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DIVERSITY OF INSECT POLLINATORS CAPTURED FROM FEMALE OIL PALM FLOWERS IN LADANG JERANGAU, TERENGGANU

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Abstract: Low population of insect pollinators in oil palm plantations is one of the factors that contributes to low fruit sets of the oil palm tree, *Elaeis guineensis*. This study was conducted in an oil palm plantation in Terengganu to determine the species diversity of insect pollinators observed on female oil palm flowers and to compare the insect species composition between two anthesis days. Insect pollinators were captured using bottle traps placed on 12 female flowers (one trap per flower) from 1000 hr to 1100 hr on days two and three of anthesis. Sampling was conducted between December 2019 and January 2020, and again from July to October 2020. Accordingly, the trapped insects were then observed under a dissecting microscope for species identification. A total of 174 individuals from 15 species were recorded in this study. The most common insects observed were the two known oil palm pollinators, *Elaeidobius kamerunicus* and *Pyroderces* sp., which accounted for 55% and 16% of the total captures, respectively. The Shannon diversity index calculated for the insects visiting the female oil palm flowers was $H' = 1.618$. Moreover, comparison between the two anthesis days indicates that the insect diversity was higher on the second day (Shannon diversity index, $H' = 1.6327$) than on the third day ($H' = 1.3679$). However, this was not significantly different at $p = 0.05$. Several other insects were also reported, indicating potential as pollinators by visiting the flowers on both anthesis days, although with much lower abundance. Thus, this study contributes to the knowledge of other potential insects as pollinators of oil palm trees. Hopefully, this study will benefit plantation managers in implementing entomofauna-friendly management in the oil palm plantations.

Keywords: *Elaeidobius kamerunicus, Pyroderces* sp., anthesis days*, Elaeis guineensis,* abundance.

Introduction

Elaeis guineensis (African Oil Palm) is a plant species under the family Arecaceae. The African Oil Palm is a monoecious tree, characterised by the presence of both female (pistillate) and male (staminate) flowers on the same plant, although they occur separately (Adam *et al*., 2011; Sambathkumar & Ranjith, 2015). In particular, the male flower is long, finger-like, with cylindrical spikelets, whereas the female flower is spirally arranged around the rachis of the spikelet (Yaakub *et al*., 2023). Notably, this tree has been extensively and successfully cultivated in Malaysia, despite being far from its origin in West Africa, due to the similar weather conditions throughout the year. This is characterised by a wet, dry, and humid tropical climate with a relatively high rainfall rate (Corley & Tinker, 2016). In the early 1870s, this oil palm was introduced as an ornamental plant in Malaysia. However, the demand for human food and secondary industrial uses has continued to increase. For example, in 2023, the export of palm oil and palm products from Malaysia reached approximately Ringgit Malaysia 100 billion (Parveez *et al*., 2024). This has led to Malaysia being the world's second-largest producer and exporter of palm oil after Indonesia.

From over 30 insect orders, Coleoptera, Diptera, Lepidoptera, and Hymenoptera are the four most dominant in terms of the number of identified species (Stork, 2018). Of these, insects from the order Hymenoptera and Diptera, such as bees and dipteran flies, respectively, are the major pollinator groups for agricultural crops (Wojcik, 2021). In the case of commercial oil palm (genus *Elaeis*), the insect pollinators are predominantly the coleopteran weevils from the genus *Elaeidobius* (Appiah & Agyei-Dwarko, 2013; Melendez & Ponce, 2016; Li *et al*., 2019). In Malaysia, *Elaeidobius kamerunicus* (oil palm weevil), together with *Thrips hawaiiensis* (Hawaiian Flower Thrips) and *Pyroderces* sp. (Cosmet Moth), are the main pollinators of the oil palm (Syed, 1979; Wahid & Kamarudin, 1997). The latter two species are the native pollinators, while the weevil was introduced in late 1981 from Cameroon to improve oil palm production in Malaysia (Teo, 2015). This has demonstrated a promising result in terms of fruit yield compared to before the introduction of the weevil.

According to Riley *et al.* (2022), oil palm fruit set levels were acceptably high when the population density of insect pollinators was high. Therefore, the low population density of insect pollinators in oil palm plantations may lead to a lower fruit yield. Moreover, observations on female oil palm flowers are significant for improving oil palm production, as the female flower will develop into a fruit bunch (Godswill *et al.*, 2016). Hence, this study aims to reveal the diversity and abundance of insect pollinators observed from the female oil palm flowers. In addition, the study's objectives were to determine the species diversity of insect pollinators observed on female oil palm flowers in an oil palm plantation in Terengganu and to compare the species composition of insect species between two anthesis days (days two and three). Essentially, this study hopes to provide valuable information for the conservation of the insect pollinators in oil palm plantations.

Materials and Methods

Study Site

The samplings were conducted at two separate sessions at Terengganu Development and Management (TDM) Ladang Jerangau (Figure 1), located at coordinates 4°57'45"N 103°9'59"E. The first sampling session was conducted from December 2019 to January 2020, with monthly rainfall of 516 mm and 116 mm, respectively. Meanwhile, the second sampling session was conducted in July, August, September, and October 2020, with monthly rainfall of 119 mm, 243 mm, 187 mm, and 428 mm, respectively.

Figure 1: The location of the sampling site (red point) at Ladang Jerangau, Terengganu Development and Management (TDM) plantation, Terengganu

Source: Google Maps

Trappings of the Floral Visitors and Identification of the Insect Pollinators

In this study, the passive insect trapping method was employed, where 12 modified bottle traps were set up at 12 female flowers (one bottle trap per flower, Figure 2) for 1 hour from 1000 hr until 1100 hr. Although anthesis of the female flowers occurred between three and four days (Yaakub *et al*., 2023), trappings of the insects were conducted during the second (hereafter day two) and third (hereafter day three) day of anthesis, during the peak secretion of anise-like odor by the female flowers (Auffray *et al*., 2017). The traps were tended to immediately once the insects were observed entering the bottle trap. Consequently, the trapped insects were extracted using a long forcep and transferred into individual vials containing a 70% ethanol solution. Accordingly, the vials were taken to Universiti Malaysia Terengganu's laboratory for further identification of the insects.

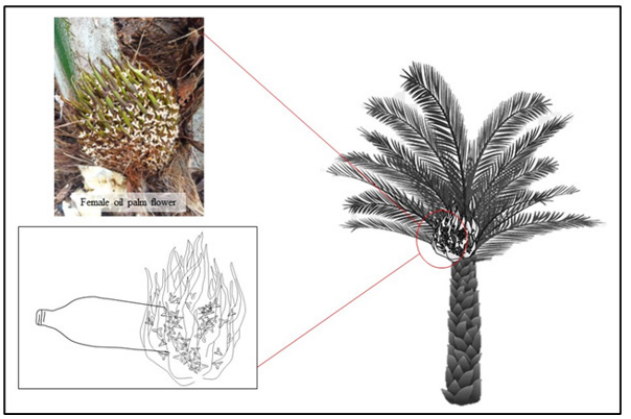

Figure 2: A graphic representation of bottle trapping conducted to capture the insects visiting female oil palm flowers in Ladang Jerangau, Terengganu

In the laboratory, the insects were extracted from the vial for observation under a dissecting microscope (Zeiss Stemi 2000-C, Manufacturer Carl Zeiss Southeast Asia, Singapore) with 0.65x - 5.0x magnification, attached to an eyepiece camera (Dino-eye AM 423X, Anno Electrics Corporation, Taiwan). Images of the insects were then taken using the DinoCapture Software. At the same time, identification of the insects from the photos was conducted by referring to multiple sources. This includes websites/digital library (e.g., Centre for Agriculture and Biosciences International [CABI] Digital Library: https://www.cabidigitallibrary.org/, and Biodiversity of Singapore: https://singapore.biodiversity.online/), identification manuals, and published materials that provided photos of the insects in oil palm plantations, particularly in Malaysia (e.g., Halim *et al*., 1988; Kamaruddin *et al*., 2017). In addition, comparisons were made with insect individuals captured for other studies at the same sampling site.

Data Analysis

Paleontological Statistics (PAST) software version 4.11 was used to analyse the recorded data. The diversity of insect pollinators observed from the female inflorescence was determined using the Shannon diversity index (*H'*), the Simpson diversity index (*D*), and richness indices (Margalef index, $R_{1,}$ and Menhinick index, R_2). The diversity t-test for *H'* and *D* was then used to compare the species diversity between the two anthesis days (day two and day three).

Results and Discussion

Diversity of Insects

A total of 174 individuals of 15 species (Figure 3) from six orders were observed from the female flowers. These were Coleoptera, Dermaptera, Diptera, Hymenoptera, Lepidoptera, and Thysanoptera (Table 1). In addition to the unknown species listed as Hymenoptera sp., two taxa from the order of Diptera were identified only to the family level (Phoridae sp. and Sciaridae sp.). The order Hymenoptera displayed the highest species richness, with a total of six species. Conversely, Coleoptera, Lepidoptera, and Thysanoptera were each represented by a single species. Although Hymenoptera presented the highest number of species, they were recorded in only 17 individuals, representing only 9% of the total captures. In contrast, Coleoptera, despite having only one species, which was *E. kamerunicus*, recorded the highest number of individuals, with 96 individuals (55%). Similarly, Lepidoptera, with one species, *Pyroderces* sp., ranked second in terms of individual count, with 28 individuals (16%). In addition, *Chelisoches morio*, Sciaridae sp., *Monomorium* sp., *Solenopsis geminata*, and

Tapinoma melanocephalum recorded only a single individual.

The introduction of *E. kamerunicus* to Malaysia was aimed at enhancing oil palm pollination and increasing the oil production (Basri *et al*., 1983). In addition, *Pyroderces* sp. is one of the native oil palm pollinators. However, it was noted to be an inefficient pollinator due to its small body size and limited mobility (Meléndez & Ponce, 2016), as well as its activity being limited to only two to three hours after dusk (Tan & Wahid, 1984). In line with this, predatory insects such as an earwig species (*C. morio*) and several ant species (*Monomorium* sp., *S. geminata*, and *T. melanocephalum*) were also recorded at the female flowers. Predation on insect pollinators can lead to negative consequences for the oil palm fruit yield (Muhammad Luqman *et al*., 2017; Li *et al*., 2019). Nevertheless, with only one individual of each species, this indicated a low threat of predation on the pollinators in the study area.

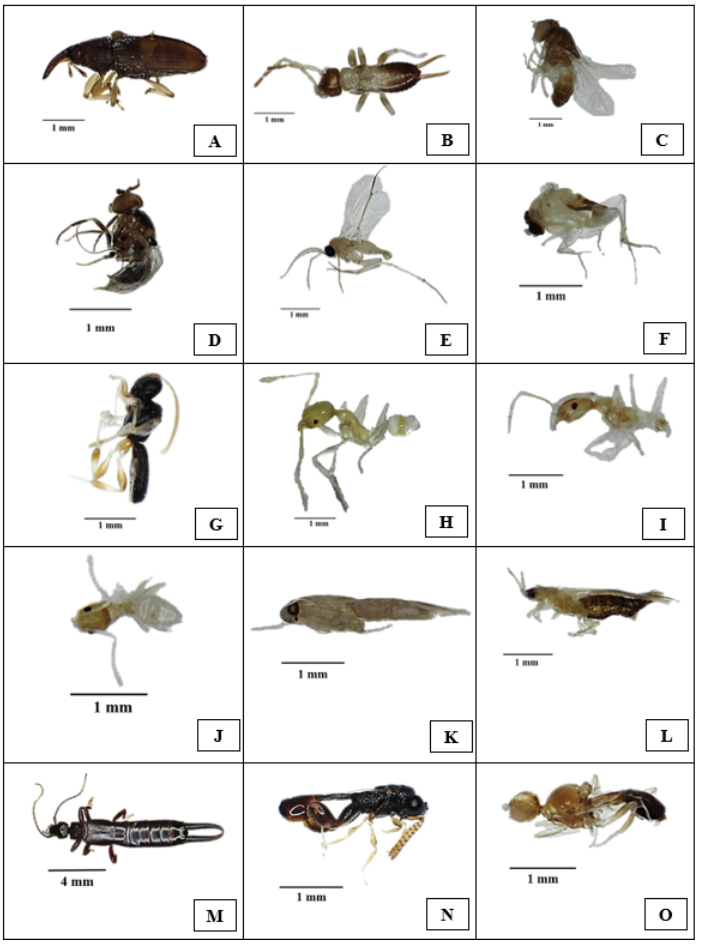

Figure 3: Photo of the 15 insect species captured at the female oil palm flowers in Ladang Jerangau, Terengganu. (A) *Elaeidobius kamerunicus* (B) *Forficula auricularia* (C) *Drosophila melanogaster* (D) *Drosophila suzukii* (E) Sciaridae sp. (F) Phoridae sp. (G) *Dolichogenidea metesae* (H) *Anoplolepis gracilipes* (I) *Solenopsis geminata* (J) *Tapinoma melanocephalum* (K) *Pyroderces* sp. (L) *Thrips hawaiiensis* (M) *Chelisoches morio* (N) Hymenoptera sp. (O) *Monomorium* sp.

Table 1: List of identified insect species at the female oil palm flowers

Order	Family	Scientific Name	Common Name	Total Captures
Coleoptera	Curculionidae	*Elaeidobius kamerunicus*	Oil Palm Weevil	96
Dermaptera	Chelisochidae	*Chelisoches morio*	Black Earwig	1
	Forficulidae	*Forficula auricularia*	Earwig	5
Diptera	Drosophilidae	*Drosophila melanogaster*	Lesser Fruitfly	16
		Drosophila suzukii	Spotted Wing Fruitfly	2
	Phoridae	Phoridae sp.	Scuttle Flies	2
	Sciaridae	Sciaridae sp.	Fungus Gnat	1
Hymenoptera	Braconidae	*Dolichogenidea metesae*	Wasp	10
	Formicidae	*Anoplolepis gracilipes*	Yellow Crazy Ant	2
		Monomorium sp.	Ant	1
		Solenopsis geminata	Tropical Fire Ant	1
		Tapinoma melanocephalum	Ghost Ant	1
	-	Hymenoptera sp.	Parasitoid Wasp	2
Lepidoptera	Cosmopterygidae	*Pyroderces* sp.	Cosmet Moth	28
Thysanoptera	Thripidae	*Thrips hawaiiensis*	Hawaiian Flower Thrip	6
			Total number of individuals	174
			Total number of species	15

Furthermore, the values for the diversity indices calculated for the insects recorded from the female oil palm flowers are as follows: Shannon index, H' = 1.618, Simpson index, D = 0.341, Margalef index, R_1 = 2.714, and Menhinick index, R_2 = 1.137. A high diversity of insects was recorded in the oil palm plantation by Siregar *et al.* (2016) in Indonesia, likely due to the high density of oil palm flowers. The study also captured all insects present in the oil palm plantation, whereas the present study was limited to female oil palm flower visitors. Female oil palm flowers are known to secrete an anise-like odor to attract the insects (Lajis *et al.,* 1985). Due to a lack of food sources, the insects stay on the inflorescence only briefly (Syed, 1979). This was due to the fact that these insects were attracted to the flower's secretions. Nevertheless, the insects are more diverse and in higher abundance at the male flowers (Egonyu *et al.,* 2021) due to the availability of pollen grains as their primary food source (Syed, 1979; Sambathkumar & Ranjith, 2011, 2015).

Comparison Between Anthesis Days

In total, seven species were recorded as present on both anthesis days (Figure 4), including *E. kamerunicus*, *F. auricularia*, *D. melanogaster*, Phoridae sp., *A. gracilipes*, *S. geminata*, and *Pyroderces* sp. (Table 2). Meanwhile, for the two species with the highest abundance, *E. kamerunicus* presented higher numbers on day three (51 individuals) as compared to day two (45 individuals). In contrast, *Pyroderces* sp. indicated higher numbers for day two (16 individuals) as compared to day three (12 individuals). Moreover, four species (*C. morio, D. suzukii, T. melanocephalum,* and *T. hawaiiensis*) were recorded only on day two. Conversely, four species (Sciaridae sp., *D. metesae, Monomorium* sp., and Hymenoptera sp.) were only recorded on day three.

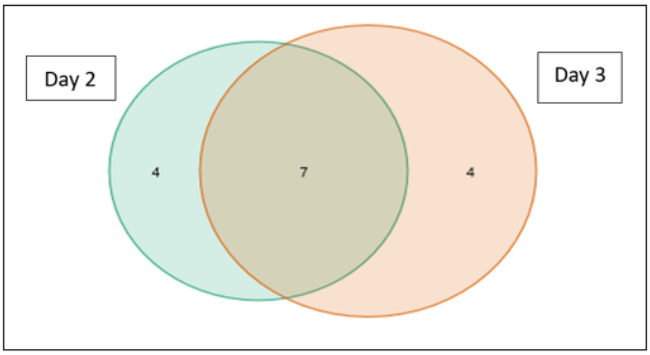

Figure 4: The Venn diagram of the number of insect species for each anthesis day

Table 2: Insect abundance recorded at the female oil palm flowers for each anthesis day

Species	Number of Individuals	
	Day 2	Day 3
Elaeidobius kamerunicus	45	51
Chelisoches morio	1	0
Forficula auricularia	4	1
Drosophila melanogaster	10	6
Drosophila suzukii	2	0
Phoridae sp.	1	1
Sciaridae sp.	0	1
Dolichogenidea metesae	0	2
Anoplolepis gracilipes	4	6
Monomorium sp.	0	1
Solenopsis geminata	1	1
Tapinoma melanocephalum	1	0
Hymenoptera sp.	0	1
Pyroderces sp.	16	12
Thrips hawaiiensis	6	0

Although a similar number of species were recorded (11 species), the number of individuals was higher on day two, with 91 individuals, compared to 83 individuals on day three (Figure 5). A comparison of the diversity of insects between day two and day three reveals that day two exhibited higher *H*' and *D* values (Table 3). However, the diversity t-test analysis performed revealed no significant difference in the diversity of insects between day two and day three at Ladang Jerangau for both *H*' (diversity t-test = 1.4493, $p > 0.05$) and *D* (diversity t-test = -1.5955, $p > 0.05$).

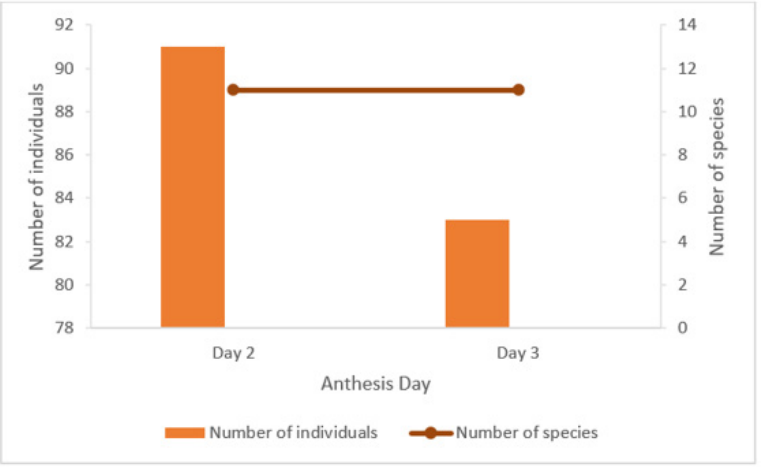

Figure 5: Comparison of the total number of individuals and the total number of insect species between the two anthesis days

Table 3: Shannon *H*' and Simpson (*D*) indices calculated for the diversity of insects according to the anthesis day

Diversity index	Day 2	Day 3	Diversity t-test	*p*-value
Shannon index, *H*'	1.6327	1.3679	1.4493	0.1491
Simpson index, *D*	0.2967	0.4104	-1.5955	0.1126

According to Auffray *et al*. (2017), the peak active period of *E. kamerunicus* on the female flower during the first two days of anthesis was between 1000 hr and 1200 hr, which is during the optimum secretion of the anise-like odor by the flower. The synchronisations between odor release and the active time of the weevil likely increased the abundance of *E. kamerunicus* at the flower, making them an efficient pollinator of the oil palm (Syed, 1979; Syed *et al*., 1982; Yue *et al*., 2015; Li *et al*., 2019).

The diversity of insects at the female flowers was discovered to be similar on the second and third days of anthesis. During the early anthesis phase, the female flower was observed to emit a stronger anise-like odor, which attracts insects (Yue *et al*., 2015). These insects, particularly those present on both day two and day three, are more likely to serve as reliable pollinators for the oil palm flowers. These results are crucial for plantation management, as the application of pesticides during this period could be detrimental to these pollinating agents, potentially disrupting the pollination of the oil palm flowers.

Conclusions

In conclusion, a high richness of insects was recorded visiting the female oil palm flowers. Furthermore, the insects recorded on both anthesis days indicated a non-significant difference between the two days. Note that the diversity of insect species recorded at the study site was low (*H*' = 1.618). Of 15 species identified, seven were reported to visit the flowers on both days, indicating higher potential as pollinators for the oil palm flowers. From these, two species with the highest abundance were *E. kamerunis* and *Pyroderces* sp., confirming their importance as pollinators of oil palm trees. Meanwhile, the other five species, *F. auricularia*, *D. melanogaster*, Phoridae sp., *A. gracilipes,* and *S. geminata,* were also significant pollinators for the oil palm trees.

However, they were less critical due to their much lower abundance present at the female flowers. Several of these insects, such as *F. auricularia*, *A. gracilipes*, and *S. geminata,* are nevertheless predatory insects. Hence, it is recommended that a detailed study to be conducted on the ecological role of these insects as potential pollinators in oil palm plantations in the future to further confirm their significant role as pollinators for oil palm trees.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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