Jurnal Perlindungan Tanaman Indonesia, Vol. 30, No. 1, 2026: 47−56
DOI: 10.22146/jpti.101784
Available online at http://jurnal.ugm.ac.id/jpti
ISSN 1410-1637 (print), ISSN 2548-4788 (online)

Research Article

Oviposition Preferences of Rhinoceros Beetle (*Oryctes rhinoceros*) at Various Ages of Decomposed Oil Palm Trunk

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Received November 28, 2024; revised January 16, 2025; accepted July 21, 2026

ABSTRACT

Oil palm trunk (OPT) waste serves as a substrate for oviposition, growth, and development of the rhinoceros beetle (*Oryctes rhinoceros* Linnaeus) (Coleoptera: Scarabaeidae). This study aimed to identify the preferred OPT ages post-felling for beetle oviposition. The research was conducted at the Insectarium of the Indonesian Oil Palm Research Institute, Unit Marihat, Pematang Siantar, North Sumatra, from October to December 2023. A choice test method was employed, involving eight treatments: pure OPT aged 3, 7, and 12 months (chopped into 1−4 cm fragments); OPT aged 3, 7, and 12 months mixed with organic fertilizer and sawdust; sawdust; organic fertilizer; and a food source (sugarcane and pineapple). Three arenas were established, each with 32 adult beetles (21 females, 11 males). Females were maintained under controlled conditions and introduced into treatment containers at standardized density. Observations were conducted three times, starting seven days post-release. Adult abundance was highest in pure OPT aged 12 months (2.2 individuals) and mixed OPT aged 3 months (1.44 individuals). Egg deposition was assessed by opening the media and extracting its contents. Eggs were found in pure OPT aged 3 and 7 months, mixed OPT aged 3, 7, and 12 months with organic fertilizer and sawdust, and organic fertilizer alone. The highest egg count (41) occurred in mixed OPT aged 3 months. The findings support sustainable pest management and offer a basis for future research on beetle oviposition and development, particularly in relation to substrate age, texture, and nutritional composition.

Keywords: eggs of rhinoceros beetle; oil palm trunk waste; *Oryctes rhinoceros*; oviposition preference

INTRODUCTION

The rhinoceros beetle is a significant pest of oil palm that can cause considerable damage. It can infest both immature (TBM) and mature oil palm (TM) (Ripin *et al.*, 2021). The damage caused by this pest can lead to reduced production, stunted growth, and even plant mortality (Manjeri *et al.*, 2014). The resulting yield losses from rhinoceros beetle infestations can range between 40−90% during the first year of harvest (Chung *et al.*, 1999). Additionally, canopy damage can reach up to 15%, leading to a reduction in oil palm yields by approximately 25% (Samsudin *et al.*, 1993).

Despite the application of various control methods, including chemical pesticides, biological agents, and cultural control practices, rhinoceros beetle populations continue to thrive. Chemical control often leads to environmental concerns and resistance development, while biological control agents, such as viruses or predators, have had limited success in large-scale plantation settings (Marshall *et al.*, 2017). Consequently, sustainable and targeted management strategies remain a priority in oil palm plantations to mitigate the impact of these pests.

The persistent presence and increasing populations of rhinoceros beetles are often linked to the

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growing volume of organic waste in oil palm plantations (Abidin *et al*., 2014; Bakeri *et al*., 2023; Pradipta *et al*., 2020). One notable contributor to the increase in waste is the widespread replanting of oil palm, which has surged over the past decade (Ardana *et al*., 2022; Petri *et al*., 2024). Replanting activities generate a large volume of organic materials, including oil palm trunks, empty fruit bunches, fronds, and leaves. Among these, oil palm trunks (OPT) represent the largest volume of waste and are favored by the rhinoceros beetle for mating, oviposition, and reproduction (Erwinsyah, 2008; Fauzana & Ustadi, 2020; Pulingam *et al*., 2022).

The age of OPT post-logging is hypothesized to be a crucial determinant of oviposition preference due to changes in trunk moisture content, texture, and microbial activity over time. Similar studies in other insect species, such as the wood-boring beetle (Buprestidae) and termites, have shown that the stage of decomposition plays a pivotal role in reproductive site selection. This suggests that as oil palm trunks decompose, they may become more or less suitable for oviposition based on structural and environmental factors that influence larval survival.

Although there has been extensive research on the behavior and life cycle of rhinoceros beetles (Manley *et al*., 2018; Chung *et al*., 1999), studies focusing on the oviposition behavior in relation to the age and decomposition stages of oil palm trunks are scarce. Most research has concentrated on the beetle's attraction to organic waste in general, but specific factors influencing oviposition site selection, such as trunk age and decomposition stage, have not been thoroughly examined. Rhinoceros beetles are known to prefer oviposition media composed of small-sized materials over larger ones, with depths exceeding 15 cm and good aggregation (Hinckley, 1973; Manley, 2017; Manley *et al*., 2018). According to Abidin *et al*. (2014), rhinoceros beetle larvae can be found in oil palm trunks resulting from replanting activities between 6 to 18 months after logging. This indicates that oviposition can occur in trunks aged less than 6 months. This knowledge gap hampers the development of effective timing and strategies for pest control during replanting activities.

Understanding the oviposition preferences of rhinoceros beetles based on the age of oil palm trunks is crucial for optimizing pest management strategies. By identifying the trunk ages most vulnerable to infestation, disposal or treatment efforts can be timed more effectively. This approach could disrupt the beetle's reproductive cycle, reduce population growth, minimize crop losses, and enhance the sustainability of oil palm production.

MATERIALS AND METHODS

This study was conducted from October 2023 to December 2023 at the Insectarium of the Indonesian Oil Palm Research Institute (IOPRI), Marihat Unit, Siantar, North Sumatra. The equipment and materials used included 60×60×100 cm iron cages, pheromone traps, sprayers, and containers with a diameter of 10.5 cm and height of 17 cm. The OPT waste utilized in the study was obtained from the field and was aged 3, 7, and 12 months post-logging. These OPT wastes were then shredded.

Oviposition Media Preparation

The OPT wastes, as the primary material, were collected from the Balimbingan Plantation, PTPN IV, Tanah Jawa District, Simalungun Regency, North Sumatra (Latitude: 2.883948°, Longitude: 99.147668°). The large chunks of OPT wastes were shredded into smaller pieces, approximately 1−4 cm in size, to allow for their placement and mixing with other materials into the containers, which had pre-drilled holes on the bottom. The additional materials included a commercial organic fertilizer and sawdust derived from rubberwood. The carbon content (C) of the OPT waste sourced from the field was approximately 54.73% at 3 months, 50.21% at 7 months, and 51.32% at 12 months.

Experimental Design

A choice test was used in this study where adult beetles (imagoes) were placed in an arena to freely select their preferred oviposition media and compare oviposition preferences across different waste ages and material compositions. A total of 8 oviposition media were tested in this study. These included 3 pure OPT waste media, specifically 3A (3-month-old OPT), 7A (7-month-old OPT), and 12A (12-month-old OPT). Additionally, 3 mixed media were prepared by combining OPT waste with

organic fertilizer and sawdust, labeled as 3M, 7M, and 12M, with a media height composition of 2 parts OPT waste to 1 part mixture (organic fertilizer and sawdust). To serve as controls, 2 media were included: organic fertilizer (OF) and sawdust (S). In addition to the treatments, a separate container was provided as a feeding area (FA) containing pineapple, sugarcane, and jelly. The experiment was conducted in 3 replicated arenas with identical cage setups. The positions of the 8 oviposition media within the cage were arranged randomly (Figure 1).

Infestation of Adult Rhinoceros Beetles in the Arena

The adult rhinoceros beetles (imago) used in this study were sourced from the Marihat Plantation in Siantar, North Sumatra. The collection process began with the setup of pheromone traps (Figure 1a) in both immature (TBM) and mature (TM) oil palm plantations. The traps were observed weekly and captured beetles were counted and separated by sex. Male and female beetles were then introduced into each experimental arena/cage, with varying population sizes as outlined in Table 1. The average sex ratio of the beetles in each cage was maintained at 2:1 (female), following the guidelines of Bedford (1976). The placement of males and females in the oviposition arenas was based on the research of Rahayuwati (2002), which indicated that 20% of rhinoceros beetles captured via pheromone traps had not mated. Thus, the presence of males was expected to facilitate fertilization and enhance the oviposition process.

Observation Variables and Data Analysis

The variables observed in this study included the number of adult beetles (male and female), the number of eggs laid in each treatment medium, and the number of damaged eggs. Observations were conducted at three intervals: 1, 2, and 4 weeks post-application. The collected data were analyzed using

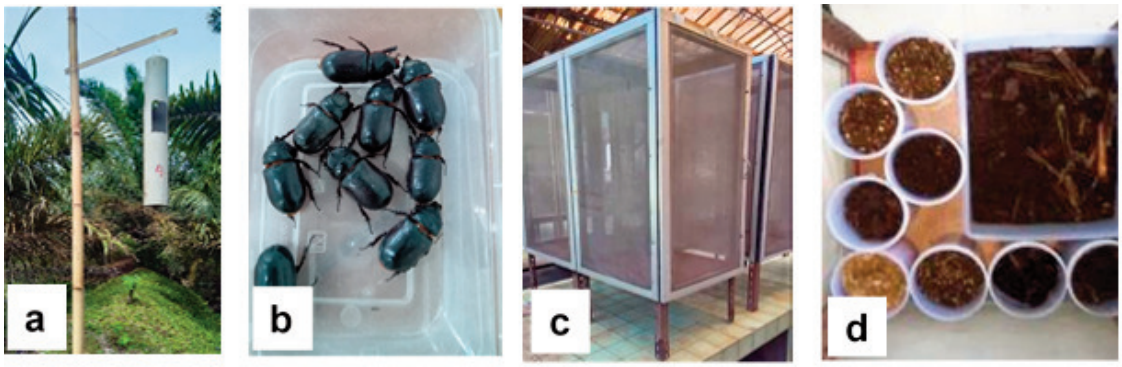


Figure 1. Equipment and materials used to examine *Oryctes rhinoceros* oviposition preferences in oil palm trunk waste media of various ages: (a) pheromone trap, (b) rhinoceros beetles captured using the pheromone trap, (c) metal cage (arena) for adult beetles, (d) oviposition media placed inside the cage/arena.

Table 1. Population of *Oryctes rhinoceros* in the oviposition arena

Arena	Population per week									Average		
	1			2			3					
	F	M	Total	F	M	Total	F	M	Total	F	M	Total
1	22	12	34	23	14	37	24	13	37	23	13	36
2	19	9	28	18	10	28	26	10	36	21	10	30
3	17	11	28	17	10	27	25	11	36	20	11	30
Total	58	32	90	58	34	92	75	34	109	64	33	97
Average	19	11	30	19	11	31	25	11	36	21	11	32

Note: F: Female, M: Male.

a non-parametric statistical approach, specifically the Kruskal-Wallis test, to assess differences in the number of beetles and eggs across treatments. The analysis was performed using SPSS version 16 software.

To determine the proportion of beetles and eggs in each oviposition medium, the following formulas were employed:

$$\text{Percentage of beetles in medium a} = \left(\frac{\text{Number of beetles in medium a}}{\text{Total number of beetles in all media}}\right) \times 100\%$$

$$\text{Percentage of eggs in medium a} = \left(\frac{\text{Number of eggs in medium a}}{\text{Total of eggs in all medium}}\right) \times 100\%$$

Note: a is the oviposition media (3A, 7A, 12A, 3M, 7M, 12M, OF, or S).

RESULTS AND DISCUSSION

Number of Imago Rhinoceros Beetles in the Oviposition Media

Rhinoceros beetles (*Oryctes rhinoceros*) captured using pheromone traps (natural population) and introduced into the choice test arena did not all survive throughout the experiment. The average survival rate of female beetles during the first, second, and third observations was 66%, 71%, and 41%, respectively, while the survival rates for males were 80%, 65%, and 44%. These data indicate a progressive increase in mortality of the beetles over the course of the experiment. However, the remaining beetle population within the arena was still sufficient for conducting oviposition trials and egg collection.

It was observed that not all surviving beetles entered the oviposition media; some individuals remained near the feeding area. The statistical analysis revealed a significant difference in the percentage of the natural beetle population found in the oviposition media compared to those in the feeding area (Figure 2). This indicates a clear behavioral preference of the beetles regarding media selection within the test environment.

Figure 3.1 also showed that the number of female imago did not differ significantly in the first observation. However, subsequent observations revealed significant differences. It is suspected that during the first observation, not all female imago had been fertilized or still required mating with males. Another hypothesis is that the female imago remaining at the feeding site required more time to access the oviposition media. Considering the oviposition media were only 10 cm in diameter and 12 cm in depth, it has limited capacity to accommodate female oviposition.

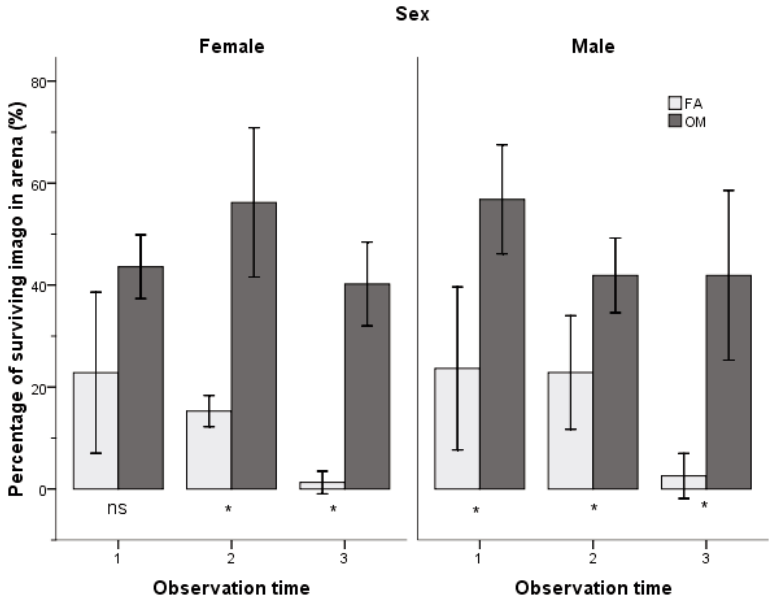


Figure 2. Percentage of surviving rhinoceros beetle imago across three observation time, 1: One week after imago release, 2: Two weeks after imago release, 3: Four weeks after imago release, FA: Feeding area, OM: Oviposition media, *: Indicates a significant difference between oviposition media and feeding sites (p value < 0.05), ns: Not significant.

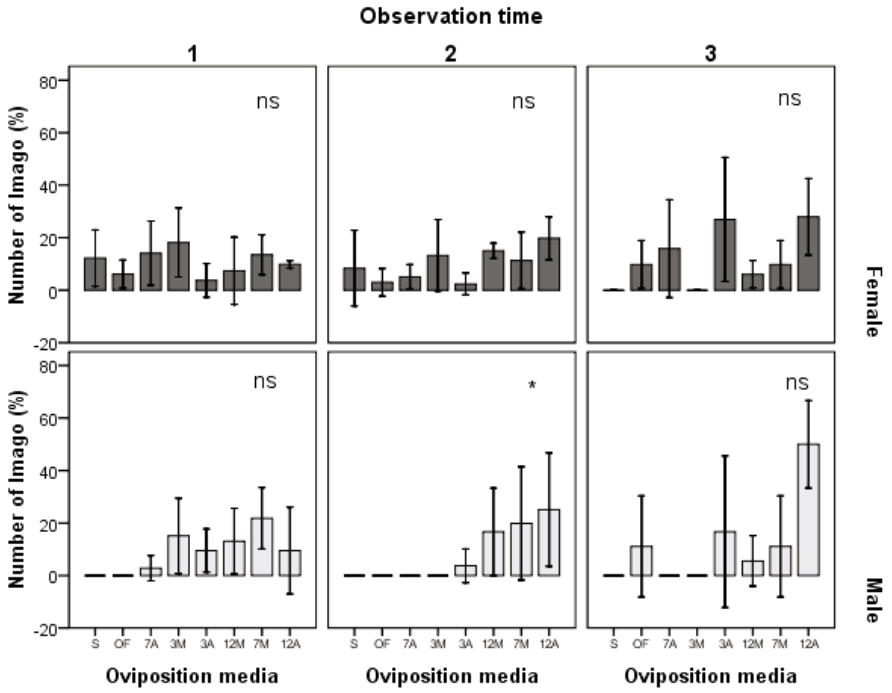


Figure 3. Percentage of imago *Oyctes rhinoceros* on oviposition media, S: Sawdust, OF: Organic fertilizer, 3A: Pure 3-month-old oil palm trunk waste, 7A: Pure 7-month-old oil palm trunk waste, 12A: Pure 12-month-old oil palm trunk waste, 3M: Mixed media of 3-month-old oil palm trunk waste, 7M: Mixed media of 7-month-old oil palm trunk waste, 12M: Mixed media of 12-month-old oil palm trunk waste, 1: One week after imago release, 2: Two weeks after imago release, 3: Four weeks after imago release *: Significant difference (p value < 0.05), ns: Not significant.

The number of imago on oviposition medias were analyzed and indicated that the female numbers did not differ significantly across oviposition media during three consecutive observations (Figure 3). Rhinoceros beetles infestation across all media suggested that each medium was potential breeding site which was consistent with previous findings stating its ability to oviposite in various habitats (Moore *et al.*, 2017). These beetles are commonly found in their feeding sites (oil palm plants) and breeding sites (organic waste such as livestock manure, oil palm trunk waste, and empty fruit bunches) (Bakeri *et al.*, 2023; Pradipta *et al.*, 2020).

Female rhinoceros beetles infestation demonstrated to be not significantly affected by age variance of OPT waste (Figure 3.1). The OPT waste aged 3 to 12 months remained suitable as a breeding site for rhinoceros beetles. This aligned with field studies and surveys conducted by Abidin *et al.* (2014). However, a closer examination revealed that female beetles across the three observations to show a preference for 3-month-old OPT waste media (both pure and mixed). Although the effects were not significant, this indicated that the age of OPT waste may still influence breeding site preference.

Male rhinoceros beetles entering the oviposition media showed slight differences compared to females. In the second observation, significant differences were detected between the oviposition media. Overall, the observations indicated that male beetles were most commonly found in media 12A, 12M, and 7M. In contrast, fewer beetles infested the organic fertilizer (OF) and sawdust (S), likely because these media were not typical food sources or hosts. This was consistent with previous studies that combined sawdust with other materials for rhinoceros beetle habitats. Sawdust was more suitable for egg-laying when mixed with cattle manure (Sasauw *et al.*, 2017) and served as a proper larval habitat when combined with empty fruit bunches and rice husks (Fauzana *et al.*, 2023).

Sawdust is also hypothesized to become overly wet when exposed to water, and its low porosity

causes excessive moisture retention, which may deter imago to avoid potential diseases for their offspring. Romadhon *et al.* (2023) demonstarted that most organic fertilizers have unstandardized C/N ratios, which may affect their nutritional suitability for insect development. One example is cattle manure-based organic fertilizer with a C/N ratio of 8.41 and a pH of 7.6 which falls below the Indonesian Ministry of Agriculture threshold of 15−25. This condition indicates low carbon availability and advanced decomposition, potentially influencing substrate selection for oviposition by females rinocheros beetle. In contrast, oil palm trunk, which represents the natural breeding substrate of rinocheros beetle , generally possesses a higher C/N ratio during the early stages of decomposition. Previous studies reported that the C/N ratio of undecomposed oil palm trunk was 58.42, decreasing to 37.18 during intermediate decomposition and to 14.24 after 6−7 months of decomposition (Nasamsir *et al.*, 2017). The higher carbon availability in decomposing oil palm trunk may provide more favorable environment for microbial activity and larval development, thereby contributing to its suitability as an oviposition substrate for rinocheros beetle.

Rhinoceros Beetle Eggs in Oviposition Media

Eggs were only found in 5 of the 7 media even though female rhinoceros beetles infested all medias. The highest to lowest egg counts were in 3M, 3A, 7M, OF, 12M, and 7A (Table 2). Some eggs were damaged, with only shells remaining. A total of 116 eggs were recorded, consisting of 93 intact and 23 damaged eggs. All five media with eggs contained OPT waste, while no eggs were found in 12A and S.

Majority of the eggs were found in mixed media (OPT waste + sawdust + organic fertilizer). This aligns with the observations of Hinckley (1973) which noted that imago tend to oviposit primarily in media that were sufficiently soft and capable of compacting. Additionally, rhinoceros beetles preferred substrates with smaller particle sizes over larger ones (Manley *et al.*, 2018).

The mixed media treatments (3M, 7M, and 12M) visually contained more fine and small substrates, which tend to clump and compact easily when exposed to water (Figure 4). In contrast, the untreated OPT waste (without additives) had coarser and larger chunks that were less likely to compact (Figure 4). However, not all untreated OPT waste media were unsuitable for oviposition, as evidenced by treatment 3A, which had relatively finer and less coarse characteristics. The variability in media characteristics, despite the same age, is likely due to natural differences in decomposition rates, texture, or hardness, as the materials were sourced from nature and inherently diverse.

Table 2. Number of *Oryctes rhinoceros* eggs in oviposition media

Oviposition media	Number of eggs				Percentage of eggs (%)	Damaged eggs (%)
	Observation time			Total		
	1	2	3			
3A	34	1	0	35	29.81	45
7A	1	0	0	1	0.83	100
12A	0	0	0	0	0.00	-
3M	12	0	29	41	35.28	0
7M	12	4	0	16	13.33	9
12M	9	0	0	9	8.24	6
OF	5	0	9	14	12.50	26
S	0	0	0	0	0.00	-
Total	73	5	38	116	100.00	

Note: OF: organic fertilizer, S: sawdust, 3A: pure 3-month-old oil palm trunk waste, 7A: pure 7-month-old oil palm trunk waste, 12A: pure 12-month-old oil palm trunk waste, 3M: Mixed media of 3-month-old oil palm trunk waste+organic fertilizer+sawdust, 7M: Mixed media of 7-month-old oil palm trunk waste+organic fertilizer+sawdust, 12 M Mixed media of 12-month-old oil palm trunk waste+organic fertilizer+sawdust, 1: One week after imago realese, 2: Two week after after imago realese, 3: Four week after imago realese.

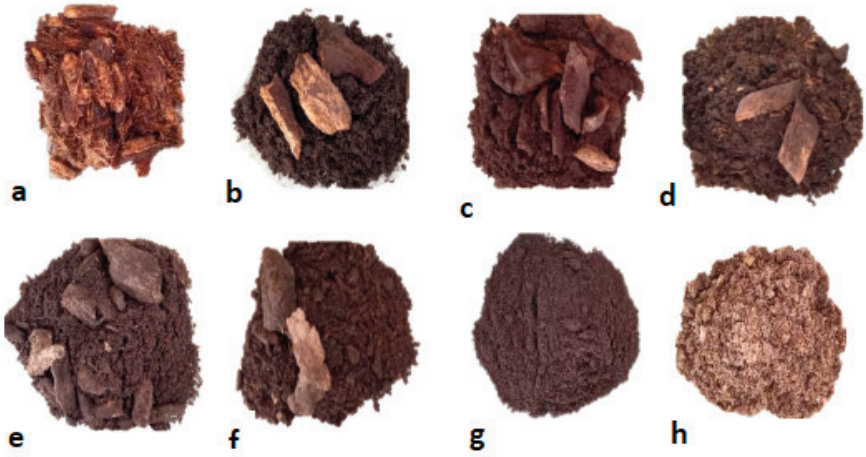


Figure 4. Visual comparison of oviposition media: a) (3A) Pure 3-month-old oil palm trunk waste, b) (3M) Mixed media of 3-month-old oil palm trunk waste+organic fertilizer+sawdust, c) 7A) Pure 7-month-old oil palm trunk waste d) (7M) Mixed media of 7-month-old oil palm trunk waste+organic fertilizer+sawdust, e) (12A) Pure 12-month-old oil palm trunk waste f) (12M) Mixed media of 12-month-old oil palm trunk waste+organic fertilizer+sawdust, g) (OF) Organic fertilizer, h) (S) Sawdust.

According to Fissore *et al.* (2016), decomposition rates of organic substrates are influenced by multiple interacting factors, including soil texture, moisture, microbial activity, and mineral composition, which vary significantly even within similar-aged materials. These findings support the assumption that naturally sourced substrates, such as oil palm trunk waste, may exhibit inconsistent physical properties due to environmental and biological variability during decomposition.

The factors influencing imago oviposition in the media are likely not limited to physical characteristics such as texture, fineness, and ease of compaction, but also include nutritional content. In this context, nutritional content refers to the availability of organic matter, decomposed plant residues, and essential nutrients such as nitrogen, phosphorus, and potassium, which may support microbial activity and create favorable conditions for egg-laying. Media containing organic fertilizer and decomposed oil palm trunk (OPT) are likely to release soluble nutrients and maintain higher moisture levels, both of which are known to influence oviposition behavior in *Oryctes rhinoceros*. These components may also contribute to the suitability of the substrate for subsequent larval development.

If media preference was solely influenced by texture, it would be expected that imago would have laid more eggs in the OF media. However, the data showed that imago predominantly chose media that were not only fine in texture but also nutritionally suitable for the survival of their offspring, such as treatment 3M. In this treatment, the 3-month-old OPT waste had the highest organic carbon (54.71%) and nitrogen (1.11%) contents before the experiment, compared with the 7-month-old OPT waste (52.73% C and 0.98% N) and the 12-month-old OPT waste (48.87% C and 0.94% N). Meanwhile, the carbon content of organic fertilizer is considerably lower, ranging from 9–32%, according to the Indonesian National Standard.

Carbon and nitrogen are essential nutritional components for insect development. Carbon serves primarily as an energy source, whereas nitrogen is required for protein synthesis, tissue formation, and larval growth. Nitrogen availability may also enhance microbial activity within the substrate, thereby improving its nutritional quality and suitability for larval development. This is supported by the study of Krishanti *et al.* (2023), which demonstrated that low-starch diets resulted in slower growth (in both body weight and length) of *Nicobium hirtum* (Coleoptera) larvae than diets containing higher starch levels. Therefore, the oviposition preference of female *Oryctes rhinoceros* for the 3M medium was likely associated with the

combined effects of its finer texture and higher nutritional quality, particularly its relatively higher carbon and nitrogen contents, which may provide more favorable conditions for offspring development after hatching.

CONCLUSION

The highest number of female rhinoceros beetles was found in pure 12-month-old OPT waste media, followed by the 3-month mixed media. The most preferred media for oviposition was the 3-month mixed media. Further research is needed to assess the preference for younger OPT waste (0−3 months) and the egg hatching process.

ACKNOWLEDGMENT

We would like to express our deepest gratitude to the Indonesian Oil Palm Research Institute (IOPRI) for their generous financial, material, and logistical support. Their contributions were essential to the successful execution of this research project, providing us with the necessary resources and facilities. Without their support, the scope and impact of our study would have been significantly limited. The research was funded by IOPRI Grant No. 150-2/SUPER/RPN-PPKS/VIII/2023.

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