

MORPHOMETRIC VARIATIONS IN *Elaeidobius kamerunicus* FAUST AND THEIR INFLUENCE ON THE QUANTITY AND VIABILITY OF CARRIED POLLEN

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ABSTRACT

*Animal-mediated pollination is crucial for oil palms, with the weevil *Elaeidobius kamerunicus* (EK) as its primary pollinator. However, inconsistent pollinator efficiency limits yield stability. While often linked to abundance, the roles of male and female weevils and their effects on pollen transfer quality remain unclear. This study investigated morphometric differences between male (N = 201) and female EK (N = 192) regarding pollinator efficiency. Weevils were sampled quarterly over one year at an early-mature oil palm estate. Laboratory analyses showed that male EK possessed larger body dimensions, including total length and body surface area. Conversely, females had significantly longer snouts ($p < 0.001$). While no significant difference was found in total pollen quantity between sexes, female EK carried a significantly higher proportion of viable pollen (43.09% in females, while 33.57% in males; $p = 0.007$). This is likely due to their specialised snout morphology, allowing deeper access to fresher, protected pollen within compact male inflorescences. These results challenge the assumption that larger male body size indicates greater pollinator effectiveness. The findings reveal a previously underestimated role for female EK and suggest that behaviour and physiology are critical to pollen transfer viability. Further research into these factors is necessary to optimise pollination strategies in plantations.*

Keywords: *Elaeidobius kamerunicus*, oil palm pollination, pollen viability, pollinator efficiency, sexual dimorphism.

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INTRODUCTION

Almost 90% of the modern angiosperm species rely on animal-mediated pollination to sexually reproduce (Aizen et al., 2009; Hasegawa et al., 2021).

Likewise, pollination via animals is economically crucial in agriculture, especially in enhancing the productivity of crops (Li et al., 2019; Redhead et al., 2020). In the oil palm industry, insect pollination is important as it is one factor that

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increases fruit set and oil yields (Mohamad et al., 2023). Given that even small reductions in pollination efficiency can lead to substantial yield losses, optimising pollination processes is critical for improving productivity and sustainability in oil palm plantations. *Elaeidobius kamerunicus* (EK), a curculionid weevil, is the primary insect pollinator of *Elaeis guineensis* commercially planted in Malaysia.

Pollination in oil palm is achieved through the fertilisation of ovules following the transfer of pollen grains to receptive female inflorescences (FI). This process is facilitated by EK, which is attracted to the flowers by the release of estragole (Siswanto & Soetopo, 2020; Teo, 2015), a volatile organic compound produced during anthesis. While EK visits both male inflorescences (MI) and FI due to this shared scent, the actual pollination event is an incidental consequence of the weevils depositing viable pollen on the stigma during their foraging activities (Anggraeni et al., 2013; Beaudoin-Ollivier et al., 2017). EK is host-specific to the MI, where it feeds on pollen (Appiah & Agyei-Dwarko, 2013; Meléndez-Jácome et al., 2019) and spends most of its life cycle (Muhammad Nasir et al., 2023). Consequently, their reproduction rate and population activity are strongly associated with the availability of these inflorescences (Anggraeni et al., 2013). Due to this close obligate association, the movement of EK between floral structures remains the primary mechanism for effective pollen transportation (Haran et al., 2020).

The effectiveness and the critical importance of EK for oil palm pollination have been well established (Mohamad et al., 2023; Zulkefli et al., 2020). EK populations rely on MI as food source and breeding ground, reinforcing their status as specialised pollinators of oil palm (Siswanto & Soetopo, 2020; Tambunan et al., 2020). A widely held assumption is that male EK carry more pollen than females, largely based on the findings of Appiah and Agyei-Dwarko (2013), who proposed that effective entomophilous pollinators tend to be larger and hairier, offering greater surface area for pollen adherence. This view is supported by Tambunan et al. (2020), who reported that larger weevils carried heavier pollen loads.

Recent studies, however, emphasise that pollinator effectiveness is not solely determined by size or pollen quantity, but also by functional traits such as morphology, behaviour, and pollen handling efficiency (Gintoron et al., 2023; Swaray et al., 2021; Zulkefli et al., 2024). In addition, emerging studies on EK population dynamics highlight temporal fluctuations in abundance and their implications for pollination success under varying environmental conditions (Swaray et al.,

2021; Zulkefli et al., 2024). Male EK are generally larger than females, providing a greater surface area for pollen adherence (Dzulhelmi et al., 2022; Siswanto & Soetopo, 2020; Tambunan et al., 2020). They also tend to have more bristles or setae, which are thought to enhance pollen attachment and transport efficiency (Dhileepan, 1992; Haran et al., 2020).

However, while previous studies by Abd Latip et al. (2019) and Muhammad Nasir et al. (2020) have documented morphometric variations across broader geographic regions, they primarily focused on pollinator abundance and total pollen load. There remains a significant knowledge gap regarding how sex-specific morphological traits influence the viability of the transported pollen, particularly in specific environments such as peat ecosystems. This study addresses this gap by explicitly examining sex-related morphological traits as a mechanistic basis for pollen transfer efficiency.

Therefore, the objectives of this study were to (i) quantify and compare the morphometric traits of male and female EK, and (ii) evaluate differences in total and viable pollen loads between sexes. To evaluate these dynamics, we established two testable hypotheses: (i) That despite having a smaller body surface area, the specialised snout morphology of female EK provides a functional advantage in accessing fresher, more viable pollen grains within the compact MI; and (ii) that this morphological advantage, combined with behavioural differences, results in females carrying a higher proportion of viable pollen compared to males, regardless of the total quantity carried.

MATERIALS AND METHODS

Study Area

The study was conducted in a mature oil palm estate located in Beluru, Miri, Sarawak, East Malaysia (4° 3' 2.535" N, 114° 13' 7.514" E). The palms within the plot were five years old (early mature) and maintained under consistent management practices, including standard fertiliser regimes and pest management. The site experiences an average monthly rainfall ranging from 89 to 498 mm, with minimum temperatures of 23.5°C–24.8°C and maximum temperatures of 30.1°C–32.4°C.

Weevil Collection

To capture population dynamics across a full annual cycle, weevil collection was conducted quarterly, specifically in August 2022, November 2022, February 2023 and May 2023. This three-month interval was strategically selected to account for regional climatic shifts between

monsoon periods, encompass both peak and trough oil palm flowering phenology, and ensure the sampling of distinct generations based on the 14- to 21-day life cycle of EK. During each sampling period, EK were systematically collected from both MI and FI over a five-day interval with daily observations.

Male inflorescences (MI). A total of 10 anthesising MI were randomly selected and sampled. Nine spikelets were selected from each inflorescence: Three each from the top, middle and bottom sections, following the method described by Mohamad et al. (2021). Spikelets were carefully cut and then kept individually in a labelled paper envelope. All spikelets were brought back to the Entomology Laboratory, Universiti Putra Malaysia Kampus Bintulu, and kept in the -80°C freezer (New Brunswick U570, Eppendorf, Germany) until further lab work was carried out (1–2 weeks).

Female inflorescences (FI). Ten receptive FI were randomly selected and individually enclosed using fine mesh nylon drawstring bags, which were carefully secured at the base. Observations were conducted daily between 10.00 and 12.00 hr, coinciding with the peak activity period of the weevils. Weevils found outside the bags were collected using aspirators and transferred into labelled vials on the same day. Any weevils trapped inside the bags were retained by carefully removing the bag from the inflorescence, ensuring minimal disturbance. Bags were then kept in separate resealable plastic bags. All labelled vials and nylon bags were brought back to the Entomology Laboratory, Universiti Putra Malaysia, Bintulu, and kept in the -80°C freezer (New Brunswick U570) until further lab work was carried out (1–2 weeks).

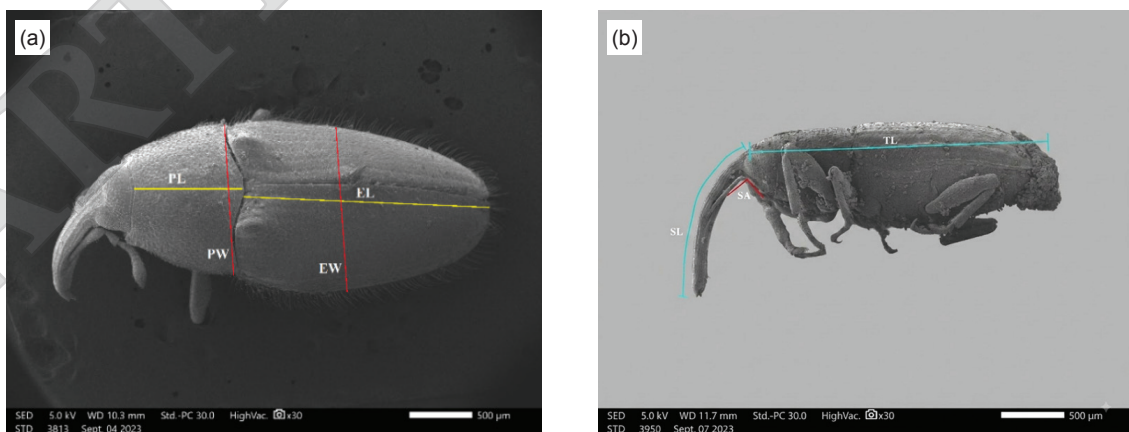
Morphometric Measurements

On every sampling occasion, following identification, 60 male and female weevils from each inflorescence type (MI and FI) were separated and photographed using a stereo microscope (Olympus SZ61, Evident Corporation, Japan) equipped with a digital camera (XCAM-1080PHD, ToupTek, China). Morphometric measurements were subsequently conducted using ToupView software (version x64, ToupTek, China). Seven morphometric characters were measured: Total length (TL), pronotum length (PL), pronotum width (PW), elytral length (EL), elytral width (EW), snout length (SL) and snout angle (SA) (Figure 1) (Abd Latip et al., 2019; Muhammad Nasir et al., 2020). A total of 393 weevils (201 males and 192 females) were separated and photographed using a stereo microscope (Olympus SZ61) equipped with ToupView software to ensure measurement accuracy. Body surface area (BSA) was also estimated using Equation (1) (Dzulhelmi et al., 2022):

$$BSA = \pi \times \frac{\text{Length of weevil}}{2} \times \frac{\text{Width of weevil}}{2} \quad (1)$$

Pollen Analysis

Because EK is highly host-specific and samples were collected directly from the spikelets of anthesising EK inflorescences, the pollen loads extracted from the weevils were reasonably assumed to be oil palm pollen. While formal palynological identification was not conducted to rule out trace environmental contaminants, the obligate mutualism between EK and the oil palm ensures



Note: PL - pronotum length; PW - pronotum width; EL - elytral length; EW - elytral width; TL - total length; SL - snout length; SA - Snout angle. Weevils were photographed using a field-emission scanning electron microscope (FESEM), JSM-IT500HR (JEOL, Japan).

Figure 1. (a) Dorsal and (b) lateral measurements of adult *Elaeidobius kamerunicus*.

that the overwhelming majority of the collected grains belong to the host plants. To quantify the pollen load, weevil samples were individually transferred into a 1.5 mL microcentrifuge tube. Next, 200 μ L of pollen germination solution (boric acid and sucrose) was pipetted into each microcentrifuge tube. The tubes were briefly vortexed (10 s) to obtain a homogenised solution and then left for 4 hr to allow the pollen grains to germinate (Permana et al., 2017). Subsequently, 100 μ L of the pollen germination solution was pipetted onto both sides of the hemocytometer slides and observed under the binocular compound microscope (Leica DM500, Leica Microsystems, Germany).

The numbers of viable and non-viable pollen grains were counted and recorded for each 200 μ L pollen germination solution within every microcentrifuge tube. Pollen viability (PV) was determined through the liquid culture method, where grains were considered viable if they exhibited germ tube protrusion (pollen tube growth) reaching a length at least equal to the diameter of the pollen grain. In contrast, non-viable grains were identified by their shrivelled, deformed appearance, lack of cytoplasmic content (appearing empty), or failure to initiate tube growth. Total pollen quantity was categorised into two metrics: Pollen Carrying Capacity (PCC) and Pollen Load (PLoad). PCC refers to the quantity of pollen carried by weevils collected from anthesising MI and was determined using Equation (2), whereas PLoad refers to the quantity carried by those found on receptive FI, calculated using Equation (3) (Dhileepan, 1992). Determination of the pollen viability (PV) was calculated using Equation (4).

$$PCC = \frac{\text{Total number of pollen}}{\text{Number of squares}} \times \frac{\text{Dilution factor}}{\text{factor}} \times 10^4 \quad (2)$$

$$PLoad = \frac{\text{Total number of pollen}}{\text{Number of squares}} \times \frac{\text{Dilution factor}}{\text{factor}} \times 10^4 \quad (3)$$

$$PV = \frac{\text{Number of viable pollen}}{\text{Number of viable + nonviable pollen}} \times \frac{\text{Dilution factor}}{\text{factor}} \times 100 \quad (4)$$

Data Analysis

The overall data distribution was first assessed using the Shapiro-Wilk test. Since the data followed a non-parametric distribution, the Mann-Whitney

U test was applied to evaluate morphometric and pollen differences between male (N = 201) and female (N = 192) EK, as well as between individuals collected from MI and FI. Additionally, a Spearman's rank correlation test was performed to determine the relationship between specific morphometric traits (such as SL and BSA) and the quantity or viability of the pollen carried by the weevils. All statistical analyses were conducted at a 95% confidence level.

RESULTS AND DISCUSSION

Body Morphometric Variations Between Male and Female *Elaeidobius kamerunicus*

Table 1 presents the morphometric measurements of male (N = 201) and female EK (N = 192) collected during the study. Significant differences were observed in six traits, with males exhibiting larger TL, PL, PW, EL, EW and BSA. Conversely, females displayed significantly larger SL. No significant difference was found in SA. Representative images of male and female EK are shown in Figure 2.

In the present study, EK exhibited significant sexual dimorphism (Table 1), a pattern where males displayed larger overall body dimensions (TL, PL, PW, EL, EW and BSA) compared to females. This pattern aligns with findings from previous studies (Abd Latip et al., 2019; Siswanto & Soetopo, 2020; Tambunan et al., 2020). This contrasts with many other beetle species where females are typically larger (Budečević et al., 2021). This dimorphism is likely driven by intrasexual selection, where a larger body size provides a competitive advantage for males during male-male competition to secure access to mates (Muhammad Nasir et al., 2020).

Body Morphometric Variations of *Elaeidobius kamerunicus* in Male and Female Inflorescences (MI and FI)

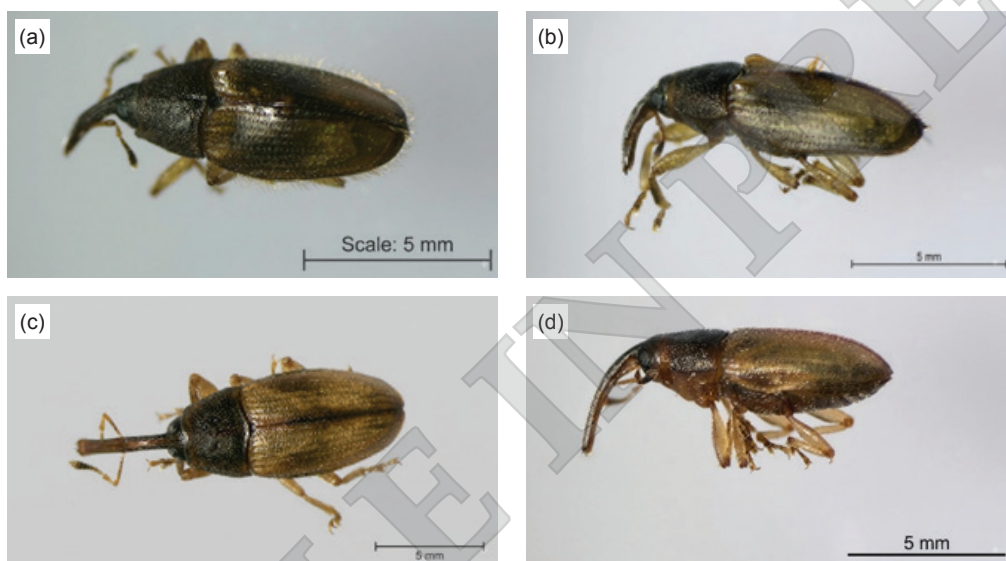
Further analyses compared the morphometrics of weevils captured at different inflorescence types to understand how floral architecture might influence pollinator traits. Among male EK, those collected from MI exhibited significantly longer SL, whereas those from FI had larger SA (Table 2). Similarly, female EK found in MI had significantly greater SL and BSA compared to individuals found in FI (Table 3).

While efficient pollinators must visit both MI and FI to facilitate pollen transfer, these comparisons were conducted to determine if the compact structure of the MI acts as a "morphological filter" (a physical mechanism where the architectural

TABLE 1. MORPHOMETRIC COMPARISONS BETWEEN FEMALE AND MALE *Elaeidobius kamerunicus*

Morphometric characters	Unit	Mean measurement		p-value
		Female	Male	
Total length (TL)	mm	2.651 ± 0.013	3.114 ± 0.017	<0.001
Pronotum length (PL)	mm	0.668 ± 0.010	0.748 ± 0.006	<0.001
Pronotum width (PW)	mm	0.927 ± 0.008	1.082 ± 0.006	0.009
Elytral length (EL)	mm	1.682 ± 0.013	2.058 ± 0.013	<0.001
Elytral width (EW)	mm	1.117 ± 0.008	1.258 ± 0.007	<0.001
Snout length (SL)	mm	1.248 ± 0.008	0.996 ± 0.014	<0.001
Snout angle (SA)	°	98.565 ± 0.774	99.639 ± 0.883	0.007
Body surface area (BSA)	mm ²	2.337 ± 0.034	3.091 ± 0.023	0.003

Note: Female - N = 192; male - N = 201.



Note: Weevils were photographed with a stereo microscope, Olympus SZ61, fitted with an XCAM-1080PHD digital camera.

Figure 2. (a, b) Male and (c, d) female *Elaeidobius kamerunicus* collected in the present study.

design of a habitat selectively favours insects with specific physical traits while mechanically hindering others). This analysis does not suggest that specific morphotypes are restricted to a single inflorescence type, as weevils must visit both to function as pollinators. Instead, it explores how contrasting floral architectures may exert a morphological filtering effect. For instance, an elongated snout may provide a functional advantage for navigating the narrow, confined spaces within the compact spikelets of anthesising MI, whereas the more open structure of FI presents fewer physical barriers, likely imposing fewer mechanical constraints on diverse morphotypes.

Morphometrics Across Inflorescence Types

The architectural differences between MI and FI may act as a morphological filter, potentially explaining the variation in EK traits observed

across different floral environments. An anthesising MI consists of elongated spikelets where individual staminate flowers release pollen gradually from the top to the bottom over a period of 2–3 days. This staggered anthesis within the cylindrical spikelet structure creates narrow, confined spaces between the flowers. MI are typically compact, cylindrical and densely packed with spikelets bearing staminate flowers arranged tightly along the rachillae (Corley & Tinker, 2016; Meléndez & Ponce, 2016). It is hypothesised that this dense floral architecture creates narrow, confined spaces that are physically challenging to navigate. Our results (Table 2 and 3) show that individuals collected from MI exhibited significantly longer SL and smaller SA. This pattern suggests that such structural complexity may favour individuals with more slender, elongated snouts, potentially facilitating deeper penetration into the spikelets for more efficient foraging.

TABLE 2. MORPHOMETRIC COMPARISONS OF MALE *Elaeidobius kamerunicus* IN FEMALE AND MALE INFLORESCENCES

Morphometric characters	Unit	Mean measurement		<i>p</i> -value
		FI	MI	
Total length (TL)	mm	3.123 ± 0.027	3.109 ± 0.023	0.710
Pronotum length (PL)	mm	0.752 ± 0.010	0.746 ± 0.007	0.606
Pronotum width (PW)	mm	1.077 ± 0.012	1.085 ± 0.010	0.613
Elytral length (EL)	mm	2.044 ± 0.021	2.066 ± 0.017	0.432
Elytral width (EW)	mm	1.252 ± 0.013	1.261 ± 0.010	0.613
Snout length (SL)	mm	0.953 ± 0.013	1.018 ± 0.011	<0.001
Snout angle (SA)	°	103.766 ± 1.378	97.541 ± 1.086	<0.001
Body surface area (BSA)	mm ²	3.081 ± 0.052	3.096 ± 0.044	0.417

Note: Male *Elaeidobius kamerunicus* - N = 201; FI - female inflorescences; MI - male inflorescences.

TABLE 3. MORPHOMETRIC COMPARISONS OF FEMALE *Elaeidobius kamerunicus* IN FEMALE AND MALE INFLORESCENCES

Morphometric characters	Unit	Mean measurement		<i>p</i> -value
		FI	MI	
Total length (TL)	mm	2.627 ± 0.029	2.649 ± 0.019	0.500
Pronotum length (PL)	mm	0.687 ± 0.022	0.662 ± 0.012	0.292
Pronotum width (PW)	mm	0.920 ± 0.008	0.930 ± 0.008	0.348
Elytral length (EL)	mm	1.668 ± 0.022	1.703 ± 0.017	0.205
Elytral width (EW)	mm	1.107 ± 0.010	1.123 ± 0.009	0.232
Snout length (SL)	mm	1.216 ± 0.027	1.269 ± 0.013	0.027
Snout angle (SA)	°	99.851 ± 1.193	97.565 ± 1.031	0.233
Body surface area (BSA)	mm ²	2.291 ± 0.038	2.350 ± 0.033	0.497

Note: Female *Elaeidobius kamerunicus* - N = 192; FI - female inflorescences; MI - male inflorescences.

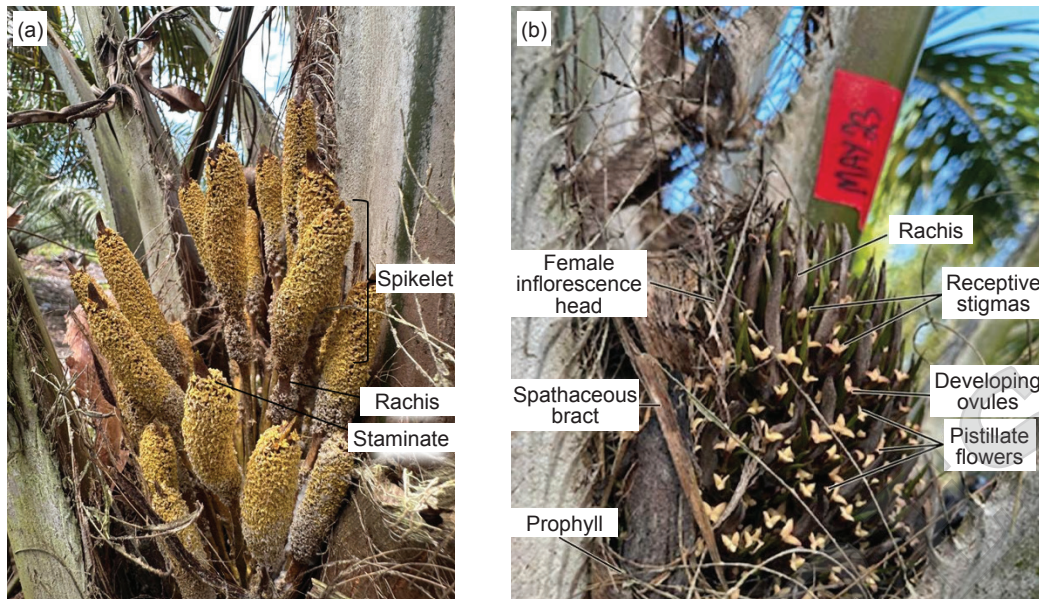
Additionally, the compact structure of MI is thought to serve as a protective barrier, sheltering pollen from tropical stressors such as UV radiation, desiccation and microbial degradation. Because spikelets release pollen gradually over several days, more viable pollen grains are often located deeper within the protected floral recesses, which have not yet been fully exposed to the external environment. Hence, it is likely that fresher and more viable pollen could be found deeper within the male floral structures.

In contrast, FI are larger and possess a more open arrangement to facilitate pollen reception. This structure presents fewer physical barriers and likely does not require specialised morphological traits for access. This openness may encourage visitation from a broader range of the EK population, including those with shorter snouts who can deposit pollen without the mechanical constraints imposed by the male floral architecture.

Interestingly, our findings regarding pollen attachment contrast with some previous studies

that emphasise the presence of setae (hairs) as the primary factor for pollen transport. While setae are undoubtedly important, pollen grains are also abundantly attached to smooth areas of the exoskeleton lacking setae. This suggests that in the dense, pollen-rich environment of a MI, total BSA may be as significant as hairiness for carrying capacity. Larger individuals, particularly males, provide a greater surface area for incidental pollen adhesion as they navigate the tight spaces between staminate flowers.

While no direct behavioural observations were conducted to track individual movement, these findings collectively suggest that the MI architecture acts as a filter, favouring specific morphotypes. This morphological specialisation, combined with available surface area for pollen adhesion, appears to be a key factor in how EK interacts with the contrasting structures of MI and FI to mediate successful pollination. *Figure 3* illustrates these contrasting floral structures, which directly influence EK foraging behaviour and trait distribution.



Note: The image cluster includes several finger-like spadices. Thin lines point to different structures, including: (a) Rachis - points to the main central axis of a spikelet branch; staminate - points to the small male florets covering the spadix; spikelet - points to one of the spreading finger-like branches; (b) rachis - points to the central axis visible within the head; female inflorescence (FI) head - points to the main globular cluster of flowers; spathaceous bract - points to the main fibrous protective sheath, partially dry; prophyll - points to the outermost smaller bract at the base; receptive stigmas - points to the prominent, open, tripartite tips of multiple individual flowers; developing ovules - points to the base of multiple individual flowers; pistillate flowers - points to a grouping of the small pale flowers; fibrous mesh - points to the cluster of natural dry fibre around the base.

Figure 3. High-resolution botanical photographs of the (a) anthesising male (MI) and (b) receptive female inflorescences (FI).

Pollen Quantity and Viability

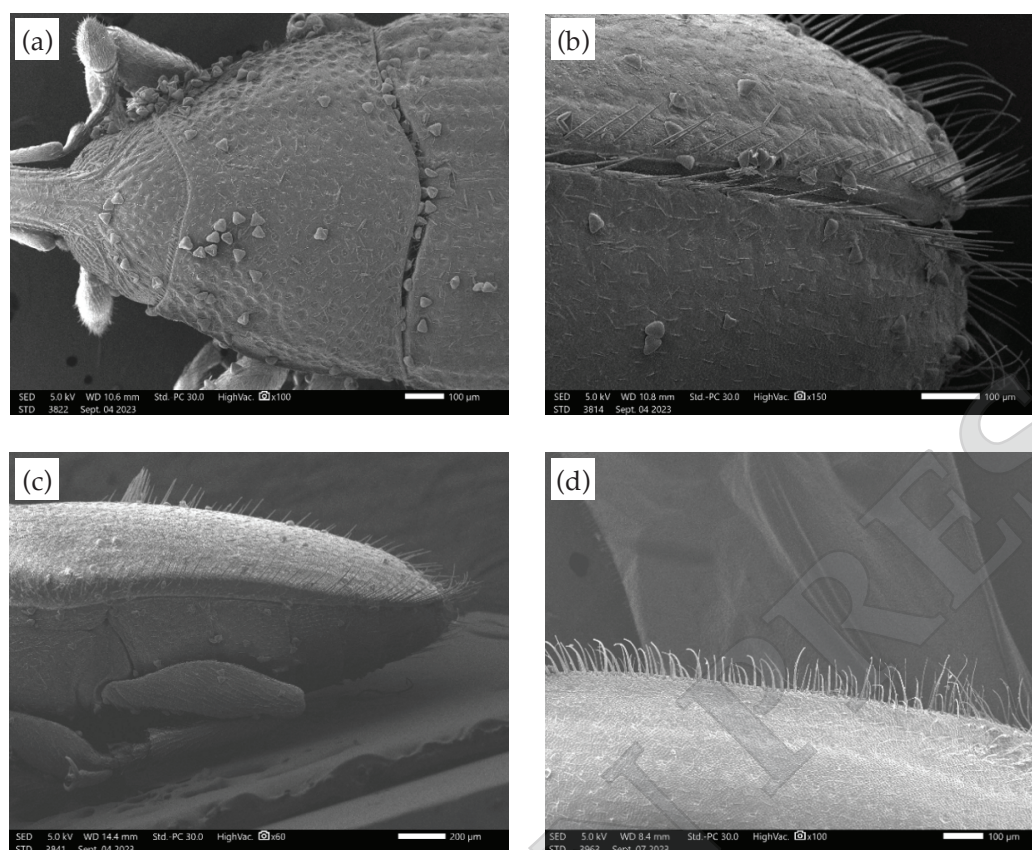
The pollen quantity and viability transported by male and female EK were systematically assessed and compared based on three quantitative indicators: Overall pollen quantity, PCC and PLoad, and three viability indicators: Overall PV, PV from MI (PVmi), and PV from FI (PVfi). As summarised in Table 4, two statistically significant differences were observed. Female EK carried pollen with significantly higher overall viability ($p = 0.011$), as well as a higher proportion of PVfi compared

to PVmi ($p = 0.007$). In contrast, no significant difference was found in the total pollen quantity carried between male and female EK, based on both PCC and PLoad measurements.

Figure 4 presents the dorsal and lateral views of male and female EK collected in this study, showing scattered pollen grains adhered to various body surfaces, particularly around the thorax and abdomen. While previous studies emphasise the importance of setae for adherence, our results show that pollen grains can also be found in high abundance on smoother body surfaces without setae.

TABLE 4. COMPARISONS OF POLLEN QUANTITY AND VIABILITY BETWEEN FEMALE AND MALE *Elaeidobius kamerunicus*

Pollen variables	Pollen data (average per weevil)		p-value
	Female	Male	
Pollen quantity			
Overall	$1.87 \times 10^7 \pm 6.21 \times 10^7$	$2.96 \times 10^7 \pm 6.48 \times 10^7$	0.078
Pollen carrying capacity (PCC)	$2.90 \times 10^7 \pm 9.52 \times 10^7$	$4.28 \times 10^7 \pm 9.35 \times 10^7$	0.147
Pollen load (PLoad)	$4.27 \times 10^6 \pm 2.26 \times 10^7$	$2.79 \times 10^6 \pm 1.89 \times 10^7$	0.514
Pollen viability (%)			
Overall	43.09 ± 3.72	33.57 ± 3.69	0.011
Pollen viability in male inflorescences (PVmi)	23.49 ± 3.37	23.97 ± 3.37	0.888
Pollen viability in female inflorescences (PVfi)	70.43 ± 6.35	53.11 ± 6.37	0.007



Note: Observe the presence of pollen on smooth chitinous surfaces, indicating incidental adhesion. Weevils were photographed with a field emission scanning electron microscope (FE-SEM) JSM-IT500HR.

Figure 4. (a, b, c) Pollen scattered on the pronotum and elytral area and (d) bristles or setae of a male *Elaeidobius kamerunicus*.

Our results (Table 4) show no significant difference in total pollen quantity (PCC or PLoad) between sexes, despite males having a significantly larger BSA. This result stands in contrast to the commonly held assumption that male EK are the dominant pollinators, primarily due to their larger body size and greater density of setae (traits previously associated with a 40%–50% increase in pollen adherence and transport efficiency compared to females) (Dzulhelmi et al., 2022; Tambunan et al., 2020). While Figure 4 demonstrates that pollen can adhere to smooth chitinous surfaces lacking setae (suggesting that larger BSA provides more available space for incidental attachment), this did not translate into a higher pollen load for males. This implies that female *E. kamerunicus* compensate for their smaller size through specialised behaviours or their snout morphology, which allows them to reach higher-density pollen zones within the floral spikelets, as previously suggested by Matsumura et al. (2021) and Muhammad Nasir et al. (2020).

Spearman's rank correlation analysis revealed a significant positive correlation between SL and PV ($r_s = 0.78$, $p < 0.01$), supporting the hypothesis that snout morphology influences the quality of pollen accessed. Conversely, no significant

correlation was found between BSA and total pollen quantity ($r_s = 0.12$, $p > 0.05$).

Pollen located deeper within the inflorescence is likely more viable because it is: (i) Better protected from desiccation, UV radiation and microbial contamination; (ii) may undergo delayed dehiscence, resulting in "fresher" pollen; and (iii) is situated in a more stable microenvironment with higher humidity. Supporting this, Permana et al. (2021) demonstrated that female EK alone can produce significantly higher fruit set across all sections of a bunch compared to males.

Furthermore, behavioural factors may contribute to these differences. While male EK are more abundant at MI (Dzulhelmi et al., 2022), they often remain there for extended periods associated with feeding activities. Rather than actively prioritising pollen transfer, pollen transport in EK occurs incidentally as a by-product of their foraging and movement between inflorescences. This behavioural tendency may increase the probability that males carry and transfer older, less viable pollen. In contrast, females may arrive at receptive FI more promptly, reducing the time pollen is exposed to degradative tropical conditions. Collectively, these results challenge existing paradigms and underscore

the underappreciated role of female EK as highly efficient and critical pollinators in oil palm plantations.

CONCLUSION

This study provides valuable new insights into the morphology and pollination efficiency of EK, challenging the long-standing assumption that male weevils are the primary contributors to oil palm pollination. While males are generally larger, our findings reveal that the total amount of pollen carried by both sexes is comparable. Crucially, female EK carry a significantly higher proportion of viable pollen, which is a critical determinant of successful fertilisation. This functional advantage is likely attributable to their specialised snout morphology. These results redefine our understanding of pollination dynamics and emphasise the dominant role of female EK. Future studies should integrate direct behavioural observations and microclimatic measurements within inflorescences to clarify the exact mechanisms linking morphology to pollination efficiency.

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