ISSN 2228-9860 eISSN 1906-9642 CODEN: ITJEA8

International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies

http://TuEngr.com

Oryctes rhinoceros Infestation and its Interaction with Oil Palm Damage in Selected Oil Palm Plantation

Muhamad Amirul Fathi Mat Ripin[1] and Siti Noor Hajjar Md. Latip[2]*

[1] *Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, MALAYSIA.*
[2] *Sustainable Crop Protection Research Group, Universiti Teknologi MARA, Shah Alam Campus, 40450, Selangor, MALAYSIA.*
Corresponding Author (Tel: +60-193099525, Email: noorhajar@uitm.edu.my).

Paper ID: 12A9S

Volume 12 Issue 9

Received 29 July 2021
Received in revised form 14 October 2021
Accepted 22 October 2021
Available online 26 October 2021

Keywords:
Agricultural pests; Insect pest; Palm damage; Rainfall distribution; Infestation level; Tropical pests; Pest control management.

Abstract

Oryctes rhinoceros is among the most destructive pests that are incessant to the palm crops. *O. rhinoceros* is amongst Malaysia's longest existing agricultural pests, despite extensive efforts through effective control management strategies. This study's purposes are to evaluate the infestation level of *O. rhinoceros* and the effectiveness of control measures in controlling this insect pest and to determine the interaction between the percentage of palm damage and average rainfall distribution at selected oil palm estate in Kelantan. All secondary data used were collected from April to September 2020 based on damage assessment evaluations on the palm in six replanting blocks. The highest level of *O. rhinoceros*' infestation occurred during April and July 2020. However, these palm damage severities were successfully reduced from 5.41% to 2.12% by September 2020 through control management follow-up after the pests' population was detected. Meanwhile, the result showed a positive relationship between the interaction of percentage palm damage and average rainfall distribution. Based on this study, the results offer useful information on how to perform proper control management for *O. rhinoceros*.

Disciplinary: Crop Protection, Agriculture.

Cite This Article:

Ripin, M. A. F., Latip, S. N. H. M., (2021). Oryctes rhinoceros infestation and its interaction with oil palm damage in selected oil palm plantation. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies, 12*(9), 12A9S, 1-10. http://TUENGR.COM/V12/12A9S.pdf DOI: 10.14456/ITJEMAST.2021.187

1 Introduction

Each oil palm (*Elaeis guineensis* Jacq.) is recognized in the global market as the most productive oilseed crops (Kushairi et al., 2019) that contribute almost 30 percent of the world's

total edible oil production in 2017 and ranked as the top place amongst 16 other vegetable oils as the world's most consumed oil. In 2020, Indonesia and Malaysia collectively generate palm oil of about 63.40 metric ton, representing approximately 84% of production for palm oil worldwide. The oil palm has become a major crop and commodity worldwide (Corley & Tinker, 2003; Shuit et al., 2009; Lai et al., 2013). Despite these economic advantages, the palm oil industry might be affected by some issues particularly climate change, labour shortage issues, limited agricultural land, and pests and disease infestation (Low et al., 2016). In recent decades, economic loss due to pest attacks has increased and it has become among the critically important aspects that need to be taken immediately with proper practices because the disruption caused by the pest's attack could affect the oil palm productivity and yield (Dionisio et al., 2015; Oliveira et al., 2014).

A pest problem can become severe and could incur high input costs due to delays in controlling the pest infestations. Some of Malaysia's oil palm's critical pests include rodents, large mammals, and insects, particularly bagworms, nettle caterpillars, termites, bunch moths, and rhinoceros beetle which have become problematic and source of major yield decline in most oil palm plantations. Among those pests in Malaysia, *Oryctes rhinoceros* is one of the most destructive pests that bring incessant to the palm crops (Nurulhidayah & Norman, 2016), especially in an area of plantations which practice zero burning technique during replanting and have poor field hygiene and sanitation condition. It is also among the longest present agricultural pests in Malaysia, despite extensive efforts through effective control management strategies. In Malaysian plantations, the average crop loss caused by rhinoceros beetles during the first year of harvesting is estimated 40-92% (Manjeri et al., 2013).

Generally, most censuses have been conducted in Malaysia to collect crucial data on a population of pests or to identify the severity of damage caused by the pest infestation in the field. However, it is not fully established in all estate plantations because some farmers might consider that the census activity is not essential and only wastes time and budget. Usually, an approach is made when the attack is severe. Although insecticides' usage successfully controls pests, extensive usage can consequently encourage pest resurgence that can lead to pest outbreaks (Chung et al., 1993; Chenon & Pasaribu, 2005). Disruptive chemicals are broad-spectrum long residual contact (BSLRC) pesticides to which a broad range of insect groups are susceptible. This could trigger a disturbed ecological balance between pests, resulting in the development of pesticide resistance in pests and causing persistence in the environment with the potential for degradation.

Early monitoring activity such as installing pheromone traps within the fields as an indicator to assess the beetle population earlier before performing the preventive control measures is essential rather than to cure the infected palm. Typically, the *O. rhinoceros* population tends to increase parallel with months after felling and chipping. According to the study by Abidin et al. (2014), the population levels of *O. rhinoceros* cannot be controlled through partial burning of chipped trunks that resulted in failure which only pollutes the environment. Hence, this study aims to evaluate the infestation level of *O. rhinoceros* and the effectiveness of control measures for

controlling this insect pest and to determine the interaction between the percentage of palm damage and average rainfall distribution at selected oil palm estate in Kelantan.

2 Literature Review

2.1 *Elais guineensis* (Oil Palm)

Oil palm (*Elaeis guineensis*) is one of the major oleaginous plants and is considered as the most effective oil-producing crop in the world (Murphy, 2014). This crop has been revealed to be the 'golden crop' that can substantially improve economic and social growth (World Growth, 2011; Pacheco et al., 2017; Nambiappan et al., 2018) while having a minimal effect on land use compared to other oilseed crops (Anderson, 2008; Miller, 2015; D'Enghien, 2016). The world's leading producers 8 of palm oil are Indonesia, Malaysia, Thailand, Colombia, and Nigeria (USDA, 2020). The African oil palm (*Elaeis guineensis* Jacq.) species is the commercial planting material used in Malaysia and Indonesia. As a perennial crop, oil palm stands tall against all other oilseed crops, which can grow up to 20 m tall (Adam et al., 2005) and has a productive lifespan exceeding 20 years. However, in the oil palm industry nowadays, this pest problem remains unresolved. A pest problem can become severe and could incur high input costs due to delays in controlling the pest infestations. Furthermore, the oil palm is a host for a large number of threats as oil palm is a monocropping situation that is favourable and ideal place for a variety of pests such as insects, vertebrates, and diseases based on the area it is planted (Sundram & Intan, 2017). The outbreaks of key insect pests, such as the *Oryctes rhinoceros*, have greatly affected oil palm development's sustainability throughout many tropical regions of the world, including Malaysia.

2.2 *Oryctes rhinoceros*

Oryctes rhinoceros is amongst Malaysia's longest existing agricultural pests and has witnessed various phases of control and management strategies. *O. rhinoceros* is the only one that has been recorded and presented in the Asian region as an oil palm pest (Wood, 1968). However, the living species of rhinoceros beetles contain more than 39,960 species spread all over the world but their greatest diversity reached the New World (Endrödi, 1985; Schoolmeesters, 2020). The ecosystem in oil palm plantation is an ideal habitat for *Oryctes rhinoceros* to breed and develop, especially in zero burning replanting fields which have abundance of decomposed trunks of the former stand and at the accumulation of oil palms empty fruit bunches that are very attractive and suitable for breeding sites of the *O. rhinoceros* (Pradipta et al., 2020; Norman & Basri, 1997; Abidin et al., 2014; Salim & Hosang, 2013). Normally, the harmful outbreaks of *O. rhinoceros* frequently develop in replanting areas (Zelazny et al., 1992; Chenon & Pasaribu, 2005; Salim & Hosang, 2013). Decomposed oil palm trunks provide extensive *O. rhinoceros* breeding sites, and zero burning regulations contribute to the rising of *O. rhinoceros* population (Purba & Sudharto, 2000; Abidin et al., 2014).

The *O. rhinoceros* attacks on oil palm occur in both mature and immature areas (Norman & Basri, 2004; Molet, 2013). However, the attack is more lethal to the young growing palm below four years old than the mature palms (Rizuan et al., 2014; Wood, 1968). The adult *O. rhinoceros* will

usually damage and destroy the growing portion of the palm, such as the developing fronds and spears of oil palms, which lead to ragged appearances on the damaged part that mainly causes the formation of wedged-shaped gaps or cuts leaves, holes in petioles, and snapped-off spears which affects the yield of the palm (Samsudin et al., 1993; Dionisio et al., 2015; Oliveira et al., 2014). The first step highly recommended among the control and management techniques of this pest is emphasizing crop residue management and ground cover management at the replanting area by properly managing the field sanitation which includes removing or destroying organic material that promotes larval growth as it helps to control the *O. rhinoceros'* population; thus, avoiding sudden population outbursts. A hygienic plantation ground can be achieved by clearing rotting logs, stumps, dead palms, and waste piles that may serve as breeding grounds (Gressit, 1953; Wood, 1968; Schmaedick, 2005). Meanwhile, managing ground cover through the planting of legume cover crop (LCC) could act as a vegetative barrier that contributes to concealing the material from the *O. rhinoceros* as a potential breeding site. It also hinders *O. rhinoceros* attack from locating young palms (Wood, 1968). Once cover crops exceed over 70 cm in height, the *O. rhinoceros* is not present. In Malaysia, the widely cultivated cover crops include *Centrosema pubescens* and *Pueraria javanica* (Norman et al., 2005). However, *O. rhinoceros* can still take advantage of this material as a breeding site that may shelter abundant immature stages (Norman et al., 2005). Despite that, most of the farmers use broad-spectrum insecticides due to the presence of different insect species in oil palm plantations. Furthermore, the price is lower, easily accessible, low cost to operate, and produces fast result which could suppress the presence of pest population within a short time, thus making these insecticides the primary choice among farmers (Norman, 1994; Kuntom et al., 2007). A study conducted by Salim et al. (2015) indicated that the most rapid result could be observed 30 days after a single chemical insecticide is implemented. Consequently, the *O. rhinoceros* larval population fell below the economic threshold level (ETL). Chemical control has become the primary control mechanism in managing *O. rhinoceros'* outbreaks in most plantations in Malaysia. Although insecticides' usage successfully controls pests, extensive usage can consequently encourage pest resurgence that can lead to pest outbreaks.

3 Method

3.1 Sampling and Data Collection

The oil palm trees in the plantation were planted in 2002. However, during the sampling, the oil palm trees that underwent the census activity were newly planted and mostly under 4 years old that would be considered as immature oil palm trees. All the secondary data were taken from the estate to access the status of palms infested by *Oryctes rhinoceros*. Damage assessment evaluations were done through visual estimation on damaged palm fronds and spears. The data were monthly collected from April to September 2020. The data recorded were then used to reflect the severity of damage caused by the *O. rhinoceros*. The census was generated and recorded by the oil palm plantation management through systematic sampling conducted in six replanting blocks (PR18A,

PR18B, PR18C, PR19A, PR19B, PR19C) and the selected area was newly planted which was susceptible to pest attack. This plot will determine the percentage of damage caused by *O. rhinoceros* based on the different age of palms in the field. The age of the palm is identified based on the block name. Besides, the rainfall data were also taken from the rain gauge of the estate placed in an open area.

3.2 Data Analysis

Based on the data obtained from the estate, all qualitative analysis was carried out in this study using the statistical analysis software of MINITAB, version 19.1 (Minitab Inc.). The mean data collected based on census number were carried out using a paired t-test to determine the improvement result between census numbers. The percentage of palm damage and average rainfall distribution was then used to determine the interaction between both factors. The interpretation of relationship strength is based on the Pearson correlation coefficient (r).

4 Result and Discussion

Out of six censuses implemented during damage assessment, it was found that the highest mean number was detected in block PR19A (mean: 5.78), while the lowest mean number was detected in block PR18A (mean: 1.78) and PR18B (mean: 1.78), as presented in Table 1. Based on the observation in this study, it was noted that majority of the infested palm damage was less than two years old which was still under development stage. Therefore, the result suggests that adults *O. rhinoceros* prefer to infest more on younger palms in the field than those older ones since they are more susceptible to their attack. According to the previous report by Wood (1968), replant palms with less than one year of age are often killed by *O. rhinoceros'* attack. Chung et al. (1999) estimated that losses due to the infestation of *O. rhinoceros* on 21-month-old palm had lowered the production of fresh fruit bunches (FFB) to almost 80% in the first year after the attack. This statement agrees with Cik Mohd Rizuan et al. (2014) who stated that the attack is usually broader and more lethal to most young growing palm that ranges less than four years old.

Table 1: Percentage of palm damage caused by Oryctes rhinoceros in selected block

Block	PR18A		PR18B		PR18C	
	Mean	SD	Mean	SD	Mean	SD
%Palm damage	1.78	2.01	1.78	2.01	3.11	1.62

Block	PR19A		PR19B		PR19C	
	Mean	SD	Mean	SD	Mean	SD
%Palm damage	5.78	1.82	2.89	1.97	5.00	2.76

Based on the analysed result, the first census mean conducted in April was compared to the final census mean conducted in September 2020. Each census was subjected to a paired t-test to determine significant differences between these two variables at a 5% level of significance. The mean of the final census was significantly lower (P-value = 0.02) than the first census conducted (Table 2). This finding showed that the pests' population, particularly *O. rhinoceros*, could be reduced through control management follow-up after it was detected by conduction census activity

as many previous studies had been reported. Samsudin et al. (1993) stated that if no control measure is undertaken, severely attacked palms might suffer high crop loss of up to 25% per year. Therefore, inspection activity that follows up the upkeeping is crucial to maintain the palm is in good condition from being affected by pests' outbreaks. Examples of control measures previously done include the usage of chemical insecticides, planting cover crops, destruction of the breeding site, and the use of biocontrol agents such as the entomopathogenic fungus, *Metarhizium anisopliae*, and *Oryctes nudivirus* (OrNV) (Ramle et al., 2007; Bedford, 2014).

Table 2: Paired T-test of severity palm damage and census in selected estates

	Paired Differences			T-Value	df	P-Value
	Mean	SD	SE Mean			
Difference	-3.00	2.59	1.06	-2.84	5	0.02

Note: ** Significant level at $P \leq 0.05$
SE Mean - standard error mean, df - degree of freedom.

The correlation coefficient result showed an upward slope on a scatterplot which indicated a positive linear relationship between the monthly census of the percentage of palm damage with the average rainfall distribution (mm) in Lepan Kabu estate (Figure 1). The positive correlation ($r = 0.94$) indicated that when average rainfall distribution (mm) increases, the percentage of palm damage also tends to increase. The second and third stages of *O. rhinoceros* larvae prefer the moist environment of the rotting trunks (Wood, 1968). Therefore, the presence of these early instars should prove that during the wet season, breeding activities are prevalent (Norman et al., 2001). A previous laboratory study showed that to obtain the satisfactory development of *O. rhinoceros*, over 77% of the moisture content of 36°C is required (Norman et al., 2001). Previous observation by Catley (1969) stated that low moisture content level might be harmful to *O. rhinoceros'* larvae. Additionally, according to Catley (1969), *O. rhinoceros'* activity and growth development rate are very much influenced by temperature. For example, under a dry environment or poor nutritional condition, *O. rhinoceros'* larval growth and development are frequently disrupted, resulting in smaller-sized adults. As reported by Williams (1961), and Williams and Osman (1960), for a large group of insect taxonomic groups, the insect activity increased with the increase of temperature, from 18°C to the optimum temperature of 29°C. Favourable conditions for *O. rhinoceros'* larval development are temperature between 27-29°C and RH between 85-95% (Bedford, 1980). Meanwhile, temperature exceeding the optimum threshold resulted in the decline of insect activity. Similarly, less activity was detected at temperatures below the minimum threshold. The breeding of *O. rhinoceros* was directly affected by rainfall conditions of the area.

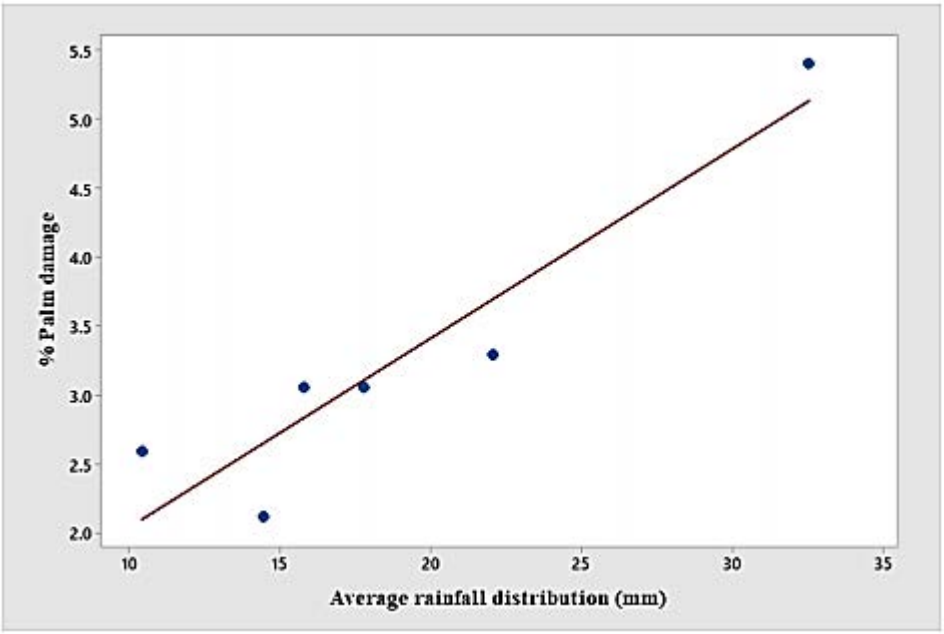

Figure 1: Relationship between the percentages of palm damage with average rainfall distribution.

5 Conclusion

The palm damage severities were successfully reduced from 5.41% to 2.12% by September 2020 through control management follow-up after the pests' population was detected. The pest attack incidents will keep on increasing if mitigation and control measures are not implemented. Therefore, a field census activity is crucial to determine the pest density in the field. Additionally, through field census, it would soundly inform the management if a control measure should be taken simultaneously to cut the cost since pest management is usually costly. Meanwhile, the interaction between the percentage of palm damage and average rainfall distribution shows a strong positive relationship, which means that both factors are closely related. It is suggested that field inspection should be done periodically to monitor the *O. rhinoceros'* population in the oil palm field and to ensure that this pest is under controlled condition. In addition, knowledge of *O. rhinoceros'* incidence in the oil palm field is of great importance to conduct proper control and management activity.

6 Availability of Data and Material

Data can be made available by contacting the corresponding author.

7 Acknowledgement

The author gratefully acknowledged the support from Ministry of Higher Education through the FRGS Research Grant (600-IRMI/FRGS 5/3/ 058/2019).

8 References

Abidin, C., Ahmad, A., Salim, H., & Hamid, N. (2014). Population dynamics of Oryctes rhinoceros in decomposing oil palm trunks in areas practicing zero burning and partial burning. *Journal of Oil Palm Research, 26*(2), 140-145.

Adam, H., Jouannic, S., Escoute, J., Duval, Y., Verdeil, J. L., & Tregear, J. W. (2005). Reproductive developmental complexity in the African oil palm (Elaeis guineensis, Arecaceae). *American Journal of Botany*. DOI: 10.3732/ajb.92.11.1836

Anderson, J. M. (2008). Eco-friendly approaches to sustainable palm oil production. *Journal of Oil Palm Research*.

Bedford, G. O. (1980). Biology, Ecology, and Control of Palm Rhinoceros Beetles. *Annual Review of Entomology*. DOI: 10.1146/annurev.en.25.010180.001521

Bedford, G. O. (2014). Advances in the control of rhinoceros beetle, Oryctes rhinoceros in oil palm. *Journal of Oil Palm Research, 26*, 183-194.

Catley, A. (1969). The coconut rhinoceros beetle Oryctes rhinoceros (Coleoptera: Scarabaeidae: Dynastinae). PANS Pest Articles and News Summaries. DOI: 10.1080/04345546909415075

Chenon, R. D., & Pasaribu, H. (2005). Oryctes rhinoceros Management at PT. Tolan Tiga (SIPEF Group) North Sumatera Indonesia. *Oil Palm Technical Meeting*. 13-14 September 2005: Yogyakarta, Indonesia. P.102-113.

Chung, G. F., Cheah, S. S., & Balasubramaniam, R. (1999). Effects of pest damage during immature phase on early yield of oil palm. *Proc. of the 1999 PORIM International Palm Oil Congress: Emerging Technologies and Opportunities in the Next Millennium*. P.456-466.

Chung, G. F., Sim, S. C., & Tan, M. W. (1993). Chemical control of rhinoceros beetles in the nursery and immature oil palms. *Proc. of the 1991 PORIM International Palm Oil Development Conference – Progress, Prospects & Challenges towards the 21st Century*: Module 1- Agriculture Conference.

Cik Mohd Rizuan, Z. A., Abu Hassan, A., Hasber, S., & Noor Hisham, H. (2014). Population dynamics of Oryctes rhinoceros in decomposing oil palm trunks in areas practicing zero burning and partial burning. *Journal of Oil Palm Research, 26*, 140-145.

Corley, R. H. V., & Tinker, P. B. H. (2003). Chapter 1: The origin and development of the oil palm industry. *The Oil Palm*. 4th Ed., Blackwell Publishing, United States. P.1-26.

D'Enghien, P. B. (2016). Davos and Food security: The facts on oilseed efficiency. http://theoilpalm.org/davos-and-food-security-the-facts-on-oilseed-efficiency/

Dionisio, L. F. S., Lima, A. C. S., De Morais, E. G. F., Correia, R. G., Dos Santos, A. V. F., & Dos Santos Ximenes, C. K. (2015). Distribuição espacial de Metamasius hemipterus (Coleoptera: Curculionidae) em plantio de dendê (Elaeis guineensis Jacq) em Roraima. DOI: 10.18227/1982-8470ragro.v9i3.2517

Endrödi, S. (1985). *The Dynastinae of the World*. Dr. W. Junk Publisher, Dordrecht. 800 p.

Gressit, J. L. (1953). The coconut rhinoceros beetle (Oryctes rhinoceros L.) with particular reference to the Palau Islands. *Bishop Museum Bulletin*.

Kuntom, A., Yew Ai, T., Kamaruddin, N., & Chee Beng, Y. (2007). Pesticide Application in the Oil Palm Plantation. *Oil Palm Bulletin*.

Kushairi, A., Ong-Abdullah, M., Nambiappan, B., Hishamuddin, E., Bidin, M. N. I. Z., Ghazali, R., Subramaniam, V., Sundram, S., & Parveez, G. K. A. (2019). Oil palm economic performance in Malaysia and R&D progress in 2018. *Journal of Oil Palm Research, 31*(2), 165-194. DOI: 10.21894/jopr.2019.0026

Lai, Z. Y., Chua, H. B., & Goh, S. M. (2013). Influence of process parameters on the strength of oil palm kernel shell pellets. *Journal of Materials Science*. DOI: 10.1007/s10853-012-6897-x

Low, E. T. L., Singh, R., Nookiah, R., Ong-Abdullah, M., Ooi, L. C. L., Lakey, N. D., Smith, S. W., Ordway, J. M. & Sambanthamurthi, R. (2016) New frontiers for the oil palm industry through genome technology. *The Planter, 92*(1087), 701-710.

Manjeri, G., Muhamad, R., Faridah, Q. Z., & Tan, S. G. (2013). Morphometric analysis of Oryctes rhinoceros (L.) (Coleoptera: Scarabaeidae) from oil palm plantations. *Coleopterists Bulletin. 67*, 194-200. DOI: 10.1649/0010-065X-67.2.194

Miller, R. (2015). Smart land use: Palm oil is the world's most efficient oil crop. http;//www.palmoilhealth.org/sustainability/most-efficient-oil-crop/

Molet, T. (2013). CPHST Pest Datasheet for Oryctes rhinoceros., USA: USDA-APHIS-PPQ-CPHST. https://caps.ceris.purdue.edu/webfm_send/2206

Murphy, D. J. (2014). The future of oil palm as a major global crop: Opportunities and challenges. *Journal of Oil Palm Research*.

Nambiappan, B., Ismail, A., Hashim, N., Ismail, N., Shahari, D. N., Idris, N. A. N., Omar, N., Salleh, K. M., Hassan, N. A. M., & Kushairi, A. (2018). Malaysia: 100 years of resilient palm oil economic performance. *Journal of Oil Palm Research*. DOI: 10.21894/jopr.2018.0014

Norman, K. (1994). Control of some insect pests of oil palm (Elaeis guineensis). Paper presented during a student Seminar in Pesticides Application Course at Silwood Park, Imperial College, United Kingdom.

Norman, K. (2001). *Kajian Persekitaran dan Infestasi Kumbang Badak, Oryctes rhinoceros (Linn.) (Coleoptera: Scarabaeidae) dalam Ekosistem Tanam Semula Sawit*. Ph.D. dissertation. Faculty of Science and Technology, Universiti Kebangsaan Malaysia, Bangi, Malaysia. 270p.

Norman, K., & Basri, M. W. (1997). Status of rhinoceros beetle, Oryctes rhinoceros (Coleoptera: Scarabaeidae) as a pest of young oil palm in Malaysia. *The Planter, 73*(850), 5-21.

Norman, K., & Basri, M. W. (2004). Immigration and activity of Oryctes rhinoceros within a small oil palm replanting area. *Journal of Oil Palm Research, 16*, 64-77.

Norman, K., Basri, M. W., & Ramle, M. (2005). Environmental factors affecting the population density of Oryctes rhinoceros In A Zero - Burn Oil Palm Replant. *Journal of Oil Palm Research*.

Nurulhidayah, S. A., & Norman, K. (2016). Growth and longevity of the insect predator, Sycanus Dichotomus Stal. (Hemiptera: Reduviidae) fed on live insect larvae. *Journal of Oil Palm Research, 28*(3), 471-478. DOI: 10.21894/jopr.2016.2804.08

Oliveira, C. M., Auad, A. M., Mendes, S. M., & Frizzas, M. R. (2014). Crop losses and the economic impact of insect pests on Brazilian agriculture. *Crop Protection*. DOI: 10.1016/j.cropro.2013.10.022

Pacheco, P., Gnych, S., Dermawan, A., Komarudin, H., & Okarda, B. (2017). The palm oil global value chain: Implications for economic growth and social and environmental sustainability. The palm oil global value chain: Implications for economic growth and social and environmental sustainability. DOI: 10.17528/cifor/006405

Pradipta, A. P., Wagiman, F. X., & Witjaksono. (2020). The potency of collecting larvae of Oryctes rhinoceros L. (Coleoptera: Scarabaeidae) in the oil palm plantation. *Agrivita*. DOI: 10.17503/agrivita.v42i1.2489

Purba, R. Y., & Sudharto, P. S. (2000). Utilization of Baculovirus oryctes as Oryctes rhinoceros L. control in oil palm plantations. Oil Palm Research Report Fiscal Year 1999-2000 DIP.119/XXiX/007/4/1999. Indonesian Oil Palm Research Institute, Medan.

Ramle, M., Norman, K., Ang, B. N., Ramlah Ahmad Ali, S., & Basri, M. W. (2007). Application of powder formulation of Metarhizium anisopliae to control Oryctes rhinoceros in rotting oil palm residues under leguminous cover crops. *Journal of Oil Palm Research*.

Salim, & Hosang, M. L. A. (2013). Oryctes rhinoceros aggression in several coconut kopyor production centers and potential application of entomopathogenic Metarrhizium anisopliae. *Buletin Palma, 14*(1), 47-53.

Salim, H., Che, C. S., Ahmad, A. H., & Al-Shami, S. A. (2015). Efficacy of insecticide and bioinsecticide ground sprays to control Metisa plana walker (Lepidoptera: Psychidae) in oil palm plantations, Malaysia. Tropical Life Sciences Research.

Samsudin, A., Chew, P. S., & Mohd, M. M. (1993). Oryctes rhinoceros: breeding and damage on oil palms in an oil palm to oil palm replanting situation. *The Planter, 69*, 583-591.

Schmaedick, M. A. (2005). Coconut Rhinoceros Beetle. American Samoa Community College Community & Natural Resources Cooperative Research.

Schoolmeesters, P. (2020). Scarabs: World Scarabaeidae Database (version 2020-10-06). In: Roskov, Y., Ower, G., Orrell, T., Nicolson, D., Bailly, N., Kirk, P. M., Bourgoin, T., DeWalt, R. E., Decock, W., Van-Nieukerken

E., Penev L. (Eds.). *Species 2000 & ITIS Catalogue of Life, 1 December 2020*. Digital resource at http://www.catalogueoflife.org. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858.

Shuit, S. H., Tan, K. T., Lee, K. T., & Kamaruddin, A. H. (2009). Oil palm biomass as a sustainable energy source: A Malaysian case study. *Energy*. DOI: 10.1016/j.energy.2009.05.008

Sundram, S., & Intan, N. A. M. A. (2017). South American Bud rot: A biosecurity threat to South East Asian oil palm. *Crop Protection*. DOI: 10.1016/j.cropro.2017.07.010

USDA (2020). World production, market and trade reports. https://www.fas.usda.gov/data/oilseedworld-market-and-trade

Williams, C. B. (1961). Studies in the effect of weather conditions on the activity and abundance of insect populations. Philosophical Transactions of the Royal Society of London. *Series B, Biological Sciences*. DOI: 10.1098/rstb.1961.0011

Williams, C. B., & Osman, M. F. H. (1960). A New Approach to the Problem of the Optimum Temperature for Insect Activity. *Journal of Animal Ecology*. DOI: 10.2307/2277

Wood, B. J. (1968). *Pest of Oil Palms in Malaysia and their Control*. Incorporated Society of Planters, Kuala Lumpur. 204p.

World Growth. (2011). The Economic Benefit of Palm Oil to Indonesia, Virgina: World Growth. World Growth Palm Oil Green Development Campaign.

Zelazny, B., Lolong, A., & Pattang, B. (1992). Oryctes rhinoceros (Coleoptera: Scarabaeidae) populations suppressed by a baculovirus. *Journal of Invertebrate Pathology, 59*, 61-68. DOI: 10.1016/0022-2011(92)90112-H

Muhamad Amirul Fathi bin Mat Ripin is a postgraduate student at Universiti Teknologi MARA, Melaka in Faculty of Plantation and Agrotechnology. He has a Bachelor degree in Bachelor of Science (Hons) Plantation Technology and Management from Universiti Teknologi MARA. His research interest is Agriculture Entomologyin major plantation crops.

Dr. Siti Noor Hajjar Md Latip is an Associate Professor and Head of Crop Protection at Faculty of Plantation and Agrotechnology, UiTM Melaka, Jasin Campus. She obtained her Master of Science in Conservation Biology from Universiti Kebangsaan Malaysia (UKM) and Doctor of Philosophy in Agricultural Entomology from Faculty of Agriculture, Universiti Putra Malaysia (UPM). Her current research focuses on formulating biopesticides for controlling insect pest, insect toxicity, molecular entomology and promoting integrated pest management for Sustainable Agriculture.