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Research Article
Elaeidobius kamerunicus (Coleoptera: Curculionoidea): Activity on Oil Palm Flower in Central Kalimantan, Indonesia

[1]Agus Dana Permana, [1]Ramadhani Eka Putra, [2]Agus Susanto and [3]Amin Setyo Leksono

[1]School of Life Sciences and Technology, Institut Teknologi Bandung, Jl. Ganesha 10 Bandung, 40132, Indonesia
[2]Department of Pest and Plant Disease, Faculty of Agriculture, Universitas Padjadjaran, Jatinangor, 45363, Indonesia
[3]Departments of Biology, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya, Indonesia

Abstract
Background and Objective: *Elaeidobius kamerunicus* Faust (Coleoptera: Curculionoidea) is a weevil pollinator oil palm flower, *Elaeis guineensis* Jacq. (Arecales: Arecaceae) Jacq. Male and female inflorescences attracted the weevil, male inflorescences appeared to provides nectar and pollen but female inflorescences seemed provides the weevils with nectar. The objective of this research was to determine the dynamics of *E. kamerunicus* activity in pollinating oil palm flowers in Kumai, Central Kalimantan, Indonesia. **Materials and Methods:** The population of *E. kamerunicus* that visited male flowers was calculated by taking a sample of 9 spikelets from male inflorescences, while the number of *E. kamerunicus* that come to female inflorescence was calculated by counting the weevil around the flower. **Results:** The results of this study showed that peak activity of *E. kamerunicus* on oil palm flowers occurred between 11.00-12.45. The male flowers blossomed occurred for 6-7 days to complete their inflorescence, while those of the females completed their cycle for 4-5 days. The oviposition of *E. kamerunicus* females fluctuated from 05.00-18.00. The number of females oviposits in the flower peaked at 09.00. Temperature and maximum light intensity had a positive correlation with the overall density of *E. kamerunicus* and oviposition by female weevils. The Minimum light intensity affects the abundance and visitation of *E. kamerunicus* on oil palm flowers. **Conclusion:** The abundance of *E. kamerunicus* population in Kumai was established and could give possibility resulting in the better fruit set of oil palm. Conservation efforts can be conducted by maintaining the abundance of the population, especially on the days and hrs of peak abundance of weevils.

Key words: Behaviour, *E. kamerunicus*, oil palm, oviposition, pollination, population, weevil

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Corresponding Author: Agus Dana Permana, School of Life Sciences and Technology, Institut Teknologi Bandung, Jl. Ganesha 10 Bandung, 40132, Indonesia Tel: +62222500258/+62811226895

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The global demand for vegetable oils and their derivatives has driven an increase in oil palm production and led to the expansion and intensification of palm oil in Southeast Asia and Africa[1-4]. According to the Food and Agriculture Organization (FAO), Indonesia and Malaysia accounted for 81.90% of global oil palm fruit production in 2017, an increase of 179.72% from 2000-2017 which is projected to continue in the future[5-7]. Palm oil is made from palm fruit, so the amount of oil palm fruit set plays an important role in the production of palm oil and the oil palm fruit sets can be obtained from the successful pollination of flowers assisted by *E. kamerunicus*.

Oil palm, *Elaeis guineensis* is the most productive plant to produce vegetable oi and oil palm plantations have helped a lot in increasing the gross domestic product in Indonesia as well as in several Asian countries[7,8]. However, the boom in the palm oil industry increases the risk of deforestation, peatland loss and decreased biodiversity and carbon emissions[9-13]. Expansion plans for oil palm plantations in Indonesia have become the subject of political and environmental debates between environmentalist and development actors[14-17]. A similar situation is also experienced by Malaysia. Environmental sustain ability considerations have led to pressure on Malaysia to increase output rather than increase planted area[18]. An effort to increase crop yield has been carried out through the development of inbreeding plants in Indonesia and Malaysia. Several research institutions have carried out hybridization to obtain superior seed through extensive germplasm sources[3]. Despite advances in oil palm research and development, palm fruit yields are still insufficient to meet the growing demands of mills. Among these causes may be attributed to this narrow plant genetic base[19]. In addition, the pollination process also plays an important role in determining the success of oil palm production.

Parthenocarpic fruit can occur due to imperfect pollination processes, for example, the use of inefficient pollinating agents[20]. The study of various pollinator species is very important to do, including studying the behaviour of these species in transferring pollen[21]. The male flower of palm is closely related to the pollinating insect of the order Coleoptera and family Curculionidae, *Elaeidobius kamerunicus*. These pollinator weevils are very important for oil palm plantations in Indonesia and other Asian countries. *E. kamerunicus* is a pollinating weevil for oil palm flowers, an insect originating from Cameroon as well as a very efficient and dominant pollinator of oil palm[22,23]. In the 1969-1980s, this weevil was introduced to Indonesia and several Asian countries to improve the fruit production of local oil palm plantations[24]. It increased the production of fruit sets and oil yield. A study showed that the male flowers of this palm species are used for foraging, reproduction and nesting by this insect[25,26]. *Elaeidobius kamerunicus* can reproduce optimally in both the rainy and summer season. The introduction of this weevil into oil palm plantations increases fruit formation and increases remarkably oil palm yields[24]. In addition, *E. kamerunicus* has increased the pollination of oil palm flowers and increased fruit production. In general, these weevils prefer the male flowers of *E. guineensis* for oviposition[27]. Females of *E. kamerunicus* can live longer than males[28] and this is very important for the development of this insect in producing offspring. Climatic conditions have a very significant influence on the population dynamics and activity of this pollinator[29]. The weevils can reproduce optimally in both rainy and summer seasons. Therefore, we consider climate as a factor in this experiment.

Variations in the abundance of weevils are influenced by the aroma released by the male flowers during the anthesis period. The results of previous surveys and research reports showed the presence of volatile organic compounds in the inflorescences of *Elaeis guineenses*. Oil palm flowers can excrete a volatile compound, know as estragole, this compound is mostly produced by the male flowers and can be an attractant for *E. kamerunicus*[30]. Pollen from male flowers will stick to the body of *E. kamerunicus* and when these weevils arrive at the female flowers, pollen will be released and finally the pollination process occur[22].

Although many studies have been conducted, however, the activities and behaviour of males and females of oil palm weevils during this process, especially related to oviposition of female weevils are relatively unknown. In this paper, we reported the activity of *E. kamerunicus* in pollinating oil palm flowers in Kumai, Central Kalimantan, Indonesia which is may provide basic information to understand the interaction between oil palm flower, oil palm weevil and management strategies for pollination.

MATERIALS AND METHODS

Study site: The study was carried out in Kumai, Central Kalimantan, Indonesia (02°17'36.3" S, 111°48'15.7" E) from January, 2014-2015 . The oil palm plantation site is located on flat ground at an altitude of 30-50 m above sea level. Seven years old oil palm trees were used for this research on an oil palm plantation with 45,000,000 ha and the palm trees were planted 9 m apart from each other. The average annual temperature in Kumai range from 23-35°C, with around 1,500 mm of annual rainfall and 12 hrs of sunshine.

Number of *E. kamerunicus* in oil palm flowers: Five plots were designed to observe populations of *E. kamerunicus*. Four oil palm trees were observed in each observation plot. The distance between the observation plots is 50 m. The number of male and female flowers per hectare and the number of spikelets per male flower was calculated for the conversion of the number of *E. kamerunicus* per male flower and per Ha. The beetles were collected during the male flowers in full anthesis. The weevils were sampled from 9 spikelets of full anthesis male flowers (3 from above, 3 in the middle and 3 below) by directly cut the spikelet and put it in the plastics bag. Before counting, insects were treated with alcohol until they died and the number of weevil individuals in each spikelet was counted. Every month the sampling was carried out for 6 days at the time of full anthesis.

Number of *E. kamerunicus* visiting the male and female flower at the peak of the inflorescence: The number of *E. kamerunicus* that visited male and female flowers were visually observed in the same observation plot between 05:00-18:00. Observations on male flowers were carried out on the 3rd day of blooming male flowers, while the number of *E. kamerunicus* that visited female flowers was observed on the second day. Weevil oviposition was observed and recorded at the same period.

Measurement of abiotic factors: The abiotic factors measured included temperature, maximum light intensity and minimum light intensity. Measurements were made hourly from 05:00-18:00 on each plot, for 5 consecutive days along with observations of weevil visits to flowers.

Data analysis: Monthly population abundance data of *E. kamerunicus* were analyzed descriptively. Data on the difference in mean visits of *E. kamerunicus* on male and female flowers and data on oviposition were analyzed using general linear model analysis of variance. The relationship between the abundance of *E. kamerunicus* in male and female flowers and oviposition with environmental factors was analyzed by Pearson correlation. The results of statistical analysis are considered significant if $p<0.05$. All statistical analyzes were performed using SPSS version 16.

RESULTS AND DISCUSSION

***Elaeidobius kamerunicus* on male inflorescences:** The number of *E. kamerunicus* that visited male inflorescences fluctuated from month to month. The population experienced a slight increase from January to May and peaked in June, then decreased until August (Fig. 1). The population density of *E. kamerunicus* during this study was higher than the density standard made by Oil Palm Research Center, Indonesia (population of *E. kamerunicus*) 20,000 individuals (ha). The population increased again in September and decreased from October-December. This result consistent with the other study, which reported that most of the *E. kamerunicus* population was lower in the rainy season (November-February) compares to that in the summer season (May-September). This result was higher than a study in Malaysia[31]. The peak abundance of *E. kamerunicus* occurred in April and September because in these months the number of adult weevil emergence per spikelet reached its peak[32]. Many factors cause differences in the number of *E. kamerunicus* populations, including plant age, natural enemies and abiotic factors. The presence of predators of this weevil including spiders, mites, ants, nematodes and rats negatively affects the population of *E. kamerunicus*[32].

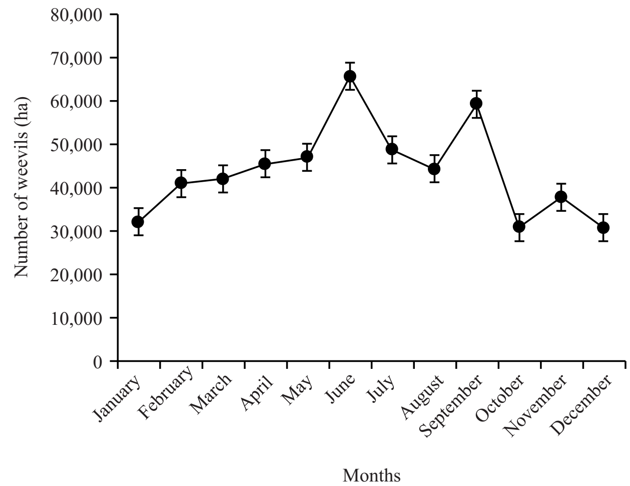

Fig. 1: An average number of *E. kamerunicus* on the male inflorescences

Abundance of *E. kamerunicus* visiting male and female flower during anthesis day: In general, more female weevils recorded visited both male (34.2 individuals) and female (25.9 individuals) inflorescences on oil palm than the male ones (6 and 11 individuals respectively) (Fig. 2a-b). Statistical analysis indicated that the mean of *E. kamerunicus* females was significantly higher than males ($F = 10.7$, $p<0.01$). At the beginning of male inflorescence, only a few *E. kamerunicus* was found in the flowers. The number of *E. kamerunicus* on male flowers reached its peak after the flower are 3 days old

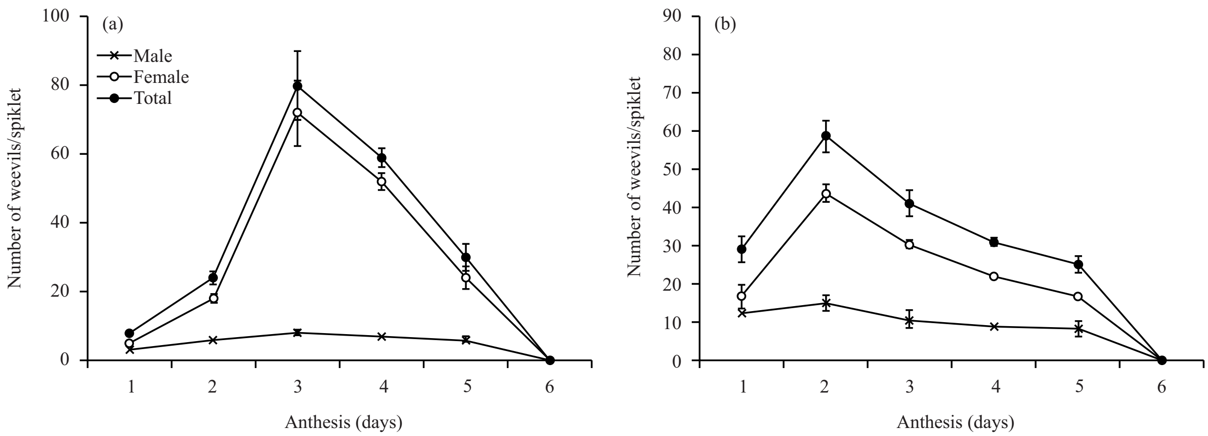

Fig. 2(a-b): Total number (±SE) of *E. kamerunicus* on (a) Male and (b) Female inflorescence

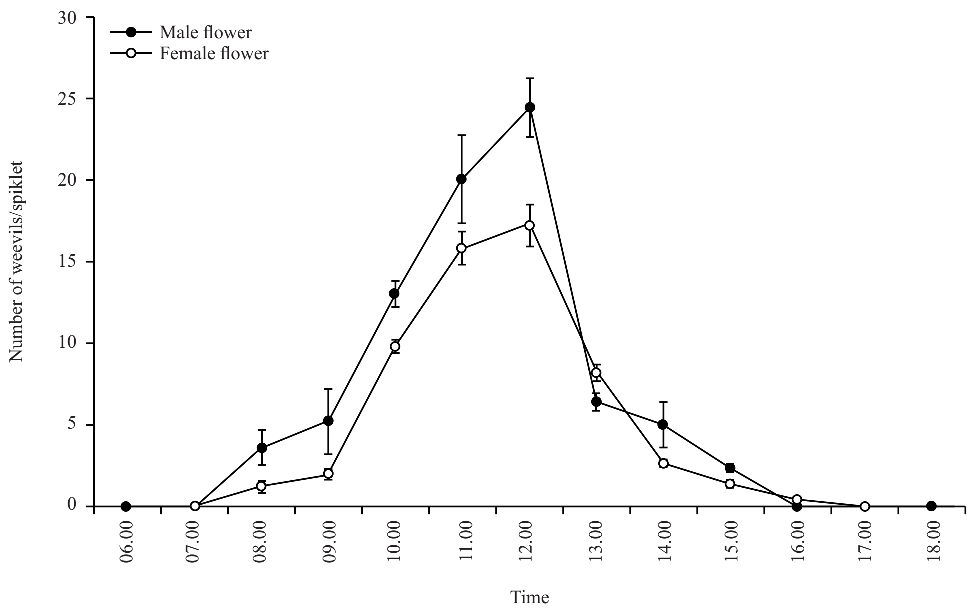

Fig. 3: Visiting time of *E. kamerunicus* on oil palm flower at anthesis

when the flowers have fully bloomed and 80 adults weevils pe 1 spikelet were found. From the 4th day of male inflorescence up to senescence, the number of adult *E. kamerunicus* weevils progressively decreased until the 6th day (Fig. 3). The adult weevils were not observed in the inflorescence on the 6th and 7th days.

The female flower of oil palm needed 4-5 days to complete their inflorescences and the highest number of *E. kamerunicus* visiting female flowers was on day 3 (Fig. 2a), then the number of *E. kamerunicus* gradually decreased on the female inflorescences until the 6th day (Fig. 2b). The mean of weevils visiting female inflorescences (36.9±6) was less abundant compared to the number of weevils visiting male inflorescences (40.2±12.9), however, statistical analysis indicated that the mean was not significant (F = 0.7, $p<0.05$).

The male flower of oil palm needed 6-7 days to complete their inflorescence up to senescence. At the beginning of the male inflorescences, the numbers of *E. kamerunicus* visited the flower only one-third of the 3rd and 4th day of full bloom.

The results of this study indicated that on male inflorescences, the population of female *E. kamerunicus* were always lower than the population of males *E. kamerunicus*. The results were consistent with the other study[33], Those studies stated that the male's weevils often aggregated and maximum abundance usually occurred on day 3 of male inflorescence. Oil palm male flowers were the habitat for *E. kamerunicus*, adult weevils mated and laid their

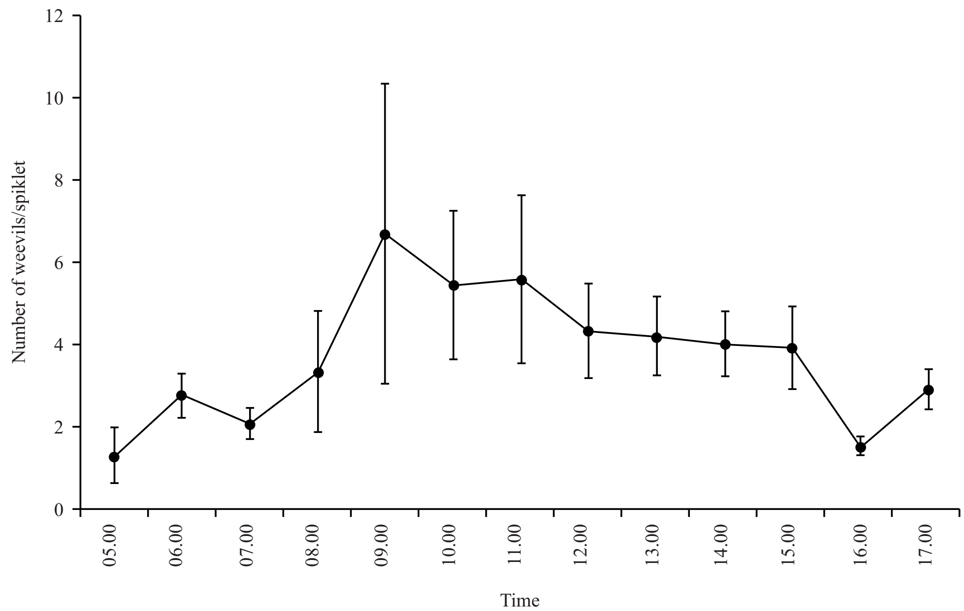

Fig. 4: Number of oviposition by female *E. kamerunicus* on male inflorescences

eggs on these flowers at the dusk. These findings are consistent with the other studies[26,28]. The male flowers may secrete estragole which has a distinct anise-like odour, the secretion tends to be very strong and occurs when the male flowers begin to fully bloom[33,34].

The increase in the abundance of *E. kamerunicus* population density began at the beginning of blooming until the 3rd day, then decreased on the 4th day. The beetle population increased from the first to the third day and decreased from the 4th-6th day of blooming[22]. The results of another study reported that the excretion of estragole by hybrid oil palm was very strong so that it could increase the number of *E. kamerunicus*[30]. Pollen coupled with the scent produced by flowers generally fascinated insect populations[32].

Abundance of *E. kamerunicus* visiting flower within the peak day (3rd in male and 2nd day in female inflorescences): The number of adult weevil was very active in the 3rd day male inflorescences from 10.00 until 12.00, slightly active from 08:00-09:00 and 13:00-15:00 (Fig. 3). There was no weevil activity after 16:00. Adult *E. kamerunicus* was very active on the 2nd day of female inflorescences, the highest activity takes place between 10:00 up to 13:00. Although from 08:00-10:00, adult weevils have started to be active as well as from 13:00-16:00, They were inactive between 06:00-07:00 and there was no weevil activity after 17:00 (Fig. 3).

It has been previously reported that the peak of the population of *E. kamerunicus* in male flowers occurred twice, at 12:00 and 17:00, while in female flowers the peak of *E. kamerunicus* abundance occurred 3 times at 11:30, 14:00 and 18:00[32]. The results of this study showed that the abundance of *E. kamerunicus* decreased in the afternoon and was not found after 17:00. Different environmental factors including, temperature, duration of sunshine may affect the activity of the visit *E. kamerunicus*. Adult *E. kamerunicus* were prefers to stay on the spikelets to mate and laid eggs at the beginning of the day and dusk.

Numbers oviposition in male inflorescences: The oviposition of *E kamerunicus* fluctuated from 05:00-18:00. The number of females oviposits in the flower increased from 05:00-06:00 and then decreased at 07:00. It increased again from 07:00 and peaked at 09:00 from 12:00 in the noon to 15:00, the number of females tends to stagnate, then decreased at 16:00 (Fig. 4). Previous studies related to oviposition generally analyzed the number and length of time weevils lay eggs. The average number of eggs laid by female insects per day in the other study was 1.63 eggs and the number of eggs for a lifetime was 57.64$\pm$8.29 eggs[29]. The other study reported that the average number of eggs laid by female insects per day is 2.6 eggs[27]. Egg production and larvae development depend on the nutrition of the host plant, especially its vitamin, carbohydrate, protein and fat[35].

Table 1: Pearson's correlation value between *E. kamerunicus* activity and abiotic factors

Variables	Temperature	Maximum light intensity	Minimum light intensity	Humidity
Abundance in male flower	0.681*	0.668*	0.809**	-0.643*
Abundance in female flower	0.651*	0.621*	-0.605*	0.672*
Oviposition	0.842***	0.671*	0.715**	-0.816***
Total abundance	0.672*	0.652*	0.795**	-0.630*

Value following asterisk mean that the correlation between variables are significant with *p<0.05, **p<0.01, ***p<0.001

Effect of abiotic factors: All abiotic factors measured had a significant effect on the abundance of *E. kamerunicus* visiting on both male and female flowers of Palm Oil. Temperature and Maximum light intensity were positively correlated with the abundance of *E. kamerunicus* and oviposition by female weevils. The effect of Minimum light intensity on *E. kamerunicus* visiting on both male and female flowers is inconsistent. Minimum light intensity has a positive effect on Abundance in male fallers but the effect on the female flower was vice versa. Humidity tends to hurt all variables of *E. kamerunicus* except for visits to female flowers (Table 1).

The high weevil population is generally found in an area with a temperature range of 31-32°C and with relative humidity between 70-75%. The higher temperature support weevil activities include foraging. Insect activity is faster and more efficient at higher temperatures because insects need heat from the environment to start their metabolism. The temperature for pollinators to visit flowers is effective in the range of 25-35°C[24]. The visit of *E. kamerunicus* to female flower inflorescences was positively correlated with temperature but it has a negative correlation with air humidity. Another study showed that monthly rainfall is positively correlated with the population density of *E. kamerunicus*[32], so there was a tendency that the rainy season would favour weevils for breeding. Meanwhile, a long dry season with very hot weather may reduce the population of these weevils[29].

The results of this research can be useful in determining the right time to calculate the number of pollinators who visit oil palm flowers, especially on female flowers. By counting pollinators on female flowers, it is possible to predict the oil palm fruit set more accurately than counting pollinators on the male flower. The calculation of the percentage of fruit set can be done from the same flower visited by the pollinator, which has not been done in this study.

CONCLUSION

The abundance of *E. kamerunicus* reached its peak on the 3rd day of anthesis on male inflorescences and the 2nd day of female inflorescences. The abundance of *E. kamerunicus* population was established and could give possibility resulting in the better fruit set of oil palm. Temperature and maximum light intensity were positively correlated with the overall abundance of *E. kamerunicus* and oviposition by female weevils. The effect of minimum light intensity on *E. kamerunicus* visiting on both male and female flowers was inconsistent. Minimum light intensity has a positive effect on the abundance in male flowers but the effect on the female flower was vice versa. Humidity tends to hurt all variables of *E. kamerunicus* except for visits to female flowers. Conservation efforts can be conducted by maintaining the abundance of the population, especially on the days and hrs of peak abundance of weevils.

SIGNIFICANCE STATEMENT

This study discovers the number of *E. kamerunicus* that visit oil palm female flower during inflorescence, which can be beneficial for increasing pollinators visiting female flowers by bringing pollen so that it will be useful in implementing strategies to increase the oil palm fruit set. This study will help the researcher to uncover the critical areas of pollination ecology, that many researchers were not able to explore. Thus a new theory on population dynamics in pollination ecology can be obtained.

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