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Research

The Insect Pest Management Strategies and Their Influence on The Emergence Rate of *Elaeidobius kamerunicus* Faust (Coleoptera: Curculionidae) From The Post-Anthesising Male Inflorescence of Oil Palm, *Elaeis guineensis*

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ABSTRACT

Elaeidobius kamerunicus is the main pollinating insect of oil palm, *Elaeis guineensis* in Malaysia. *Elaiedobius kamerunicus* feeds and breeds on the oil palms' male inflorescences. The weevil presence is vital for the successful pollination of oil palm, thus ensuring satisfactory fruit bunch production. MPOB recently reported that the declining quality of oil palm fruit bunch, mainly due to insufficient pollination, had affected the national average oil extraction rate. In part, this scenario was caused by the declining pollinator population. As such, the factors affecting the pollinators' population need to be investigated. One of the critical criteria in estimating the population of *E. kamerunicus* in the field is to measure the emergence rate of the new adult *E. kamerunicus* from the post-anthesis male inflorescence (PAMI). The study to investigate the rate of *E. kamerunicus* adult emergence and their sex ratio was conducted for four months at nine oil palm estates in Malaysia by using PAMI samples that were brought to the laboratory and observed for two weeks. The results have shown that the number of adult weevils that emerged from PAMI was about 36-47 individuals, and the female-to-male ratio for the emerged progenies was 2.33-4.46: 1. Indiscriminate application of broad-spectrum pyrethroid insecticide, cypermethrin has negatively influenced the weevil emergence rate in the field. Whereas, minimal impact on the emergence rate was observed in areas applied with biopesticide. This study showed that the application of cypermethrin could threaten the future population of the pollinating weevil in the field. As such, the excessive application of such insecticides in the field is discouraged and should be replaced by biopesticides to complement other Integrated Pest Management (IPM) strategies. In addition, further investigation is needed to understand how the gender ratio of the progeny could affect the future population of *E. kamerunicus.*

Key words: Female: male ratio, oil palm, pollinating weevil, progeny emergence

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INTRODUCTION

Insect pollinators play a vital role in the delivery of viable pollen from the male reproductive structures of a flower to the female reproductive structures to ensure adequate pollination. In oil palm, this process is mainly conducted by the oil palm pollinating weevil, *Elaeidobius kamerunicus* Faust (Coleoptera: Curculionidae), which was first introduced from Cameroon to Malaysia in July 1980 (Syed *et al*., 1982). Before its importation, the fruit set formation of the crop was poor due to the inefficiency of the native pollinators (Syed, 1979), and manual-assisted pollination was too laborious and costly. After screening and host-specificity tests by the Malaysian Department of Agriculture (Kang & Zam, 1982), the mass release of the weevils was carried out on 21 February 1981 (Syed *et al*., 1982; Kang and Zam, 1982). Subsequently, the population of the newly-introduced weevils was successfully established in oil palm estates throughout Malaysia (Basri *et al*., 1987) without any harmful effects on the native oil palm

pollinators (Basri & Norman, 1997). Since then, the population level of *E. kamerunicus* in oil palm estates has been continuously monitored (e.g., Daud & Idris, 2016; Sulaiman *et al*., 2018; Mohamad *et al*., 2021). However, it was recently reported that the inferior quality of oil palm fruit bunch had affected the oil extraction rate (Parveez *et al*., 2021). This scenario was partly caused by the declining pollinator population (Prasetyo *et al*., 2014). Environmental and ecological factors can influence the survival rate and fecundity of insects. In curculionids, these factors include temperature (e.g., Xu *et al*., 2009), the activity of natural enemies (e.g., Pinkham & Oseto, 1987), and larval crowding (e.g., Dowd & Kok, 1981). Monitoring the emergence rate of insects is instrumental in predicting their population dynamics and the influence of environmental factors on their survival rate, fecundity, and behavior (Liu *et al*., 2021). In addition, the larval mortality of weevil can be influenced by oil palm estate management practices. Indiscriminate application of broad-spectrum insecticides such as cypermethrin, fipronil, and dinotefuran can cause a significant reduction in the rate of adult weevil emergence (Ming & Bong, 2017; Asib & Musli, 2020). The sex ratio of the newly-emerged weevils is another crucial parameter to monitor. Female-biased sex ratio was suggested to influence the senescence rate, especially in a wild insect population (Rodrı´guez-Mun˜oz *et al*., 2019). The purpose of this study was to compare the rate of *E. kamerunicus* emergence from the male inflorescence of oil palm and its sex ratio at the chosen study sites with variegated pest management practices.

MATERIALS AND METHODS

Sampling of Post-Anthesising Male Inflorescences (PAMI)

The sampling of inflorescences was done from September to December 2019 at nine oil palm estates comprising young mature DxP palms in selected sites in Malaysia (Table 1).

Table 1. List of study sites

Site	Estate Name	Location	GPS Coordinate
1	MPOB Sessang	Roban, Sarawak	N1°53'58" E111°12'19"
2	TH Kenyalang Estate	Pusa, Sarawak	N1°40'15" E111°13'13"
3	Ta Ann Kuala Igan Estate	Igan, Sarawak	N2°46'27.58" E111°44'54.23"
4	FELCRA Tembeling Tengah	Jerantut, Pahang	N 04°13’18.01243” E 102°23’13.63052”
5	Sg Bebar Selatan	Rompin, Pahang	N 03°4’55” E103°21’26”
6	MPOB Jerantut	Jerantut, Pahang	N 04°17’14.44776” E 102°24’44.12113”
7	FELDA Chuping	Kangar, Perlis	N06°029’5.60292” E100°019’40.3896”
8	RISDA Keratong Estate	Keratong, Pahang	-NA-
9	TH Ulu Chukai Estate	Hulu Chukai, Terengganu	-NA-

A subplot measuring 10 hectares was chosen at each study location. At each site, an area of 10 hectares was selected for the study. The male inflorescences of oil palm provide breeding sites and food sources for *E. kamerunicus* (Syed, 1981). The weevil pupates in the spent male inflorescences (Jagoe, 1934; Syed, 1981). As a result, to quantify the weevil's emergence rate, PAMI sampling was required. Two PAMI aged a week post-anthesis were randomly sampled during the monthly sampling. Nine spikelets from each PAMI were then sampled by random selection of three spikelets each from the PAMI's top, middle, and bottom regions. Three spikelets were cut from each inflorescence from the inflorescences' top, middle, and bottom parts. Sampled spikelets were kept in muslin-covered conical flasks in the Entomology Laboratory, MPOB Sessang Research Station and MPOB Head Office, Bandar Baru Bangi. The observation of the emergence of *E. kamerunicus* from each spikelet was conducted for two weeks. A total of 648 spikelets were collected throughout the study period, and the rate of *E. kamerunicus* emergence from each spikelet was recorded.

The emerged weevils were sexed according to the description by Latip *et al*. (2019). Generally, the males have a shorter and stouter proboscis (length: 0.83 mm) (Dzulhelmi *et al*., 2020). They usually feed on anther filaments. The females, however, have a longer proboscis (length: 1.08 mm) and feed on the anther tube (Syed, 1980). Finally, the female-to-male ratio was recorded.

The rate of emergence and the sex ratio of the weevils were subjected to Analysis of variance (ANOVA) and Tukey comparison of means using Minitab 17™. In addition, the insect pest infestation levels and their management at each study plot were surveyed to decipher the data better.

RESULTS AND DISCUSSION

The analysis of data collected in the study sites revealed significant differences based on the average rate of *E. kamerunicus* adult emergence (Figure 1). The average emergence rate can be classified into

four (4) categories; less than 30 individuals; 30-40 individuals; 40-50 individuals, and more than 50 individuals.

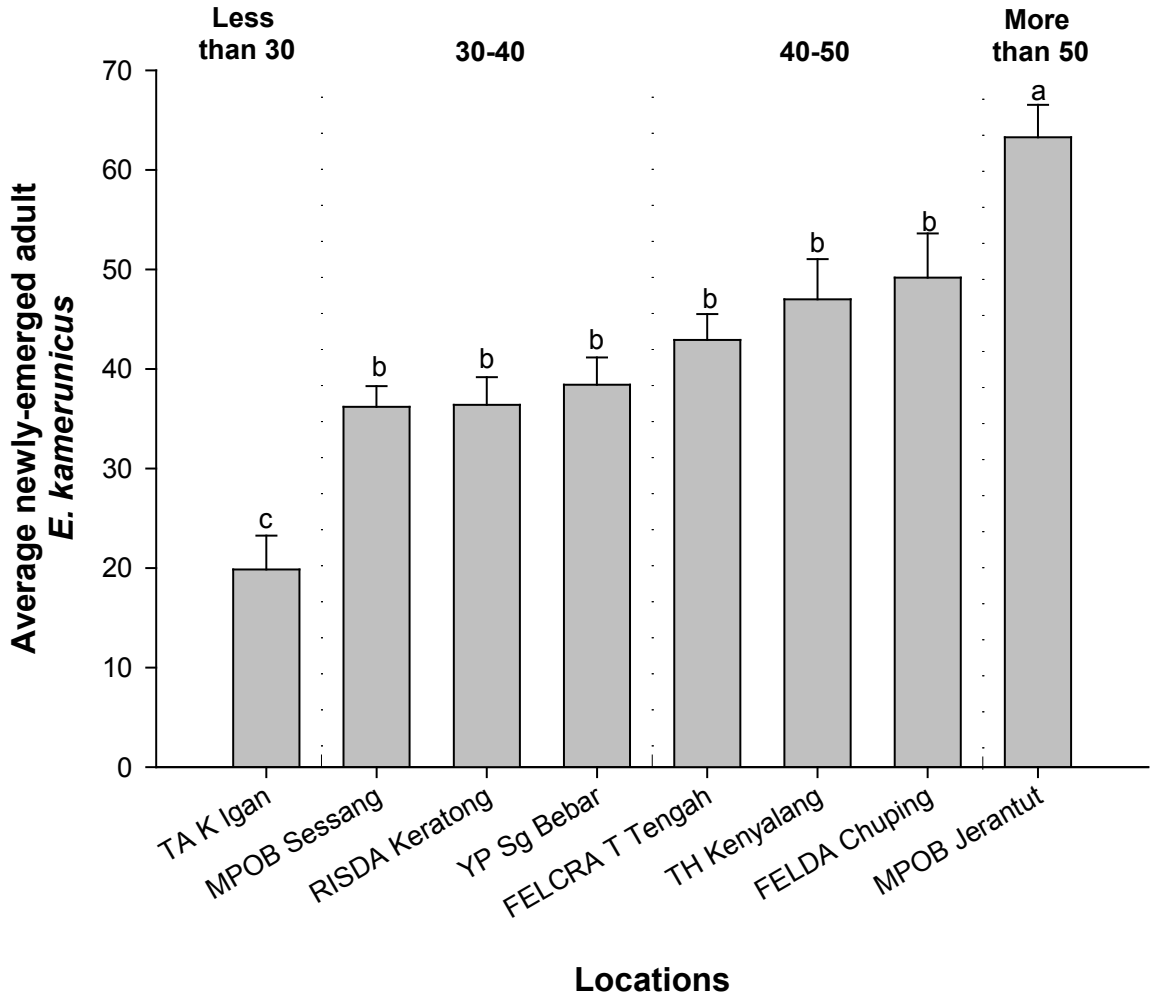

Fig. 1. Comparison of the average emergence rate of *Elaeidobius kamerunicus* between the studied sites. Means sharing the similar letter(s) are not significantly different from each other (P<0.05)

ANOVA of means shows that MPOB Jerantut has a significantly higher average rate of *E. kamerunicus* emergence at 63.28 individuals (Figure 1). FELDA Chuping, THP Kenyalang, and FELCRA Tembeling Tengah have an average emergence rate of more than 40 individuals, 49.17,46.99, and 42.92 individuals, respectively. As for Sg Bebar Estate, RISDA Keratong, and MPOB Sessang, the average emergence rate was 38.42,36.39, and 36.18 individuals, respectively. TA Kuala Igan Estate recorded a significantly lowest average *E. kamerunicus* emergence rate compared to other study sites, with an average of 19.85 individuals. Most areas recorded the average emergence rate ranging from 36-47 individuals/spikelet, except for Igan Estate samples, which recorded a distinctly lower emergence rate (20 weevils/spikelet). The findings were within the range of the value suggested by Ming and Bong (2017), who reported that the rate of *E. kamerunicus* emergence was 43 weevils/spikelet.

To better comprehend which factor could influence the rate of *E. kamerunicus* emergence, information on the level of insect pest infestations and their management practices was obtained from each study site. *Tirathaba* was the primary insect pest present in two sites located in peat soil areas in Sarawak (i.e., TA Kuala Igan & THP Kenyalang). Meanwhile, other study sites reported no prevalent insect pest infestations. Based on their management practice, it was found that only TA Kuala Igan estate used chemical-based pesticides (Cypermethrin 5.5% and Fipronil 5.0%) before the trial period. Cypermethrin is a fourth-generation pyrethroid insecticide that affects the nerve action of the targeted organisms (Smith & Sonderlund, 1998; Farag *et al*., 2021). To control the pest population (i.e., *Tirathaba* sp and *Coptotermes curvignathus*), usual practices involve direct application of the insecticides on the crown region of the palm, coincidentally exposing *E. kamerunicus* to the insecticides during the process. Cypermethrin is known to have profound deleterious effects on *E. kamerunicus* (Ming & Bong,

2017; Prasetyo & Susanto, 2019; Asib & Musli, 2020; Ismail *et al*., 2020). Although the application of the insecticides was conducted selectively based on symptoms and pest population census, a heavy infestation of the insect pests may mean that a greater number of palms were treated, explaining a significantly lower number of new individual weevils' emergence in the estate. On the other hand, in THP Kenyalang estate, the *Tirathaba* population was managed by using the biological control agent *Bacillus thuringiensis*. Several studies have indicated that *B. thuringiensis* is effective in managing the larval populations of *Tirathaba* (i.e., Masijan *et al*., 2015; Mohamad *et al*., 2017; Prasetyo *et al*., 2018) and, most importantly, application of *B. thuringiensis* has been proven to have minimal effects on the population of *E. kamerunicus* (Ahmad *et al*., 2009; Ming & Bong, 2017; Prasetyo *et al*., 2018).

In addition to the emergence rate, the sex ratio of the newly emerged *E. kamerunicus* was also analyzed (Figure 2 & Figure 3). The rate of *E. kamerunicus* emergence at MPOB Jerantut was significantly higher than at most of the study sites (Figure 2). The area recorded an average of 18 newly emerged males compared to 13.53,12.13,11.88, and 11.13 individuals at THP Kenyalang, FELDA Chuping, RISDA Keratong, and FELCRA Tembeling Tengah, respectively. Meanwhile, in Sg Bebar Estate, MPOB Sessang, and TA Kuala Igan, the average rate of newly-emerged males was significantly lower than in other study sites at 9.76, 9.32, and 7.43 individuals, respectively.

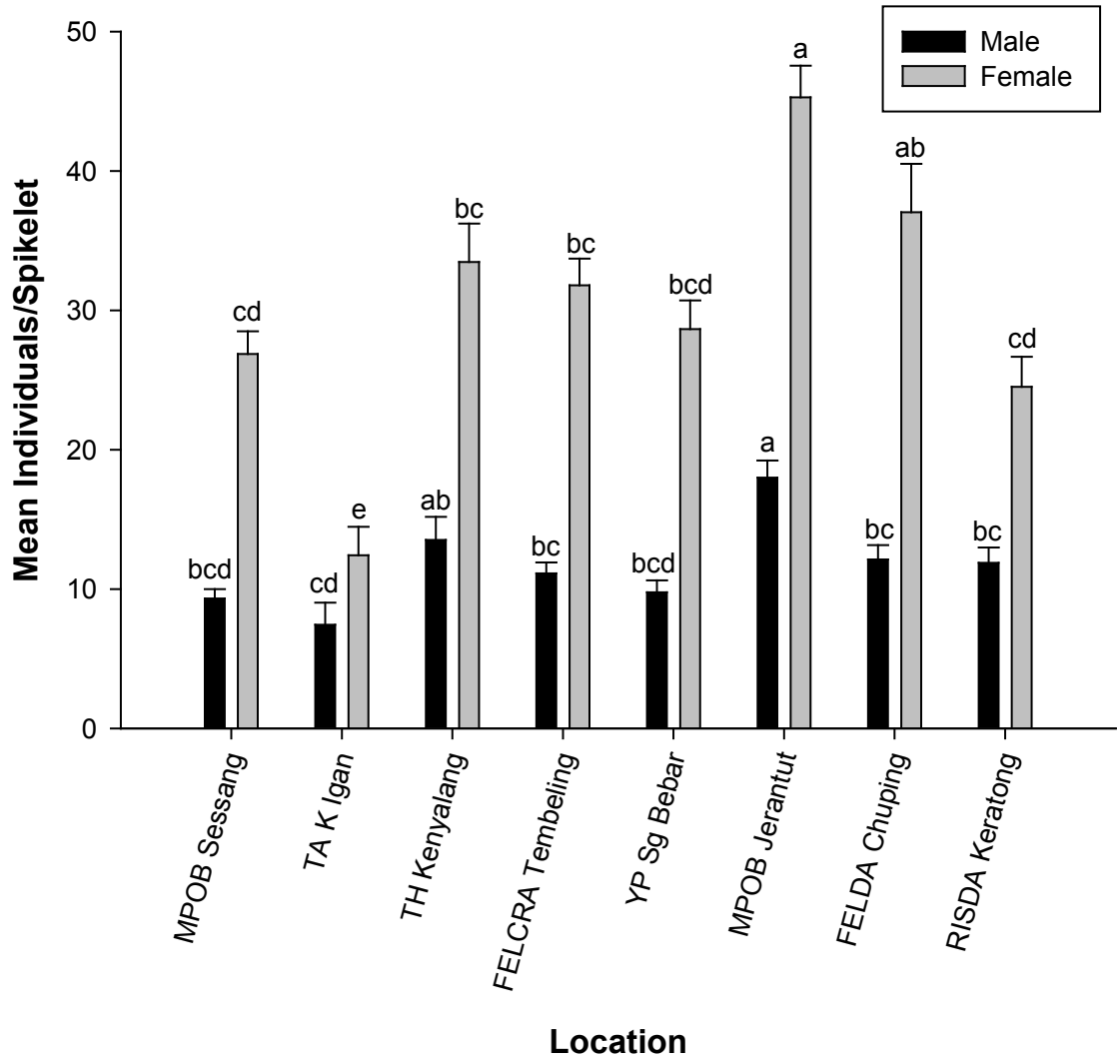

Fig. 2. Comparison of the average emergence rate of different sexes of *Elaeidobius kamerunicus* between the study sites. Means sharing the similar letter(s) are not significantly different from each other (P<0.05)

Similarly, the rate of female adult emergence in MPOB Jerantut was significantly higher than in other study sites (Figure 2). The average rate of female emergence in the area was 45.28 individuals, markedly higher than those recorded in FELDA Chuping (37.04 individuals), TH Kenyalang (33.46 individuals), FELCRA Tembeling Tengah (31.79 individuals), Sg Bebar Estate (28.65 individuals), MPOB Sessang (26.89 individuals), and RISDA Keratong (24.51 individuals). Meanwhile, the rate of female adult emergence in TA Kuala Igan was significantly lower than in other study sites, with an average emergence rate of 12.42 individuals.

The sex ratio (female to male individuals) in all study sites ranged from an average of 2.33 to 4.46. Comparatively, the MPOB Sessang (4.46) ratio was significantly greater than the ratio recorded at THP Kenyalang (2.33). No significant differences were observed between these two areas (Figure 3). In all study locations, the ratio heavily favored the females, which is congruent with the findings by Yue *et al*. (2015).

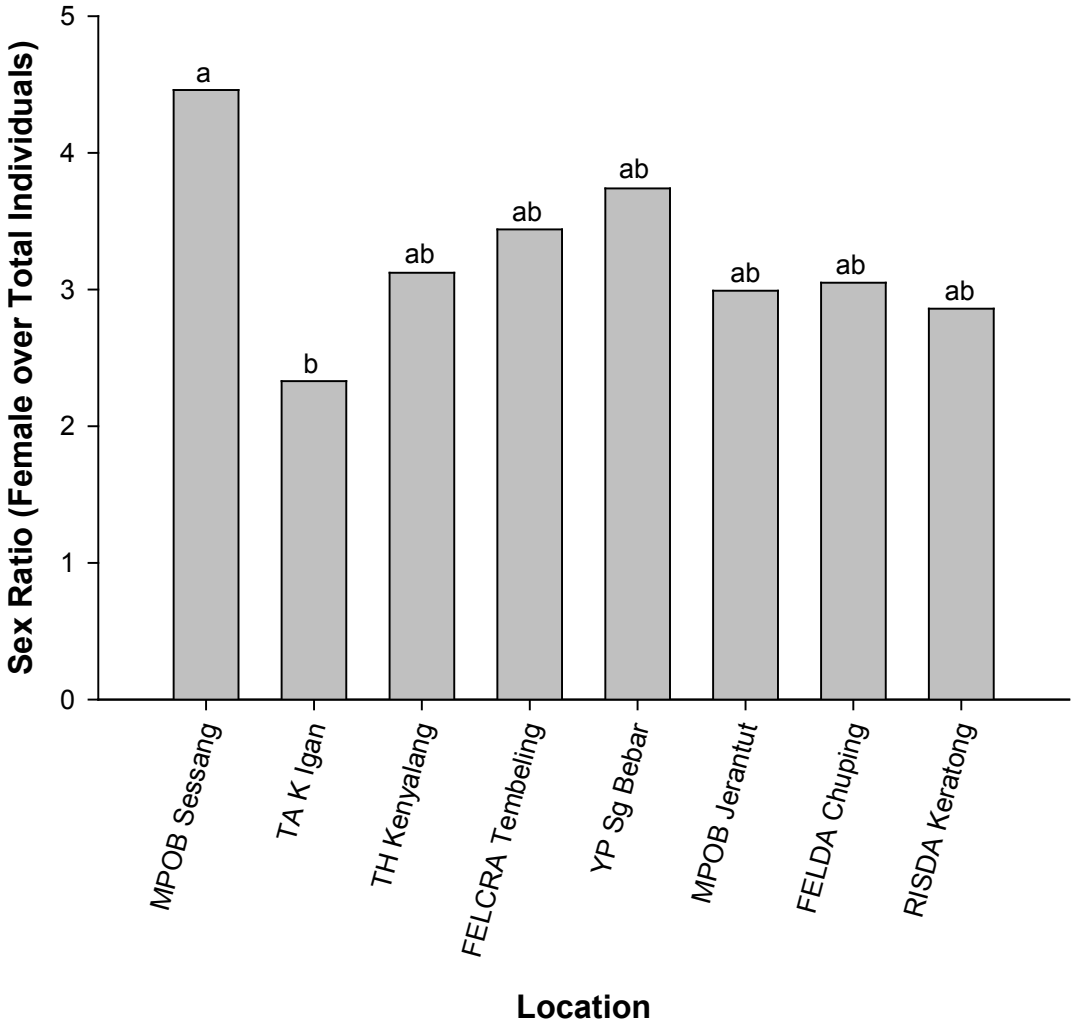

Fig. 3. Comparison of the sex ratio of the newly-emerged *Elaeidobius kamerunicus* (female: male) between the study sites. Means sharing the similar letter(s) are not significantly different from each other (P<0.05)

Elaeidobius kamerunicus had a relatively high female-to-male ratio compared to other reported Coleopteran insects. The female-to-male ratio for *Neochetina bruchi* and *N. eichhorniae* (Coleoptera: Curculionidae) is noted at 1.16-2.22:1 (Ray & Sushikumar, 2015) and for *Ceutorhynchus* sp, a pest of rapeseed, the female to male sex ratio is in the range of 0.25-1:1 (Milovac *et al*., 2010). Meanwhile, in the case of *Ceutorhynchus* sp, males are more abundant than females. The sex ratio of the insect population can influence the rate of mortality, and phenotypic senescence (e.g. Rodrı´guez-Mun˜oz *et al*., 2019 & Adler & Bonduriansky, 2011). The male lifespan was observed to be lower in heavily male-biased populations, while in female-biased populations, the rate of phenotypic senescence in both

sexes can become slower. Consequently, a female-biased population can benefit the overall insect population growth (Rodrı´guez-Mun˜oz *et al*., 2019). A female-biased sex ratio benefits population growth, as potentially more females are available for reproduction. Furthermore, for *E. kamerunicus*, a higher female-to-male ratio can improve pollination. Due to its superior size and the presence of hairy setae, the males have a greater pollen-carrying capacity than the females (Dhileepan, 1992; Lumentut & Hosang, 2016; Dzulhelmi *et al*., 2022). Nevertheless, due to its smaller size, the females can reach the inner part of the female inflorescences (Prasetyo *et al*., 2018). As a result, both sexes of *E. kamerunicus* play a crucial function in ensuring the formation of a satisfactory fruit set. Moreover, smaller females of *E. kamerunicus* develop faster than males and require less food. Therefore, Syed (1979) stated in the event of highly-competitive larval conditions (i.e. high population levels of adult weevils) and limited breeding sites which necessitate oviposition regulation in females of *E. kamerunicus*, the female progenies are likely to emerge in greater volume.

Sex allocation is highly variable in many taxa, sometimes even between closely related species. The underlying mechanisms are still poorly understood. One of the proposed factors that could distort or influence the sex ratio in many arthropods is the intracellular symbionts or bacteria-induced sex ratio (Kageyama *et al*., 1998; Wang *et al*., 2020). Endosymbiotic *Wolbachia* (Rickettsiales: Anaplasmataceae) infection in *E. kamerunicus* was recently reported (Rushidi *et al*., 2023). The bacteria infection was said to be capable of transforming the genetic males into females, influencing the sex ratio of the population (Narita *et al*., 2007). Another known factor that influences the insect sex ratio is the age of ovipositing females, where older females were found to lay more female eggs compared to the younger ovipositing females as found in parasitic Hymenoptera *Coeloides sordidator* (Kenis,1996), the copulation history and the age of male parent, extreme temperature (King, 1987) as well as host weight (Kishi, 1970; Mendel, 1986). However, the actual cause of the lower female-to-male ratio in newly emerged adult weevils TA Kuala Igan was unclear.

The distinctly lower emergence rate and the female-to-male ratio might negatively affect the population levels of *E. kamerunicus* in TA Kuala Igan, which might significantly jeopardize pollination. Omar (2011) reported that natural pollination would substantially decline if the *E. kamerunicus* population were reduced by 30%. Indiscriminate use of broad-spectrum insecticides can only compound the problem. Hence, to minimize the incidences of the high number of parthenocarpic fruit bunches, a corrective action (e.g., weevil population supplementation or local importation of weevil) is undoubtedly required for areas with a low emergence rate.

CONCLUSION

In conclusion, the emergence rate reported in this study is consistent with previous studies. The average rate of weevil emergence at the study sites ranged from 36-47 weevils/spikelet. Female-biased populations were observed in all study locations, with ratios ranging from 2.33-4.46:1. Excessive application of broad-spectrum insecticide has affected the weevil emergence rate at one of the study sites. Therefore, practices that may jeopardize the weevil emergence and the weevil population in oil palm plantations should be avoided. Application of biological control agents, alternative target-specific insecticides, and establishment of natural enemies populations in the plantation area is recommended.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

ETHICAL STATEMENT

Not Applicable

REFERENCES

Adler, M.I. & Bonduriansky, R. 2011. The dissimilar costs of love and war: Age-specific mortality as a function of the operational sex ratio. Journal of Evolutionary Biology, 24: 1169-1177. https://doi.org/10.1111/j.1420-9101.2011.02250.x

Ahmad, N., Ahmad Ali, S.R.A., Mohd Masri, M.M. & Basri, M.W. 2009. Effect of *Bacillus thuringiensis*, TERAKIL-1 and TERACON-1 against oil palm pollinator, *Elaeidobius kamerunicus* and beneficial

insects associated with *Cassia cobanensis*. Journal of Oil Palm Research., 21(2009): 667-674.
Asib, N. & Musli, N.N. 2020. Effect of six insecticides on oil palm pollinating weevil, *Elaeidobius kamerunicus* (Coleoptera: Curculionidae). Serangga, 25(2): 1-9.
Basri, M.W. & Norman, K. 1997. Role and effectiveness of *Elaeidobius kamerunicus*, *Thrips hawaiiensis* and *Pyroderces* sp. in pollination of mature oil palm in Peninsular Malaysia. Elaeis, 9: 1-16.
Basri, M.W., Zulkefli, M., Halim, A.H. & Mohd Tayeb. D. 1987. The population census and the pollination efficiency of the weevil, *Elaeidobius kamerunicus* in Malaysia - A status report, 1983-1986. Proceedings of 1987 Oil Palm/Palm Oil Conference- Agriculture. Kuala Lumpur. 23-26 June 1987. pp. 535-549.
Daud, S.N.S.M. & Idris, A.G. 2016. Population density of oil palm pollinator weevil *Elaeidobius kamerunicus* based on seasonal effect and age of oil palm. AIP Conference Proceedings, 1784: 060051. https://doi.org/10.1063/1.4966889
Dhileepan, K. 1992. Pollen carrying capacity, pollen load and pollen transferring ability of the oil palm pollinating weevil *Elaiedobius kamerunicus* Faust in India. Oleagineux, 4(2): 55-61.
Dowd, P. & Kok, L. 1981. Impact of larval crowding on survival of *Rhinocyllus conicus* (Coleoptera: Curculionidae). Environmental Entomology, 10(4): 472-473. https://doi.org/10.1093/ee/10.4.472
Dzulhelmi, M.N., Razi, A.N., Kalog, N. S.F., Murdi, A.A., Su, S. & Hazmi, I.R. 2022. Assessment on pollen carrying capacity and pollen viability of *Elaeidobius kamerunicus* (Coleoptera: Curculionidae). The Phillippine Agricultural Scientist, 105(3):309-314.
Farag, M.R., Alagawany, M., Bilal, R.M., Gewida, A.G.A., Dhama, K., Abdel-Latif, H.M.R., Amer, M.S., Rivero-Perez, N., Zaragoza-Bastida, A . & Binnaser, Y.S. 2021. An Overview on the Potential Hazards of Pyrethroid Insecticides in Fish, with Special Emphasis on Cypermethrin Toxicity. Animals, 11(2021): 1880. https://doi.org/10.3390/ani11071880
Jagoe, R.B. 1934. Observations and experiments in connection with pollination of oil palm. Malayan Agriculture Journal., 22: 598-606.
Kageyama, D., Hoshizaki, S. & Ishikawa, Y. 1998. Female-biased sex ratio in the Asian corn borer, *Ostrinia furnacalis*: Evidence for the occurrence of feminizing bacteria in an insect. Heredity, 81: 311-316. https://doi.org/10.1046/j.1365-2540.1998.00391.x
Kang S.M. & Zam A.K. 1982. Quarantine aspects of the introduction into Malaysia of an oil palm insect pollinator. Proceedings International Conference on Plant Protection in the Tropics, Kuala Lumpur: Plant Protection Society Malaysia.
Kenis, M. 1996. Factors affecting sex ratio in rearing of *Coeloides sordidator* (Hym: Braconidae). Entomophaga, 41: 217-224. https://doi.org/10.1007/BF02764247
King, B.H. 1987. Offspring sex ratios in parasitoid wasps. The Quarterly Review of Biology, 62(4): 367-396. https://doi.org/10.1086/415618
Kishi, Y. 1970. Difference in the sex ratio of the pine bark weevil parasite, *Dolichomitus* sp. (Hymenoptera: Ichneumonidae), emerging from different host species. Applied Entomology and Zoology, 5(3): 126-132. https://doi.org/10.1303/aez.5.126
Latip, N. F.A., Idris, A.G., Hazmi, I.R., Abidin, C. M. R.Z., Sartiami, D., Yacob, S. & Muhammad Nasir, D. 2019. Morphometric comparison of the oil palm pollinator *Elaeidobus kamerunicus* Faust (Coleoptera: Curculionidae) from Malaysia, Indonesia and Liberia. The Coleopterists Buletin, 73(3). 746-756. https://doi.org/10.1649/0010-065X-73.3.746
Liu, J., Wang, C., Desneux, N. & Lu, Y. 2021. Impact of temperature on survival rate, fecundity, and feeding behavior of two aphids, *Aphis gossypii*, and *Acyrthosiphon gossypii*, when reared on cotton. Insects, 12(2021): 565. https://doi.org/10.3390/insects12060565
Lumentut, N. & Hosang M. L.A. 2016. Demografi kumbang *Elaeidobius kamerunicus* Faust (Coleoptera: Curculionidae) sebagai serangga pollinator pada tanaman kelapa sawit. Buletin Palma, 17(1): 89-95. https://doi.org/10.21082/bp.v17n1.2016.89-95
Masijan, Z., Kamarudin, N., Moslim, R., Sintik A.G., Ahmad, S.N. & Ali, S.R.A. 2015. Bunch moth, *Tirathaba rufivena* (Lepidoptera: Pyralidae) infestation census from oil palm plantation on peat soil in Sarawak. Serangga, 20(1): 43-53.
Mendel, Z. 1986. Hymenopterous parasitoids of bark beetles [Scolytidae] in Israel: Relationship between host and parasitoid size, and sex ratio. Entomophaga, 31: 127-137. https://doi.org/10.1007/BF02372364
Milovac, Ž., Pešić, S., Kereši, T. & Marinković, R. 2010. Weevils (Coleoptera: Curculionoidea)- Important members of rapeseed entomofauna in vicinity of Novi Sad. Kragujevac Journal of Science, 32: 141-148.
Ming, S.C. & Bong, C.F. 2017. Effect of different insecticides on the survival of the oil palm pollinator, *Elaeidobius kamerunicus* (Coleoptera: Curculionidae). The Planter, 93(1100): 777-788. https://doi.org/10.56333/tp.2017.017
Ming, S.C. & Bong, C.F. 2017. Effect of different insecticides on the survival of the oil palm pollinator, *Elaeidobius kamerunicus* (Coleoptera: Curculionidae). The Planter, 93(1100): 777-788. https://doi.org/10.56333/tp.2017.017
Mohamad, S.A., Masijan, Z., Ramle, M., Sulaiman, M.R., Ming, S.C., Siaw, T.C., Norman, K., Siti

Ramlah, A.A. & Siti Nurulhidayah, A. 2017. Biological agents and insecticides to control bunch moth, *Tirathaba rufivena* in oil palm estates in Sarawak, Malaysia. Journal of Oil Palm Research, 29(3): 323-332. https://doi.org/10.21894/jopr.2017.2903.04

Mohamad, S.A., Siti Nurulhidayah, A., Syarif, M.N.Y., Sulaiman, M.R., Hung, K.J., Mohammed, M.A. & Mazmira, M.M.M. 2021. Population abundance of oil palm pollinating weevil, *Elaeidobius kamerunicus* Faust and its relation to fruit set formation in mineral and peat soil areas in Peninsular Malaysia. Serangga, 26(2):107-117

Narita, S., Kageyama, D., Nomura, M., & Fukatsu, T. 2007. Unexpected mechanism of symbiont-induced reversal of insect sex: feminizing Wolbachia continuously acts on the butterfly *Eurema hecabe* during larval development. Applied and Environmental Microbiology, 73(13):4332-4341. https://doi.org/10.1128/AEM.00145-07

Omar, D. 2011. Toxicity of TMOF against the oil palm pollinator, *Elaeidobius kamerunicus* Faust. Final Report. Department of Plant Protection, Faculty of Agriculture, Universiti Putra Malaysia.

Parveez, G.K.A., Ahmad Tarmizi, A.H., Sundram, S., Loh, S.K., Ong-Abdullah, M., Poo Palam, K.D., Mohamed Salleh, K., Mohd Ishak, S. & Idris, Z. 2021. Oil palm economic performance in Malaysia and R&D progress in 2020. Journal of Oil Palm Research, 33(2): 181-214.

Pinkham, J. D. & Oseto, C. 1987. Natural enemies and their mortality rates on *Smicronyx fulvus* LeConte (Coleoptera: Curculionidae) Larvae. Environmental Entomology, 16(6): 1302-1304. https://doi.org/10.1093/ee/16.6.1302

Prasetyo, A.E. & Susanto, A. 2019. Pengaruh insektisida terhadap aktivitas dan kemunculan kumbang baru *Elaeidobius kamerunicus* Faust (Coleoptera: Curculionidae) pada bunga jantan kelapa sawit (*Elaeis guineensis* Jacq.). Jurnal Penelitian Kelapa Sawit, 27(1): 13-24. https://doi.org/10.22302/iopri.jur.jpks.v27i1.66

Prasetyo, A.E., Lopez, J.A., Eldridge, J.R., Zommick, D.H. & Susanto, A. 2018. Long term study of *Bacillus thuringiensis* application to control *Tirathaba rufivena*, along with the impact to *Elaeidobius kamerunicus*, insect biodiversity and oil palm productivity. Journal of Oil Palm Research, 30(1): 71-82.

Prasetyo, A.E., Purba, W.O. & Susanto, A. 2014. *Elaeidobius kamerunicus*: Application of hatch and carry technique for increasing oil palm fruit set. Journal of Oil Palm Research, 26(3): 196-202.

Prasetyo, A.E., Rozziansha T.A.P., Pwiritama, H., Wening, S., Susanto, A. & De Chenon, R.D. 2018. Bio-ecological perspective of *Elaeidobius kamerunicus* related to oil palm fruit set in Indonesia. 19th International Oil Palm Conference, 26-28 September 2018. Cartagena de Indias Convention Centre, Colombia.

Ray, P. & Sushikumar. 2015. Population dynamics and sex ratio of two biocontrol agents of water hyacinth. Indian Journal of Weed Science, 47(2): 188-192.

Rodríguez-Muñoz, R., Boonekamp, J.J., Fisher, D., Hopwood, P. & Tregenza, T. 2019. Slower senescence in a wild insect population in years with a more female-biased sex ratio. Proceedings of the Royal Society Biological Sciences, 286: 20190286. https://doi.org/10.1098/rspb.2019.0286

Rushidi, M.N.A., Muhammad Luqman Hakim, A., Salmah, Y. & Hazmi, I.R. 2023. Detection and Characterization of endosymbiont wolbachia (Rickettsiales: Anaplasmataceae) in *Elaeidobius kamerunicus* (Coleoptera: Curculionoidea), pollinating agent of oil palm, and its relationships between populations. Tropical Life Sciences Research, 34(3): 95-111. https://doi.org/10.21315/tlsr2023.34.3.5

Smith, T.J. & Sonderlund, D.M. 1998. Action of the pyrethroid insecticide cypermethrin on rat brain IIa sodium channels expressed in xenopus oocytes. Neurotoxicology, 19(6):823-832.

Sulaiman, M.R., Mohamad, S.A., Syarif, M.N.Y., Ahmad, S.N., Masri, M.M.M., Masijan, Z., Moslim, R. & Kamarudin, N. 2018. Status on oil palm fruit set and pollinating weevil in Malaysia. Workshop on Insect Pollination Efficiency in Oil Palm. 1 March 2018. Selangor, Malaysia.

Syed R .A., Law I.H. & Corley R. H.V. 1982. Insect pollination of oil palm: Introduction, establishment and pollinating efficiency of *Elaeidobius kamerunicus* in Malaysia. The Planter, 58: 547-561.

Syed, R.A. 1979. Studies on oil palm pollination by insects. Bulletin of Entomological Research, 69: 213-224. https://doi.org/10.1017/S0007485300017673

Syed, R.A. 1981. Insect pollination of oil palm: Feasibility of introducing *Elaeidobius* spp. into Malaysia. Oil Palm News, 25: 2-16.

Wang, Y., Ren, F., Yao, Y., Sun, X., Walling, L.L., Li, N.N., Bai, B., Bao, X.Y., Xu, X.R. & Luan, J.B. 2020. Intracellular symbionts drive sex ratio in the whitefly by facilitating fertilization and provisioning of B vitamins. The ISME Journal (2020). https://doi.org/10.1038/s41396-020-0717-0

Xu, P., Zheng, Y.L., Lv, X.Z., Yao, S.T., Chen, X.X. 2009. Biological characteristics of *Cionus latefasciatus* (Coleoptera: Curculionidae) and effects of temperature on its growth and development. Journal Economic Entomology, 102(3):1039-1043. https://doi.org/10.1603/029.102.0323

Yue, J.J., Yan, Z., Bai, C., Chen, Z.T., Lin, W.F. & Jiao, F.Z. 2015. Pollination activity of *Elaeidobius kamerunicus* (Coleoptera: Curculionoidea) on oil palm on Hainan Island. Florida Entomologist, 98(2):499-505 (2015). https://doi.org/10.1653/024.098.0217