Malays. Appl. Biol. (2006) 35(1): 15–26

ECOLOGY AND RESPONSE OF *AMORPHOPHALLUS BORNEENSIS* (ENGL.) ENGL. & GEHRM TO SHADING

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ABSTRACT

The distribution of *Amorphophallus borneensis* (Engl.) Engl & Gehrm, that is considered a new record in Sarawak, was resoluted by using 6 plots of 1 hectare (100 m x 100 m) that were subdivided into 25 subplots (20 m x 20 m) at Gunung Gayu, Padawan. The total number of plants of *A. borneensis* in the 6 plots was 138 plants. Generally the plants occurred 2 to 4 meter from the large trees such as *Shorea macropyhlla*, *Koompassia excelsa*, *Durio zibethinus* and *Baccaurea macrocarpa*. The petioles were ranged between 0.95 mm – 20.5 mm diameter above ground surface petiole diameter with their height between 120.5 cm – 180.5 cm. The dry weight of 32 individual plants sampled were in the ranged of 4.5 g – 660.1 g. There was a strong relationship in the vegetative parts of *A. borneensis* that was between height and ground surface petiole diameter ($y = 34.41x + 29.80$ in which $R^2 = 0.899$). The forest at Gunung Gayu was dominated by *Shorea macrophylla* (IV = 64.21), *Durio zibethinus* (IV = 21.87), *Baccaurea macrocarpa* (IV = 17.87), *Baccaurea angulata* (IV = 16.73) and *Koompassia excelsa* (IV = 15.18). The high percentage of sand (82 ± 0.85%) indicated that *A. borneensis* grown in well-drained soil. The effects of shading were also studied on *A. borneensis* under three different shade levels (0%, 50% and 75% shade levels). The result indicated that the plants were growing well under 75% shade level.

ABSTRAK

Taburan *Amorphophallus borneensis* (Engl.) Engl & Gehrem yang dipercayai rekod penemuan pertama di Sarawak telah ditentukan di kawasan Gunung Gayu dengan menggunakan 6 plot dengan keluasan satu hektar bagi setiap plot (100m x 100m) dan dibahagikan kepada 25 subplot (20m x 20m). Jumlah keseluruhan *A. borneensis* bagi 6 plot tersebut adalah 138 individu dengan purata 23 individu dalam 1 hektar. Kebanyakan daripadanya tumbuh dalam jarak antara 2 hingga 4 meter dari pokok-pokok besar seperti *Shorea macropyhllum*, *Koompassia excelsa*, *Durio zibethinus* dan *Baccaurea macrocarpa*. Diameter petiol di permukaan tanah bagi *A. borneensis* rata-ratanya mempunyai julat di antara 0.95mm – 20.5mm manakala tinggi keseluruhannya pula lebih banyak dalam lingkungan 120.5cm – 180.5cm. Berat kering purata bagi 32 pokok yang mempunyai julat antara 4.5g – 660g ialah 116.98g. Hubungan di antara ketinggian dan diameter batang di permukaan tanah memberikan korelasi yang lebih kuat antara bahagian-bahagian pokok ($y = 34.41x + 29.80$ which $R^2 = 0.899$). Bagi struktur hutan di Gunung Gayu, spesies yang paling dominan ialah *Shorea macrophyllum* (IV = 64.21) diikuti oleh *Durio zibethinus* (IV = 21.87), *Baccaurea macrocarpa* (IV = 17.87), *Baccaurea angulata* (IV = 16.73), dan *Koompassia excelsa* (IV = 15.18). Peratusan pasir sebanyak 82 ± 0.85% dalam komposisi tanah menunjukkan *A. borneensis* hidup dengan subur dalam struktur tanah yang mempunyai pengudaraan yang baik bagi menjamin pertumbuhan akarnya. Kesan lindungan keatas tumbesaran *A. borneensis* telah dijalankan dengan mengunakan tiga tahap lindungan (0%, 50% dan 75% lindungan). Keputusan menunjukkan *A. borneensis* tumbuh lebih baik pada tahap lindungan 75%.

Key words: *Amorphophallus borneensis*, distribution, soil composition, shading, biomass allocation

INTRODUCTION

Amorphophallus (Araceae) is a tropical fleshy herbs growing from creeping or tuberous rhizomes or corms that comprises of 170 species (Wiart, 2000). The plant has an underground tuber from which the single leaflet arises and at maturity, followed by the variable sizes of inflorescences depending on the species. The flowers are minute

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and borne at the base of the spadix within an encircling bract or spathe. The flower also functions in attracting the insect and bird which act as pollinators. Hetterscheid (1994) registered that only 13 species of *Amorphophallus* are found in Borneo where 6 in Sarawak, 3 in Sabah and 4 in Kalimantan. Ipor *et al* (2004) discovered a new species from Mulu National Park, Miri and named as *A. julaihii*. The majority of *Amorphophallus* species seemed to be pioneers in disturbed vegetations. Many are found in forest margin, open forest, on (steep) slopes, in disturbed parts of primary forests, and sometime in very exposed parts in limestone karst areas (Hetterscheid, 1994). Some species of *Amorphophallus* have dietary values of their rhizomes and for cooking ingredient (Wiart, 2000). It is also known as an ornamental plant for certain people. *Amorphophallus borneensis* (Engl.) Engl. & Gehrm is endemic to the Borneo Island and can be found growing in the secondary forest or on the lime stone area (Hetterscheid & Ittenbach, 1996). This species requires rich organic matter and well-drained soils (Hetterscheid & Ittenbach, 1996) for good growth development. In terms of growth rate, the *A. borneensis* needs a few years to reach a mature state. According to Hetterscheid & Ittenbach (1996), the *A. borneensis* have low survival rate on areas that are always wet and are exposed directly to the sunlight. Therefore, this study was conducted to understand the ecology and to determine the effect of shading on the growth and development of *A. borneensis*. The results are essential for detail scientific documentation and conservation of the *Amorphophallus* species.

MATERIALS AND METHODS

Distribution and growth pattern of *Amorphophallus borneensis* (Engl.) Engl & Gehrm at Gunung Gayu, Padawan

The distribution pattern of *A. borneensis* was determined by establishing six plots of 1 hectare (100 m x 100 m) that were subdivided into 25 subplots (20 m x 20 m). All *A. borneensis* plants were tagged and their stem circumferences above ground surface as well as their height were measured. In another assessment, 32 plants were randomly and carefully collected to determine the growth pattern and biomass allocation of *A. borneensis*. The height, dry weight and fresh weight for tuber, stem and leaflet, the number of leaflets and leaflet area were taken. All of the vegetative parts of *A. borneensis* were separated and oven dried at 60ºC for 7 days to determine the total dry weight, leaflet weight ratio (LWR), stem weight ratio (SWR), tuber weight ratio (TWR), leaflet area ratio (LAR) and specific leaf area (SLA) of the individual plant. The leaflet area was measured by using *AT Delta-T Scan* (DELTA-T Devices LTD, England).

Floristic composition and total above ground biomass estimation at Gunung Gayu, Padawan

One-hectare plot (100 m x 100 m) that subdivided into 25 subplots of 20 m x 20 m was established as mentioned previously. All trees with diameter at breast height (DBH) $\geq$5 cm were measured and identified. The total leaflet area, basal area relative frequency, relative density and importance value of the trees were determined according to the method described by Brower *et al*. (1990) and the total estimated above ground biomass was determined by method derived by Yamakura *et al* (1986).

Soil analysis

Soil was sampled at every plots of the surveyed area. For every subplot, soil was taken at 0 – 25 cm depth from 5 holes. The sampled soil was then mixed for further analysis such as the pH (Hense, 1979; Mc Lean, 1986), soil organic carbon (C) (Dewis & Freistes, 1970), nitrogen (N) amount (Anon, 1980; Beitz, 1974), cation exchange capacity (CEC), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na) base saturation (BS) (Anon, 1980) and the percentage of clay, silt and sand.

Growth analysis in the green house at UNIMAS

Newly germinated seedlings were raised in the green house. The seedlings were transplanted into a polybag (10 cm x 12 cm) containing of soil mixtures of topsoil, sand and organic matter in a ratio of 3:1:1. After two weeks, 50 uniform seedlings were selected randomly and transferred each at the different shading regimes that were at 0% shading (directly exposed to sun light), 50% shading (50% exposure to sun light) and 75% (25% exposure to sun light). The 50% and 75% shade level were made using a lathe net. Watering was carried out every early in the morning and in the evening.

On the first day of transfer, five healthy seedlings were selected randomly and were labelled for the vegetative measurement in each light regime. The vegetative measurements included the height, number of leaflets and petiole diameter at ground surface. The following assessments were conducted for every two weeks until the 10^{th} week.

In another assessment, ten uniform plants were selected randomly after 30 days of planting to determine the biomass allocation. Leaflets,

petiole, roots and tubers of 5 seedlings were separated from each other, washed and then oven dried at 60ºC for 72 hours to determine their dry weight. The leaflet area was also measured using the AT Delta-T Scan (DELTA_T devices LTD, England) before oven dried. The second harvest of the remaining five plants was conducted after 60 days of planting using the same procedure as mentioned above. The growth analysis and biomass allocation were assessed using the method described by Patterson (1980).

RESULT AND DISCUSSION

Distribution and growth pattern of *Amorphophallus borneensis* (Engl.) Engl & Gehrm at Gunung Gayu, Padawan

Gunung Gayu is mainly secondary forest comprised of mature *dusun* (mixed planting of local fruit trees) planted by the local people. In the six plots surveyed, the *A. borneensis* population was considered low in density with mean of 23 plants per plot. From the survey conducted, plot 4 had the highest number of plants with 33 plants, followed by plot 1 (30 plants), plot 6 (27 plants), plot 2 (20 plants), plot 5 (15 plants) and lastly plot 3 (13 plants) (Figure 1).

Through observations, the *A. borneensis* can be found growing either solitary or in clumps in a group of two or three. This indicated that the species can be dispersed by animals such as birds, porcupines, and insects. According to Hetterschied & Vliet (1996), the occurrence of the blue-berried species in the northern most range of *Amorphophallus* suggested that the dispersal by a particular group of birds were restricted to that particular geography

Figure 2a shows that the petiole diameters on ground surface of *A. borneensis* were mostly ranged between 0.95 mm – 20.5 mm (64 plants). This was followed by 51 plants for 20.5 mm – 40.5 mm, 10 plants for 40.5 mm – 60.5 mm, 9 plants for 60.5 mm – 80.5 mm and 4 plants for 80.5 mm – 100.5 mm.

Figure 2b shows that 28 plants had their petiole length ranged from 120.5 cm – 180.5 cm. This was then followed by 39 plants for the height ranging from 60.5 cm – 120.5 cm, 41 plants for the height ranging from 120.5 cm – 180.5 cm, 17 plants for the height ranging from 180.5 cm – 240.5 cm and 13 plants for the height ranging from 240.5 cm – 300.5 cm. Among the 138 plants surveyed, the highest ground surface petiole diameter recorded was 10 cm with its height of 210 cm.

From the 32 plants sampled, the data revealed that the height was 132.62 ± 8.84 cm with tuber 20.11 ± 1.03 cm depth, 3.30 ± 0.28 cm for petiole diameter, 128.28 ± 14.95 for total leaflets, 6140.36 ± 921.91 cm^2 for total leaflet area per plant, 251.03 ± 52.59 g for tuber fresh weight, 625.97 ± 125.28 g for petiole fresh weight, 212.84 ± 34.14 for leaflet fresh weight, 61.12 ± 15.13 g for tuber dry weight, 32.59 ± 6.51 g for stem dry weight, and 23.28 ± 4.06 g for leaflet dry weight (Table 1). The dry weight of 32 plants was ranged from 4.5g to 660g with the mean of 116.98g.

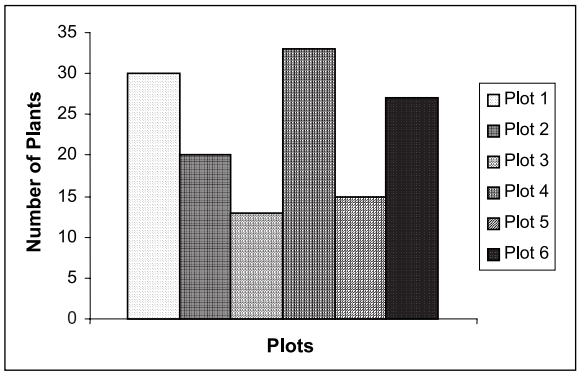

Fig. 1. The total number of *A. borneensis* plants in of 1ha plot at Gunung Gayu, Padawan.

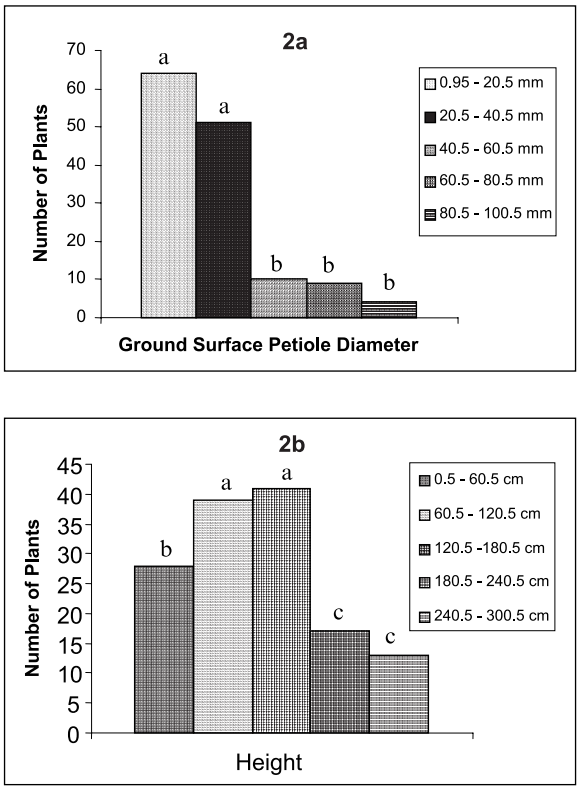

Fig. 2. The total number of plants according to their (2a = different ground surface petiole diameter (mm), 2b = plant height (cm)). Means sharing the same letter within the same cluster are not significantly different at $P \leq 0.05$ according to Duncan's Multiple Range Test.

Table 1. The morphological characteristics of *A. borneensis* plants sampled from Gunung Gayu Padawan

Plant number	Height (cm)	Depth of tuber (cm)	Ground surface petiole diameter (cm)	Number of leaflets	Dry weight (g)		
					Tuber	Petiole	Leaflet
1	47.0	18.0	0.903	12	5.03	1.22	1.45
2	63.0	11.0	1.318	45	3.09	2.53	3.93
3	109.0	18.0	2.129	57	15.26	7.86	9.32
4	134.0	13.0	3.544	154	35.91	21.58	23.09
5	122.0	20.0	2.912	79	108.67	18.76	20.56
6	51.0	10.0	0.818	15	4.02	1.71	1.60
7	220.0	19.0	5.317	128	230.72	77.83	38.11
8	136.0	15.0	3.372	163	73.41	31.34	21.41
9	155.0	21.0	5.394	225	76.03	52.41	25.56
10	138.0	30.0	3.371	149	85.03	20.23	8.48
11	170.0	23.0	3.567	73	45.00	35.51	9.69
12	144.0	22.0	3.069	104	30.65	21.45	5.73
13	226.0	35.0	6.300	201	420.25	145.91	93.92
14	156.5	25.0	3.530	99	61.99	42.61	35.86
15	173.0	24.0	3.900	155	26.73	31.75	34.32
16	140.0	30.0	3.400	117	22.46	28.41	22.85
17	121.0	30.0	3.100	159	97.88	23.83	22.71
18	167.0	23.0	4.700	254	217.11	51.25	44.73
19	65.0	14.0	1.510	43	12.55	4.75	4.16
20	83.0	18.0	1.400	18	17.50	5.12	2.86
21	244.5	26.0	7.000	312	43.70	163.32	99.94
22	110.5	18.5	4.000	268	21.06	33.96	30.03
23	144.5	21.0	4.200	194	20.48	42.93	37.18
24	135.5	18.0	3.000	104	22.28	15.38	14.42
25	105.5	20.0	2.500	109	104.20	12.90	21.82
26	162.0	19.0	4.300	252	26.14	45.25	31.95
27	124.5	15.0	3.000	127	4.03	18.07	16.83
28	104.0	19.0	1.920	45	2.81	8.83	5.44
29	108.5	17.0	2.400	75	37.48	15.00	9.93
30	105.0	20.0	2.100	58	45.06	12.53	14.90
31	216.8	20.0	6.300	283	38.61	46.45	30.33
32	62.0	11.0	1.200	28	0.54	2.14	1.82
Mean	132.62	20.11	3.30	128.28	61.12	32.59	23.28
Std. Error	8.85	1.03	0.28	14.95	15.13	6.51	4.06

The growth pattern of *A. borneensis* varied between plants and different plots. The large trees like durian (*Durio zibethinus*), engkabang jantung (*Shorea macrophyllum*), kemayau (*Santria rubiginosa*), bintawak (*Artocarpus anisophyllus*), tapang (*Kompassia excelsa*), ucung (*Baccaurea angulata*) and kuini (*Mangifera odorata*), influenced the survival of the *A. borneensis*. Through field observation, the *Amorphophallus* plants frequently occurred 2 – 4 meter from all these trees. It was possible that the *A. borneensis* grows better in moderate shading with sufficient amount of soil for growing media.

Most of the sampled plants were in the ranged between 120.5 cm – 180.5 cm of height (Table 1). The tallest plant recorded was at 244.5 cm with the ground surface petiole diameter 7 cm and the total dry weight of 306.96 g. The smallest plants recorded were 47.0 cm height with the ground surface petiole diameter of 0.903 cm and the total dry weight was only 7.7g.

The total dry weight of each 32 plants was not influenced by the ratio of its weight (Table 2). The highest leaflet weight ratio was 0.432 from sample 27, the highest petiole weight ratio was 0.532 from sample 21 and the highest of tuber weight ratio was 0.750 from sample 25. For specific leaflet area, the highest was 747.64cm^2/g from sample 12 while for the highest leaflet area ratio was recorded as 141.15cm^2/g from sample 2.

Table 2. The total dry weight, leaflet weight ratio (LWR), petiole weight ratio (SWR), tuber weight ratio (TWR), specific leaflet area (SLA) and leaflet area ratio (LAR) of *A. borneensis* at Gunung Gayu, Padawan.

Plant no.	Total dry weight (g)	LWR (g/g)	PWR (g/g)	TWR (g/g)	Leaflet area (A) (cm^2)	SLA (cm^2/g)	LAR (cm^2/g)
1	7.70	0.188	0.158	0.653	460	317.24	59.74
2	9.55	0.412	0.265	0.324	1348	343.00	141.15
3	32.44	0.287	0.242	0.470	2736	293.56	84.34
4	80.58	0.287	0.268	0.446	6055	262.23	75.14
5	147.99	0.139	0.127	0.734	3625	176.31	24.49
6	7.33	0.218	0.233	0.548	491	306.88	66.98
7	346.66	0.110	0.225	0.666	7117	186.75	20.53
8	126.16	0.170	0.248	0.582	5175	241.71	41.02
9	154.00	0.166	0.340	0.494	13931	545.03	90.46
10	113.74	0.075	0.178	0.748	4201	495.40	36.94
11	90.20	0.107	0.394	0.499	4626	477.40	51.29
12	57.83	0.099	0.371	0.530	4284	747.64	74.08
13	660.08	0.142	0.221	0.637	18474	196.70	27.99
14	140.46	0.255	0.303	0.441	9286	258.95	66.11
15	92.80	0.370	0.342	0.288	8302	241.90	89.46
16	73.72	0.310	0.385	0.305	6647	290.89	90.17
17	144.42	0.157	0.165	0.678	5968	262.79	41.32
18	313.09	0.143	0.164	0.693	7785	174.04	24.87
19	21.46	0.194	0.221	0.585	1471	353.61	68.55
20	25.48	0.112	0.201	0.687	926	323.78	36.34
21	306.96	0.326	0.532	0.142	24676	246.91	80.39
22	85.05	0.353	0.399	0.248	7932	264.14	93.26
23	100.59	0.370	0.427	0.204	9595	258.07	95.39
24	52.08	0.277	0.295	0.428	3793	263.04	72.83
25	138.92	0.157	0.093	0.750	4894	224.29	35.23
26	103.34	0.309	0.438	0.253	8388	262.54	81.17
27	38.93	0.432	0.464	0.104	5281	313.78	135.65
28	17.08	0.319	0.517	0.165	1981	364.15	115.98
29	62.41	0.159	0.240	0.601	2348	236.46	37.62
30	72.49	0.206	0.173	0.622	4193	281.41	57.84
31	115.39	0.263	0.403	0.335	9652	318.23	83.65
32	4.50	0.404	0.476	0.120	857	470.88	190.40
Total	3743.43	7.516	9.508	14.980	196498	9999.71	2290.38
Mean	116.98	0.235	0.297	0.468	6141	312.49	71.57

The vegetative parts of *A. borneensis* showed that the relationship between height and tuber fresh weight was $y = 104.13x + 0.114$ with $R^2 = 0.455$ (Figure 3a), between height and tuber dry weight was $y = 113.14x + 0.319$ with $R^2 = 0.297$ (Figure 3b), between ground surface petiole diameter and tuber fresh weight was $y = 2.386x + 0.004$ with $R^2 = 0.459$ (Figure 3c), between ground surface petiole diameter and tuber dry weight was $y = 2.692x + 0.010$ with $R^2 = 0.282$ (figure 3d) and lastly between height and ground surface petiole diameter was $y = 34.41x + 29.80$ with $R^2 = 0.899$ (Figure 3e).

Floristic composition and estimation of above ground biomass

The total of 373 trees from 63 species was surveyed within six plots of one hectare each at Gunung Gayu, Padawan. The entire Gunung Gayu was mainly comprised of *dusun* established by the Bidayuh community more than 100 years ago. The forest was mixture of common local fruit species such as durian (*Durio zibethinus*), rambutan (*Naphelium lappaceum*), tampoi (*Baccaurea* spp), nangka (*Artocarpus heterophyllus*), cempedak (*Artocarpus integer*), and others. The gigantic conspicuous presence of tapang trees (*Koompassia excelsa*) was

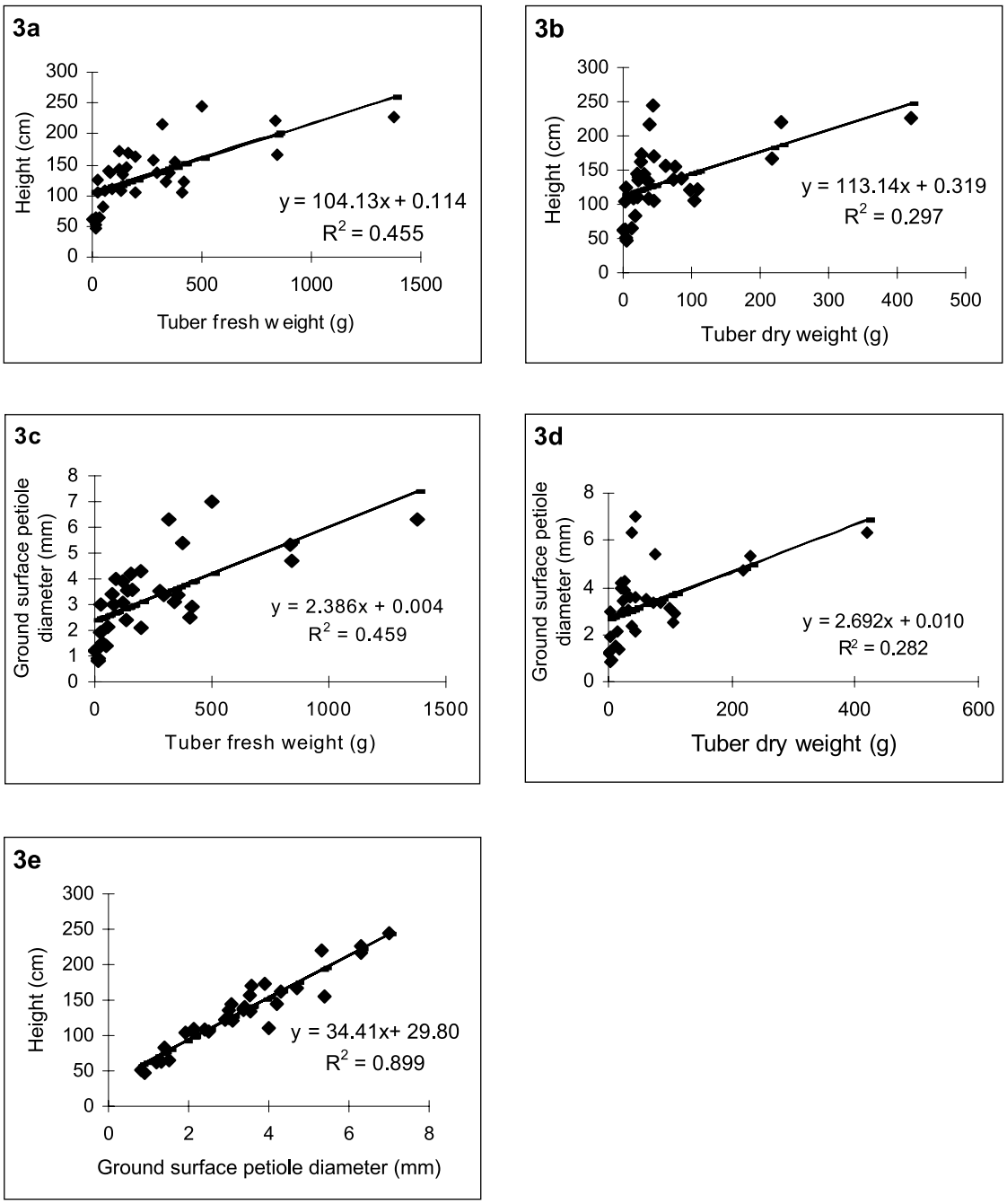

Fig. 3. The relationship between vegetative parts of *A. borneensis* (3a = between height and tuber fresh weight, 3b = between height and tuber dry weight, 3c = between ground surface petiole diameter and tuber fresh weight, 3d = between ground surface petiole diameter and tuber dry weight and 3e = between height and ground surface petiole diameter) from Gunung Gayu.

traditionally kept for natural bee keeping. These are the economic activity for the people who live there.

A. borneensis seemed to be one of the pioneers in this occasionally disturbed vegetations. The forest floor was frequently cleared by slashing the saplings, herbaceous plants and bamboos particularly during fruit seasons. It also can be found at forest margin, in open forest, on (steep) slopes, in disturbed parts of primary forest, and sometimes in very exposed parts in limestone karst areas (Hetterschied, 1994). The woody plants give an important canopy for the growth of *A. borneensis*.

The five most dominant species recorded was *Shorea macrophylla* (63 plants) with importance value (IV) = 64.21 (Table 3). This was followed by *Durio zibethinus* (21 plants) with IV = 21.87,

Table 3. Relative density (Rd), relative frequency (Rf), relative dominance (RD) and important value (IV) and estimated above ground biomass of trees with DBH ³ 5cm from the secondary forest at Gunung Gayu, Kuching

Species	Rd	Rf	RD	IV
Shorea macrophylla (de Vr.) Ashton	16.62	9.13	38.46	64.21
Durio zibethinus Murray	5.54	5.39	10.94	21.87
Baccaurea macrocarpa (Miq.) Mull. Arg.	8.18	7.05	2.63	17.87
Baccaurea angulata Merr.	8.71	5.81	2.21	16.73
Koompassia excelsa (Becc.) Taubert	1.32	1.66	12.20	15.18
Lansium domesticum Correa	5.80	4.56	1.81	12.18
Mangifera odorata Griffith	3.69	4.98	2.04	10.71
Santiria rubiginosa Bl.	4.75	4.15	0.84	9.74
Sandoricum koetjape Merr.	3.17	3.32	2.21	8.70
Ganua kingiana (Brace ex King & Gamble) H.J. Lam	2.11	1.24	3.88	7.23
Garcinia bancana (Miq.) Miq.	1.85	2.90	2.25	7.00
Eusideroxylon zwageri Teysmann & Bennendijk	2.90	2.49	1.10	6.50
Artocarpus anisophyllus Miq.	1.06	1.24	3.14	5.44
Artocarpus integer (Thunb.) Merr.	1.58	2.07	1.64	5.29
Ficus aurata (Miq.) Miq.	2.11	2.49	0.59	5.19
Xanthophyllum affine Korth.	1.58	1.66	1.93	5.17
Cleistanthus coriaceus Airy Shaw	1.58	2.49	0.47	4.55
Hevea brasilliensis (Willd. Ex A. Juss.) Muell. Arg.	1.85	2.07	0.39	4.31
Dacryodes rostrata (Bl.) Lam	1.58	0.41	1.75	3.75
Dracontomelon dao (Blanco) Merr. & Rolfe	1.06	1.24	0.89	3.19
Baccaurea motleyana (M.A.) M.A.	1.06	1.66	0.30	3.01
Artocarpus dadah Miq.	1.06	1.66	0.13	2.85
Ardisia polyactis Mez	1.06	1.66	0.07	2.79
Nephelium lappaceum L.	1.06	1.24	0.48	2.78
Artocarpus odoratissimus Blanco	0.26	0.41	1.95	2.63
Elaeocarpus sp.	0.79	1.24	0.45	2.49
Knema intermedia (Blume) Warb.	1.06	1.24	0.15	2.45
Diospyros siamang Bakh.	0.79	1.24	0.38	2.41
Bhesa paniculata Arn.	0.79	1.24	0.34	2.37
Mallotus leucodermis Hk. f.	1.06	0.83	0.21	2.09
Euodia malayana Ridl.	0.26	0.41	1.14	1.81
Eugenia sp.	0.79	0.83	0.16	1.79
Litsea nidularis Gamble	0.53	0.83	0.43	1.79
Artocarpus sarawakensis Jarrett	0.53	0.83	0.12	1.48
Artocarpus nitidus Trec.	0.53	0.83	0.11	1.47
Aporusa symplocoides (Hk. f.) Gage	0.53	0.83	0.06	1.42
Polyalthia cauliflora Hk. f. et Thoms.	0.53	0.83	0.06	1.42
Ardisia syneura Scheff.	0.53	0.83	0.05	1.41
Scolopia spinosa (Roxb.) Warb.	0.53	0.83	0.04	1.40
Callicarpa longifolia Lam.	0.53	0.83	0.03	1.39
Polyalthia glauca (Hassk.) Boerl.	0.53	0.83	0.03	1.39
Gluta sp.	0.53	0.83	0.03	1.38
Grewia omphacarpa Miq.	0.53	0.41	0.25	1.19
Adinandra dumosa Jack	0.53	0.41	0.08	1.02
Artocarpus kemando Miq.	0.26	0.41	0.16	0.84
Palaquium gutta (Hk. F.) Baillon	0.26	0.41	0.10	0.78
Dillenia excelsa (Jack) Gilg	0.26	0.41	0.10	0.77
Myristica malaccensis Hk. f.	0.26	0.41	0.06	0.74
Alstonia scholaris (L.) R. Br.	0.26	0.41	0.06	0.74
Memecylon paniculatum Jack	0.26	0.41	0.06	0.74
Monocarpia marginalis (Scheff.) Sinclair	0.26	0.41	0.05	0.73
Pometia pinnata J. R. Forster & J. G. Forster	0.26	0.41	0.04	0.72
Neolamarckia cadamba (Roxb.) F. Bosser.	0.26	0.41	0.04	0.72
Artocarpus elasticus Reinw. ex Blume	0.26	0.41	0.04	0.72
Horsefieldia grandis (Bl.) Warb.	0.26	0.41	0.03	0.71
Fordia coriacea Dunn	0.26	0.41	0.03	0.71
Alseodapha sp.	0.26	0.41	0.03	0.71
Canthium didymum Gaertn	0.26	0.41	0.02	0.70
Symplocos sp.	0.26	0.41	0.02	0.70
Dendrocnide stimulan (L.f.) Chew	0.26	0.41	0.02	0.70
Aglaia sp.	0.26	0.41	0.02	0.70
Shorea gibbosa Brandis	0.26	0.41	0.01	0.69
Shorea leprosula Miq.	0.26	0.41	0.01	0.69

Baccaurea macrocarpa (31 plants) with IV = 17.87, *Baccaurea angulata* (33 plants) with IV = 16.73, and *Koompassia excelsa* (5 plants) with IV = 15.18.

The total estimated above ground biomass was 164982.88kg/ha or 164.98 ton/ha (Table 4). The total estimation above ground biomass contributed the highest TAGB is *Shorea macrophylla* (52736.31kg/ha), followed by *Koompassia excelsa* (39805.10kg/ha), *Durio zibethinus* (24264.16kg/ha), *Artocarpus anisophyllus* (5758.56kg/ha) and *Ganua kingiana* (5630.89kg/ha).

Soil Analysis

According to Hettersceihd and Ittenbach (1996), there were two types of soil needed for *Amorphophallus* development. Both should be rich in organic matter and trace elements, but one must be well drained and must not contain loam, while the other may be heavier and enriched with loam. This division corresponds with two major climate preferences of *Amorphophallus* species. Those strongly seasonal climates can be grown in the heavier soil and includes all species with elongated tubers, and those from Africa, China, Japan, India, Thailand, Indochina, Philippines, eastern Indonesia, New Guinea and Australia. This large group of species will be referred to as Group I. While the species from Sumatra, Borneo (Kalimantan, Sarawak, Sabah and Brunei), and west Malaysia are set as Group II. Group II species grows in well-drained soil because their roots only survive in well-aerated soil.

The soil composition in Table 5 shows that the pH of the soil at Gunung Gayu was 5.59 ± 0.09 which indicated that the *A. borneensis* grows better in acidic soil. The mean percentage of nitrogen (N) in the soil was 0.25 ± 0.01 % while carbon (C) was 3.32 ± 0.09. The other elements such as calcium (Ca) was 10.23 ± 1.09 (+cmol/kg), magnesium (Mg) was 1.04 ± 0.06 (+cmol/kg), kalium (K) was 0.25 ± 0.01 (+cmol/kg), natrium (Na) was 0.05 ± 0.01 (+cmol/kg), and cation exchange capacity (CEC) was 18.77 ± 0.64 (+cmol/kg). Among these five elements, cation exchange capacity (CEC) had the highest concentration, followed by calcium (Ca), magnesium (Mg), kalium (K) and natrium (Na).

The base saturation (BS) rate in Gunung Gayu soil was 60.1544 ± 4.6605. The percentage of clay, silt and sand in the soil were 8.9 ± 0.6137%, 9.1± 0.5454% and 82 ± 0.8539% each respectively. From the data recorded, this showed that the *A. borneensis* grows well in well-drained soils that were important for the aeration of the roots for survival.

Effect of shading on *A. borneensis* seedlings

From the study conducted, all the seedlings placed under the different shading regimes showed slow increment in the number of leaflets (Figure 4a). There was significant different for the number of leaflets development under the 50% and 75% shading regimes. However, there was no significant development for the number of leaflets under 0% shading regimes. The number of leaflets showed higher increment at 75% shade levels after two weeks of transfer into the shade levels. The development for the number of leaflets at 0% shade level only showed the increment of leaflets on the tenth week of transfer. This result indicated that the developments of number of leaflets were greatly affected by the shade level. *A. borneensis* seemed to be growing well in higher shade levels. The plants under 50% shade level only showed increment in the number of leaflets on the sixth week.

In Figure 4B, the plant height was significantly differed between shade levels. The plants under 75% shade level were the tallest followed by the plants under 50% and 0% shade level with 22.4 cm, 17.0 cm and 12.1 cm each respectively on the tenth week of transfer.

The petiole diameter above ground surface was significantly higher in 50% and 75% shade level as compared to those from 0% shade level (Figure 4c). On the tenth week, the petiole diameters at ground surface for both 50% (7.68 cm) and 75% (7.25 cm) shade level were nearly the same while 4.78 cm for 0% shade level.

Effect of shading on biomass allocation of *A. borneensis*

The result showed that the highest plant dry weight were recorded from the 50% shade level, followed by 75% and 0% shade level with 2.10 g, 0.62 g and 0.30 g each respectively (Table 6). The highest total leaf area (cm^2) was recorded at 75% shade level (194.6 cm^2), followed by 50% shade level (171.0 cm^2) and lastly 0% shade level (45.0 cm^2). Total leaflet area from both 50% and 75% shade had significantly different with those from 0% shade. The result indicated that leaflets under higher shading were broader and bigger in sizes compares to plants that were exposed to sun light which were narrower. Higher shade level tends to produce larger leaflet area and through observation, the colour of the leaflets under 75% shade level were the darkest.

The leaflet weight ratios (LWR) were the highest for 75% (0.49), followed by 0% (0.39) and lastly 50% (0.21) shade level. The petiole weight ratio (PWR) was recorded the highest at 75% (0.28), followed by 0% (0.20) and 50% (0.13)

Table 4. The basal area (BA), leaf area index (LAI) and estimated above ground biomass of the tree species with DBH e•5cm at Gunung Gayu. Kuching

Species	Total individual trees	Average DBH (cm)	BA (cm^2)	LAI (cm^2)	Ws (kg)	WB (kg)	WL (kg)	Biomass (kg/ha)
Shorea macropyhlla (de Vr.) Ashton	63	49.6	89461.73	2076.49	42896.19	9594.18	245.95	52736.31
Koompassia excelsa(Becc.) Taubert	5	94	28383.26	1712.65	32462.51	7142.17	200.43	39805.1
Durio zibethinus Murray	21	15.4	25442.74	1220.22	19876.11	4248.24	139.81	24264.16
Artocarpus odoratissimas Blanco	1	76	4534.16	455.44	4771.91	937.59	49.07	5758.56
Ganua kingiana (Brace ex King & Gamble) H.J. Lam	8	39	9023.18	448.49	4666.87	915.74	48.27	5630.89
Artocarpus anisophyllus Miq.	4	55	7309.62	427	4346.5	849.31	45.82	5241.63
Sandoricum koetjape Merr.	12	24.1	5141.89	299.75	2603.45	493.56	31.46	3128.47
Mangifera odorata Griffith	14	10.6	4736.25	272.37	2266.15	426.12	28.42	2720.68
Dacryodes rostrata(Bl.) Lam	6	40.9	4076.91	259.22	2109.35	394.96	26.96	2531.27
Baccaurea macrocarpa (Miq.) Mull. Arg.	31	14.18	6129.21	255.64	2067.34	386.63	26.57	2480.54
Garcinia bancana (Miq.) Miq.	7	34.5	5238.66	252.26	2027.81	378.81	26.19	2432.81
Xanthophyllum affine Korth.	6	22.38	4481.05	224.96	1717.77	317.76	23.19	2058.73
Artocarpus integer (Thunb.) Merr.	6	34.6	3806.94	218.75	1649.47	304.4	22.51	1976.38
Lansium domesticum Correa	22	18.1	4202.87	191.22	1357.37	247.63	19.51	1624.51
Baccaurea angulata Merr.	33	12.8	5151.56	177.6	1219.51	221.08	18.04	1458.63
Eusideroxylon zwageri Teysmann & Bennendijk	11	12	2568.46	177.47	1218.22	220.83	18.03	1457.08
Dracontomelon dao (Blanco) Merr. & Rolfe	4	5.6	2072.25	176.8	1211.64	219.57	17.95	1449.16
Euodia malayana Ridl.	1	58	2640.74	169.77	1142.39	206.3	17.2	1365.89
Santiria rubiginosa Bl.	18	8.5	1947.89	118.2	675.98	118.35	11.71	806.03
Litsea nidularis Gamble	2	31	994.79	102.08	546.57	94.5	10.02	651.09
Eleocarpus sp.	3	16.5	1054.93	100.98	537.99	92.93	9.9	640.82
Ficus aurata (Miq.) Miq.	8	5.5	1373.79	95.23	494.16	84.93	9.3	588.4
Nephelium lappaceum L.	4	7.3	1112.91	90.78	461.08	78.93	8.84	548.85
Cleistanthus coriaceus Airy Shaw	6	8.8	1101.65	78.1	370.73	62.65	7.54	440.91
Bhesa paniculata Arn.	3	21.4	781.77	66.4	292.96	48.82	6.34	348.13
Diospyros siamang Bakh.	3	10.1	878.9	61.74	263.63	43.66	5.87	313.16
Hevea brasilliensis (Willd. Ex A. Juss.) Muell. Arg.	7	6.9	901.88	57.94	240.46	39.61	5.49	285.56
Baccaurea motleyana (M.A.) M.A	4	10.5	687.32	57.35	236.88	38.99	5.43	281.29
Grewia omphacarpa Miq.	2	15.7	573.43	52.39	207.78	33.93	4.93	246.64
Mallotus leucodermis Hk. f.	4	16.5	486.19	47.72	181.45	29.4	4.47	215.31
Artocarpus kemando Miq.	1	22	379.94	45.7	170.43	27.51	4.26	202.2
Eugenia sp.	3	18.5	381.09	36.39	122.49	19.39	3.35	145.23
Artocarpus nitidus Trec.	2	14.3	264.34	30	92.53	14.41	2.73	109.66
Knema intermedia (Blume) Warb.	4	9.93	342.24	28.11	84.23	13.04	2.55	99.81
Artocarpus sarawakensis Jarrett	2	6	282.6	25.8	74.38	11.43	2.32	88.14
Artocarpus dadah Miq.	4	6.5	311.76	22.35	60.37	9.17	1.99	71.53
Dillenia excelsa (Jack.) Gilg	1	16.8	221.56	19.85	50.85	7.64	1.76	60.25
Myristica malaccensis Hk. f.	1	13.7	147.34	19.82	50.73	7.62	1.76	60.11
Adinandra dumosa Jack	2	13.7	180.5	19.74	50.42	7.57	1.75	59.74
Palaqium gutta (Hk. f.) Baillon	1	17.5	240.41	19.54	49.68	7.46	1.73	58.87
Alstonia scholaris (L.) R. Br.	1	13.2	136.78	14.33	31.68	4.63	1.24	37.55
Memecylon paniculatum Jack	1	13.2	136.78	14.33	31.68	4.63	1.24	37.55
Pometia pinnata J. R. Forster & J. G. Forster	1	11.5	103.82	14.2	31.26	4.57	1.23	37.06
Monocarpia manginalis (Scheff) Sinclair	1	12.4	120.7	14.05	30.77	4.49	1.22	36.48
Aporusa symplocoides (Hk. f.) Gage	2	7.4	139.71	14.03	30.72	4.48	1.22	36.42
Polyalthia cauliflora Hk. f. et Thoms.	2	6.4	145.19	13.66	29.56	4.3	1.18	35.05
Ardisia polyactis Mez	4	5.2	168.5	13.44	28.88	4.2	1.16	34.24
Neolamarckia cadamba (Roxb.) F. Bosser.	1	10.6	88.2	12.72	26.64	3.85	1.1	31.59
Horsefieldia grandis (Bl.) Warb.	1	10.1	80.08	11.91	24.23	3.49	1.02	28.74
Ardisia syneura Scheff.	2	5.8	114.61	11.28	22.39	3.21	0.96	26.56
Scolopia spinosa (Roxb.) Warb.	2	8.3	87.24	10.49	20.15	2.87	0.89	23.91
Fordia coriacea Dunn	1	9.5	70.85	9.8	18.24	2.58	0.83	21.65
Callicarpa longifolia Lam.	2	8.8	80.42	9.57	17.62	2.49	0.81	20.92
Polyalthia glauca (Hassk.) Boerl.	2	6.5	66.33	8.56	15	2.1	0.72	17.82
Artocarpus elasticus Reinw. Ex Blume	1	10.5	86.55	8.26	14.25	1.99	0.69	16.93
Canthium didymium Gaertn	1	8	50.24	8.24	14.18	1.98	0.69	16.85
Symplocos sp.	1	8.4	55.39	7.78	13.05	1.81	0.65	15.51
Alseodapha sp.	1	9.6	72.35	7.32	11.95	1.65	0.61	14.21
Gluta sp.	2	5.6	60.92	7.03	11.27	1.55	0.58	13.4
Dendrocnide stimulant (L. f.) Chew	1	8.5	56.72	6.8	10.73	1.47	0.56	12.76
Aglaia sp.	1	8	50.24	6.78	10.69	1.47	0.56	12.72
Shorea gibosa Brandis	1	6.5	33.17	5.12	7.11	0.95	0.42	8.48
Shorea leprosula Miq.	1	5.9	27.33	3.02	3.3	0.42	0.24	3.96
								164983 kg/ha or 164.982 ton/ha

Table 5. The pH, organic carbon, nitrogen, exchangeable potassium, sodium, calcium, magnesium CEC and base saturation in soil composition at Gunung Gayu

Sample	(+cmol/kg)						% BS	% N	% C	% Clay	% Silt	% Sand
	Dry pH	CEC	Ca	Mg	K	Na						
P1	5.30	18.40	10.18	1.76	0.24	0.03	66.36	0.27	3.58	2.50	13.50	84.00
P2	4.90	16.40	5.71	1.91	0.26	0.02	48.17	0.26	3.30	7.50	8.50	84.00
P3	5.60	19.60	13.99	1.21	0.28	0.07	79.34	0.29	3.72	7.50	13.50	79.00
P4	5.10	20.20	6.05	0.63	0.21	0.01	34.16	0.24	3.04	10.00	11.00	79.00
P5	5.40	17.40	8.84	1.05	0.28	0.03	58.62	0.31	3.82	10.00	11.00	79.00
P6	6.00	19.80	11.41	0.84	0.14	0.02	62.68	0.31	4.08	7.50	8.50	84.00
P7	6.00	22.20	16.63	1.08	0.25	0.04	81.08	0.27	3.40	5.00	6.00	89.00
P8	6.10	28.80	18.42	0.94	0.24	0.03	68.16	0.30	3.86	7.50	8.50	84.00
P9	6.10	19.80	15.37	1.06	0.20	0.05	84.24	0.23	2.91	7.50	8.50	84.00
P10	6.10	21.00	17.53	1.05	0.23	0.05	89.81	0.26	3.39	7.50	8.50	84.00
P11	6.30	19.20	15.47	0.87	0.26	0.06	86.77	0.19	3.03	5.00	6.00	89.00
P12	6.30	22.20	16.65	1.05	0.16	0.07	80.77	0.23	3.02	10.00	6.00	84.00
P13	6.20	21.40	19.50	1.04	0.31	-0.01	97.38	0.26	3.50	10.00	11.00	79.00
P14	6.10	17.80	6.53	0.57	0.12	-0.02	40.45	0.21	2.88	5.00	6.00	89.00
P15	4.70	17.80	0.77	0.49	0.36	0.02	9.21	0.20	3.03	10.00	16.00	74.00
P16	5.10	18.20	3.73	0.79	0.23	0.08	26.54	0.25	3.51	10.00	8.50	81.50
P17	5.50	17.00	9.41	0.99	0.24	0.06	62.94	0.25	3.28	10.00	8.50	81.50
P18	5.90	20.80	14.26	1.29	0.30	0.06	76.49	0.32	4.22	10.00	6.00	84.00
P19	5.40	15.40	6.63	1.05	0.23	0.03	51.56	0.18	2.32	10.00	6.00	84.00
P20	4.90	16.60	1.50	0.88	0.29	0.17	17.11	0.20	2.55	17.50	8.50	74.00
P21	5.60	18.80	11.97	0.88	0.23	0.08	70.00	0.22	3.17	7.50	8.50	84.00
P22	5.20	18.60	5.44	1.08	0.34	0.08	37.31	0.25	3.41	10.00	6.00	84.00
P23	5.10	13.80	4.33	1.35	0.29	0.05	43.62	0.21	2.90	15.00	11.00	74.00
P24	5.40	15.00	7.57	1.09	0.33	0.08	60.47	0.25	3.71	10.00	11.00	79.00
P25	5.40	13.00	7.77	0.99	0.31	0.11	70.62	0.25	3.33	10.00	11.00	79.00
Mean	5.59	18.77	10.23	1.04	0.25	0.05	60.15	0.25	3.32	8.90	9.10	82.00
Std Error	0.10	0.64	1.10	0.06	0.01	0.01	4.66	0.01	0.09	0.61	0.55	0.85

Table 6. Effect of shading on vegetative growth, leaf area production and biomass allocation of *A. borneensis* (30^{th} day harvest). Values shading the same letter within column are not significantly different at $P \leq 0.05$ according to Duncan's Multiple Range Test

Shade Level	Plant Dry Weight (g)	Total Leaf Area (cm^2)	LWR (g/g)	PWR (g/g)	RWR (g/g)	TWR (g/g)	SLA (cm^2/g)	LAR (cm^2/g)
0%	0.30a	45.0a	0.39b	0.20ab	0.19a	0.21a	378.4a	150.8b
50%	2.10c	171.0b	0.21a	0.13a	0.46b	0.19a	404.4a	87.7a
75%	0.62b	194.6b	0.49c	0.28b	0.12a	0.12a	678.9b	331.6c

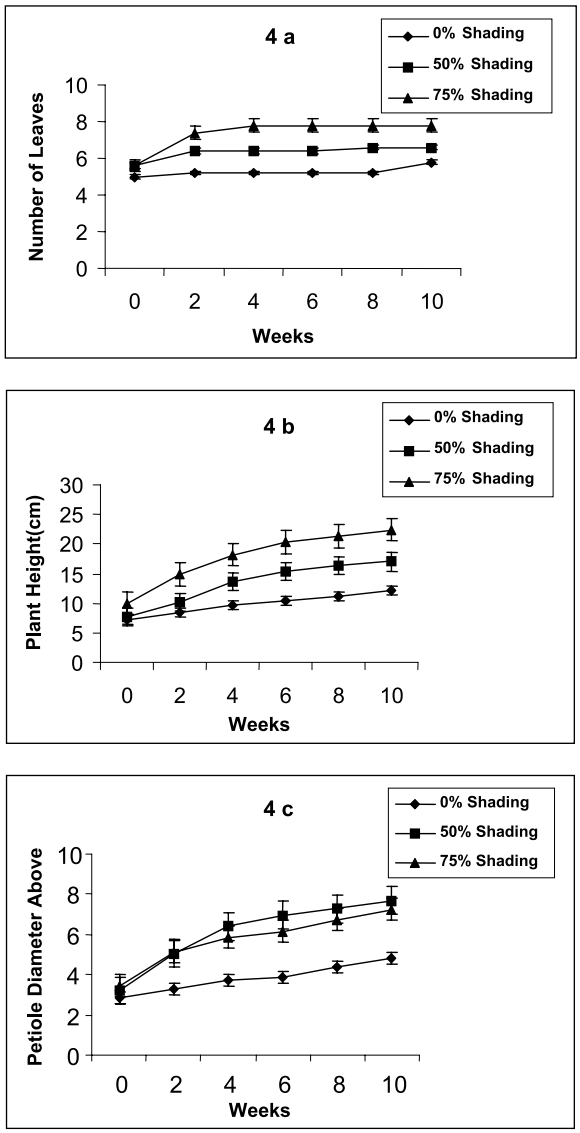

Fig. 4. Effect of shading on (4a = number of leaflets, 4b = plant height (cm), 4c = Petiole Diameter Above ground Surface (cm)) of *A. borneensis*. Vertical bars are values of standard error.

shade level. However, there was no significant different between shade level. As for root weight ratio (RWR), the highest ratio were recorded from 50% (0.46), followed by 0% shade level (0.19) and lastly 75% (0.12) shade level. The TWR from different shade had no significant difference. The tuber weight ratio (TWR) were the highest at 0%, followed by 50% and 75% shade level with 0.21, 0.19 and 0.12 each respectively.

The specific leaflet area (SLA) tended to increase with increase in shading. Highest SLA was recorded at 75%, followed by 50% and 0% shading with 678.88 cm^2/g, 404.43 cm^2/g and 378.36 cm^2/g each respectively. The plants 75% shade had larger leaflets compared to plants grown in 50% and 0% shading. The leaflets at 0% shade level tend to be narrower. LAR values were 150.80 cm^2/g, 87.65 cm^2/g and 331.58 cm^2/g for 0%, 50% 75% shade levels respectively.

Table 7. Effect of shading on dry matter production (DMP), net assimilation rates (NAR, leaf area duration (LAD) of *A. borneensis* during 30^{th}–60^{th} day interval. Values sharing the same letter within column are not significantly different at $P \leq 0.05$ according to Duncan's Multiple Range Test

Shade	DMP (g)	NAR ($g/dm^2/day$)	LAD (dm^2/day)
0%	0.94a	0.32a	2429.84a
50%	1.90a	0.28a	6121.25b
75%	0.87a	0.12a	6362.81b

There was no significantly difference of dry matter productions (DMP) from shade levels. At 50% shading, DMP was 1.90 g, 0.94 g for 0% shade and 0.87 from 75% shade (Table 7). The net assimilation rates (NAR) were recorded the highest at 0% shade level (0.32 $g/dm^2/day$) and the lowest at 75% shade level (0.12 $g/dm^2/day$). The leaflet area duration (LAD) recorded at 75% shade was 6362.81 dm^2/day, 6121.25 dm^2/day for 50% shade and 2429.84 dm^2/day for 0% shade.

CONCLUSION

The genus *Amorphophallus* have been divided into various groups. They are the Paeonifolius, Lambii, Gigas, Beccarii, Manta, Carneus, Dactylifer and the Longituberosus groups (Hetterscheid, in prep). All of the three species, *A. borneensis*, *A. hewittii* and *A. lambii* belong to the Lambii group. Apart from that, the other species belonging to the Lambii groups are *A. plicatus* Bok & Lam, *A. tinekeae* and *A. titanum* (Becc.) Becc. ex Arcangeli. The Lambii group are widely distributed in the West Malesia (Sumatra, Borneo, Sulawesi).

The *A. borneensis* is originally found in southern and western Kalimantan. There are two varieties of *A. borneensis*: one is *A. borneensis* var. *borneensis*, the other being *A. borneensis* var. *winkleri* Engl. The type locality of *A. borneensis* var. *borneensis* is Pagat, Kalimantan Selatan, Indonesia collected by Aldolf Engler in November 1882. As for *A. borneensis* var. *winkleri*, the type locality is in Indonesia, Southeast Kalimantan, between Lumo Sibak and Murah Benangin collected in August 1908 also by Engler. The occurrence of this species is a new record in Sarawak. *Amorphophallus borneensis* can be found growing in the secondary forest and on the lime stone area. This species can be found growing in

either dense shade or out in the open on cleared land. It is a lowland plant and grows well in warm and humid climate. The petiole has variable forms of colours, some are very dark, nearly black base colour to black and green to a red-dominated form. The petiole is slightly rough.

The study showed that the population of *A. borneensis* at Gunung Gayu, Padawan was low in density. The ground surface stem diameter mostly ranges between 0.95mm to 20.5mm while its height was mostly among 120.5cm to 180.5cm. There was a strong relationship between height and ground surface stem diameter in which R^2 = 0.899. *A. borneensis* often grows 2 to 4 meter from the largest trees such as durian, engkabang, tapang, and others. This indicated that *A. borneensis* grows better in moderate shading. The forest structure showed that the five most dominant species with the occurrence of *A. borneensis* were *Shorea microphyllum*, *Durio zibethinus*, *Baccaurea macrocarpa*, *Baccaurea angulata*, and *Koompassia excelsa* with their importance value (IV) of 64.21, 21.87, 17.87, 16.73 and 15.18 each respectively. *A. borneensis* also grows better in acidic soil (pH 5 - 6) and the soil must be well aerated for better root growth.

The study revealed that the *A. borneensis* were able to grow well in shaded conditions. Through observations, the *A. borneensis* were developing well under 75% shade level and also 50% shade level. Shading also greatly affects the biomass allocation of the plants. Further studies should also be conducted in understanding the life cycle of the *A. borneensis* in order to ensure the survival of the *A. borneensis*. The studies about the environmental factors that are compatible to the *A. borneensis* are also recommended to obtain sustainable population of *A. borneensis*. In Borneo, this species is continuously threatened due to the human activities such as logging, deforestation and shifting cultivation. This plant is observed to be restricted in ranges especially geologically and there is possibility that the species may suffer local extinction.

The study on ecology and systematics on *A. borneensis, A. hewittii* and *A. lambii* as to determine the relationship and genetic relatedness between the three species is urgently needed. The morphological variations between species should be identified and compared of their linkage to geology and geographical distribution. Identifying the relationships between these species will lead to the understanding of the current taxonomic status between the three species.

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