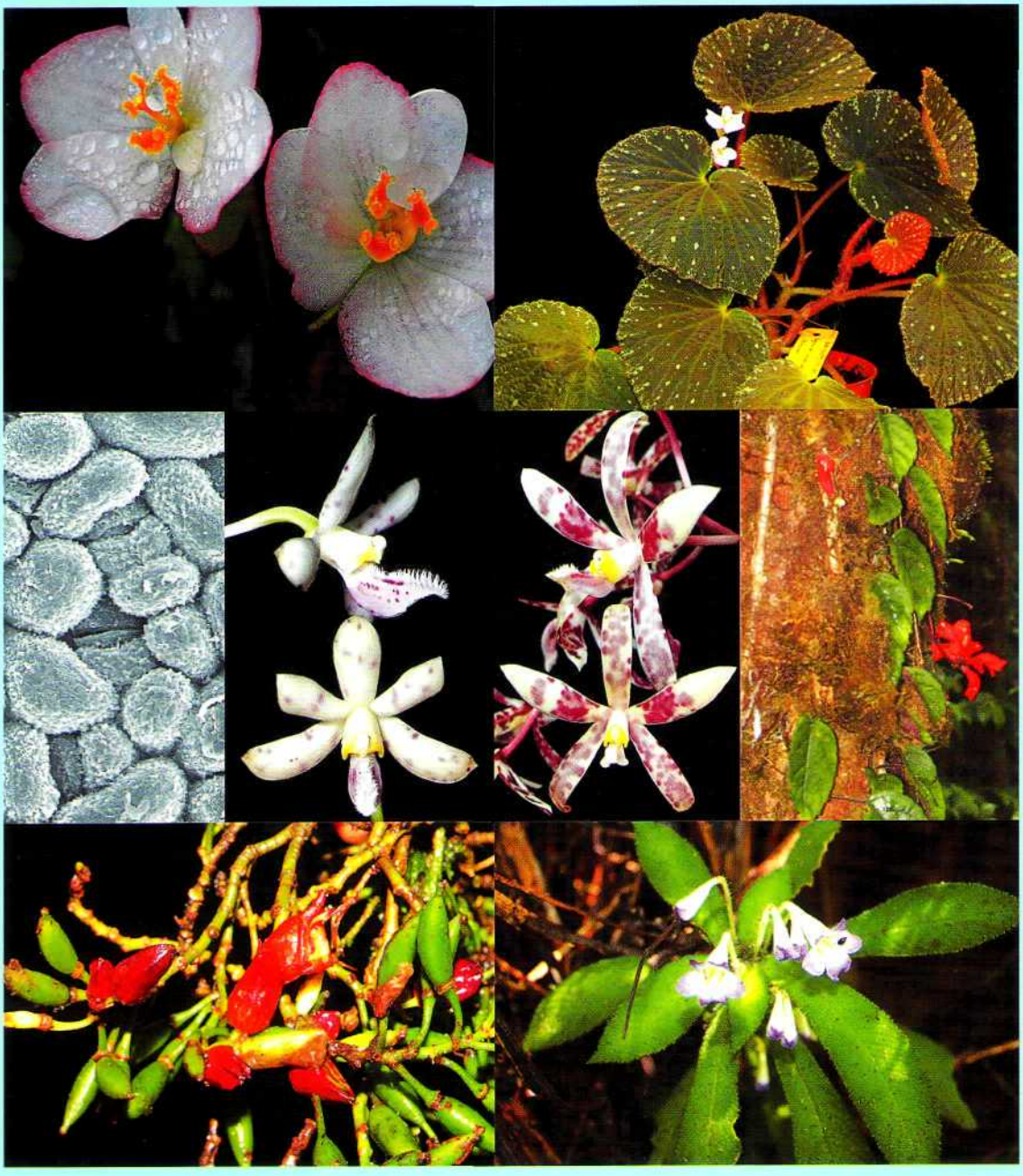

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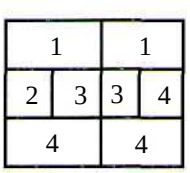

Cover images: 1. *Begonia holosericeoides* (female flower and habit) (Begoniaceae; Ardi *et al.); 2.* Abaxial cuticles of *Alseodaphne rhododendropsis* (Lauraceae; Nishida & van der Werff); *3. Dipodium puspitae, Dipodium purpureum* (Orchidaceae; O'Byrne); 4. *Agalmyla exannulata, Cyrtandra coccinea* var. *celebica, Codonoboea kjellbergii* (Gesneriaceae; Kartonegoro & Potter).

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THE DIVERSITY AND ABUNDANCE OF GROUND HERBS IN LOWLAND MIXED DIPTEROCARP FOREST AND HEATH FOREST IN BRUNEI DARUSSALAM

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ABSTRACT
ZAINI, N. H. & SUKRI, R. S. 2014. The diversity and abundance of ground herbs in lowland mixed dipterocarp forest and heath forest in Brunei Darussalam. *Reinwardtia* 14(1): 73 – 78. — Herbaceous plants are important components of total plant species richness in tropical forests. Ground herb diversity and abundance were studied in a lowland Mixed Dipterocarp forest (Andulau) and a heath forest (Bukit Sawat) in Brunei Darussalam, Borneo. At each site, all ground herbs in twenty randomly selected 10 × 10 m subplots within a one hectare permanent plot were censused and identified. The study recorded a total of 20 families and 32 genera of ground herbs, with the family Zingiberaceae as the most abundant at both sites. Thirteen genera were recorded only at Andulau and 7 genera were exclusive to Bukit Sawat, with twelve genera common to both sites. Ground herb species richness appear higher at Andulau than Bukit Sawat (37 *vs.* 29), but this difference was not statistically significant at the subplot level. However, ground herb abundance and density were significantly higher at Bukit Sawat than Andulau (n = 846 *vs.* 385; 4230 *vs.* 1925 individuals ha^{-1}). The more open canopy at Bukit Sawat may provide higher light availability here than at Andulau, which is characterised by a closed canopy. We suggest that light availability is the most important environmental factor influencing ground herb density and abundance at these sites.

Keywords: Borneo, tropical forests, species richness, Zingiberaceae, light availability.

ABSTRAK
ZAINI, N. H. & SUKRI, R. S. 2014. Keanekaragaman dan kelimpahan tumbuhan herba di lantai hutan dipterokarpa dataran rendah dan hutan kerangas di Brunei Darussalam. *Reinwardtia* 14(1): 73 – 78. — Tumbuhan herba penting sebagai penyusun komponen dari keseluruhan kelimpahan jenis hutan tropis. Keanekaragaman tumbuhan herba di lantai hutan dipterokarpa dataran rendah (Andulau) dan hutan kerangas (Bukit Sawat) di Brunei Darussalam, Borneo telah dipelajari. Pada tiap lokasi, semua tumbuhan herba yang terdapat pada 20 subplot berukuran 10 × 10 m pada plot permanen 1 ha didata serta diidentifikasi. Hasil studi menunjukkan terdapat 20 suku dan 32 marga tumbuhan herba, tercatat Zingiberaceae sebagai suku paling melimpah. Tiga belas marga hanya terdapat di Andulau dan tujuh marga hanya terdapat di Bukit Sawat, dengan dua belas marga terdapat di kedua lokasi. Kelimpahan jenis tumbuhan herba lebih tinggi di Andulau daripada di Bukit Sawat (37 *vs*. 29), tetapi perbedaan tersebut tidak nyata pada tingkat subplot. Perbedaan nyata terdapat pada kelimpahan jenis serta kerapatan tumbuhan herba di Bukit Sawat yang lebih tinggi dari-pada Andulau (n = 846 *vs*. 385; 4230 *vs*. 1925 jenis ha^{-1}). Makin terbukanya kanopi di Bukit Sawat menyebabkan ketersediaan cahaya lebih tinggi daripada di Andulau. Dari hasil studi diketahui bahwa ketersediaan cahaya adalah faktor lingkungan yang paling penting yang mempengaruhi kerapatan dan kelimpahan jenis tumbuhan herba.

Kata kunci: Borneo, hutan tropis, kekayaan jenis, Zingiberaceae, ketersediaan cahaya.

INTRODUCTION

There is an increasing realization that herb diversity contributes significantly to total plant species diversity in a tropical forest (Gentry & Dodson, 1987; Costa, 2004). For example, the understorey of Neotropical forests are typically species rich, with herbaceous plants accounting for 21 to 47% of total plant species (Croat, 1978; Gentry & Dodson, 1987; Costa, 2004). Herbaceous plants are known to represent 8 to 29% of total plant species richness in moist to wet forests, 53% in dry forests and up to 6% in forests on white sandy soils (Hall & Swaine, 1976;

Whitmore *et al*., 1984; Gentry & Dodson, 1987; Gentry & Emmons, 1987). Despite this, studies of herb diversity in aseasonal Southeast Asian tropical rain forests remain few in comparison to studies on tree diversity.

We studied ground herbs at two contrasting lowland forests in Brunei Darussalam. Throughout our work, we have adopted the ground herb definition by Poulsen & Balslev (1991) in which ground herbs are defined as herbaceous plants that are rooted on the forest floor. Although this definition typically includes those of facultative terrestrial species such as juvenile and fallen epiphytes, and climbers, we have chosen to focus on ground herbs which are completely rooted on the forest floor, hence excluding epiphytes and climbers. However, we included as ground herbs, climbers that were recorded at ground level. Our aim was to compare ground herb diversity between a lowland mixed dipterocarp forest (MDF) and a heath forest (HF) in Brunei Darussalam. Specifically, we asked the question: Is there a difference in the diversity, density and abundance of ground herbs between these two forest types?

METHOD

Study sites

The study sites were located within a lowland MDF at the Andulau Forest Reserve, located about 4 km southwest of Sungai Liang (4^o 39' 26"N, 114^o 30' 57"E) and a HF at the Bukit Sawat Forest Reserve, located about 11 km south of Sungai Liang (4^o 34' 37"N, 114^o 30' 11"E; see N. H. Zaini, 2013). Field work was conducted within two 0.96 ha permanent forest plots belonging to Universiti Brunei Darussalam (Davies & Becker, 1996) in the Belait District. The two sites differ in their topography, with a mainly flat terrain at Bukit Sawat and a more gently undulating topography at Andulau (Davies & Becker, 1996).

Within each 0.96 ha plot, twenty 10 × 10 m subplots were randomly selected for census of ground herbs, amounting to a total sampling area of 0.2 ha at each study site. The Andulau subplots has an elevational range of 54 to 89 m above sea level (asl) while those at Bukit Sawat were at 25 to 60 m asl.

Census of ground herbs

All ground herbs within the 20 selected subplots at each study sites were tagged and their coordinates recorded. Voucher specimens of censused ground herbs at both sites were collected and identified at the Brunei National Herbarium (BRUN). In addition, several specimens were identified at the Sandakan Herbarium (SAN) of the Sabah Forest Research Centre. Where possible, specimens were identified to species level, or otherwise grouped to morphospecies. Photographic records were also taken for each of the ground herb censused.

Statistical analysis

The diversity of ground herbs between Andulau and Bukit Sawat was determined using the Inverse Simpson's Index (D_s). The Inverse Simpson's Index was used as it takes into account the number of species present and the abundance of each species (Magurran, 2004), with a larger D_s value indicating higher diversity. We calculated species richness as the number of species recorded in each subplot, abundance as the total number of ground herb individuals per subplot, and density as the number of individuals per hectare. Differences in diversity, species richness, abundance and density between the two sites were calculated using Student's t-test. All statistical analyses were conducted using R 2.15.2 (R Development Core Team, 2012).

RESULTS

Differences in species richness, species diversity, density and abundance of ground herbs

A total of 20 families were recorded from both the Andulau and Bukit Sawat sites. Fifteen families were recorded in Andulau and 13 families at Bukit Sawat (Table 1). The total number of genera recorded were higher in Andulau (n = 25) than at Bukit Sawat (n = 19). Similarly, total species richness of ground herbs was higher at Andulau (n = 37) than at Bukit Sawat (n = 29). However, this apparent between-site difference in species richness was not significant at the subplot level ($t = -0.166$, $p = 0.869$).

Despite the higher number of genera and species recorded at Andulau than Bukit Sawat, ground herb abundance was significantly higher at Bukit Sawat subplots than the Andulau subplots (n = 846 vs. 385; $p < 0.006$). The density of ground herbs (number individuals per ha) were significantly lower in Andulau (1925 individuals ha^{-1}) than at Bukit Sawat (4245 individuals ha^{-1}; $p < 0.006$).

The most abundant family at both sites was Zingiberaceae which recorded a total of 119 and 298 individuals at Andulau and Bukit Sawat respectively (Table 2). Other abundant families

Table 1. Ground herbs abundance, density and diversity (Inverse Simpson's Index) for lowland Mixed Dipterocarp Forest at Andulau and Heath forest at Bukit Sawat in Belait District. At each site, a total of twenty 10 × 10 m subplots were randomly selected and sampled for all ground herbs. All values are means (with standard error) with the exception of total area sampled and total number of family which are displayed as the total number.

	Andulau	**Bukit Sawat**
Total area sampled (ha)	0.2	0.2
Total number of family	15	13
Total number of genera	5.9 ± 0.4	5.8 ± 0.4^{NS}
Species richness (total number of species)	6.4 ± 0.4	6.5 ± 0.4^{NS}
Abundance (total number of individuals)	19.3 ± 2.5	42.5 ± 7.1**
Density (number of individuals ha^{-1})	1925 ± 251.0	4245 ± 707.4**
Inverse Simpson's Index	1.60 ± 0.18	1.45 ± 0.10^{NS}

** significant at $p < 0.05$; ^{NS} = Not Significant at $p > 0.05$

include Araceae (Andulau = 67; Bukit Sawat = 169), Orchidaceae (Andulau = 28; Bukit Sawat = 121) and Pandanaceae (Andulau = 65; Bukit Sawat = 82). For these four abundant families, as well as for Lindsaeaceae, Myrsinaceae and Woodsiaceae, Bukit Sawat consistently showed higher abundance of individuals than Andulau. In contrast, the family Vitaceae showed a higher abundance at Andulau (n = 67) compared to Bukit Sawat (n = 14).

We recorded a total of 32 genera at both sites, with the highest number of genera shown by Araceae (n = 5), Zingiberaceae (n = 4) and Orchidaceae (n = 3; Table 2). The most abundant genus at Andulau was *Pandanus* (Family Pandanaceae; n = 62) followed by *Pterisanthes* (Family Vitaceae; n = 56), and *Scindapsus* (Family Araceae; 49 individuals; see Table 2). Three genera at Andulau were represented by a single individual each: *Amydrium* (Family Araceae), *Huperzia* (Family Lycopodiaceae) and *Selaginella* (Family Selaginellaceae). The most abundant genus at Bukit Sawat was *Boesenbergia* (Family Zingiberaceae; n = 289) followed by *Scindapsus* (Family Araceae; n = 162) and *Pandanus* (Family Pandanaceae; n = 64). Two genera at Bukit Sawat were represented by a single individual each: *Dischidia* (Family Apocynaceae) and *Curculigo* (Family Hypoxidaceae).

A total of thirteen genera were found only at Andulau, seven only at Bukit Sawat and twelve were present at both sites (Fig. 1). Families that were recorded at both sites include Araceae, Lindsaeaceae, Myrsinaceae, Orchidaceae, Pandanaceae, Vitaceae, Woodsiaceae and Zingiberaceae. Seven families were exclusive to Andulau (Araliaceae, Blechnaceae, Cyatheaceae, Lycopodiaceae, Melastomataceae, Selaginellaceae and Tectariaceae) while five families were only found at Bukit Sawat (Apocynaceae, Hypoxidaceae, Nepenthaceae, Rubiaceae and Schizaeceae).

DISCUSSION

Despite a lack of significant difference in ground herb species richness and diversity at the subplot level between Andulau and Bukit Sawat, there was a significant difference in ground herb abundance and density, both of which were higher at the HF subplots in Bukit Sawat than in the lowland MDF subplots at Andulau. We suggest that the non-significant differences in species richness and diversity may be partly due to the small sampling area of 0.2 ha at each forest site. Small sample sizes can underestimate species diversity estimations and affect species distribution model predictions (Wisz *et al*., 2008). Additionally, some ground herbs censused in this study were identified only to morphospecies, and so the total number of species at each site presented here may be an underestimate of the actual species richness.

The high abundance of Zingiberaceae at both Andulau and Bukit Sawat is consistent with findings of Poulsen (1996) at a 1-ha lowland MDF plot at Kuala Belalong, which also recorded Zingiberaceae as the most abundant family there. The Brunei checklist records 13 genera of Zingiberaceae (Coode *et al*., 1996), while a survey of the Heath forests at Nabawan, Sabah have recorded 10 of the Bornean Zingiberaceae genera (Nabawan Project, 1996). Globally, the highest diversity of Zingiberaceae is in Southeast Asia,

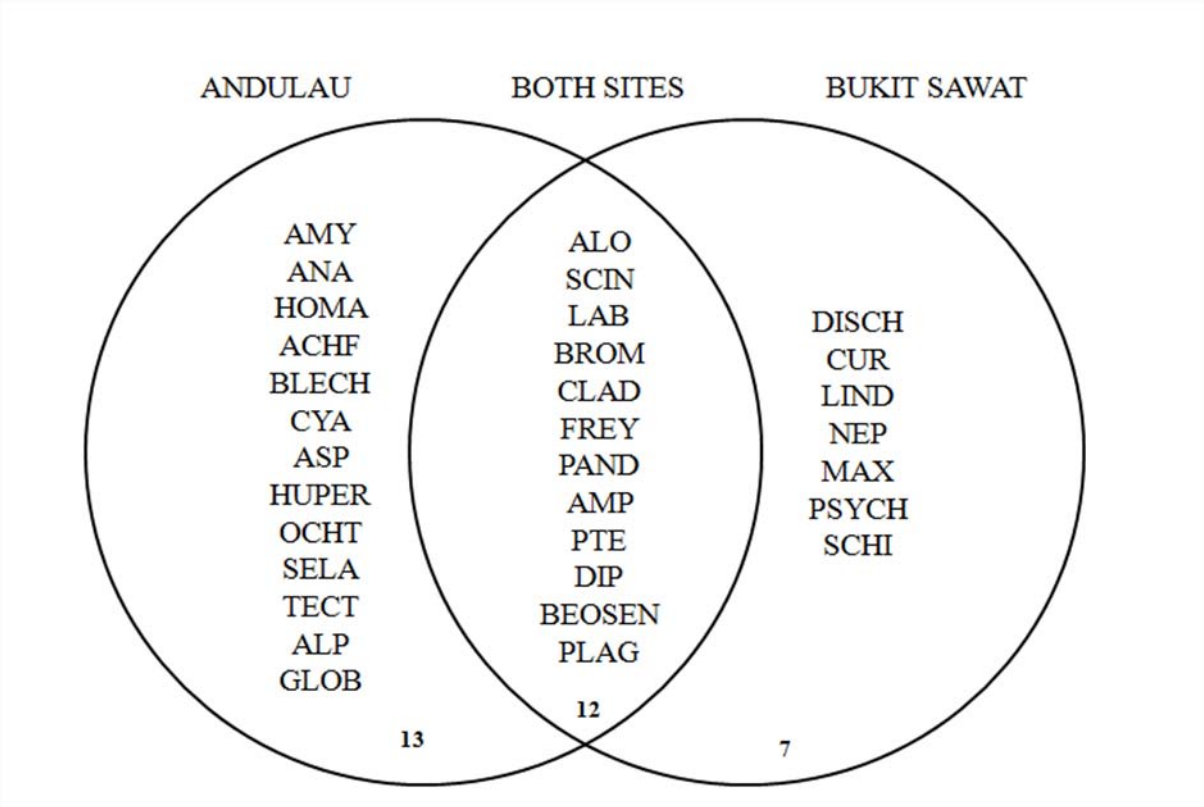

Fig. 1. Venn-diagram to illustrate the distirbution of ground herbs, represented by genera, recorded at Andulau and Bukit Sawat in the Belait District. The codes for each genus and their definitions are listed in Table 2.

with Borneo alone recording 19 genera, 4 of which are endemic to Borneo (Lamb *et al*., 2013).

The species richness of Zingiberaceae was higher in Andulau than at Bukit Sawat, however Zingiberaceae abundance was higher at Bukit Sawat. This was similarly recorded by Gobilik (2008) in upland heath forest in Serudong, Southern Sabah, where the diversity of Zingiberaceae was lower. Additionally, higher Zingiberaceae density and abundance were linked with environmental variables of light and precipitation as open, wet and humid conditions provide better environment for growth of Zingiberaceae (Poulsen, 2006). Canopy openness appear to be greater at Bukit Sawat than Andulau. This may potentially explain why there was a higher abundance of Zingiberaceae at Bukit Sawat, with *Boesenbergia* alone comprising 289 individuals. In contrast, Andulau has a lower total number of individuals (n = 119) for Zingiberaceae family.

Differences in light availability may result from differences in the canopy structure (Rich *et al*., 1993), and the two forest sites in the present study have been shown to exhibit significant differences in canopy structure (Hassan, 2012). Higher photosynthetically active radiation (PAR) was also recorded in the Bukit Sawat plots than at Andulau (Zaini, 2013). This in turn may affect the reflection and transmission of light to the forest floor, thereby influencing the growth of ground herbs under the canopy (Poulsen and Pendry, 1995). Differences in light intensity can also affect seed germination under the closed canopy environment (Smith, 1987). Additionally, the density and abundance of many ground herbs could be influenced by forest gaps, as their reproduction and growth may depend on these gaps (Smith, 1987).

CONCLUSION

Ground herbs diversity was not significantly different between the lowland Mixed Dipterocarp forest at Andulau and the Heath forest at Bukit Sawat, although their density and abundance were significantly higher at Bukit Sawat than Andulau. Light variablility may potentially be an influential factor for any differences in the diversity, density and abundance of ground herbs between the two forest types in this study. However, an increased sampling of ground herbs coupled with a quantitative measurement of the light environment is needed to elucidate these effects.

Table 2. Population attributes of ground herbs in twenty 10 × 10 m subplots located in lowland Mixed Dipterocarp Forest and Heath Forest at Andulau and Bukit Sawat respectively. Families are arranged in alphabetical order.

No.	Family	Genus	Site Presence	Abundance		Genus Code
				Andulau	Sawat	
1	Apocynaceae	*Dischidia*	Sawat	0	1	DISCH
2	Araceae	*Alocasia*	Both	8	7	ALO
		Amydrium	Andulau	1	0	AMY
		Anadendrum	Andulau	7	0	ANA
		Homalomena	Andulau	2	0	HOMA
		Scindapsus	Both	49	162	SCIN
3	Araliaceae	*Schefflera*	Andulau	2	0	SCHF
4	Blechnaceae	*Blechnum*	Andulau	11	0	BLECH
5	Cyatheaceae	*Cyathea*	Andulau	2	0	CYA
6	Hypoxidaceae	*Curculigo*	Sawat	0	2	CUR
7	Lindsaeaceae	*Asplenium*	Andulau	2	0	ASP
		Lindsaea	Sawat	0	33	LIND
8	Lycopodiaceae	*Huperzia*	Andulau	1	0	HUPER
9	Melastomataceae	*Ochthocharis*	Andulau	4	0	OCHT
10	Myrsinaceae	*Labisia*	Both	2	7	LAB
11	Nepenthaceae	*Nepenthes*	Sawat	0	11	NEP
12	Orchidaceae	*Bromheadia*	Both	19	59	BROM
		Claderia	Both	9	59	CLAD
		Malaxis	Sawat	0	3	MAX
13	Pandanaceae	*Freycinetia*	Both	3	18	FREY
		Pandanus	Both	62	64	PAND
14	Selaginellaceae	*Selaginella*	Andulau	1	0	SELA
15	Rubiaceae	*Psychotria*	Sawat	0	55	PSYCH
16	Schizaeceae	*Schizaea*	Sawat	0	39	SCHI
17	Tectariaceae	*Tectaria*	Andulau	10	0	TECT
18	Vitaceae	*Ampelocissus*	Both	11	11	AMP
		Pterisanthes	Both	56	3	PTE
19	Woodsiaceae	*Diplazium*	Both	4	14	DIP
20	Zingiberaceae	*Alpinia*	Andulau	24	0	ALP
		Boesenbergia	Both	16	289	BOESEN
		Globba	Andulau	42	0	GLOB
		Plagiostachys	Both	37	9	PLAG

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