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Oryctes rhinoceros Beetles, an Oil Palm Pest in Malaysia

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Authors' contributions

This work was carried out in collaboration between all authors. Author GM performed the literature searches, reviewed all relevant materials and wrote the manuscript. The final manuscript was read and approved by Authors GM, RM and SGT.

Mini-Review Article

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ABSTRACT

Oryctes rhinoceros, commonly known as the rhinoceros beetle is an important agricultural pest that is known to inflict serious damage on young oil palm trees. Many researches have been conducted on its development, life cycle, habitat, management and genomic variation ever since the need to understand this pest arose. *Oryctes rhinoceros* is among the longest present agricultural pest in Malaysia and it has witnessed the formulation and implementation of various phases of control and management strategies. To date, research and development activities are still ongoing in Malaysia for the successful management of this pest. In this review, we look into details on the characteristics of this pest, the modes of its introduction into Malaysia, as well as the events that helped to establish and contribute to the proliferation of this pest as a major oil palm threat in Malaysia. The progressive development of various research and development activities concerning the management and control of this pest are also highlighted.

Keywords: Oryctes rhinoceros; rhinoceros beetle; oil palm pest; Malaysia.

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1. INTRODUCTION

The oil palm, *Elais guineensis* Jacq. is a native West African plant [1]. It was first introduced into Southeast Asia in 1848 when it was planted in the Bogor Botanic Gardens, Java, as an ornamental plant. Subsequently, it was commercially developed as a plantation crop in Sumatera. In Malaysia, this plant was first introduced by Sir M. H. Fauconnier during 1911 and 1912. This later led to the establishment of Tennamaram Estate, the first Malaysian commercial oil palm estate in 1917 [2]. Since its early introduction into Malaysia in 1911, oil palm plants have rapidly developed to become the number one commercial crop of the country resulting in Malaysia being the second highest producer of palm oil in the world after Indonesia [3]. However, various hurdles and trials were faced by planters and researchers throughout the process. Amidst the various problems that arose, attacks by *Oryctes rhinoceros* beetles had been an unremitting dilemma faced by Malaysian planters. Often, beetle attack results in loss of productivity, irreversible damage to plants and plant death. Attacked oil palm plants are also predisposed to further lethal secondary infestation by the red palm weevils (*Rhynchophorus* spp.). In Malaysia, *O. rhinoceros* has established its self as a major Coleopteran pest of the oil palm industry and this had been made possible by a series of events that began with the development of this pest in Malaysia through the coconut industry up to its establishment as an oil palm pest due to several plantation practices that caused unanticipated population increase. To date, the severity and impact of the damage by *O. rhinoceros* is often observed and recorded in plantations throughout the country to aid monitoring and control practices. Various control measures and integrated pest management strategies have been applied in field and constant research and developments are undertaken to improvise control measures as well as to improve the understanding on the *O. rhinoceros* its self.

2. TAXONOMIC CLASSIFICATION

Oryctes rhinoceros being an important agricultural pest has been widely studied in various aspects over a very long period of time. Incomplete taxonomic studies on this beetle began very early and constant revisions were made in the classification of this beetle. This species was originally described as *Scarabaeus rhinoceros* by Linnaeus. In further taxonomic work published in 1840, this beetle was called *Oryctes stentor* Castelnau. Finally, with the establishment of the zoological nomenclature system, this species was renamed as *Oryctes rhinoceros* [4]. *Oryctes rhinoceros* is a member of the superfamily Scarabaeoidea which has been on the face of the earth for as long as 200 million years [5]. Out of the 42 species in this genus [4] only *O. rhinoceros* is present as an oil palm pest in the Asian region [6]. Locally in Malaysia, this beetle is known as the ‘kumbang badak’, whereby ‘kumbang’ means beetle and ‘badak’ means rhinoceros.

3. BIOLOGY AND HABITAT OF THE RHINOCEROS BEETLES

Several works had been done on the life cycle of this pest which comprises four stages namely egg, larva, pupa and imago with the duration of each stage being variable, depending on climatic conditions, nutrition and humidity of the different localities in which the developmental process occurred [4,7-9]. Generally the whole life cycle lasts for around four to nine months allowing for more than one generation per year [10]. Throughout this period the female lays 70 to 100 eggs [8]. Adult beetles have been observed to mate right after their first feeding once they have left their pupal site [11]. These observations further conclude and support the fact that *O. rhinoceros* are robust, long-lived and highly productive and this contributes towards the large and frequent events of beetle attack [12].

There is a clear difference in the choice of habitats between the immature and the adult *O. rhinoceros* beetles. A dead standing coconut palm which has been previously affected by disease, pest or lightning provides a suitable breeding environment for the immature beetles [13]. Materials like compost, sawdust heaps, rotting logs, decaying vegetable, bridges made of coconut trunk, dead pandanus, old latrines, sugar cane bagasse, rice straws and also humus rich soil also serve as suitable habitats for immature beetles [4,6,8,14-15]. Meanwhile, the adults spend most of their life time on fresh plants but they also return to decomposing sites for mating and breeding [11-12]. Studies were also conducted by several researchers to understand the role of abiotic factors in the beetles' habitat selection. It was successfully revealed that ground cover of more than 70 cm, decomposing tree trunk with 77% moisture content, soil pH lower than 4.2 and a high rainfall are important features in the beetles' habitat which increase their population density [16].

4. ESTABLISHMENT OF THE RHINOCEROS BEETLE IN MALAYSIA

Oryctes rhinoceros began to establish themselves in Malaysia with the emergence of coconut cultivation. Beetles were previously introduced into Malaysia from other countries via various activities such as shipping and cargo transportation of timber, nursery trade and transportation of habitat material. As the beetles have a range of hosts, they soon adapted well to survive on coconut trees which were abundant along the Malaysian coastline. This slowly led to the establishment of the *O. rhinoceros* populations along the east and west coast of Malaysia. Later on in the 1970s, oil palm estates were developed on ex-rubber land. Old rubber trees were uprooted and left to rot in the newly developed oil palm planting sites as estate owners and small holders could not afford complete clearing due to the high cost of planting the palms. In addition, during that time land owners disregarded the importance of field sanitation and the consequences of improper field management. In this case, a combination of readily available suitable breeding ground in the form of rotting rubber tree stumps as well as abundant food resources provided by the young oil palm trees led to a drastic increase in the beetle population in Malaysia [17].

In addition, enforcement of the Zero Burning Concept [Environment Quality Clean Air: Amendment Regulation, 2000] in Malaysia further aggravated the situation. Previous replanting techniques adopted felling, shredding, partial burning and complete burning as common practices at replanting sites [18]. These methods minimized the availability of suitable breeding sites for *O. rhinoceros*. However, under the new Zero Burning Concepts, open burning was not permitted due to environmental pollution issues and this led to increasing numbers of rotting materials [19]. In addition, an under planting technique was also introduced to overcome burning problems. In this technique, new palms were planted under old palms which were gradually poisoned [9]. It was found that the techniques introduced by the Zero Burning Concepts facilitated the increase in the beetle population as windrowed and poisoned plant biomass took two years to decompose [20]. In addition, practices of piling old palm around nurseries, leaving dead palms standing upright and usage of empty fruit bunches as fertilizers for young palms are common practices in Malaysia and these contributed greatly to the increase in the beetle population in the country [21-22]. Above all, an ideal climate as well as suitable geographic landscapes of an altitude less than 900 m and suitable ecological surroundings in addition to food availability and plentiful breeding ground further facilitated the rapid spread of this pest [4].

5. INCIDENCE OF RHINOCEROS BEETLE ATTACK IN MALAYSIA

In Malaysia, articles on the attack of this pest on local plantation in the west and east coasts of Peninsular Malaysia appeared a few years after the introduction of this crop into our country [23]. Beetle attacks were more serious in the west coast of Peninsular Malaysia due to the earlier usage of the land for coconut cultivation [24,17]. Immature and young mature palms are the major targets of this pest. This was proven during an 18 months of observation in a two-year-old oil palm replanting site in northern Perak that revealed the presence of 200 adult beetles per acre [25]. It was observed that the beetles were present in most estates within one to six months after replanting. This observation further confirmed that replanting sites played an important role as a breeding ground for the beetles in Malaysia [25].

The feeding activity of the beetles causes major crop loss in many coconut and oil palm plantations. As the beetles are nocturnal and feeding as well as mating activities are carried out at night, many events of initial attacks go unnoticed. Often, the beetle bores into the base of the cluster of unopened fronds (spears) of the young oil palms, damaging several of the still-furled fronds [9]. This boring activity produces holes on the petioles and ‘V’ shaped cuts on leaves as they unfold. The beetle’s mandibles are used to chisel the inner part of the palm while the horn, clypeus and tibiae are used to bore holes. Beetles did not ingest the solid plant material but sucked the juices [4]. Damage to the inflorescence due to the beetle attack often leads to a reduction in the photosynthesizing area resulting in decreased or delayed fruit production [4,18,26]. Continuous attacks on young oil palms may often be lethal.

Due to the gregarious nature of this beetle, usually more than one beetle attacks a single palm and this often results in serious damage and often plant death. Such incidences have a negative impact on the oil palm production and the industry. Serious damage to plantations due to *O. rhinoceros* attacks have been well documented in Malaysia. Damage by *O. rhinoceros* could cause an average crop loss of 40% to 92% during the first year of harvesting [22]. In addition, more than 15% reduction in canopy size had also been observed due to beetle attack [27]. Reduction in canopy size often results in reduced photosynthetic activity, delayed plant maturity, reduced fruit bunch size and an approximately 25% crop loss [18].

6. CONTROL AND MANAGEMENT OF RHINOCEROS BEETLES: RELATED RESEARCH AND DEVELOPMENTS IN MALAYSIA

With the increasing number of beetles, the damage faced by the oil palm industry was significant. This brought upon the interest to control and manage this incessant pest. A successful pest management technique generally incorporates the applications of several control techniques together with a fair understanding and appreciation of the surrounding ecological factors [28]. Records highlighting devastating damages to palm crops by the *O. rhinoceros* have raised concern on the importance of the establishment of suitable eradication methods. Biological control agents, chemical controls, mass trapping and cultural controls are commonly practiced in managing the beetle population with each procedure having a different success rate [28].

The first step that is highly recommended among the control and management techniques of this pest is the proper management of field sanitation as it helps to the control beetle population thus avoiding sudden population outbursts. A hygienic plantation ground can be achieved by clearing standing logs, stumps and rubbish piles that may serve as breeding grounds [4,6]. Apart from that, three commonly used pulverizing techniques in Malaysia namely the Enviro Mulcher Method, The Mountain Goat Method and The Beaver Method are often applied [20]. All three pulverization techniques proved to be useful as the decomposition period of the felled palm could be reduced, thus restricting the availability of the breeding grounds for the beetles. Planting of a cover crop is also important as it acts as a physical barrier to the breeding sites. Beetles were not present when cover crops measured more than 70 cm in height. *Centrosema pubescens* and *Pueraria javanica* are among the commonly grown cover crops in Malaysia [16].

When considering chemical control procedures, direct application of insecticides is not an appropriate technique in the management of this beetle due to its insufficiently exposed situation. Nevertheless, a variety of chemical treatments have been considered for managing *O. rhinoceros*. According to [29] lambdacyhalothrin, cypermethrin, fenvelarate, monocrotophos and chlorpyrifos were effective at both the nursery stage and in field trials. Lambdacyhalothrin effectively reduced the number of broken spear dieback while carbofuran and cypermethrin were effective in reducing the number of holes on the spears and fronds [9,29,30]. Gamma benzene hexachloride, aldrin and carbaryl were used to control the larval stage. Naphthalene balls had also been considered once as a prophylactic method [4,17]. Although various chemical control methods have been tried on the population *of O. rhinoceros*, this choice of treatments are still not effective and it imposes health and environmental hazards.

The usage of biological control agents to control this beetle is another option that has been looked into for a long time. The release of natural predators into the fields was recorded in the early 1950s to 1970s. Among the list of natural predators that were tried were *Scolia patricialis* (Hymenoptera), *Scolia procer* (Hymenoptera) and *Catascopus fascialis* (Coleoptera). Unfortunately, this has proven to be a futile method as these natural pests failed to establish themselves and produce satisfactory results [8,31].

Later on, the use of *Oryctes* virus as a biological control agent in the 1960s was a milestone in the classical biological control procedure. *Baculovirus oryctes* was originally discovered in Malaysia and identified as *Rhabdionvirus oryctes* [32]. Since then, it has been introduced into many countries. The presences of three *Oryctes* viral types were revealed in Malaysia [33]. Virus type A, was common throughout the peninsula but showed less efficacy than the restricted virus type B. Meanwhile, type C was only found in Sabah and appeared to have little effect on either larvae or adult beetles. This study also revealed that the *Oryctes* virus is widespread in Malaysia and is transmitted readily in the adult beetle populations. However, the incidence of the virus in the larvae, pupae, and neonate adults was low [34] which could lead to the emergence healthy adults. Therefore, controlling the beetles using the virus needs to be based on localized release of high virulence virus strains and integration with other control procedures.

The entomopathogenic fungus, *Metarhizium anisopliae* is another common biological control agent that has been used to control the *O. rhinoceros* beetles [35]. Known as the green Muscardine fungus, it generally attacks larvae. Further development of *M. anisopliae* as a potential biopesticide in Malaysia has also been studied [33,35-36]. *M. anisopliae* variety major [37] is the most virulent isolate which has the potential to kill 100% of the third instar larvae of *O. rhinoceros* between 12 to 14 days after treatment [35]. *M. anisopliae* can remain lethal for a long period of time. However, the limited mobility of the fungus between the breeding sites is a drawback. Field applications using both fresh spore solution and broadcasting of the solid substrate with spores onto the breeding sites were observed to significantly reduce the beetle population, especially the larvae [35]. To date, various attempts to release the fungus into the plantations have been carried out [35-36,38]. Continuous investigations are being pursued to further improvise the usage of this biopesticide. In addition, various application strategies, formulation and modes of introducing the fungus into the plantations are consistently being studied [35,38-39,40-42].

Apart from that, several trapping techniques have been considered by planters in order to manage this pest. In the earlier days, self-constructed trapping pits in the form of coconut logs or compost pits that are similar to the natural breeding sites were used. Some work on light trapping methods had also been tried [6]. However the light traps were found to be an inefficient control method. The beetles were attracted to the light but the results were merely beneficial for monitoring purposes. Recent advances have modified the concept of mass trapping by incorporating the usage of the species specific semiochemical called aggregation pheromone. Currently, mass trapping using an aggregation pheromone with the active component ethyl 4-methyloctonoate is the commonly used technique by many Malaysian plantation owners to trap and monitor the beetles in young oil palm replanting sites [43-44]. This technique gained popularity among plantation managers due to its efficiency and economical value [9]. The pheromone traps are also integrated with biological control agents like *M. anisopliae* and also *B. oryctes* [30] to improve the management and control procedures.

Ethyl 4-methyloctanoate was first found in Indonesia to be the major aggregation pheromone component produced by the beetle males [43]. Male-produced attractants have been referred to as aggregation pheromones, because they result in the arrival of both sexes at a calling site leading to an increase in the density of beetles at the pheromone source. Aggregation pheromones are useful for mate selection, defense against predators and for overcoming host resistance through mass attack [45]. In *O. rhinoceros* beetles, the aggregation pheromone helps the insect to find mates, breeding sites and food [46-47]. To further improve the efficiency of mass trapping using pheromone traps, the influence of these traps on the immigration activity of the beetles into the replanting sites was studied [47]. Apart from that, it was also found that the occurrence of the aggregation pheromone was irregular in different beetle samples suggesting a possible influence of specific conditions that controlled the production of this pheromone by the male beetles [48]. Selective attraction level to the pheromone traps had also been claimed to be observed among the beetle populations (Chung, Ebor Research, Sime Darby Plantations, pers. comm. 2002) suggesting the possible occurrence of a cryptic species complex. This hypothesis stimulated interest to study on the pest's genome.

With interest to understand the *O. rhinoceros* beetles and to improve management and control techniques, much research work was conducted on this pest's development and life cycle [4], habitat [16] and management [29,35]. However, little work has been carried out on the population genetic structure of this pest species until recently. This scope of research gained interest with the claim of selective attraction levels among the beetles to the pheromone trap and the possible presence of a cryptic species complex. This hypothesis led to the detailed analysis of the population genetic variation and genetic structure of *O. rhinoceros* from several locations in Malaysia.

It is acknowledged that speciation events are crucial in pest management as accurate detection and monitoring of the individuals are extremely important. The detection of a cryptic complex is difficult as it often occurs in small population sizes [48]. However, the failure to identify the presence of reproductively isolated pest species could result in serious errors in pest management control strategies [49]. Therefore, several studies [50-51] were carried out to study the molecular genetic variation of this pest from several locations in Malaysia. By studying the genetic structure of this beetle the researchers intended to identify any isolated gene pool that could relate to the presence of a cryptic species complex that could have resulted from prezygotic isolation behavior such as variations in communication signals like pheromones which often contribute to reproductive isolation between sympatric species [52].

Based on the use of randomly amplified polymorphic DNA (RAPD) markers [50] and randomly amplified microsatellite markers (RAMs) [53], the possible presence of two separate gene pools in *O. rhinoceros* had been reported. However, when a morphometric analysis of *O. rhinoceros* was performed [54] it revealed that the beetles are morphologically indistinguishable; consequently strengthening the need for further molecular analysis of the insect. Hence, to obtain more concrete results, species specific codominant single locus DNA microsatellite marker were for *O. rhinoceros* [55]. As such microsatellite markers are powerful and promising genetic markers that allow analysis of fine-scale ecological questions concerning population genetics and species-level population structures [56], it was hoped that this set of markers would provide definitive answers on the species status of this pest. However, the subsequent analysis on the genetic structure of this insect pest species using the newly developed codominant microsatellite markers indicated no isolated gene pools. The Peninsular Malaysian *O. rhinoceros* population was close to panmixia as only low to moderate differentiation occurred between geographical populations from different locations such as Selangor, Perak, and Pahang in the peninsula and a high gene flow occurred among them. Overall, beetles of the different population interacted freely, thus permitting gene flow between closely and distantly located populations. Based on this study, the possibility of a cryptic complex occurring in *O. rhinoceros* was ruled out [51]. This study showed that the selective attraction exhibited by the beetles toward the pheromone trapping system was not due to prezygotic isolation behavior that is commonly exhibited by cryptic species of a sympatric nature but to other yet unknown environmental or behavioral factors. As the non-existence of a cryptic species complex has been confirmed, the current pest management strategies can be carried out without worrying about the influence of possible genetic variations in the beetles towards the success of the control techniques. However, there always exist possibilities of changes in the genetic structure of a pest like *O. rhinoceros* which is widely exposed to insecticides. If such a situation arises, future genetic studies on the beetle populations from any other regions could be conducted with ease by using the codominant microsatellite markers developed [55].

7. CONCLUSION

Malaysia shares a very close and undeniable relationship with the *Oryctes rhinoceros* beetle. Although this beetle has been a pest that is much feared by oil palm planter, incidence of beetle attack has in fact contributed towards the various development and improvement in the scope of science and pest management. In our battle to control this beetles, the researcher of the country has contributed toward great understanding of this beetle which will be beneficial worldwide and in fact contribute towards future ideas and theories in the management of other similar pests.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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