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Original Article

Variation in body size and morphometric trait of *Elaeidobius kamerunicus* Faust. (Coleoptera: Curculionidae) from Indonesia, Malaysia, and Cameroon

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ABSTRACT

Elaeidobius kamerunicus Faust. is an insect pollinator introduced from Africa and has become the main pollinator of oil palm (*Elaeis guineensis* Jacq.) in Indonesia. The presence of *E. kamerunicus* in Indonesia is reported to increase the fruit set of oil palm. However, the success of pollination shown by the proportion of normal fruit fluctuates under field conditions and tends to decline from year to year. The ineffectiveness of this pollination is caused by the reduced visitation activity of *E. kamerunicus* to female inflorescences. The performance of pollinator, including the issue of body size is thought to be one of the factors that cause a decrease in efficiency and effectiveness of pollination. This study aimed to determine the differences in body size of *E. kamerunicus* from Indonesia, Malaysia and Cameroon specifically. The studies were carried out from October 2018 to May 2019. Adults of *E. kamerunicus* were taken from male anthesising flowers, ten parts of the body were measured. This study showed that there were variations in the body size of *E. kamerunicus* among Indonesia, Malaysia, and Cameroon. The largest body size was found in *E. kamerunicus* from Cameroon, whilst the smallest body size was observed in Malaysian populations for both male and female. The difference in body length (BL) between native and introduced populations reached 0.22 mm (males) and 0.32 mm (females). These findings indicate that introduced populations exhibit smaller body sizes compared to native populations. Information on the variation in the body size in this study might be valuable for developing management strategies to increase oil palm fruit set in Indonesia.

Key words: body size, *Elaeidobius kamerunicus*, oil palm, polinator, variation

INTRODUCTION

Elaeidobius kamerunicus Faust. is the main pollinator of oil palm (Caudwell 2001; Prasetyo & Susanto 2016; Zulkefli et al. 2021) This pollinating insect originated from Africa and was introduced to Indonesia from Malaysia in 1982. *Elaeidobius kamerunicus* was officially released in Indonesia in 1983 (Lubis 1992). One of the reasons for the introduction of *E. kamerunicus* into Indonesia was because this insect has a larger body size, that it can carry more pollen compared to other species (Syed 1979). The presence of *E. kamerunicus* has a positive impact on oil palm plantations (Gintoron et al. 2023). Hutauruk et al. (1982) have reported that pollination by *E. kamerunicus* increases the oil palm fruit set from 44% to 75%. However, the success of pollination, as indicated by fruit set fluctuates under field conditions (Kurniawan 2010) and tends to decrease from year to year (Purba et al. 2010). The decrease in fruit set in Indonesia is also in line with the indication of a decline in the performance of *E. kamerunicus* (Rao & Law 1998; Prasetyo & Susanto 2012; Yousefi et al. 2020; Prasetyo et al. 2026). The performance of *E. kamerunicus* including the issue of body size is thought to be one of the factors causing decreased efficiency and effectiveness of pollination (Sagarra et al. 2001; Willmer & Finlayson 2014).

In more than 30 years since its introduction, the population of *E. kamerunicus* have become established and spread in various locations in Indonesia (Bakara et al. 2019) and Malaysia (Latip et al. 2019). Geographical differences among Africa, Malaysia, Sumatra, Java, Kalimantan, and Sulawesi are also thought to be factors that trigger intraspecific variations in body size (Bai et al. 2016). Therefore, we hypothesised that long-term geographic isolation has resulted in variation in body size among *E. kamerunicus* populations between native and introduced populations. To our knowledge, no quantitative comparative study has addressed intraspecific variation in body size of *E. kamerunicus* among Indonesia, Malaysia, and Cameroon, making this research necessary.

Measurement of variations in body size of insects was carried out using morphometric analysis (Daly 1985; Alvarenga et al. 2012). This morphometric analysis is reported to have been used successfully in understanding intra and interspecific body variations (Rattanawannee et al. 2007; Friedrich et al. 2014) from various groups of insects such as aphids (Foottit 1992), bees (Daly 1992), and beetles (Sanmartín & Martín-Piera 1999; Latip et al. 2019). Therefore, this study employs morphometric analysis to quantify and compare morphometric variation in *E. kamerunicus* populations from Indonesia, Malaysia, and Cameroon, thereby providing insights into the ecological and functional implications of morphological variation in this key pollinator species.

MATERIALS AND METHODS

Sampling and observation sites

The study was conducted from October 2018 to May 2019 using six populations of *E. kamerunicus* from three countries: Cameroon (Littoral Region, Douala), Malaysia (Selangor, Dengkil), and Indonesia (Siantar, North Sumatra; Bogor, West Java; Tapin, South Kalimantan; and Morowali, Central Sulawesi) (Figure 1, Table 1). These locations represent both the native range (Cameroon) and introduced populations (Malaysia and Indonesia). Morphometric measurement was carried out at the Insect Taxonomy and Biosystematics Laboratory, Plant Protection Department, IPB University, Indonesia.

Collection of *E. kamerunicus*

Adult *E. kamerunicus* from Indonesia populations were collected using purposive sampling from oil palm plantations aged 4–6 years. Weevils were captured directly from male inflorescences at anthesis using fine tweezers. A total of 200 individuals were collected per location (100 males and 100 females). Each specimen was temporarily placed in a small plastic container (2 cm × 2 cm) to prevent movement, transported to the laboratory, and preserved at −20 °C prior to measurement.

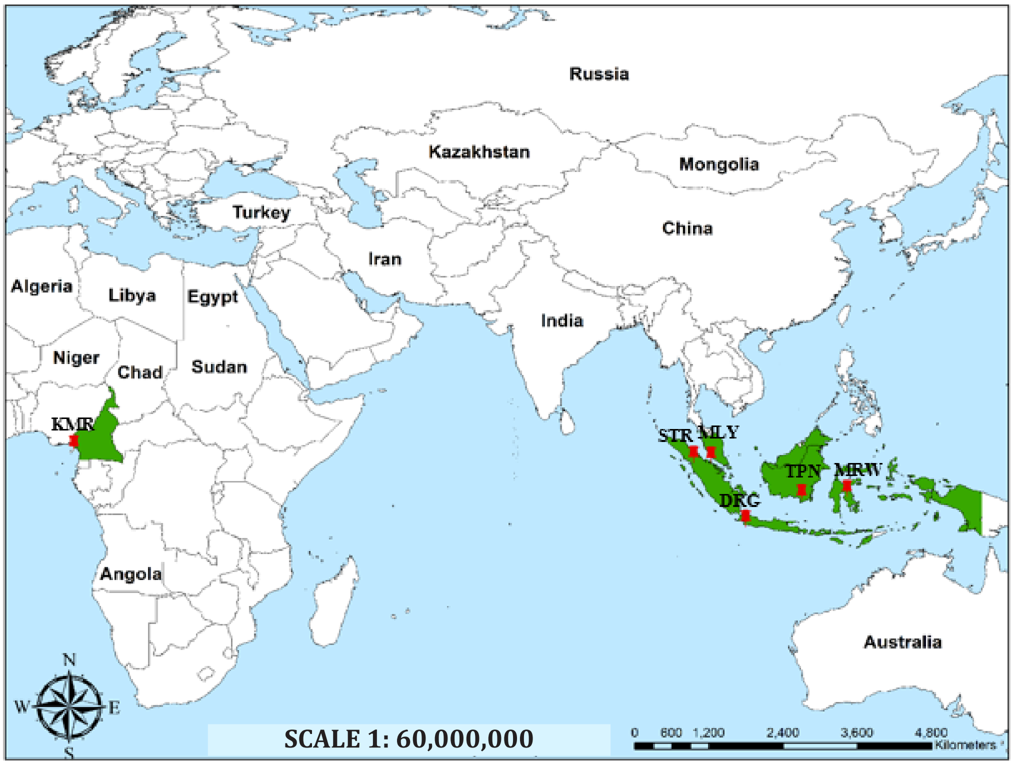

Figure 1. Localities sampled for *Elaeidobius kamerunicus*. KMR: Cameroon; MLY: Malaysia; STR: Siantar (North Sumatra); DRG: Dramaga (West Java); TPN: Tapin (South Kalimantan); MRW: Morowali (Central Sulawesi).

Specimens (100 males and 100 females) from Malaysia and Cameroon were obtained from collaborating researchers at national oil palm research institutes in each country. All samples were collected from commercial oil palm plantations and preserved using similar procedures before morphometric analysis.

Morphometric measurements

One hundred males and one hundred females adult of *E. kamerunicus* from each region were observed using a stereo microscope and body parts were measured using Dino Capture 2.0 software. Each weevil measured 10 morphometric parameters, namely thorax length (TL), thorax width (TW), thorax thickness (TT), elytra length (EL), elytra width (EW), abdomen length (AL), abdomen width (AW), abdomen thickness (AT), body length (BL), and body width (BW) (Figure 2).

Data analysis

All morphometric data were tabulated using Microsoft Excel 2016. Differences in body size between males and females of *E. kamerunicus* were analyzed using principal component analysis (PCA) (Dillon & Goldstein 1984; McGarigal et al. 2013). PCA analysis was used to find the morphometric characters contributing in the separating between males and females of *E. kamerunicus* from the 10 measured body parts. In addition, T test was also carried out to distinguish the size of each body part between male and female *E. kamerunicus*.

Prior to statistical analysis, data were tested for normality and homogeneity of variance. Normality was assessed using the Shapiro–Wilk test (Shapiro & Wilk 1965), while homogeneity of variance was evaluated using Levene's test. The difference in size of 10 body parts of males and females *E. kamerunicus* from 6 different locations were analyzed using one way analysis of variance (ANOVA), and means were separated by Duncan test at 95% confidence level using Genstat 18th Edition. Measurements data of body parts of *E. kamerunicus* from 6 locations were analyzed using a descriptive biplot analysis (Anuraga 2015) using Paleontological Statistics (PAST) version 3.18 (Hammer et al. 2001).

RESULTS

Variation in body size of *E. kamerunicus* male and female

Variations in body size of male and female *E. kamerunicus* were analyzed using PCA. The first two principal components explained 94.741% of total variance. The PCA results clearly demonstrated a distinct separation between male and female individuals. As shown in

Table 1. The geographical locations of the collecting of *Elaeidobius kamerunicus*

Country	Province	City	Geographical location	
			Latitude	Longitude
Cameroon	Littoral Region	Douala	4.6005	9.0777
Malaysia	Selangor	Dengkil	2.8587	101.6831
Indonesia	Sumatra Utara	Siantar	2.9683	99.1536
Indonesia	Jawa Barat	Bogor	-6.5490	114.8630
Indonesia	Kalimantan Selatan	Tapin	-2.7228	114.8630
Indonesia	Sulawesi Tengah	Morowali	-2.0842	121.4603

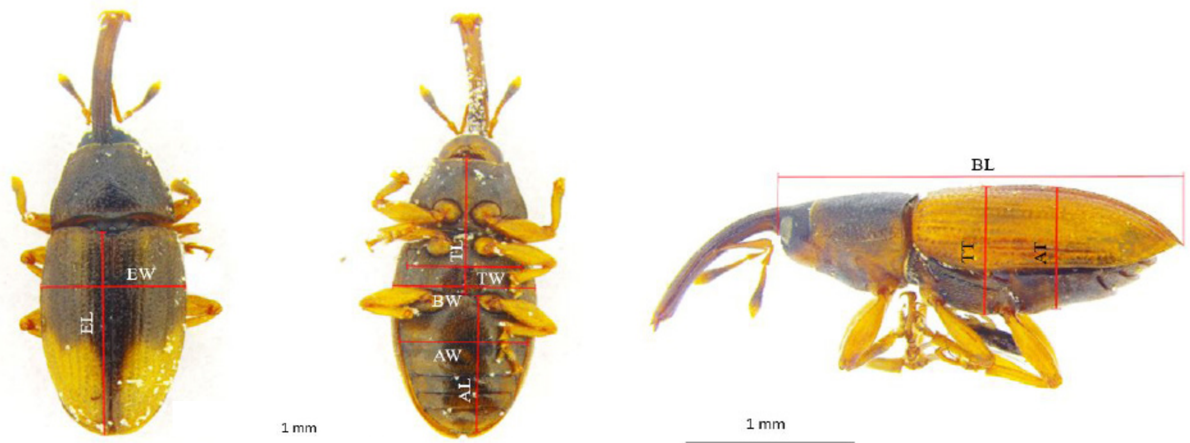

Figure 2. Body parts of *Elaeidobius kamerunicus* measured. EL: elytra length; EW: elytra width; TL: thorax length; TW: thorax width; BW: body width; AW: abdomen width; AL: abdomen length; TT: thorax thickness; AT: abdomen thickness; BL: body length.

Figure 3 based on 1,200 individuals measured (600 males and 600 females), the two groups were well differentiated.

Body length (BL) and elytra length (EL) showed highest loading scores both in PC1 and PC2 (Table 2), indicating that these two characters contributed most strongly to the differentiation between male and female among the ten morphometric characters examined.

The T-test analysis further revealed highly significant difference ($p < 0.001$) in all measured body parts between male and female *E. kamerunicus* (Table 3). Males generally exhibited larger body size than females across all locations.

Variation in body size of female *E. kamerunicus* across location

Morphometric measurements of ten body characters revealed clear variations in female *E. kamerunicus* from Indonesia, Malaysia, and Cameroon, with all variables meeting ANOVA assumptions. Female from Cameroon consistently exhibited the largest body size across most measured characters. For example, BL in Cameroon populations reached 2.97–3.11 mm, compared to 2.74–2.90 mm in Indonesian populations and 2.65–2.80 mm in Malaysian populations. A similar pattern was observed for elytra and thorax dimensions, where Cameroon populations showed higher mean values across all characters.

In contrast, female from Malaysia consistently exhibited the smallest body size for most characters. For instance, EW and TW were generally lower (0.59–0.63 mm and 0.89–0.95 mm, respectively) compared to Indonesia (0.62–0.67 mm and 0.94–1.00 mm respectively) and Cameroon (0.66–0.71 mm and 1.01–1.06 mm, respectively). However, an exception was observed in AL, where Malaysian population showed slighty higher values relative to Indonesian population (Figure 4A).

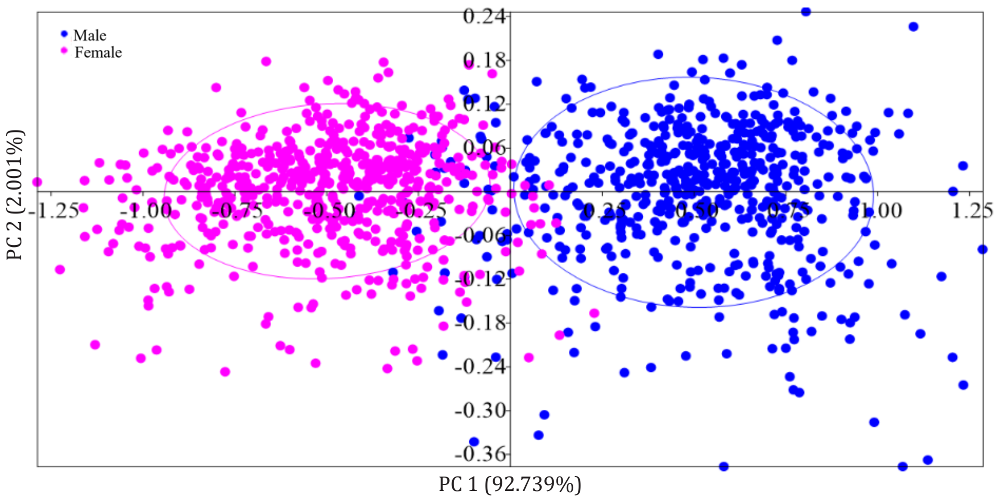

Figure 3. Principal component analysis (PCA) of male and female *Elaeidobius kamerunicus.*

Table 2. Loading scores of the first two principal component of *Elaeidobius kamerunicus*

Character	PC1	PC2
Elytra length (EL)	0.4585	0.5213
Elytra width (EW)	0.1312	0.0766
Thorax length (TL)	0.2190	0.4076
Thorax width (TW)	0.1923	0.2321
Thorax thickness (TT)	0.1551	0.0054
Abdomen length (AL)	0.3629	-0.2832
Abdomen width (AW)	0.1598	0.1578
Abdomen thickness (AT)	0.1369	0.0620
Body length (BL)	0.6556	-0.5734
Body width (BW)	0.2405	0.2541
Eigenvalue	32.75	0.71
% Variance	92.7390	2.0015
Total variance (%)	92.7390	94.7405

Variation in body size of male *E. kamerunicus* across location

A similar pattern was observed in males. Morphometric analysis showed that individuals from Cameroon consistently exhibited larger body size compared to those fom Indonesia and Malaysia. For example, BL in Cameroon populations reached 3.57–3.77 mm, compared to 3.40–3.55 mm in Indonesian populations and 3.35–3.54 mm in Malaysian populations.

Cameroon populations also showed higher values for several key characters, including EW, TT, AL, AW, BL and BW. These values were generally higher by 0.05–0.22 mm compared to Indonesia population and even more pronounced when compared to Malaysian population.

In contrast, males from Malaysia consistently exhibited the smallest body size across most characters. However an exception was observed for EW, where Malaysian populations showed values slightly higher than those from Indonesia (Figure 4B).

Biplot analysis

Biplot analysis explained 97.466% and 91.438% of total variance in females and males, respectively (Figure 5).

Table 3. Mean value of ten morphometric characters of *Elaeidobius kamerunicus*

Variable	Male		Female		P value
	n	Mean ± SD	n	Mean ± SD	
Elytra length (EL)	600	2.221 ± 0.143	600	1.747 ± 0.111	< 0.001
Elytra width (EW)	600	0.750 ± 0.058	600	0.618 ± 0.046	< 0.001
Thorax length (TL)	600	1.502 ± 0.093	600	1.295 ± 0.094	< 0.001
Thorax width (TW)	600	1.129 ± 0.075	600	0.943 ± 0.072	< 0.001
Thorax thickness (TT)	600	1.016 ± 0.061	600	0.863 ± 0.062	< 0.001
Abdomen length (AL)	600	1.593 ± 0.118	600	1.218 ± 0.091	< 0.001
Abdomen width (AW)	600	1.144 ± 0.071	600	0.997 ± 0.072	< 0.001
Abdomen thickness (AT)	600	0.952 ± 0.068	600	0.820 ± 0.065	< 0.001
Body length (BL)	600	3.416 ± 0.208	600	2.768 ± 0.186	< 0.001
Body width (BW)	600	1.432 ± 0.088	600	1.199 ± 0.080	< 0.001

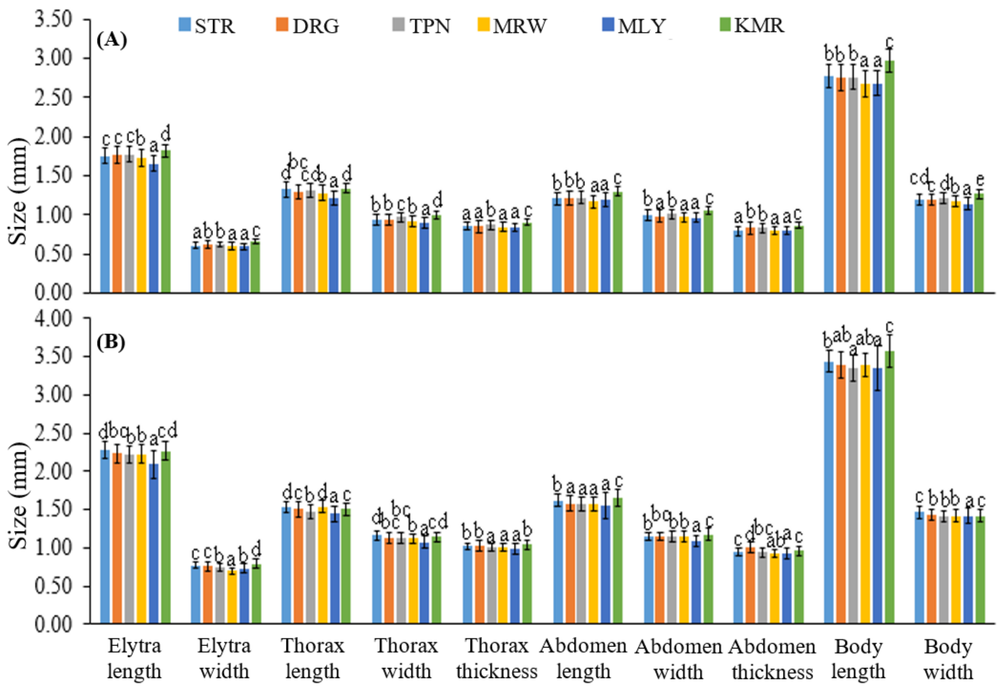

Figure 4. Variation in body size of *Elaeidobius kamerunicus.* A: female and B: male. STR: North Sumatra; DRG: West Java; TPN: South Kalimantan; MRW: Central Sulawesi; MLY: Malaysia; KMR: Cameroon. Number in the same character followed by the same letter are not significantly different in Duncan's test at 95% confidence level (α = 0.05).

BL, TL, and EL showed the highest contribution to variance, while AW, AT, and TT contributed relatively less in both sexes.

This study revealed clear geographic variation in body size among *E. kamerunicus* population from Indonesia, Malaysia, and Cameroon. Based on clustering patterns, three distinct groups were identified for both males and females (Figure 5). Group 1 consisted of individuals with a smaller body size, represented by populations from Selangor, Malaysia. Group 2 included individuals with intermediate body size, represented by populations from Siantar, Dramaga, Tapin, Morowali, Indonesia. Group 3 comprised individuals with larger body size, represented by populations from Douala, Cameroon.

DISCUSSION

This study demonstrates clear variations in body size of *E. kamerunicus* across populations from Indonesia, Malaysia, and Cameroon. Individuals from Cameroon consistently exhibited the largest body size compared to those from Indonesia and Malaysia both males and females. Similarly, Nasir et al. (2020) reported that the *E. kamerunicus* population from Cameroon was larger and morphometrically distinct from Malaysian populations, with PCA revealing a clear separation between the Cameroon and Malaysian populations. Together, these results suggest a morphological divergence in body size between native and introduced populations. However, this inference should be interpreted cautiously, as temporal data and controlled comparisons are required to confirm directional changes over time.

Variation in body size may have important functional implications for pollination. Body size is positively correlated with pollen load, as larger individuals possess greater body surface area for pollen attachment (Nabilah et al. 2011: Tambunan et al. 2020b). Multiple studies on *E. kamerunicus* have demonstrated that

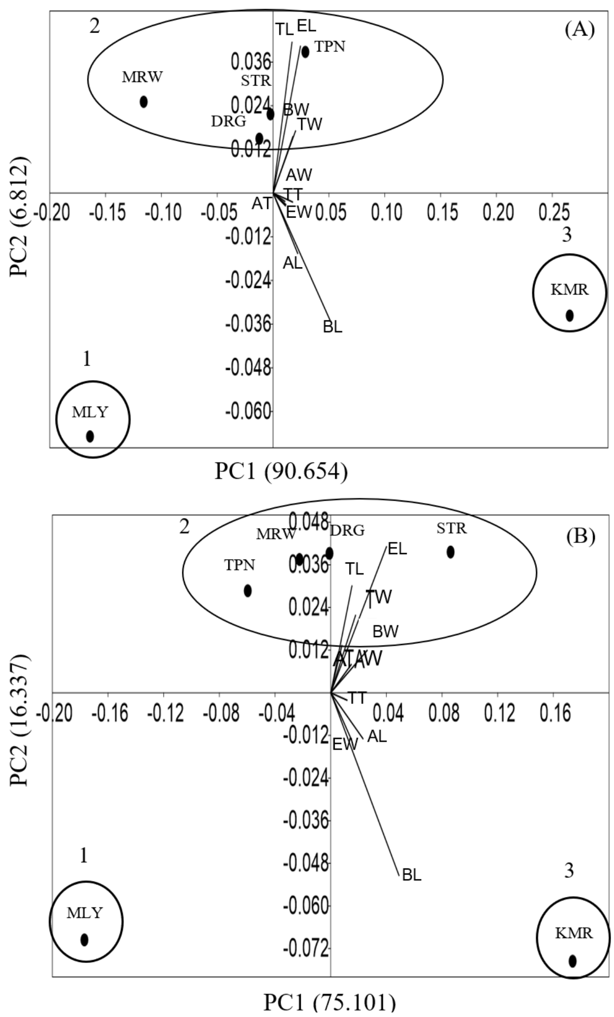

Figure 5. Population grouping based on body size with biplot analysis. A: female and B: male. TL: thorax length; TW: thorax width; TT: thorax thickness;EL: elytra length; EW: elytra width; AL: abdomen length; AW: abdomen width; AT: abdomen thickness; BL: body length; and BW: body width. KMR: Cameroon; MLY: Malaysia; STR: North Sumatra; DRG: West Java; TPN: South Kalimantan; MRW: Central Sulawesi.

larger individuals carry significantly higher pollen loads, indicating that body size is a key determinant of pollination efficiency in oil palm (Agenginardi 2011; Lesmana et al. 2014; Fikra et al. 2015; Tambunan et al. 2020b). This relationship is primarily driven by increased body surface area and the presence of setae, particularly on the elytra and thorax, which enhance pollen adherence and transport. Consequently, larger *E. kamerunicus* individuals may contribute more effectively to pollination.

Similar patterns have been observed in other pollinator taxa, such as bumblebees, where larger individuals carry and transfer more pollen than smaller ones (Willmer & Finlayson 2014; Neto & Schlindwein 2025). Since fruit set is influenced by pollen load, with higher pollen deposition generally increasing fruit set (Nerson 2009), a reduction in body size may potentially affect pollination effectiveness. Nevertheless, direct causal relationships between body size variation and field-level pollination outcomes require further empirical validation.

From an ecological and evolutionary perspective, variation in insect body size is shaped by both genetic factors and environmental conditions (Atkinson 1996; Chown & Gaston 2010). A previous genetic study based on the COI gene (Tambunan et al. 2020a) did not identify specific genetic mechanisms regulating body size in *E. kamerunicus*. Therefore, the observed size variation in Indonesia and Malaysia may be influenced by environmental factors such as climate, host plant conditions, or resource availability, rather than genetic divergence alone. Continuous adaptation to new environments can lead to shifts in morphological traits over time (Jannah 2014), although further integrative studies combining morphometric, genetic, and ecological data are needed to confirm these mechanisms.

CONCLUSION

Intraspecific body size variations of *E. kamerunicus* formed three distinct groups, with Cameroon population exhibiting the largest body size, Malaysia the smallest, and Indonesia intermediate values in both males and females. These results, supported by key morphometric characters such as body length (BL) and elytra length (EL), indicate morphological divergence between native and introduced populations. Notably, the difference in body length (BL) between native and introduced populations reached 0.22 mm (male) and 0.32 mm (female). This variation may have important implications for pollination efficiency, highlighting the need for further studies linking body size with ecological performance.

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