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A Preliminary Study on the Diversity and Abundance of *Onthophagus* Species (Coleoptera: Scarabaeidae) in an Oil Palm Plantation, Peninsular Malaysia in Relation to Carbon Dioxide and Soil Organic Matter

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ABSTRACT

Dung beetles are important bioindicator species in an ecosystem. The relationship between the CO_2 concentration and percentage of soil organic matter (SOM) with the diversity and abundance of *Onthophagus* species was investigated as a model genus in a model sampling area in an oil palm plantation in the southern part of Peninsular Malaysia. In total, 554 samples belonging to 25 species of *Onthophagus* were collected. No significant differences in CO_2 concentration during the day and night across the stations were found, except DCO_2S1 vs DCO_2S2 ($p = 0.014$, $p < 0.05$). Also, the diversity and abundance of species did not differ significantly (H'= 2.250 [diurnal] and H'= 1.854 [nocturnal]; $p > 0.05$). The dung beetle species recorded specifically during the day were *O. aphodiodes*, *O. denticollis*, *O.* cf. *pacificus*, *O. dayacus*, *O.* sp. 1, *O. penicillatus*, *O. peninsulocupreus*, and *O.*"hairy group" (H'= 1.739), while *O. babirussoides*, *O. phaenids*, *O. insicus*, *O. paraphamaeomorphos*, *O. peninsularis*, and *O. parachandrai* (H'= 1.677) were observed at night. Furthermore, no relationship was discerned between % SOM vs diversity indices (r = 0.348), evenness (r = -0.289), and richness (r = 0.972) of dung beetles. This is the first study in Malaysia to illustrate a lack of relationship between CO_2 concentration and SOM with *Onthophagus* spp. The preliminary data of this research

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can be used for future studies on diversity and ecology of dung beetles in relation to CO_2 and SOM.

Keywords: CO_2, correlation, diurnal, Malaysia, nocturnal, *Onthophagu*s, Scarabaeidae, SOM

INTRODUCTION

The family Scarabaeidae, which includes dung beetles is one of the largest families of beetles, with around 30,000 recorded species worldwide (Hanski & Cambefort, 1991). According to Hernandez (2001), dung beetle species can be classified as nocturnal or diurnal, depending on when they are active. Species that are active after sunrise and before sundown are considered diurnal, whereas those that are active only at nighttime are considered nocturnal. Based on Ellen (2002), more species and abundance of dung beetles with larger mean size were captured per trap during nocturnal trapping periods compared to diurnal trapping periods.

According to a study by Montes and Halffter (1995), *Onthophagus landolti*, which colonizes both horse and cow dung, is normally active between 10:00 and 11:30 h (pers. obs. E. Montes De Oca). However, colonization of dung by dung beetle species is more common at nighttime than daytime. Diurnal colonization activity is also subject to seasonal variations. Due to the exploitation of dung by crepuscular and nocturnal species, diurnal dung beetle species are less numerous than nocturnal species. In general term, diurnal colonization activity is lower than nocturnal colonization activity.

In the tropics, soil organic matter (SOM) determines the productivity and fertility of the soil, especially in highly weathered soil, where the nutrient reserves are limited or none, and the soil is managed without any external inputs of inorganic and organic fertilizers (Ywih et al., 2009). The conversion of biomass into humus (including humic acids), translocation and aggregation of carbon into subsoil prevent carbon oxidation and lead to soil organic carbon (SOC) sequestration. By moving and breaking down excrement and incorporating organic matter in the soil, the activities of dung beetles influence the availability of organic matter (Shang & Tiessen, 1997), which indirectly increase the level of soil fertility (Avendano-Mendoza et al., 2005). Dung beetles also carry out bioturbation processes (Nichols et al., 2008) and the recycling of the nutrients (Estrada & Coates-Estrada, 1991).

Dung burial activity by dung beetles has positive effects on soil fertility (Bang et al., 2005). Dung decomposition involves a range of organisms and is primarily an abiotic process. Dung pads left on fields release greenhouse gases, including CO_2 and methane. The decomposition process of dung pads by dung beetle releases greenhouse gas (GHG) fluxes, which are considered one of the abiotic factors, similar as temperature and moisture or plant and soil interactions, whereas the role of the dung fauna has received far less attention (Penttila et al., 2013).

Hutton and Giller (2003) had reported greater beetle biomass, diversity, and species richness in organic farms compared to rough and intensive grazing sites, located in County Cork and County Tipperary in Southern Ireland. They also found that the abundance of some dung beetle species, such as *Aphodius*, was significantly lower in spring and autumn on the rough and intensive farms compared to the organic ones. The biomass of *Aphodius*, however, might be considerably higher in spring, late summer, and autumn for natural and rough grazing agriculture compared to intensive agriculture. Using the detrended correspondence analysis of dung beetle assemblages from the variously managed farms, Hutton and Giller (2003) found that the seasonal abundance of dung beetle species was greater on the organic farms than the rough and intensive farm.

The objective is to study both CO_2 concentration during day and night (air parameter) and percentage of soil organic matter (SOM) (soil parameter) in the oil palm plantation and its association towards the diversity and abundance of diurnal and nocturnal *Onthophagus* spp. dung beetles.

MATERIALS AND METHODS

Study Area

This research was carried out at three different stations in an oil palm plantation areas located at Felda Lui Muda, Negeri Sembilan in the southern part of Peninsular Malaysia. The stations were separated apart and located at the coordinates N 03° 03' 15.1", E 102° 22' 02.7 (station 1), N 34° 00' 00.0", E 068° 54' 22.5 (station 2) and N 63° 03' 45.0", E 068° 54' 22.5 (station 3). The coordinates were recorded using GARMIN GPS 12 XL (12 channel).

Sampling Activity of the Dung Beetles

The adults of *Onthophagus* spp. were collected using baited pitfall traps from October 2015 until June 2016 by conducted three sampling activities for each station. Fifteen traps were placed randomly in each station, at a minimal distance of 5 m from each other. The diameter of the pitfall (bucket) traps was 17.5 cm, the circumference was 63 cm, and the height was 15.5 cm. Due to easy availability, the rotten fish was chosen as the bait. It was filled into a small cup and placed at the center of each trap. The baited pitfall traps were filled with soapy water (one-quarter of the volume of the trap) to ensure that no samples escaped from the trap. The traps were inspected four times in every 24-h cycle (12 hours interval on separate days and nights) for every sampling activity. The dung pads was also observed in each station during sampling activities. The dung beetles were collected in these two periods to identify the behavior and diel flight activities of the species: after sunrise (nocturnal) and after dark (diurnal). The adult sample of dung beetles were preserved in 70% alcohol.

Soil Sampling and Analysis of SOM

Soil samples were collected from all the stations, with three replications for each station. The samples of the soil were randomly collected from three holes that had been dug (at a depth of 15.5 cm depth) to fit the baited pitfall traps. The total of the soils collected were nine samples. The samples were wrapped in an aluminum wrapper and placed in a box to maintain the soil composition. These samples were used to determine the percentage of SOM. The soil analysis was done in accordance with Ministry of Agriculture, Fisheries and Food (MAFF) (1982) guidelines within a week after sampled.

Measurement of CO_2

The concentration of CO_2 was measured using a CO_2 meter (version 8802-EN-00) in ppm units. The CO_2 levels were recorded during sampling activities at each site during the day (06.30 – 07.00 am) and night (19.00 – 19.30 pm) with three replications for each site. CO_2 measurements were collected at that particular time because it was an active time for the diurnal (from six in the morning) and after 18-hour for nocturnal species of dung beetles (de Oca T. & Halffter, 1995). The total of nine CO_2 concentration data was recorded at both daytime and nighttime per sampling site.

Identification and Recording of the Dung Beetle Samples

The adult dung beetle specimens were identified to the species level using a stereomicroscope based on the pictorial guide (Ek-Amnuay, 2008) and dry specimens from the Center of Insect Systematics (CIS), Universiti Kebangsaan Malaysia collections.

Statistical Analysis of Species Diversity and Richness

Species diversity and abundance were analyzed using Paleontological statistics software package for education and data analysis (PAST), while Minitab 17 was used to run a *t*-test and One-Way ANOVA (p <0.05) (Minitab, 2016). Microsoft Excel was used to create the figure of CO_2 level, and PC ORD was used to run a multivariate statistical analysis of ecological communities.

RESULTS

Species Diversity and Abundance of Dung Beetles

The total of 554 adult beetles was obtained from the three sampling localities. They were identified to belong to 21 species with four species not definitely identified and were temporarily designated as *Onthophagus* sp. 1, sp. 2, sp. 3 and "hairy group" (Table 1). Diurnal species (289 individuals belonging to 19 species) consist more individuals than nocturnal species (265 individuals belonging to 17 species). The *Onthophagus* spp. found in the daytime accounted for 52.17% of the total number, while the other 47.83% of individuals were recorded at night. Of the 25 species recorded, 11 were recorded both during the day and night, eight during the day, and six at night.

With regard to diurnal species, the dominant species was *O. crassicolis* (n = 69), followed by *O. pedator* (n = 68), and *O. rugicollis* (n = 45). *Onthophagus pedator* (n = 106) was the most abundant nocturnal species, followed by *O. rugicollis* (n =

Table 1
Diversity and abundance of the nocturnal and diurnal Onthophagus *spp. in Felda Lui Muda, Serting, Malaysia*

No.		Diurnal	Nocturnal
1	*Onthophagus pacificus*	13	30
2	*Onthophagus crassicolis*	69	25
3	*Onthophagus pedator*	68	106
4	*Onthophagus waterstradti*	13	14
5	*Onthophagus rugicollis*	45	56
6	*Onthophagus orientalis*	4	1
7	*Onthophagus rutilans*	6	3
8	*Onthophagus cervus*	16	12
9	*Onthophagus proletarius*	8	4
10	*Onthophagus* sp. 2*	2	3
11	*Onthophagus* sp. 3*	16	2
12	*Onthophagus parachandrai*	0	1
13	*Onthophagus insicus*	0	2
14	*Onthophagus paraphamaeomorphos*	0	1
15	*Onthophagus peninsularis*	0	3
16	*Onthophagus babirussoides*	0	1
17	*Onthophagus phaenids*	0	1
18	*Onthophagus aphodiodes*	9	0
19	*Onthophagus denticollis*	1	0
20	*Onthophagus "*hairy group"*	1	0
21	*Onthophagus* cf. *pacificus*	1	0
22	*Onthophagus dayacus*	2	0
23	*Onthophagus* sp. 1*	8	0
24	*Onthophagus penicillatus*	5	0
25	*Onthophagus peninsulocupreus*	2	0
TOTAL		289	265

*Temporarily designated

56), and *O. pacificus* (n = 30). Only one individual of *O.* cf. *pacificus*, *O.* hairy group, and *O. denticollis* were found specifically during the day, whereas *O. babirussoides*, *O. phaenids*, *O. paraphamaeomorphos*, and *O. parachandrai* were found only at night. The other species were active both during day and night have been highlighted in Table 1.

Determination of *Onthophagus* sp. diversity during the day and night showed through the analysis of Shannon-Weiner (H'). Shannon's index accounts for both abundance and evenness of the species present, which consider proportions and not an absolute number (Gamito, 2010). Based on the data collected, the diurnal and nocturnal diversity index (H') were 2.250 and 1.854, respectively. The Shannon (H') diversity index of the dung beetles at Stations 1, 2, and 3 were 2.056, 1.974, and 2.045, respectively. Even though there are different types of species specifically found at daytime and night time, but there was no significant difference in nocturnal and diurnal species abundance (p = 0.074). The diurnal species recorded during daytime only were *O. aphodiodes, O. denticollis, Onthophagus “*hairy group”*, O. pacificus, O. dayacus, Onthophagus* sp. 1*, O. penicillatus and O. peninsulocupreus* (H’) = 1.739, and specifically found at night were *O. parachandrai, O insicus, O. paraphamaeomorphos, O. peninsularis, O. babirussoides* and *O. phaenids* (H’) = 1.677.

A high diversity index denotes high abundance and rare species. Although higher numbers of dung beetles were recorded at Station 2(n = 319) and Station 3 (n = 179) than Station 1 (n = 56), Station 1 consisted of more species with equal abundance than the other two stations. Diurnal diversity index is higher than nocturnal because as influenced by the abundance of *Onthophagus* sp. 1, *O. aphodiodes* and *O. penicillatus* (Table 1). There was no significant difference between the diurnal and nocturnal abundance of *Onthophagus* spp., with p = 0.877 ($p > 0.05$), while the abundance between stations; S1 vs S2 (p = 0.053), S1 vs S3 (p = 0.108) and S2 vs S3 (p = 0.345), also showed non-significant difference between stations.

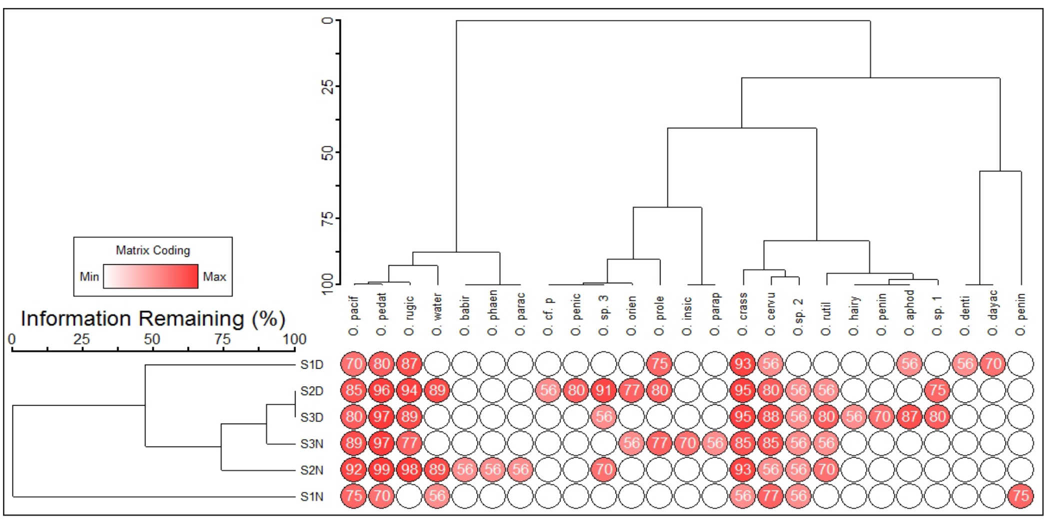

Figure 1. Abundance of diurnal and nocturnal *Onthophagus* spp. from three stations at Felda Lui Muda, Serting
S = station; D = diurnal; N = nocturnal

At 75% of similarity, the samples were divided into three different groups. The first group was S1D, the second group including S2D, S3D, S2N, and S3N, and the third group was S1N. Based on Figure 1, the highest presence probability of dung beetle found was *O. pedator*, while, the lowest abundance of dung beetle were *O. babirussoides, O. phaenids, O. parachandrai*, *O.* cf. *pacificus*, *O. paraphamaeomorphos, Onthophagus “*hairy group” and *O. denticollis*. S2D and S3D from group 2 showed very close relationship between the diversity and presence probability of *Onthophagus* spp. The diversity and presence probability of *Onthophagus* spp. was the lowest at Station 1 in group 3 during the night (S1N). Group 3 was considered as the outgroup because the diversity and presence probability of *Onthophagus* spp. shown do not match with other groups.

Day and Night CO_2 Concentration

As shown in Table 2, based on one-way ANOVA analysis of the day and night CO_2 concentration readings from three different stations, there was a significant difference in CO_2 concentrations between DCO_2S1 vs DCO_2S2 ($p = 0.014$, $p < 0.05$) only. Overall, based on two-sample *t*-test, no significant difference was shown between air CO_2 concentration of day and night time with *p*-value = 0.303 ($p > 0.05$).

Table 2
One-way ANOVA of CO_2 concentration between three stations

Station	DCO_2S1	DCO_2S2	DCO_2S3	NCO_2S1	NCO_2S2
DCO_2S2	**0.014**				
DCO_2S3	0.489	0.622			
NCO_2S1	0.868	0.390	0.996		
NCO_2S2	0.926	0.397	0.993	1.000	
NCO_2S3	1.000	0.101	0.784	0.968	0.984

D= day; N= night; CO_2=carbon dioxide; S=station; Value in bold show significant difference ($p < 0.05$)

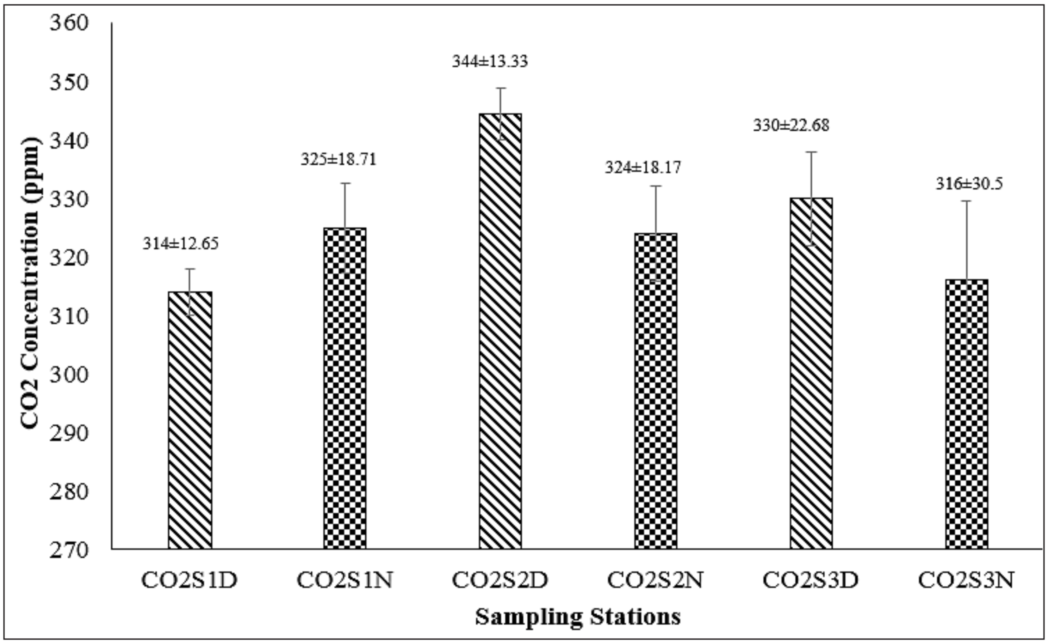

Figure 2. CO_2 concentration during day and night time at station 1, station 2 and station 3

Generally, the CO_2 concentration was higher during the daytime than at nighttime. The highest CO_2 concentrations were recorded at Station 2 during daytime, with 344 ppm (daytime), while at night, Station 1 shows the highest CO_2 concentration with 325 ppm (Figure 2).

In this study, the CO_2 concentration between day and night showed no significant differences ($p > 0.05$), which was proven by One-way ANOVA analysis, except between DCO_2S1 vs DCO_2S2 ($p = 0.014$, $p < 0.05$). Overall, based on analysis of 2-sample-t-test ($p = 0.303$, $p > 0.05$) and One-way ANOVA ($p = 0.294$, $p > 0.05$), no significant difference between CO_2 concentration during the daytime and night-time was shown.

Percentage of Soil Organic Matter (SOM)

Table 3 presents the *p*-value of SOM% among stations. There was no significant difference shows by SOM percentage between S1 vs S2 ($p = 0.918$, $p > 0.05$), while opposite results show by S1 vs S3 ($p = 0.001$) and S2 vs S3 ($p = 0.000$). No correlation coefficient shows between % SOM vs diversity indices (r = 0.348, p = 0.774), evenness (r = -0.289, p = 0.813) and richness (r = 0.972, p = 0.151) of dung beetles.

Table 3
Two-sample t-test analysis of SOM percentage (%) between Station 1, Station 2 and Station 3

p-value	S1 vs S2	S1 vs S3	S2 vs S3
% SOM	0.918	**0.001**	**0.000**

S=station; SOM=soil organic matter; Value in bold shows significant difference ($p < 0.05$)

DISCUSSION

In this study, Felda Lui Muda, an oil palm plantation located in the southern part of Peninsular Malaysia, was chosen as the model sampling site for its monocropping and nonnatural habitat. This was formerly recognized as a forest area, but it was transformed from a tropical forest habitat into a modified area because of its huge impact on the diversity and abundance of the different groups of dung beetle, most likely because it caused a rise in temperature (> 42 °C) during the day (Chown & Klok, 2011; Peyras et al., 2013). Therefore, the sampling sites of this study are the most suitable areas to measure the comparison. The baited pitfall traps, used in this study, were deemed suitable for use in the sampling activities, which involved active running insects on the soil surface, especially Carabidae and Staphylinidae. Chung (2004) had recorded a great diversity and abundance of Staphylinidae and Scarabaeidae, which were mainly dung beetles, at the ground level, justifying the use of the baited pitfall traps in this study.

In their study, Shahabuddin et al. (2005), found that the individual number of dung beetles in the agroforestry systems was the lowest, followed by young secondary forests and natural forest sites. The number of individual dung beetle samples collected from the natural forest sites (64.25 ± 9.12 samples) was three times higher than that in the agroforestry systems (22.75 ± 6.65 samples) and two times higher than that in the secondary forests with 26.25 ± 9.22 samples. Based on the assessment of the dung beetle samples obtained from their study, the authors concluded that dung beetles were mostly scattered across various habitat types, with a high overlap between the same beetle species compositions among all the studied sites. According to Davis et al. (2002), forest destruction levels from primary, logged, and plantation showed a significant decline in dung beetle diversity in Northern Borneo. Both studies can be used to support this study which demonstrates the low diversity of dung beetles in agroforestry and plantation areas. Further research needs to be done to determine the type of the dung beetle species that can be found at both natural and plantation areas to support Shahabuddin et al., (2005) findings. For example, some species found in the current study, such as *O. orientalis*, *O. rugicollis*, and *O. rutilans*, were also collected at the Malaysian Production Forest (Yamada et al., 2014).

Soil organic materials and CO_2 concentrations are two new environmental factors that have been studied and measured in this research. The results of this study do not illustrate a correlation between the percentage of SOM and the diversity, evenness, and richness of the dung beetles. Similarly, they do not suggest a significant difference between the diurnal dung beetles and their nocturnal counterparts. As for the day and night CO_2 concentrations, however, the preliminary data on the parameters and the dung beetle abundance were successfully obtained. These two factors merit further investigation and comparison, as they are believed to significantly influence the behavior of the dung beetle species. Three parameters need to be studied to identify the effects on the presence of dung beetles: (a) the existence of nocturnal and diurnal species (Whitmore, 1990), (b) the exposure to CO_2 concentrations in the dung pads (Evans & Mamo, 2016), and (c) the richness of soil nutrients (Bang et al., 2005; Bornemissza & Williams, 1970).

In addition, Nichols et al. (2007) found no nocturnal species on open lands or modified forests. Thus, the question of the environmental factors and the diurnal and nocturnal species became interesting topics for further study. Moreover, other abiotic conditions, such as pH, temperature (Navarrete & Halffter, 2008; Peyras et al., 2013), and humidity (Vulinec, 2000) of the different ecosystems are strongly believed to affect the abundance and diversity of dung beetle species (Fincher et al., 1970). However, certain species such as *O. pacificus* had been found in agricultural areas, mainly because its distribution is not affected by habitat changes (Shahabuddin et al., 2005). According to Nichols et al. (2007), some small-sized species, such as *O. orientalis*, *C. unicornis*, and *O. proletarius*, are rarely found in the forest ecosystems but can easily be found in the open land areas; similar species were collected in this study.

In this study, the average CO_2 concentration during the daytime was slightly higher (329 ppm) than that at nighttime (321 ppm). This finding is congruent with Campbell et al. (2008), in that the CO_2 during the daytime was found to be higher than the nighttime. According to Reece et al. (2011), 6CO_2 and water have been used by plants to produce O_2 and organic matter through the process of photosynthesis with the presence of light. However, the Calvin cycle process occurs at night using 3CO_2 as a source for converting to organic compounds without using direct light. This process is known as photorespiration, which involves the use of O_2 and the release of CO_2 with the presence of light.

The release of CO_2 in the oil palm plantations is influenced by autotrophs' respiration rates and the heterotrophic respiration of non-living organisms, such as soil decomposers (Koh et al., 2011). In addition, the sampling stations are located near the road, where the concentration of CO_2 in the area is affected by traffic, including the number of the vehicles present during the daytime, which is higher than the nighttime. In fact, the extent of CO_2 concentration in the air during the daytime (Station 2) may also be affected by its proximity to the swamp. In this study, the highest CO_2 concentration at night was recorded at Station 1, with only one ppm higher compared to Station 2. Further study should be conducted to determine the other biotic and abiotic factors contributing to the increment of CO_2 concentration in these sampling stations.

The results of this research illustrate that the abundance of *Onthophagus* sp. found in Stations 1 and 2 during the daytime is not significantly different (p = 0.684, $p > 0.05$), which contrasts the results of CO_2 concentrations. Hence, these data can be used to strongly suggest that the abundance and diversity of dung beetles are not influenced by CO_2 concentration in the environment. The CO_2 reading observed in this study is different from that recorded by Brooks et al. (1997), in that more CO_2 is released through respiration at night and no photosynthesis is performed by plants. Scientifically, atmospheric CO_2 concentrations may not affect the activities of the beetle species. More studies relating to CO_2 should be carried out, and additional sampling is required to obtain more samples of the beetles and more CO_2 data in the area.

The low O_2 or hypoxic condition in the dung pad is influenced by the content and concentration of CO_2 and methane (Scholtz et al., 2009), which will affect the ability of each species to survive at different CO_2 concentrations (Hoback, 2012). All beetle groups including roller, dweller, and tunneler are susceptible to hypoxic conditions at different times, depending on their behavior. When making balls from dung sources, adult dung beetles from roller group will be exposed to hypoxic conditions for several minutes (Tribe, 1976) or even hours (Osberg, 1988). Larger dung beetles are able to adapt and survive longer in hypoxic conditions compared to smaller dung beetles, mainly because of their ability to hold more air in the trachea (Hoback et al., 2000). Similar effects are expected to happen to dung beetle species if they are exposed to high CO_2 concentrations.

In this study, the impact of SOM, which forms part of the soil, on the diversity and abundance of *Onthophagus* spp. was studied. The results illustrate no significant difference in the abundance of dung beetles across all the stations. However, S1 vs S3 and S2 vs S3 have significant differences based on the *p*-value being less than 0.05. According to Shannon's diversity index (*H*'), there is little difference in the indexes of the stations, suggesting that the percentage of SOM does not influence the dung beetle diversity index. It can be concluded that the abundance of *Onthophagus* spp. is inversely proportional to the percentage of SOM. When SOM contents increase, the abundance of *Onthophagus* spp. shows no significant difference across the stations. Taking the findings of SOM and the diversity and abundance of *Onthophagus* spp. into consideration, it can be concluded that SOM contents do not have a major influence on dung beetles' activities in the oil palm plantation study area.

The composition of the soil varies according to the type of soil, and the soil type selection by dung beetles depends on the species. The communities of dung beetle have been shown to vary according to sand and clay soil types. According to Silva et al. (2015), the physical and chemical properties of soil are able to influence the structure, diversity, and reproduction of dung beetles. In addition, the survival and reproductive success of certain dung beetle species can also be affected by soil properties, such as moisture content (Martinez et al., 2009). A previous study found no difference in the overall abundance of dung beetle species, although larger paracoprid beetles tend to be dominant on sandy soils but not clay soils (Thurow et al., 1986). Soil type also influences the survival of dung beetles, with beetle larvae remaining in the soil for weeks or months before emerging as adults (Halffter & Edmonds, 1982).

Humus is the major organic component of topsoil. Humus consists of organic material produced by dead organisms, fallen leaves, and feces decomposition. Other sources of humus include the decomposition of organic matter by bacteria and fungi. Some soil-inhabiting animals, such as earthworms, consume organic matter, excrete waste, move large amounts of material to the soil surface and move the organic matter into deeper layers of the soil (Campbell et al., 2008). Dung beetles exhibit similar behavior. Based on the earlier works and the results of this study, it can be assumed that SOM is not a source of organic material to attract dung beetles, mainly because the adults and larvae from this subfamily are detritivores. They tend to use decaying organic materials for food by decomposing the mammal excrement, dead animal carcasses, and rotting plant matter (Halffter & Mathews, 1966).

In this study, the dung beetles exploited the organic matter in dung pads rather than SOM. In the study on dung beetle species' attraction to various types of bait, Goh (2014) found that most species (e.g., *O. babirusoides* and *O.vulpes*) that were active during the day were attracted to fish-baited traps and rat carcasses. In the same study, he found that small rollers tended to respond to dung-baited traps and that large rollers (e.g., *Paragymnopleurus*) were common in both fish-baited and dung-baited traps. Furthermore, some species, including *Ochicanthon* spp., *Onthophagus* cf. "babirusa group" sp. Br, and *O. rudis*, selected traps that were baited with dead millipedes, despite the presence of traps baited with rotting fish. Thus, as evident in this study and those in the literature, SOM does not seem attract dung beetles.

CONCLUSION

In conclusion, although daytime and nighttime CO_2 concentrations demonstrated no remarkable differences, except between Station 1 and Station 2 during the daytime (DCO_2S1 vs DCO_2S2), this finding does not significantly influence the diurnal and nocturnal diel flight activity of the dung beetles or their abundance and diversity. In general, the abundance and diversity of *Onthophagus* spp. were similar across all test stations ($p > 0.05$), despite different percentages of organic materials; this demonstrates that SOM does not have a significant impact on *Onthophagus* spp. and CO_2 concentration. Additional research is needed to improve our knowledge of dung beetle diurnal species (e.g., *O. dayacus*, *O. denticollis*, *O.* cf. *pacificus*, and *Onthophagus* "hairy group") and nocturnal species (e.g., *O. babirussoides*, *O. phaenids*, *O. insicus*, *O. paraphamaeomorphos*, *O. peninsularis*, and *O. parachandrai*). Additional study should be conducted to advance our understanding of the relationship between dung beetles and their environment and especially of the effect of CO_2 concentration and soil organic materials.

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