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Biological Study of the Oil Palm Pollinating Weevil (*Elaeidobius kamerunicus*) in Highland and Lowland Areas

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Abstract: This study aimed to analyze the biology of *Elaeidobius kamerunicus* in lowland and highland environments. The study was conducted at the Laboratory of the Indonesian Oil Palm Institute of Technology, Medan, from March to May 2026. Samples were collected from the Practical Plantation of the Indonesian Oil Palm Institute of Technology, located at an elevation of 14.46 m above sea level and representing the lowland site, and from PTPN IV Bah Birong Ulu Plantation, located at an elevation of 700 m above sea level and representing the highland site. Observations covered all developmental stages, including eggs, larvae, pupae, and adults. The results showed that *E. kamerunicus* developed more rapidly in the lowland environment than in the highland environment, as indicated by differences in the duration of the pre-adult stages and adult longevity between the two locations. These differences were presumed to be associated with variations in environmental temperature, which may influence insect metabolic rates and development. The findings provide scientific information that may serve as a basis for the management of *E. kamerunicus* populations to enhance pollination effectiveness and oil palm productivity under different environmental conditions.
Keywords: *Elaeidobius kamerunicus*; biology; lowland; highland

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INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is one of Indonesia's most important plantation crops and makes a substantial contribution to the national economy. Palm oil is widely used as a raw material in the food, cosmetics, oleochemical, and renewable-energy industries, resulting in sustained global demand (Rahma et al., 2019). Indonesia is among the world's leading palm oil producers and supplies approximately half of the global market (FAO, 2024). In 2024, Indonesia produced approximately 45.44 million tons of palm oil from about 16.01 million ha of oil palm plantations, with Sumatra and Kalimantan representing major production regions (Badan Pusat Statistik, 2025). Oil palm productivity is determined by multiple agronomic and biological factors, among which successful pollination is particularly important because it directly affects fertilization, fruit set, and ultimately yield (Gintoron et al., 2023).

Pollination in oil palm depends strongly on insect pollinators, particularly the African oil palm pollinating weevil *Elaeidobius kamerunicus* Faust (Coleoptera: Curculionidae). This species is regarded as the principal and most efficient pollinator of oil palm in many producing regions. During anthesis, adult weevils visit male inflorescences, where pollen adheres to their bodies, and subsequently transfer the pollen to receptive female inflorescences, thereby promoting fertilization and fruit development (Swaray et al., 2021; Gintoron et al., 2023). Following its introduction into Southeast Asia, *E. kamerunicus* substantially improved natural pollination and reduced dependence on assisted pollination practices (Nazar et al., 2017; Mohamad et al., 2023). Its establishment has therefore become an important component of oil palm production systems.

The effectiveness of *E. kamerunicus* as a pollinator depends not only on its abundance and activity but also on the successful completion of its life cycle. Male oil palm inflorescences provide both food and breeding sites, enabling the development of *E. kamerunicus* from egg through larval and pupal stages to adulthood (Hussein et al., 1991; Kahono et al., 2012). Consequently, factors affecting survival, development, reproduction, and adult longevity may influence the maintenance of pollinator populations within plantations. A recent review emphasized that *E. kamerunicus* populations and pollination efficiency are affected by complex interactions among biotic and abiotic factors, including temperature, rainfall, humidity, oil palm genotype, pollen availability, pesticide exposure, predators, parasites, and population genetic characteristics (Gintoron et al., 2023). Similarly, Yousefi et al. (2020) reported that pollinator abundance and effectiveness vary among localities and climatic conditions, indicating that environmental variation can have important implications for oil palm pollination.

Environmental conditions may be particularly relevant when oil palm is cultivated across different elevations. Highland plantations generally experience lower temperatures and potentially different humidity, light, and other microclimatic conditions than lowland plantations. Such differences may be associated with variation in insect developmental rates, survival, reproductive performance, and adult longevity. Girsang et al. (2017) demonstrated that environmental conditions are closely related to the biological development and survival of *E. kamerunicus*, whereas Fitraini et al. (2018) reported differences in the duration of developmental stages under contrasting temperature conditions. More recently, Rozziansha et al. (2023) directly compared *E. kamerunicus* populations from lowland and highland oil palm plantations in North Sumatra and found that the life cycle from egg to adulthood was considerably longer under highland conditions. Their findings further indicated substantial differences in adult longevity and reproductive characteristics between elevations, supporting the hypothesis that the biological performance of *E. kamerunicus* may vary among contrasting habitats.

Variation in the biology of *E. kamerunicus* is not necessarily determined by elevation alone. The availability and condition of anthesizing male inflorescences are also important because these structures serve as both food resources and reproductive substrates for the weevil (Kahono et al., 2012; Gintoron et al., 2023). In addition, biological and behavioral characteristics may vary among oil palm cultivars. Sendoya-Corrales et al. (2024), for example, documented the life cycle, adult longevity, oviposition behavior, and population-associated characteristics of *E. kamerunicus* in two oil palm cultivars, demonstrating that the biology of this pollinator can vary across different host and environmental contexts. Genetic factors may also contribute to population-level variation, as suspected inbreeding or endogamy has been identified as a potential factor affecting reproductive fitness and pollination performance (Prasetyo et al., 2012; Prasetyo & Susanto, 2019; Gintoron et al., 2023).

Despite increasing attention to the ecology and biology of *E. kamerunicus*, important gaps remain in understanding how its biological characteristics vary between lowland and highland oil palm environments. Previous studies have predominantly focused on developmental duration, population abundance, or pollination efficiency, whereas comparative information on additional biological and morphological characteristics, including body size, body coloration, adult longevity, and sex ratio, remains relatively limited. Moreover, differences in experimental procedures among previous studies can make direct comparisons between locations difficult. A comparative assessment using the same observational approach across contrasting elevations is therefore needed to provide a more integrated understanding of biological variation in this important oil palm pollinator.

Accordingly, the present study aimed to compare the biological characteristics of *E. kamerunicus* originating from lowland and highland oil palm plantations based on the duration of each developmental stage, adult longevity, body size, body coloration, and sex ratio. By examining these characteristics under standardized observational procedures, this study seeks to provide a more comprehensive description of biological variation between populations from contrasting elevations. The findings are expected to contribute to a better understanding of *E. kamerunicus* population biology and to provide baseline information for the development of pollinator-management strategies aimed at supporting effective natural pollination and sustainable oil palm productivity.

METHOD

Research Type and Design

This study employed a descriptive-comparative design to compare the biological characteristics of *Elaeidobius kamerunicus* originating from lowland and highland areas. The parameters observed included the duration of each developmental stage (egg, larva, pupa, and adult), body size, body coloration, and adult sex ratio. The same observational procedures were applied at both study sites to ensure that differences in biological characteristics could be compared consistently in relation to the environmental conditions of the respective areas of origin.

Study Sites and Period

The study was conducted from March to May 2026. *Elaeidobius kamerunicus* specimens were collected from two locations differing in elevation. The lowland population was obtained from the Experimental Plantation of the Indonesian Oil Palm Institute of Technology, located at an elevation of 14.46 m above sea level, whereas the highland population was collected from PTPN IV Bah Birong Ulu Estate, located at approximately 700 m above sea level. All rearing activities and observations of beetle development were carried out at the respective study locations.

Materials and Equipment

The materials and equipment used in this study included *Elaeidobius kamerunicus* specimens, a microscope, ruler, knife, plastic cups, cup lids, plastic sheets, organdy cloth, brushes, stationery, and a camera.

Sampling

Samples were collected using purposive sampling by selecting male oil palm inflorescences at the anthesis stage, as these flowers are actively visited by *E. kamerunicus*. A total of 350 adult pairs were collected from each study location as the initial population. From this population, five male–female adult pairs were randomly selected for each replicate, with four replicates established at each location. The selected adults were subsequently used to observe biological development from the egg stage through the larval and pupal stages to adulthood.

Research Procedure

Elaeidobius kamerunicus adults collected from male oil palm inflorescences at anthesis at each study site were initially screened to select active individuals in normal physical condition. From the collected population, five male–female pairs were selected for each replicate as observational samples.

Each adult pair was maintained in a plastic cup covered with organdy cloth to ensure adequate air circulation while preventing the beetles from escaping. A section of a male flower spikelet was placed in each container as both a food source and an oviposition substrate. The spikelets were replaced periodically as required throughout the rearing period.

Observations were conducted daily from oviposition until all surviving individuals developed into adults. The duration of each developmental stage was recorded, including the egg, first-instar larva, second-instar larva, third-instar larva, pupa, and adult stages. In addition, changes in body coloration were observed at each stage, body size was measured using millimeter paper and expressed in millimeters (mm), and the sex ratio of emerged adults was recorded for each replicate.

Observed Parameters

The parameters evaluated in this study included developmental duration, body size, body coloration, and adult sex ratio. Developmental duration was recorded for the egg, first-instar larval, second-instar larval, third-instar larval, pupal, male adult, and female adult stages. Duration was calculated as the number of days required for an individual to progress from one developmental stage to the next.

Body size at each stage was measured using millimeter paper and expressed in millimeters (mm). Body coloration was assessed visually to describe morphological changes occurring during development. The adult sex ratio was determined from the relative numbers of male and female adults that successfully emerged at each study location.

Data Analysis

The duration of each developmental stage of *Elaeidobius kamerunicus*, including the egg, first-instar larval, second-instar larval, third-instar larval, pupal, male adult, and female adult stages, was calculated in days and presented as the mean value for each study location. Body-size data were analyzed descriptively by calculating mean values and were expressed in millimeters (mm). Body coloration at each developmental stage was qualitatively described based on morphological observations.

The adult sex ratio was calculated from the proportion of male and female adults that successfully emerged at each study location. Differences in the developmental duration of *E. kamerunicus* between the lowland and highland populations were analyzed using an independent-samples *t*-test at a 5% significance level with SPSS software. The results were subsequently presented in tables and compared with relevant findings from previous studies to provide a basis for discussion.

RESULTS AND DISCUSSION

The biological characteristics of *Elaeidobius kamerunicus* differed between the lowland and highland populations, particularly in the duration of pre-adult development, adult longevity, and several morphological traits. In general, pre-adult development was shorter in the lowland population than in the highland population. The recorded period from the egg to pupal stage was approximately 17 days in the lowlands and 21 days in the highlands, whereas adult longevity was approximately 35 and 15 days, respectively. These findings indicate that the effect of location differed between developmental phases: pre-adult development tended to be slower in the highlands, whereas adults from the lowlands survived longer.

Differences in developmental duration may be associated with contrasting environmental conditions between the two locations. Environmental factors, particularly temperature, are known to influence insect metabolism, physiological activity, and developmental rate. Under relatively warmer conditions, metabolic activity may increase and developmental transitions may occur more rapidly, whereas lower temperatures may slow physiological processes and prolong development. However, temperature, relative humidity, and light intensity were not measured directly in the present study. Therefore, the observed differences cannot be attributed conclusively to any specific environmental variable. Fitraini et al. (2018) reported that environmental temperature influenced the duration of developmental stages of *E. kamerunicus*, whereas Girsang et al. (2017) found that suitable environmental conditions supported the development and survival of this oil palm pollinating weevil. These studies support the interpretation that local environmental conditions may contribute to variation in the development of *E. kamerunicus*.

Detailed daily observations of each developmental stage provided systematic information on the biology of *E. kamerunicus* under lowland and highland conditions. Understanding these biological characteristics is important because *E. kamerunicus* is the principal pollinator of oil palm. Lumentut and Hosang (2016) emphasized that insect pollinators play an essential role in oil palm fruit formation by facilitating pollen transfer from male to female inflorescences. Consequently, the abundance and persistence of *E. kamerunicus* populations may influence pollination success and, ultimately, oil palm productivity. Putri et al. (2021) similarly reported that *E. kamerunicus* makes a substantial contribution to oil palm pollination and may markedly improve productivity in oil palm-producing countries, including Indonesia, Malaysia, and India.

Duration of Pre-adult Development

The duration of each pre-adult developmental stage of *Elaeidobius kamerunicus* in the lowland and highland populations is presented in Table 1.

Table 1. Duration of the pre-adult developmental stages of *Elaeidobius kamerunicus* in lowland and highland areas

Stage	Lowland Duration (days)	Mean (days)	Highland Duration (days)	Mean (days)
Egg	1–2	1.5	2–3	2.5
Larval instar I	1–2	1.5	2–3	2.5
Larval instar II	4–5	4.5	5–6	5.5
Larval instar III	2–3	2.5	2–3	2.5
Pupa	3–5	4.0	4–6	5.0
Male adult	29–31	30.0	10–11	10.5
Female adult	34–35	34.5	14–15	14.5

The duration of the pre-adult stages, comprising the egg, larval, and pupal stages, was generally shorter in the lowland population than in the highland population (Table 1). The egg stage lasted an average of 1.50 days in the lowlands and 2.50 days in the highlands. A similar pattern was observed for larval instars I and II, whereas the duration of larval instar III was identical between locations. The pupal stage also tended to last longer in the highland population. Taken together, these observations indicate that developmental rates varied between populations originating from locations with different elevations.

The longer duration of several pre-adult stages in the highland population may be related to differences in habitat conditions between the two locations. Nevertheless, because environmental parameters were not quantified directly, the mechanism underlying these differences remains uncertain. The results are consistent with Girsang et al. (2017), who reported that environmental suitability affects the development and survival of *E. kamerunicus*. Although their study was conducted under different environmental and experimental conditions, the general pattern supports the possibility that characteristics of the local habitat are associated with biological development.

The present findings also agree with Fitraini et al. (2018), who reported that the duration of individual developmental stages of *E. kamerunicus* varied under different environmental conditions. Differences between the developmental durations reported in that study and those observed here may reflect variation in study location, habitat characteristics, food availability, population origin, or rearing procedures. Therefore, comparisons among studies should be interpreted cautiously, particularly when environmental variables and experimental conditions differ.

Variation in pre-adult developmental duration has ecological relevance because it may influence population turnover and the availability of adult pollinators in oil palm plantations. Faster completion of pre-adult development may increase the rate at which new adults enter the pollinating population, whereas prolonged development may delay adult emergence. Further studies incorporating direct measurements of temperature, humidity, resource availability, and other environmental variables are required to clarify the mechanisms underlying developmental variation in *E. kamerunicus*.

Adult Longevity

Adult longevity of *Elaeidobius kamerunicus* was compared between the lowland and highland populations, as presented in Table 2.

Table 2. Adult longevity of *Elaeidobius kamerunicus* in lowland and highland areas

Adult stage	Lowland longevity (days)	Mean	Highland longevity (days)	Mean
Male	29–31	30.0 days	10–11	10.5 days
Female	34–35	34.5 days	14–15	14.5 days

Adult longevity differed markedly between the lowland and highland populations (Table 2). Male adults from the lowlands lived for an average of 30.0 days, compared with 10.5 days in the highlands. Female longevity showed a similar pattern, averaging 34.5 days in the lowlands and 14.5 days in the highlands. Females also lived longer than males at both study locations.

Adult longevity is an important biological characteristic because it determines the period during which individuals can feed, mate, reproduce, and visit oil palm inflorescences. A longer adult life span may provide greater opportunities for reproductive activity and repeated visits to female inflorescences during anthesis. Therefore, the substantially longer adult longevity observed in the lowland population may have implications for the persistence and pollination activity of *E. kamerunicus* populations.

These findings are consistent with the biological importance of the adult stage described by Hussein et al. (1991), who identified the adult phase as a critical reproductive period for maintaining *E. kamerunicus* populations. Nevertheless, adult longevity in the present study differed from values reported in previous research. Such discrepancies may arise from differences in location, rearing conditions, food availability, population characteristics, or other environmental factors.

Because environmental variables were not measured directly, the present study cannot determine which factor was primarily responsible for the observed difference in adult longevity. Future research should therefore investigate adult survival together with temperature, relative humidity, food availability, and reproductive activity. Such information would improve understanding of the factors regulating the persistence of *E. kamerunicus* populations and their potential contribution to oil palm pollination.

Morphological Variation

Body dimensions of *Elaeidobius kamerunicus* in lowland and highland populations are presented in Table 3.

Table 3. Body dimensions of *Elaeidobius kamerunicus* developmental stages in lowland and highland areas

Stage	Lowland length	Lowland width	Lowland snout length	Highland length	Highland width	Highland snout length
Egg	–	–	–	–	–	–
Larval instar I	1.0 mm	1.0 mm	–	2.0 mm	1.0 mm	–
Larval instar II	3.0 mm	1.0 mm	–	3.0 mm	1.0 mm	–
Larval instar III	3.8 mm	1.3 mm	–	3.0 mm	1.4 mm	–
Pupa	2.4 mm	1.0 mm	–	2.3 mm	1.1 mm	–
Male adult	4.0 mm	1.4 mm	0.7 mm	1.5 mm	1.8 mm	0.8 mm
Female adult	3.7 mm	1.2 mm	1.0 mm	1.3 mm	1.3 mm	1.2 mm

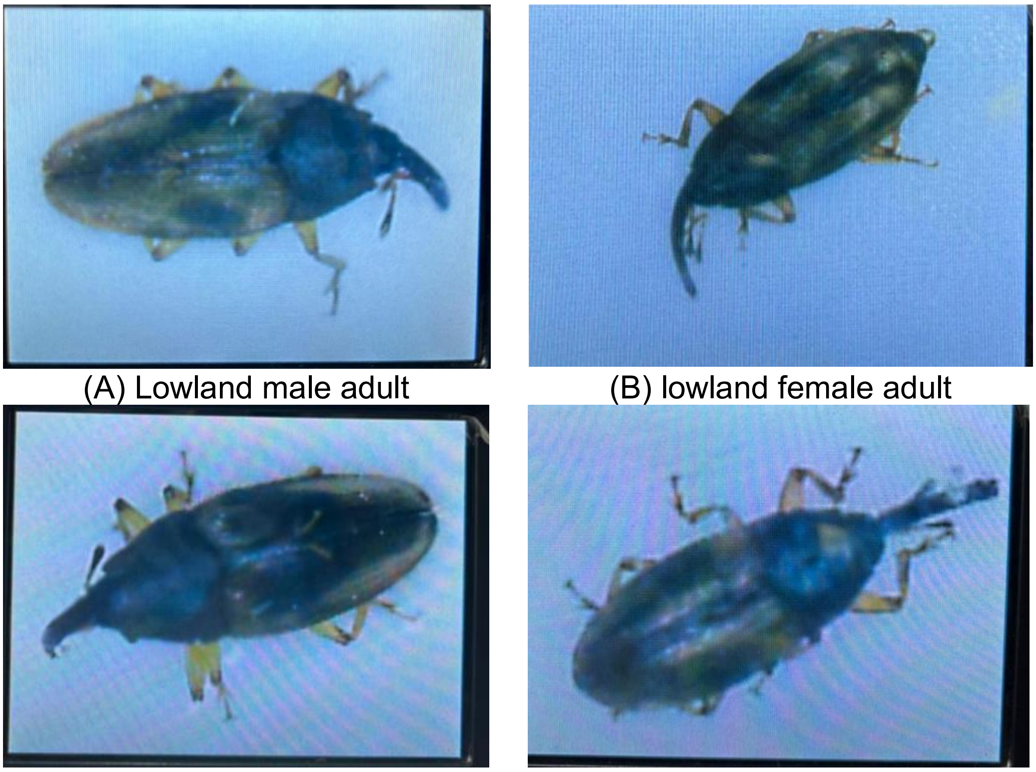
Body dimensions varied among developmental stages and between the lowland and highland populations (Table 3). Differences were observed in the length and width of larval instar I, larval instar III, pupae, and male and female adults. Adult snout length also differed between locations. However, the direction of these differences was not consistent across all traits. For example, some measurements were greater in the lowland population, whereas others were greater in the highland population. The results therefore indicate morphological variation between populations rather than a consistent tendency for one population to be larger than the other.

Body size is an important morphological trait that may reflect biological variation within a species. Variation in insect body dimensions can potentially be associated with environmental conditions, nutritional resources, developmental history, or genetic characteristics. In the present study, however, environmental variables and food quality were not measured directly, and the causes of the observed morphological differences therefore cannot be determined conclusively.

The present findings provide additional morphological information beyond the developmental-duration data emphasized in previous studies. Girsang et al. (2017) and Fitraini et al. (2018) primarily discussed the biological development of *E. kamerunicus* under different environmental conditions, whereas comparative information on body dimensions among populations from different elevations remains relatively limited. The morphological data obtained in this study may therefore provide a useful baseline for subsequent research examining phenotypic variation in *E. kamerunicus*.

Future studies should use more precise morphometric methods and larger sample sizes to determine whether the observed differences are consistent at the population level. Integrating morphological measurements with environmental data and genetic analyses would also help distinguish whether the observed variation is predominantly associated with habitat conditions, phenotypic plasticity, or genetic differentiation.

Morphological Characteristics of Developmental Stages
1. Adult Stage



(A) Lowland male adult (B) lowland female adult
(C) highland male adult (D) highland female adult

Figure 1. Adult morphology of *Elaeidobius kamerunicus* from lowland and highland populations

Adult *Elaeidobius kamerunicus* from both lowland and highland populations were generally dark brown to black. Clear sexual dimorphism was observed between males and females, particularly in the morphology of the rostrum and elytra. Male adults possessed a relatively shorter rostrum and a distinct protuberance on the elytra, whereas females had a relatively longer rostrum and lacked the prominent elytral protuberance. These morphological characteristics provide useful diagnostic features for distinguishing male and female adults.

The dark coloration observed at the adult stage reflects the development and hardening of the cuticle following adult emergence. A well-developed cuticle provides structural protection during adult activity, particularly when the beetles move among male oil palm inflorescences during anthesis (Sari & Emmi 2023). Similar morphological characteristics of adult *E. kamerunicus* have also been reported in previous biological studies of this species under different environmental conditions (Fitraini et al. 2018; Rozziansha et al. 2023).

Differences in several adult body dimensions were observed between the lowland and highland populations. However, the direction of these differences was not consistent across all measured traits. Therefore, the results are more appropriately interpreted as morphological variation between populations rather than as evidence that adults from one elevation were consistently larger than those from the other. Previous research has shown that biological and morphological characteristics of *E. kamerunicus* may vary among populations originating from different environmental conditions (Girsang et al. 2017; Rozziansha et al. 2023). Nevertheless, because temperature, humidity, food quality, and genetic variation were not measured directly in the present study, the mechanisms underlying the observed morphometric variation cannot be determined conclusively.

2. Pupal Stage


(A) Ventral view of a lowland pupa


(B) dorsal view of a lowland pupa


(C) ventral view of a highland pupa


(D) dorsal view of a highland pupa

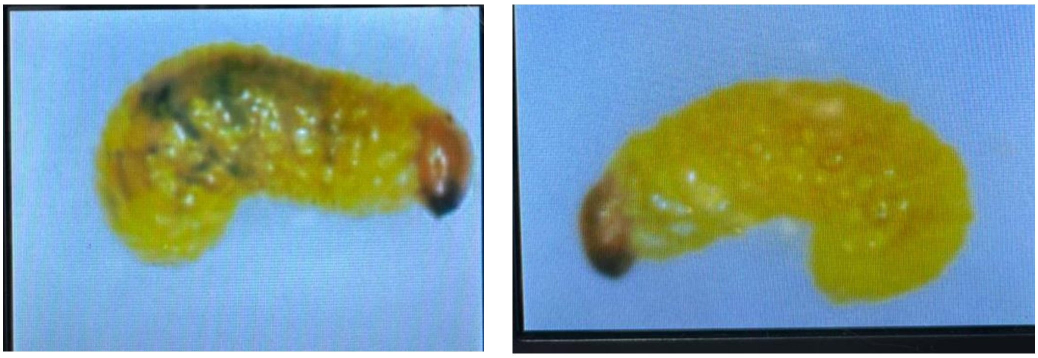
Figure 2. Pupal morphology of *Elaeidobius kamerunicus* from lowland and highland populations

Pupae from both populations were characterized by a bright yellow coloration. Two dark spots were visible on the ventral surface, while the general body form already resembled that of the adult. Developing structures such as the wings, legs, and rostrum were clearly distinguishable. These characteristics indicate substantial morphological differentiation during the pupal stage as larval structures are transformed into adult structures.

The observed pupal characteristics are consistent with previous descriptions of the developmental biology of *E. kamerunicus*, in which the pupal stage represents the transition between the final larval instar and the adult stage (Fitraini et al. 2018; Rozziansha et al. 2023). During this stage, major morphological structures associated with the adult body become increasingly recognizable before emergence.

The general pupal morphology was relatively similar between the lowland and highland populations, although differences in body dimensions and developmental duration were observed. Previous studies have demonstrated that environmental conditions can be associated with variation in the duration of developmental stages of *E. kamerunicus* (Girsang et al. 2017; Fitraini et al. 2018). In the present study, however, environmental variables were not measured directly; therefore, differences in pupal development should be interpreted as population-level variation associated with the two study locations rather than as a direct effect of elevation or temperature.

3. Third-Instar Larval Stage



(A) Lowland population (B) highland population

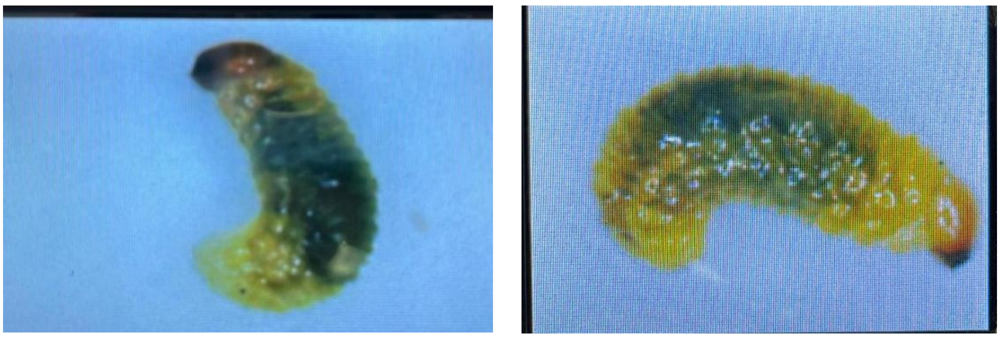
Figure 3. Morphology of third-instar larvae of *Elaeidobius kamerunicus*

Third-instar larvae from both lowland and highland populations exhibited a distinctly curved, C-shaped body. The body was predominantly deep yellow, while the head capsule was dark brown and the mouthparts showed stronger pigmentation. Compared with the earlier larval stages, third-instar larvae were more robust and showed more distinct differentiation of the head and body regions. Similar morphological characteristics of mature *E. kamerunicus* larvae have been reported by Fitraini et al. (2018).

Differences in coloration were also observed between the two populations. Some lowland larvae showed darker pigmentation along parts of the body, whereas larvae from the highland population appeared comparatively lighter. Changes in body coloration and size across larval instars have previously been documented during the development of *E. kamerunicus* (Fitraini et al. 2018). Such changes reflect the progressive development of larvae as they approach the pupal stage.

The third instar represents the final larval stage before pupation and is therefore an important phase of pre-adult development. Differences in developmental duration and body dimensions among populations have been reported under different environmental conditions (Girsang et al. 2017; Rozziansha et al. 2023). Nevertheless, the differences observed in the present study cannot be attributed directly to specific environmental factors because temperature, humidity, and food quality were not quantified.

4. Second-Instar Larval Stage



(A) Lowland population (B) highland population

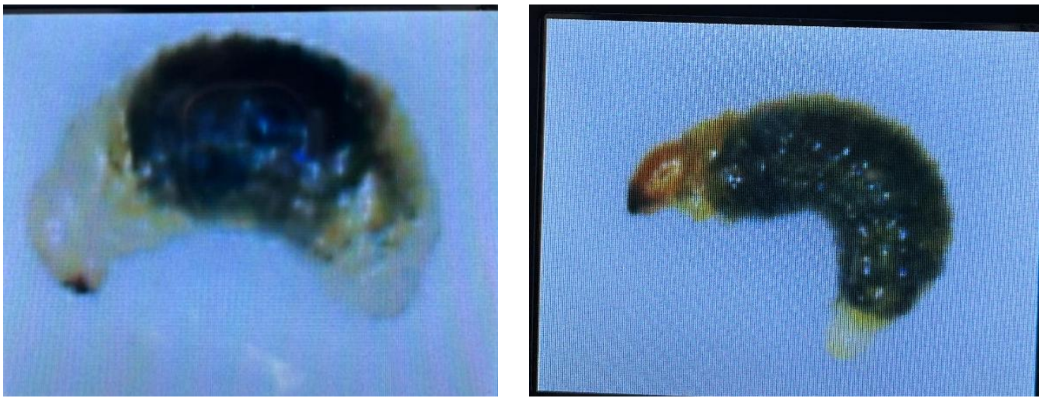
Figure 4. Morphology of second-instar larvae of *Elaeidobius kamerunicus*

Second-instar larvae were predominantly yellow, with a light-brown head capsule and darker pigmentation in the central region of the body. Compared with first-instar larvae, the body was larger and more developed, and differentiation between the head and other body regions was more clearly visible. These characteristics are consistent with the progressive morphological development of *E. kamerunicus* larvae described by Fitraini et al. (2018).

The increase in body size from the first to subsequent larval instars represents normal larval growth and development. During this period, *E. kamerunicus* larvae develop within male oil palm inflorescences, which provide both a developmental habitat and food resources. The availability of male flowers is therefore important for maintaining the population of this pollinating weevil because these structures support its immature developmental stages (Kahono et al. 2012).

Differences in the dimensions of second-instar larvae between the lowland and highland populations may indicate biological variation between locations. Previous studies have reported variation in the developmental characteristics of *E. kamerunicus* under different habitat conditions (Girsang et al. 2017; Fitraini et al. 2018; Rozziansha et al. 2023). However, multiple factors, including environmental conditions, food availability, and population characteristics, may contribute to such variation. Therefore, elevation alone should not be considered the sole factor responsible for the differences observed in this study.

5. First-Instar Larval Stage



(A) Lowland population (B) highland population

Figure 5. Morphology of first-instar larvae of *Elaeidobius kamerunicus*

First-instar larvae were the smallest among the larval stages observed. Their bodies were generally pale to yellowish, with relatively soft-looking integuments, while the head capsule was brownish and more strongly pigmented than the rest of the body. A darker region was also visible in the central part of the body. Similar characteristics have been reported for early larval stages of *E. kamerunicus*, which are generally smaller and paler than later instars (Fitraini et al. 2018).

As development progressed from the first to the second and third instars, increases in body size and changes in pigmentation became more evident. These changes provide useful morphological characteristics for distinguishing the larval stages of *E. kamerunicus*. The progressive development of immature stages is particularly important because successful completion of the larval period determines subsequent pupation and adult emergence, thereby contributing to the maintenance of pollinator populations in oil palm plantations (Hussein et al. 1991).

The developmental characteristics observed in the first-instar larvae also showed some variation between the lowland and highland populations. Previous studies have demonstrated that the developmental duration of *E. kamerunicus* can differ among locations and environmental conditions (Fitraini et al. 2018; Rozziansha et al. 2023). Nevertheless, because environmental variables were not directly quantified in the present study, the observed morphological differences should be regarded as descriptive variation between populations rather than direct responses to elevation.

CONCLUSION

The results of this study demonstrate that the biological characteristics of *Elaeidobius kamerunicus* varied between populations originating from lowland and highland areas. Differences were observed in the duration of developmental stages, adult longevity, body size, and several morphological characteristics, whereas the sex ratio showed no marked variation between the two populations. Pre-adult development was faster in the lowland population, while both male and female adults exhibited longer lifespans than those from the highland population. Variations in body size were also observed at several developmental stages, although the overall morphological characteristics remained generally similar between populations.

These findings indicate that the biological characteristics of *E. kamerunicus* may vary among populations originating from locations with different elevations. The results provide useful baseline information for understanding population variation in this important oil palm pollinator and may support the development of more appropriate pollinator population management strategies to enhance natural pollination in oil palm plantations. However, because environmental variables such as temperature and humidity were not measured directly, the factors underlying the observed biological variation cannot yet be determined conclusively. Further studies incorporating direct measurements of environmental conditions are therefore needed to clarify their relationships with the biological characteristics of *E. kamerunicus*.

RECOMMENDATION

Future studies should include more comprehensive observations of environmental conditions, particularly temperature and humidity, across different study locations. In addition, genetic analyses, including comparisons of DNA variation among *E. kamerunicus* populations from different environments, are recommended to provide a better understanding of the environmental and genetic factors associated with variation in the species' biological characteristics.

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