Pertanika J. Trop. Agric. Sci. 43 (3): 327 - 342 (2020)

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

Associations of Growth and Phenology Cycles with Environmental Variables on the Population Dynamics of Non-climbing Rattan *Calamus castaneus* Griff.

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ABSTRACT

In Malaysian forests, the population dynamics of rattan has not been fully documented. Hence, this study was aimed to investigate the population dynamics pattern of the *Calamus castaneus*, a non-climbing rattan. The association of growth and phenology cycle to environmental variables on the population dynamics were studied for one year. Three forest reserves were selected as the study sites: Segari Melintang Forest Reserve (SMFR) in Perak, Teluk Bahang Forest Reserve (TBFR), and Bukit Mertajam Forest Eco-Park (BMFEP) in Penang. The fieldwork was conducted from March 2017 until March 2018. With the plot size of 10 m × 10 m (100 m²), five plots were established in each study site. All the *C. castaneus* individuals inside the plots were marked with numbered plastic tags. A total of 180 individuals were evaluated: TBFR (52 individuals), SMFR (86 individuals), and BMFEP (42 individuals). The findings have revealed that the *C. castaneus* abundancy is comparatively similar in all sites, as shown by the Kruskal-Wallis test with no significant difference ($p > 0.05$) between all life stages. The canonical correspondence analysis (CCA) for all sites has displayed that the rattan growth parameters are closely associated with the microclimate parameters and soil properties. Overall, SMFR showed the fastest growth increment and the largest population size of *C. castaneus* among all three sites.

Keywords: Arecaceae, *Calamus castaneus*, non-climbing rattan, palm, population dynamics

ARTICLE INFO

Article history:
Received: 28 February 2020
Accepted: 16 June 2020
Published: 28 August 2020

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ISSN: 1511-3701
e-ISSN: 2231-8542

INTRODUCTION

Rattan (derived from the Malay word "rotan") is a type of a spiny climbing palm from the Arecaceae family under the subfamily of Calamoideae (Dransfield, 2001). Rattan is mostly used to make furniture (Sastry, 2001). Thirty (30) out of 106 species from 8 genera of rattan found in Peninsular Malaysia are harvested and utilized by the country's rattan industry. Rattan from the genus *Calamus* mostly has high economic value with international rattan trade over USD 6.5 billion per year (Ali & Barizan, 2001; Dransfield, 1979; Wan Ariffin et al., 2018). However, in this study, the species monitored is the non-climbing rattan, *Calamus castaneus* (Figure 1). This species has no flagellum or cirrus which usually are the climbing parts of rattan. The *C. castaneus* is easily recognized by its striking scaly chestnut-colored fruits and dull dirty grey indumentose under the leaflet. Primates such as macaques devour the sweet yet acidic taste of *C. castaneus* (Dransfield, 1979; Ruppert et al., 2016). This species prefers a watercourse area with a shady canopy to grow (Dransfield, 1979). Aside from roofing material, this species also possesses medicinal value. The fruit is utilized by the aboriginal people to treat cough (Dransfield, 1979; Sunderland & Dransfield, 2002).

Calamus castaneus is selected as the model rattan species to be studied is due to the availability of this species. It is a very familiar rattan in Peninsular Malaysia and this species can be easily found. According to Ruppert et al. (2012), this rattan species possesses broad lush green leaves which creates shade for growth of plants with low light tolerant. Dransfield (1979) stated that this genus was also known for its symbiosis with the ants. The leaves act as litter-collector which provide building materials

Figure 1. *Calamus castaneus* with yellowish-based spines

for ants to build a nest and in return provide nutrient for the host. As a result of low yield of long canes and large diameter stem, this species is rarely exploited by humans making its natural populations unaffected (Kidyoo & McKey, 2012). Hence, by knowing the importance of this species in maintaining forest ecology, further studies on its population dynamics were conducted. *Calamus* is spiny climbing palms and can climb up to 10 meters. To avoid these difficulties, *C. castaneus*, an acaulescent palm, were chosen.

In this study, the phenology of the *C. castaneus* plant was monitored for a year in three forest reserves in the northern region of Peninsular Malaysia. The focus of this article is to observe the life cycle of *C. castaneus* population for a year and to associate with its environmental requirement. Renuka and Rugmini (2007) stated that the population dynamics and population structure differed according to habitat confines. Thus, it was expected that there would be a difference in regeneration status, population size, and the relationship between plant phenology and environmental variables (e.g. climate and habitat factors) throughout the year.

MATERIALS AND METHODS

Description of the Study Sites

The study was conducted at three dipterocarp forests in the northern region of Peninsular Malaysia which were Teluk Bahang Forest Reserve (TBFR; 05° 26’ 34” N, 100° 13’ 14” E) and Bukit Mertajam Forest Eco Park (BMFEP; 05° 21’ 57” N, 100° 28’ 58” E) in Pulau Pinang as well as Segari Melintang Forest Reserve (SMFR; 04° 19’ 34” N, 100° 34’ 57” E), which is located in Perak as shown in Figure 2. The total area of the TBFR is 117 ha. This lowland dipterocarp forest is strictly protected as a Virgin Jungle Reserve (VJR). The BMFEP covers 37 ha and were well known to the locals as a

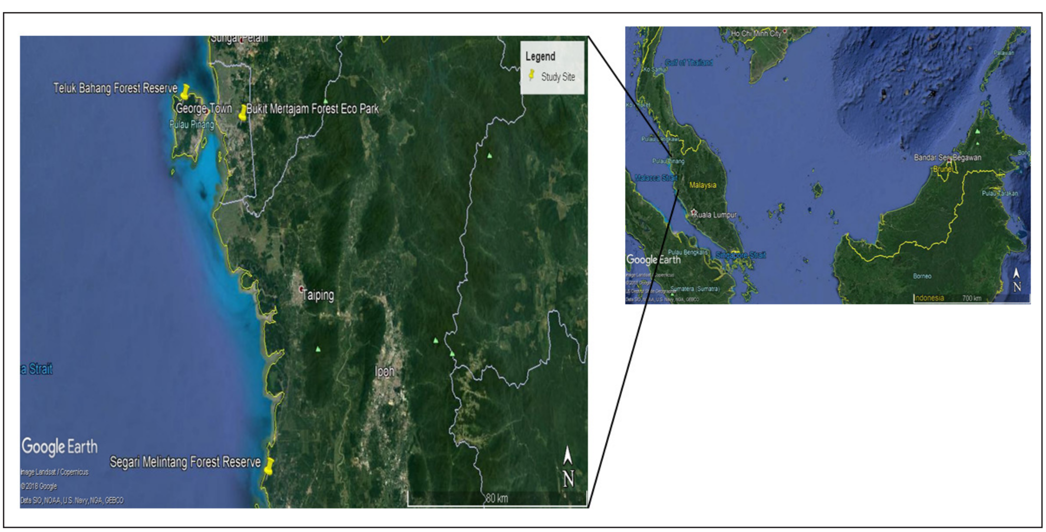

Figure 2. Map of the three study sites, which were extracted from Google Earth

famous hiking spot as it comprises of a hilly area. Both sites act as the water catchment area of which Teluk Bahang Dam is located near TBFR while Mengkuang Dam is close to BMFEP. The SMFR is located along the coastal area of the Manjung district and is mainly composed of primary coastal forest and alluvial freshwater swamp vegetation (Rusdi, 2019). There is a watercourse area inside the plot on this study site. Only 408 ha from 2741 ha of the SMFR is protected as a VJR while the rest was logged before and regenerated as Permanent Forest Reserve (PFR). This study was conducted for a year, between March 2017 to March 2018.

Plots Preparation and Rattan Assessment

Using the square plot design, five plots of 10 m × 10 m (100 m²) were established within each of the study sites. Forest trail was used as the main reference line where plots were established 500 m from the trail entrance. The cluster of rattan within the sampling plots was randomly distributed. To facilitate the monitoring of the whole population in a day, the distance between plots was fixed at 50 meters. In these plots, all individuals of the *C. castaneus* were identified and marked with numbered plastic tags (Bøgh, 1996). The identification of the specimens was based on the keys in "A Manual of the Rattans of the Malay Peninsula" (Dransfield, 1979). A complete sample of the *C. castaneus* stem with fresh sheath, inflorescences, and/or infructescences was collected from the field and deposited at the USM Herbarium. To analyze the influence of climate on the recurrence of such annual phenomena of *C. castaneus*, parameters such as plant sexes, life stages, leaf sheath number, presence of flower, fruit, and length of petiole and rachis were recorded monthly for 12 months. Only one leaf with complete petiole and rachis were tagged and recorded throughout the studies. However, three readings were taken each time to get the average length. The life stages of the studied rattan species such as its seedling, young, or adult were noted. Life stages were classified according to height since this species in an acaulescent rattan: 1) seedling - ≤ 1 meter, 2) young plant - ≥ 1 meter but without signs of flowering and fruiting, and 3) adult - ≥ a 1-meter plant that bears flower or fruit. The sexes of each plant were identified by observing the flowers or fruits from the previous seasons (Kidyoo & McKey, 2012). Meanwhile, the length of petiole and rachis were measured using a measuring tape.

Microclimate Sampling and Soil Analysis

Microclimate readings (i.e. relative humidity, air temperature, soil temperature, light intensity, percentage of gap opening, and level of disturbance) were taken *in situ* every month between 10 a.m. until 12 p.m. time range (Hardwick et al., 2015). A portable thermo-hygrometer (Hanna Instrument model HI 9564) was used to measure the air temperature and relative humidity while a portable luxmeter (Hanna Instrument model HI 97500) was used in measuring light intensity. The readings were taken 1.5 meters from the ground near the cluster of

C. castaneus inside the plots. Using a soil thermometer, the soil temperature was taken in a cleared ground that was not covered by any rocks or leaf debris to avoid damaging the soil temperature's probe. The readings were taken three times each when the meter reading was already stable. For soil analysis which includes soil bulk density, soil moisture content, soil pH, and soil texture analysis, the topsoil samples from 0 - 15 cm depth were collected using polyvinyl chloride (PVC) tube. Three soil samples were taken near the cluster of studied species. The soil samples were sealed in a zip-lock storage bag for soil analysis purposes. The soil pH was measured using a pH meter kit with a water ratio of 1: 5. The determination of soil texture was made using the hydrometer method. The percentage of sand, silt, and clay were referred to as the USDA textural triangle in determining the texture of the soil.

Canopy Gap Opening

The percentage of gap opening status and disturbance level (Table 1) were referred to as Mansor (2001).

Level of Disturbance

Table 1
Percentage range and gap opening status

Percentage range (%)	Gap opening status
0 - 25	Closed area
26 - 40	Partly closed area
41 - 60	Slightly opened area
61 - 80	Partly opened area
81 - 100	Highly opened area

The level of disturbance was modified from Mansor (2001) by Rozali (2014) using disturbance index (DI) considering certain factors such as ecology, socioeconomic, and infrastructure. The index was scaled from 1 until 5 with 1 represented as the lowest disturbed and 5 represented as the highest disturbed (Table 2).

Based on the following disturbance index (DI) calculation, the percentage of disturbance were calculated:

$$DI = g_1 + g_2 + g_3 + g_4 + g_5$$

where:
g_1 = Trails
g_2 = Number of visitors
g_3 = Land use
g_4 = Water supply
g_5 = Gap forest cover

$$\text{Percentage of disturbance} = [(g_1 + g_2 + g_3 + g_4 + g_5) / (25)] \times 100$$

Based on the total disturbance index (DI) from each plot, the percentage of disturbance were ranged as in Table 3.

Data Analysis

All *C. castaneus* individuals inside the plots were counted and the growth parameters were observed and recorded every month. To calculate the mean abundance of the *C. castaneus*, statistical package for social sciences, SPSS software version 21 was used to perform the normality test and Kruskal-Wallis test. Non-parametric of the Kruskal-Wallis test were applied as the

Table 2
Characterization for disturbance criteria

Feature	Disturbance scale
	Trails (g1)
Infrastructure:	
Unexplored forest overgrown by big trees	1
Unexplored forest and filled with bushes	2
Explored forest with small trails < 50 cm width (rarely used by visitors)	3
Explored forest with bigger trails > 50 cm width (always used by visitors)	4
Paved roads	5
	Visitors per day (g2)
Socioeconomics:	
1 - 15 visitors	1
16 - 25 visitors	2
26 - 35 visitors	3
36 - 45 visitors	4
> 45 visitors	5
	Land use (g3)
Ecology:	
Virgin forest	1
Secondary forest	2
Reserve forest	3
Agriculture	4
Clearings forest	5
	Water resource (g4)
Big streams or waterfalls	1
Watercourse	2
Recreational ponds	3
Damp	4
Dried area, no watercourse in the forest	5
	Canopy opening (g5)
0 - 25 %	1
26 - 40 %	2
41 - 60 %	3
61 - 80 %	4
81 - 100 %	5

data for this analysis violates the parametric assumptions. Microclimate data were analyzed using the parametric test: one-way ANOVA with post-hoc Tukey test.

Table 3
Percentage range and disturbance status

Percentage range (%)	Disturbance status
0 - 25	Low disturbed area
25 - 50	The moderately low disturbed area
50 - 75	The moderately high disturbed area
75 - 100	Highly disturbed area

The association between the environmental parameter on the population dynamics of the *C. castaneus* were analyzed using the canonical correspondence analysis (CCA) and was performed with the CANOCO version 4.5. CCA was used as it performs quite well with highly intercorrelated environmental variables and with a situation where not all the factors determining species composition are known (Palmer, 1993).

RESULTS

Life Stages and Population Size

A total of 180 *C. castaneus* individuals were observed during the one-year sampling period. From Table 4, Segari Melintang Forest Reserve (SMFR) displayed the most abundant of seedling (40 individuals), adult plant (41 individuals), and the fewest amount of young plant (5 individuals) compared to the other two sites. This site also showed the highest abundance (86 individuals) of *C. castaneus* followed by Teluk Bahang Forest Reserve (TBFR) (52 individuals) and lastly Bukit Mertajam Forest Eco-Park (BMFEP) (42 individuals). TBFR displayed the smallest number of seedlings individual (10 individuals), adult plant (6 individuals) but with the highest amount of young plant (36 individuals). Canopy opening and vegetation may have affected the distribution of the *C. castaneus* on the site since this species prefers shady and watercourse area.

Leaf-sheath number per individual in TBFR and SMFR showed an increment but BMFEP showed otherwise (Table 5). SMFR recorded a rapid growth on petiole and rachis length per month in all life stages. On the other hand, TBFR and BMFEP displayed a similar rate for average petiole and rachis length per month. SMFR recorded the fastest rate for an average of rachis length (adult & young) and young petiole. Generally, the rate of average adult petiole length was the same for all sites. Overall, the average height of seedling per month in SMFR was the fastest with 11.6 cm/month followed by BMFEP with 1.7 cm/month and TBFR with 0.9 cm/month. Generally, all sites showed an increasing rate of mortality with TBFR the highest followed by SMFR and BMFEP. The example of causes of mortality was a landslide, tree fall, cut by a human, scorching (leaf tip burning), predator, heavy rain, and strong wind as shown in Table 5. Recreational activities such as hiking were done by direct observation at the site and informal interviews with the locals. Based on observation, *C. castaneus* were not infected by the disease and mostly die due to natural disaster, human activities (e.g. hiking) and predation (e.g. wild boar). BMFEP ($0.084/m^2$) recorded the smallest population density meanwhile SMFR ($0.172/m^2$) the highest.

Recruitment of *Calamus castaneus*

The Kruskal-Wallis test ($p > 0.05$) in Figure 3 shows that there is no significant difference between the regeneration status of *C. castaneus* seedlings, young plants, and adult plants in all investigated forests.

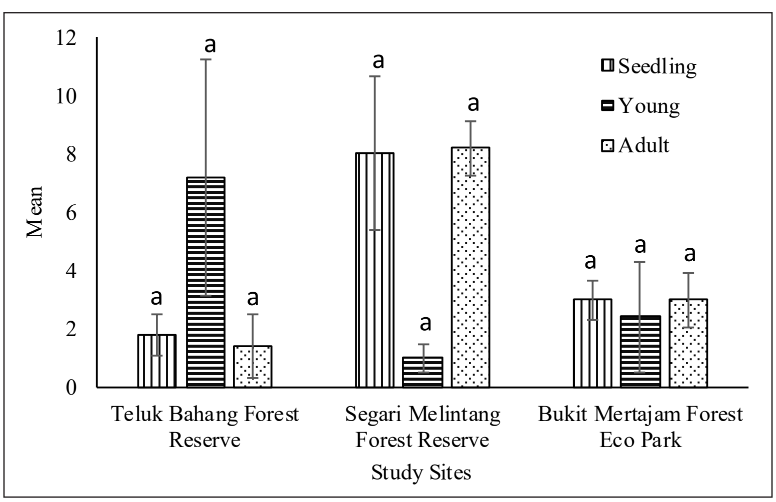

Figure 3. Mean abundance of *Calamus castaneus* in different life stages based on the Kruskal-Wallis test ($p > 0.05$). Bars (mean ± standard error) with letter 'a' showed that there was no significant difference between each site

Table 4
Number of Calamus castaneus *individuals according to different life stages in all study sites*

Life stages	Teluk Bahang Forest Reserve	Segari Melintang Forest Reserve	Bukit Mertajam Forest Eco Park
Seedling	10	40	15
Young	36	5	12
Adult	6	41	15
Total	52	86	42

Table 5
Rate of observed rattan parameters, mortality and population density of Calamus castaneus *individuals for a year*

Site	Life stages	Number of leaf sheath/ individual		Average petiole length (cm)/ month	Average rachis length (cm)/ month	The average height of seedling (cm/month)	Mortality of individuals		Causes of mortality	Population density (per m²)
		t_0	t_1				t_0	t_1		
TBFR	Adult	12	13	0.5 ± 0.1^a	0.6 ± 0.1^a	-	6	2	Landslide, tree fall, cut by human, heavy rain and strong wind	0.104
	young	8	9	0.5 ± 0.0^a	0.6 ± 0.0^a	-	36	16		
	seedling	-	-	-	-	0.9	10	4		
SMFR	Adult	12	13	9.3 ± 2.7^a	15.6 ± 4.0^b	-	41	32	Tree fall, scorching, predator, heavy rain and strong wind	0.172
	young	8	12	4.2 ± 3.1^b	4.2 ± 3.1^b	-	5	2		
	seedling	-	-	-	-	11.6	40	35		
BMFEP	Adult	11	10	0.6 ± 0.0^a	0.6 ± 0.0^a	-	15	14	Landslide, tree fall, cut by human, heavy rain and strong wind	0.084
	young	8	6	0.6 ± 0.0^a	0.6 ± 0.0^a	-	12	12		
	seedling	-	-	-	-	1.7	15	10		

Note. t_0: initial reading (taken in March 2017); t_1: final reading (taken in March 2018). Superscripts a and b indicated the significant differences at $p < 0.05$ by post-hoc Tukey test in each parameter between sites

Relationship of Environmental Variables with the *Calamus castaneus* Phenology

Table 6 shows the mean environmental variables parameter that was recorded from March 2017 until March 2018. The data was collected twice each month. One-way ANOVA was used to analyze the significant difference between each site since microclimate is a parametric data. The significant difference between sites was denoted as in Table 6. From ten variables listed, only four which were air temperature, light intensity, canopy gap opening, and soil bulk density displayed the same on each site.

The CCA of growth and environmental data which are summarized in Tables 7, 8, and 9 indicate that the species-environment correlations were low of which eigenvalues (the score of the maximized dispersion of the species on the ordination axis and the strength of an axis) were less than 0.5 (values over 0.5 often express a good division of the species along the axis). The cumulative variance explained by the first three axes of the species-environment

Table 6
Environmental variables parameter (Mean ± SE) measured from March 2017 until March 2018

Parameter	TBFR	SMFR	BMFEP
Relative humidity (%)	83.70 ± 1.34^{b}	71.59 ± 2.21^{a}	81.14 ± 2.18^{b}
Air temperature (°C)	25.0 ± 2.14^{a}	28.50 ± 1.01^{a}	25.35 ± 0.40^{a}
Light intensity (kLux)	1.00 ± 0.18^{a}	1.11 ± 0.18^{a}	1.10 ± 0.18^{a}
Soil temperature (°C)	26.15 ± 0.10^{b}	26.81 ± 0.15^{c}	24.28 ± 0.14^{a}
Canopy gap opening (%)	25.5 ± 4.77^{a}	46.7 ± 8.47^{a}	36.4 ± 5.41^{a}
Disturbance index (%)	37.6 ± 0.98^{b}	30.8 ± 2.15^{a}	60.8 ± 1.5^{c}
Soil pH	5.74 ± 0.15^{b}	6.09 ± 0.33^{b}	4.82 ± 0.05^{a}
Soil moisture content (%)	24.82 ± 0.65^{a}	32.26 ± 3.30^{a}	45.26 ± 3.70^{b}
Soil bulk density (gcm^{-3})	0.97 ± 0.12^{a}	0.91 ± 0.14^{a}	0.76 ± 0.09^{a}
Soil texture analysis	Sand	Sand	Loamy sand

Note. Superscripts a, b and c indicated the significant differences at $p < 0.05$ by post-hoc Tukey test in each parameter between sites

Table 7
Summary of the CCA of the Calamus castaneus *plant growth and environmental data in Teluk Bahang Forest Reserve*

Axes	1	2	3	4	Total inertia
Eigenvalues	0.213	0.005	0.001	0	0.651
Species-environment correlations	0.744	0.159	0.147	0.226	
Cumulative percentage variance					
of species data	32.8	33.6	33.7	33.7	
of species-environment relation	97.1	99.4	99.8	99.9	
Sum of all eigenvalues					0.651
Sum of all canonical eigenvalues					0.22

Table 8
Summary of the CCA of the Calamus castaneus *plant growth and environmental data in Segari Melintang Forest Reserve*

Axes	1	2	3	4	Total inertia
Eigenvalues	0.119	0.017	0.002	0.001	0.738
Species-environment correlations	0.555	0.236	0.48	0.282	
Cumulative percentage variance					
of species data	16.2	18.5	18.8	19	
of species-environment relation	85.1	97.4	98.9	99.8	
Sum of all eigenvalues					0.738
Sum of all canonical eigenvalues					0.14

Table 9
Summary of the CCA of the Calamus castaneus *plant growth and environmental data in Bukit Mertajam Forest Eco-Park*

Axes	1	2	3	4	Total inertia
Eigenvalues	0.193	0.008	0.002	0.001	0.699
Species-environment correlations	0.697	0.194	0.427	0.224	
Cumulative percentage variance					
of species data	27.6	28.8	29	29.2	
of species-environment relation	94.3	98.2	99.1	99.7	
Sum of all eigenvalues					0.699
Sum of all canonical eigenvalues					0.205

relationship in the CCA in TBFR was 99.8% (Table 7), SMFR is 98.9 % (Table 8), and BMFEP with 99.1 % (Table 9). The CCA ordination plot is as displayed in Figures 4, 5, and 6. The direction and length of the arrows which spread out from the centre of the ordination diagram illustrate the strength and direction accordingly between plant growth and environmental variables.

Figure 4 displayed that three out of five plant growth parameters listed in a study such as a rachis length, petiole length and the number of leaf sheath were increased as the increasing value of soil bulk density, canopy gap opening, air temperature, disturbance index level, relative humidity, soil temperature, soil pH, and percentage of soil moisture content. Light intensity gives no effect on the rattan parameter listed. The number of flowers has no relation to the environmental parameter listed.

From Figure 5, soil pH and soil bulk density give a negative influence on the number of leaf sheath produced, an average of petiole and rachis length. The higher the value of soil pH and soil bulk density will decrease the number of leaf sheath produced, an average of petiole and rachis length. Besides that, a high percentage of soil moisture content, disturbance index level, and canopy gap opening will also reduce the number of flowers produced throughout

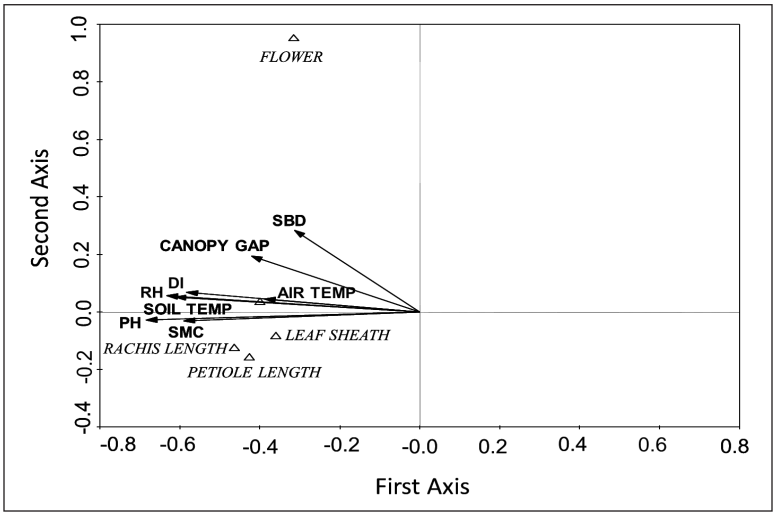

Figure 4. Ordination plot of canonical correspondence analysis (CCA) between environmental variables (arrows) and *Calamus castaneus* plant growth (triangles) in Teluk Bahang Forest Reserve. *Note*. SBD = soil bulk density; DI = disturbance index; RH = relative humidity; SOIL TEMP = soil temperature; AIR TEMP = air temperature; PH = soil pH; SMC = soil moisture content

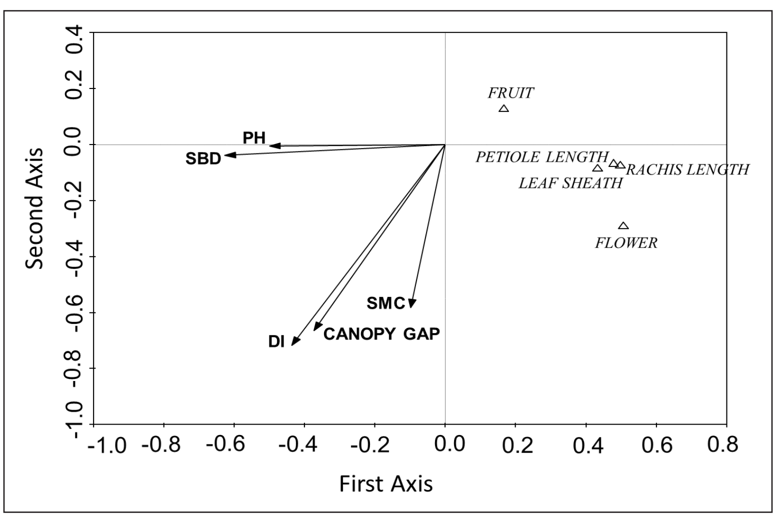

Figure 5. Ordination plot of canonical correspondence analysis (CCA) between environmental variables (arrows) and *Calamus castaneus* plant growth (triangles) in Segari Melintang Forest Reserve. *Note*. SBD = soil bulk density; DI = disturbance index; PH = soil pH; SMC = soil moisture content

the year. Meanwhile, the production of *C. castaneus* fruits in SMFR will increase by lowering the percentage of soil moisture content, percentage of canopy gap opening, disturbance index, soil bulk density, and soil pH.

All nine environmental parameters that were tested in this study had a positive influence on the rattan parameter (Figure 6). In BMFEP site, as the increasing value of soil bulk density, light intensity, percentage of canopy gap opening, disturbance index

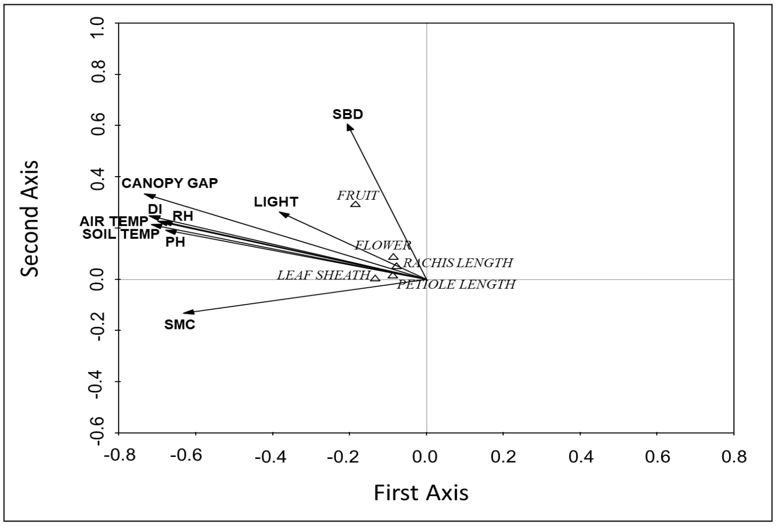

Figure 6. Ordination plot of canonical correspondence analysis (CCA) between environmental variables (arrows) and *Calamus castaneus* plant growth (triangles) in Bukit Mertajam Forest Eco-Park. *Note*. SBD = soil bulk density; DI = disturbance index; RH = relative humidity; SOIL TEMP = soil temperature; AIR TEMP = air temperature; PH = soil pH; SMC = soil moisture content; Light = light intensity

level, relative humidity, air temperature, soil temperature, soil pH, and soil moisture content would increase fruit and flower production, a number of leaf sheath produced, rachis length and also petiole length.

DISCUSSION

Recruitment, Mortality and Population Size

Segari Melintang Forest Reserve (SMFR) displayed a tremendous number of individuals followed by Bukit Mertajam Forest Eco-Park (BMFEP) and Teluk Bahang Forest Reserve (TBFR). From observation, TBFR, and BMFEP plots suffered from landslides, the tree falls from heavy rain and strong winds during monsoon season in November 2017 until January 2018. This had affected the population of *C. castaneus* in both sites. There was no significant difference ($p > 0.05$) shown after performing the Kruskal-Wallis test in all life stages in all sites. This had proven that the abundance of *C. castaneus* is the same for all sites. According to Rozali (2014), the continuation of regeneration in a locality was dependent on the abundance of seedlings in that area. This is proven by looking at the small seedlings number in BMFEP which shows a lower level of a succession of this rattan growing into the adult plants compared to the other two sites.

Although SMFR displayed the greatest number of seedlings, only a few of them would make it to the young stage. The competitiveness between the young plant with the fully established mature plant was high, thus resulting in the lower population of the young *C. castaneus* plants in this site. Throughout this study, SMFR had suffered from large tree falls in July 2017 caused by strong coastal wind during heavy rain. This finding suggests that natural disasters such as tree falls had altered the regeneration of rattan and dispersion of seedlings in the site. The tree falls had generated gap opening that caused scorching during the seedling stage. Vongkaluang (1985) stated that the high opening of the canopy and direct penetration of light might be the major cause for the non-survival of seedlings in open areas. Strong wind and tree fall had also damaged the leaf sheath of *C. castaneus*. Based on Table 5, BMFEP displayed a decreased number of leaf sheath production throughout the year. It can be concluded that all three sites experienced high mortality due to tree falls. Another cause of mortality was predation. A predator such as wild boar had been noticed eating fallen fruit of *C. castaneus* and digging soil near the clump had crushed the new rattan seedlings which result in mortality.

Besides that, a high rate of recreational activities such as hiking in a site would reduce the rattan population and creating gap opening particularly in TBFR and BMFEP (personal observation). Hikers especially in the large group tend to cut off rattan or any disturbing plants that came across the trail. The low level of rattan formation in the sites are mostly due to these undesirable conditions. A large population size in SMFR might be due to its composition of background vegetation. *C. castaneus* prefers to grow on lower hillslopes and streamsides (Dransfield, 1979). Based on the observation in this study, this species fits more in a partially cleared area with a shady canopy gap. The rattan habit of clumping makes this species to vegetate near one another, creating *C. castaneus* population. Human activities have put stress on rattan regeneration on the site. By avoiding these circumstances, the juveniles' growth might raise (Renuka & Rugmini, 2007; Rusdi, 2019).

Overall, the SMFR displayed a speedy rate for young petiole length, rachis length, and a number of leaves produced per month compared to the other two sites (Table 5). On the other hand, TBFR and BMFEP show a similar rate for rachis and petiole length. A study on a threatened rattan species by Renuka and Rugmini (2007) found that the population structure and population dynamics would differ according to habitat confines. Hence, it is estimated that the SMFR provides the most favorable habitat and the requirement for the succession and growth of the *C. castaneus*, therefore increasing the population density of this species on the site.

In a natural population, the growth rate may vary among the rattan species as it relies upon environmental factors and genetic variations (Rusdi, 2019). In addition, it is common for the Arecaceae family to develop slower during the early stage (Bøgh, 1996; Dransfield & Manokaran, 1994). Moreover, rattan species that grow under larger trees in the forest also showed a slow growth rate (Table 5) (Dransfield, 1979). According to the percentage range and gap opening status by Mansor (2001), all three sites have partly closed and slightly opened areas within a range of 25% to 47%

canopy gap opening. Thus, this might be the reason for the slow growth in the height of the seedlings compared to other parts of the listed rattan growth (Table 5).

Association Between Microclimate Parameters and Soil Properties on Population Dynamics

Most of the environmental variables; relative humidity, air temperature, light intensity, soil temperature, percentage of canopy gap opening, disturbance index, soil pH, soil moisture content and soil bulk density have had a positive influence on the *C. castaneus* plant growth; a number of the leaf sheath, petiole length, rachis length, number of flowers and fruits produced in TBFR (Figure 4) and BMFEP (Figure 6). Soil temperature can influence the community structure of any plant species through the alteration of its anatomical and physiological processes (Rozali, 2014). Warmer soil temperature as in tropical regions probably relates to the high diversity and abundance of plants and rattan species. In addition, certain minerals are needed since growth in stem diameter is possible at a high acidity level. High soil bulk density would help in increasing the rate of nutrient absorbent from the soil (Rusdi, 2019). On the other hand, high relative humidity is caused by the small opening of the forest canopy. This situation is sufficient for the growth of these rattan species as it grows under the low light requirement of a well-aged forest with dense canopies (Powling, 2004). Some rattan species depend upon the soil with adequate moisture and high light intensity to grow (Powling, 2004). Binh (2009) also stated that the increasing growth rate of rattan was dependent upon the amount of light exposure on its crown.

However, from the CCA ordination plot of the SMFR in Figure 4, it is shown that moisture content (32.26%), soil bulk density (0.91 gcm^{-3}), percentage of gap opening (46.7%), soil pH (6.09), and disturbance index (30.8%) have had a negative influence on the *C. castaneus*. Highly acidic soil may affect rattan maturity and would cause retardation in plants (Lilly, 2010). Other than that, a high bulk density of soil restricts the growth of root, inhibits the gaseous exchange in the root zone, and might also decrease the penetration of water (Brady & Weil, 2013; Lilly, 2010). Based on one year of sampling, this species does have a specific environmental condition for its growth since it favored the watercourse and shady area (Dransfield, 1979).

CONCLUSION

The abundance of the *C. castaneus* is the same since there was no significant difference in each study site. Among the three sites, SMFR recorded the fastest increment of young petiole length and rachis length for adult and young plants. Meanwhile, the rate for rachis and petiole length for TBFR and BMFEP were similar. Causes of mortality such as tree fall, landslides, heavy rain, strong winds, scorching, and predation had damaged the leaf sheath and the plants itself hence resulting in death. SMFR showed the largest population size of *C. castaneus* with 0.172 individuals per m^2.

Generally, the population size was strongly dependent on environmental factors. It can thus be concluded that almost all listed environmental parameters will give either a positive or negative influence on the phenology and mortality of the *C. casteneus* in all three sites.

ACKNOWLEDGEMENTS

The authors would like to show gratitude for the USM RU Research grant funding: 1001/PBIOLOGI/8011031 for financially supporting this research and the Peninsular Malaysia Forestry Department for issuing the respective permits.

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