LIFE STAGES, SOURCE OF INFESTATION AND CONTROL OF RHINOCEROS BEETLE *ORYCTES RHINOCEROS* (LINN) (COLEOPTERA: SCARABAEIDAE) IN A NEWLY REPLANTED OIL PALM PLANTATION

by

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PERINGKAT HIDUP, PUNCA SERANGAN DAN PENGAWALAN KUMBANG BADAK *ORYCTES RHINOCEROS* (LINN) (COLEOPTERA: SCARABAEIDAE) DALAM KAWASAN LADANG TANAM SEMULA KELAPA SAWIT

ABSTRAK

Kajian peringkat hidup *Oryctes rhinoceros* (kumbang tanduk) pada tandan kosong kelapa sawit telah dilakukan pada kawasan tanam semula Ladang FELDA Lepar Utara 05, Bandar Jengka, Pahang. Tiga peringkat instar larva (instar 1-3), prapupa dan pupa ditemui di dalam tandan kosong sawit. Walaubagaimanapun telur kumbang tidak dapat dikesan sepanjang kajian dijalankan. Larva dan pupa ditemui secara berterusan di dalam tandan kosong di sepanjang masa kajian selama 20 minggu.

Perangkap feromon sintetik *O. rhinoceros* etil 4-metiloktanuat telah digunakan selama 24 minggu untuk mengesan punca serangan kumbang tanduk pada 24 hektar ladang tanam semula kelapa sawit. Jumlah tangkapan kumbang pada setiap minggu didapati berbeza secara signifikan ($p = 0.000$). Kelimpahan kumbang betina adalah lebih banyak dari kumbang jantan dan berbeza secara signifikan ($p = 0.000$). Lebih banyak kumbang ditangkap di kawasan yang bersebelahan dengan pokok matang berbanding dengan kawasan tengah ladang ($p = 0.000$). Secara keseluruhannya kumbang betina lebih tertarik kepada perangkap feromon sintetik berbanding dengan kumbang jantan bagi semua perangkap. Tangkapan kumbang jantan ($p = 0.000$) dan kumbang betina ($p = 0.000$) bagi perangkap tepi dan perangkap tengah adalah berbeza secara signifikan.

Efikasi Bulldock® 025 EC (a.i: 2.9% w/w beta-cyfluthrin) terhadap kumbang tanduk telah dikaji pada pokok sawit yang baru ditanam selama 24 minggu. Tiga dos Bulldock® 025 iaitu 0.4, 0.5 dan 0.6 L/ha telah disembur pada selang masa 7 hari dan 14 hari. Cypermethrin dan Regent 3G telah digunakan sebagai perbandingan dan disembur pada selang masa 14 hari pada kadar 0.05 L/ha dan 30 gm/ pokok masing-masing. Regent 3G (30 gm/ pokok) juga digunakan secara berselang bersama Bulldock 025 EC (0.4 L/ha) pada selang masa 14 hari. Dua puluh pokok kelapa sawit telah dirawat dengan setiap insektisid mengunakan Rekabentuk Blok Rawak Lengkap (RCBD) yang direplikat sebanyak empat kali. Min kerosakan pada pokok yang dirawat dengan Bulldock 025 EC (0.4 L/ha) pada selang masa 7 dan 14 hari adalah masing-masing 0.03/pokok dan 0.18/pokok, dengan Bulldock 025 EC (0.5 L/ha) adalah masing-masing 0.18/pokok dan 0.33/pokok, dan dengan Bulldock 025 EC (0.6 L/ha) adalah masing-masing 0.09/pokok dan 0.13/pokok. Bagi Cypermethrin, Regent 3G dan Regent 3G berselang dengan Bulldock 025 EC (0.4 L/ha) min kerosakan untuk 14 hari rawatan adalah 0.54, 0.78 dan 0.29 bagi setiap pokok masing-masing. Semburan Bulldock 025 EC pada kadar 0.4 dan 0.6 L/ha setiap minggu dan pada kadar 0.6 L/ha setiap 2 minggu menunjukkan keputusan yang baik dalam mengawal kerosakan pokok.

Karung guni digunakan untuk mengawal kumbang tanduk di kawasan seluas 1.5 ha mengandungi 180 pokok kelapa sawit. Sembilan puluh pokok telah dipilih secara rawak dan dibalut bahagian dasarnya. Lebih banyak kerosakan direkodkan pada pokok yang tidak dibalut dengan guni ($p<0.05$) berbanding dengan pokok yang dirawat ($p<0.05$). Pokok yang dibalut juga kurang kerosakan pada dasar dan pelepah ($p<0.05$). Secara amnya kerosakan lebih tertumpu pada bahagian dasar pokok berbanding dengan pelepah bagi pokok yang dirawat ($p< 0.05$) dan tidak dirawat ($p< 0.05$). Keputusan menunjukkan guni berkesan menghalang serangan *O. rhinoceros* pada pokok sawit yang baru ditanam semula.

LIFE STAGES, SOURCE OF INFESTATION AND CONTROL OF RHINOCEROS BEETLE *ORYCTES RHINOCEROS* (LINN) (COLEOPTERA: SCARABAEIDAE) IN A NEWLY REPLANTED OIL PALM PLANTATION

ABSTRACT

The life stage of *Oryctes rhinoceros* was investigated in empty fruit bunches (EFBs) in a newly replanted area in FELDA Lepar Utara 05 Plantation, Bandar Jengka, Pahang. Three stages instar larvae (instar 1-3), prepupa and pupa were found in empty fruit bunches. However no egg was found during the study period. The larvae and pupae were continuously encountered in the EFB during 20 weeks of study.

Oryctes rhinoceros synthetic pheromone, ethyl 4-methyloctanoate traps were used to detect the source of beetle coming into a 24 ha newly replanted oil palm plantation for 24 weeks. Weekly numbers of beetles collected in the traps during the study period were significantly different ($p = 0.000$). The abundance of male and female beetles varied significantly ($p = 0.000$). More beetles were caught from the fringe traps than those in the center fields ($p = 0.000$). In general the fringe ($p = 0.000$) and centre ($p = 0.000$) traps were significantly more attractive to females than males.

The efficacy of a new insecticide, Bulldock® 025 EC (a.i: 2.9% w/w beta-cyfluthrin) was evaluated in the plantation for a period of 24 weeks. Three doses of Bulldock® 025 EC at 0.4, 0.5 and 0.6 L/ha were applied at intervals of 7 and 14 days. Cypermethrin and Regent 3G were used for comparison. Cypermethrin (0.05 L/ha) was sprayed at 14 days intervals and Regent 3G was applied at 30gm/palm at 14 days intervals. Another treatment using Regent 3G (30gm/palm) alternating with Bulldock® 025 EC (0.4 L/ha) was applied at 14 days intervals. Twenty palms were treated with each insecticide in a completely randomized block design (CRBD) experiment and were replicated 4 times. The mean number of damaged palms treated with Bulldock® 025 EC (0.4 L/ha) at 7 days and 14 days were 0.03/palm and

0.18/palm respectively, treated with Bulldock® 025 EC (0.5 L/ha) were 0.18/palm and 0.33/palm respectively and treated with Bulldock® 025 EC (0.6 L/ha) were 0.09/palm and 0.13/palm respectively. For Cypermethrin, Regent 3G and Regent 3G alternating with Bulldock® 025 EC, the mean damage for treatment at 14 day intervals were 0.54/palm, 0.78/palm, and 0.29/palm respectively. Weekly treatments of palms with Bulldock® 025 EC at 0.4 and 0.6 L/ha and with 0.6 L/ha at 2 week intervals showed promising results in controlling *O. rhinoceros*.

Gunny sacks were used as a mean to control rhinoceros beetle in a 1.5 ha subplot containing 180 oil palm trees. Ninety palms were selected randomly and wrapped with gunny sacks at their bases, while 90 others were left unwrapped. More damages occurred on unwrapped palms ($p<0.05$) compared to those wrapped ($p<0.05$). Less damage was observed in fronds and palm bases of wrapped palms ($p<0.05$). In general both treated ($p< 0.05$) and untreated ($p< 0.05$) palm bases were more preferred by the beetles compared to the fronds. The result showed the effectiveness of gunnies in preventing *O. rhinoceros* attack in newly replanted oil palms.

CHAPTER ONE:

GENERAL INTRODUCTION

The oil palm industry in Malaysia plays a major role in the development of the agriculture sector, making Malaysia the largest producer and exporter of palm oil in the world, accounting for 30% of the world's traded edible oils and fats supply (MPOC, 2006). In 2003, the value of oil palm products export recorded was RM 26.2 billion with the volume of exports approximately 16.8 million tons (Azman *et al.*, 2004). In 2004, 3.88 million hectares of land was under oil palm cultivation producing 14 million tons of palm oil.

Oil palm (*Elaeis guineensis*) originated from West Africa where it grew in the wild and later was developed into an agricultural crop. In early 1870's it was introduced in Malaya (Malaysia) as an ornamental plant. Then, in 1917 the first commercial plants were planted in Tennamaran Estate in Selangor. The cultivation of oil palm increased rapidly in the 60's under the government's diversification program to reduce the country's economic dependence on rubber and tin. The government then introduced a land settlement scheme for planting oil palm as a mean to eradicate poverty for the landless farmers and smallholders.

The genus *Elaeis*, to which oil palm belongs is one of the 220 genera in the family of Palmae (Tan, 1983). Three species are recognized within the genus: *E. guineensis*, *E. oleifera* and *E. odora.* In Malaysia *E. guineensis* mainly the *tenera* variety which is a hybrid between *dura* and *pisifera* is widely planted (MPOC, 2006)

Oil palms are attacked by a number of pests and diseases which cause retardation of growth and yield reductions. Howard (2001) classified pests of oil palms into three groups:

- Insect defoliators of palm. Larvae of some of this insect consume entire portions of the leaf blade tissue and some of them remove only the superficial tissues of the abaxial (lower) leaf surfaces, leaving the tough leaf veins intact (referred to as 'skeletonizers'). The pests of this group are mainly moth and butterflies (Lepidoptera), other insects are Orthoptera (Tettigoniidae), Coleoptera (Chrysomelidae) and Phasmatodea (stick insects).
- Sap feeders. Diverse species of the order Hemiptera pierce into the tissues of foliage or fruits of palms to feed on the juices. Sap feeding on foliage causes chlorosis while dense populations kill entire fronds, which may translate in to loss in production or affect the vigor of palms and increased their susceptibility to some diseases.

- Stem borers. These insects feed in the apical meristematic tissue and unopened fronds, sometimes penetrate the trunk. Adult of rhinoceros beetle (*Oryctes rhinoceros*) and larva of palm weevils (*Rhynchophorus* spp.) are examples of the stem borers.

Presently the oil palm plantations in many parts of the country are in the second-generation phase. Many plantations are undergoing replanting, having young plants that are prone to attack by the rhinoceros beetle. In this study, therefore, emphasis was focused on the stem borer species, *Oryctes rhinoceros* (Coleoptera: Scarabaeidae) presently the most important pest of young oil palm.

The rhinoceros beetle, *Oryctes rhinoceros* was originally a pest of coconut. Today, with the rapid expansions of oil palm cultivation and decrease of coconut cultivation the rhinoceros beetle has become the most important insect pest of oil palm especially in immature plants. The beetle breeds in the decomposed palm trunks and empty fruit bunches (EFBs). The adult beetle attacks young oil palms by boring through young leaf (spear) bases and feeding upon the tender tissues in the crown, causing emerging leaves to be shortened and distorted with the characteristic wedged shaped appearance on the damaged fronds (Liau & Ahmad, 1991)

The ‘zero burning’ replanting and the disposal of EFBs in large heaps have provided abundant on-site media for beetle breeding (Lim, 2005). Before the ban on open burning, the most common method of clearing oil palms for replanting was chip and burn method as described by McCulloch (1982). Due to its negative impact on the environment, open burning was banned under the Environmental Quality Act (Clean Air Regulation) 1978.

Pesticides play an important role in controlling outbreaks of rhinoceros beetle. Many available pesticides in the market contain varieties of active ingredients (a.i) of different trade names. However, the use of broad spectrum long residual (BLSR) pesticides against this pest has led to increased incidence of resistance in the targeted insect as well as having negative impacts on the environments (Lim, 2005). For example, Carbofuran is no longer effective in controlling rhinoceros beetle in zero burning replanting plantations (Ho, 1996; Chung *et al.*, 1991). Newer generations of insecticides are available and safer to apply, more cost-effective, better selectivity, higher potent at lower rates and with less residue problem. Today synthetic phyrethroid insecticides like cypermethrin and deltamethrin are recommended in the market for controlling this pest. These insecticides have been widely used over quite a long period. Eventually the rhinoceros beetle will develop resistance to these insecticides. Therefore, alternative pesticides are needed to control the beetle. In view of this problem, in this study the insecticide beta-cyfluthrin was introduced as an alternative to control the rhinoceros beetle. Besides using pesticides, a synthetic aggregation pheromone was also used in monitoring and controlling the rhinoceros beetle in the plantation.

Integrated Pest Management (IPM) was developed to curb the problem of rhinoceros beetle in oil palm plantations. The IPM concept included surveillance, census, monitoring and judicious use of selective pesticides and biological control (Chung & Sharma, 1999; Wood, 2005). According to Lim (2005), in IPM, good understanding of the pest biology and ecology is needed in making the correct choice of physical, cultural, chemical and biological control methods. In Malaysia IPM is implemented to control the outbreak of rhinoceros beetle. A few methods had been applied such as census on palm damages, set up pheromone traps, chemical control and biological control (Lim, 2005).

In view of the present status of rhinoceros beetle management and control, this research was undertaken with the following objectives;

1. To investigate the abundance and the structure of the life stages of *Oryctes rhinoceros* in empty fruit bunches (EFB) in an oil palm plantation.
2. To study the source of introduction of *Oryctes rhinoceros* into a recently felled and newly replanted area using pheromone traps.
3. To study the effectiveness of gunnies (fertilizer bag) to curb the frequency of attack by *Oryctes rhinoceros* in immature oil palms.
4. To evaluate the efficacy of the insecticide Bulldock 25 EC (a.i beta-cyfluthrin) in comparison to other insecticides commonly used on young oil palms to control *Oryctes rhinoceros*.

CHAPTER TWO:

LITTERATURE REVIEW

2.0 Introduction

The rhinoceros beetle belongs to the order Coleoptera which is the largest order in the Animal Kingdom (Booth *et al*., 1990), in the family Scarabaedae and subfamily Dynastinae. The Scarabaeidae is a large family of about 2000 genera and 20,000 species, which are commonly known as scarabs, chafers and dung beetles. Most of the dynastinad larvae feed on decaying organic matter and a few of them have become pests especially of palm and sugarcane. Besides *O. rhinoceros*, other species of rhinoceros beetles are *Oryctes monoceros* (Oliver) and *Oryctes boas* (Fabricius).

According to Wood (1968a), *Oryctes rhinoceros* have many common names such as rhinoceros beetle (‘kumbang badak’), black beetle (‘kumbang hitam’) and horn beetle (‘kumbang tanduk’). The *Oryctes rhinoceros* is closely associated with the coconut palm, *Cocos nucifera,* however this beetle have evolved with other palms (Hinckley, 1973). This beetle also attacks oil palm very seriously and other crops in low rate such as sugarcane, banana, pandanus and pineapple (Lever, 1979).

The rhinoceros beetle has become an important pest in oil palm plantations where both male and female adult beetles have been found to attack the trees (Chung, 2003). This beetle is a nocturnal insect, whereby it is more active during the night than in the day. The beetle attacks the palm during the night (Hartley, 1977).

2.1 Distribution

The rhinoceros beetle is widely distributed throughout Asia such as Bangladesh, Cambodia, Southern China, India, Indonesia, Laos, Malaysia, Pakistan, Philippines, Taiwan, Thailand, Vietnam and the Western Pacific and South Pacific Regional Environmental Program (SREP) areas: American Samoa, Fiji, Palau (controlled in 1980s), Papua New Guinea, Samoa, Tokelau, Wallis and Futuna (Booth *et al.*, 1990; Nishida & Evenhuis, 2000)

The beetle is thought to be a native of Southern India, Sri Lanka, Myanmar, Thailand, Peninsula Malaysian, southernmost China including Hong Kong, the Philippines, Taiwan, the Ryukyus and Indonesian Archipelago as far east as Ambon Island (Leefmans, 1884 as cited by Nishida & Evenhuis, 2000). The rhinoceros beetle first appeared in southern Myanmar and it probably originated from Malaysia and spread to the coconut growing areas of Myanmar over 15 years (Mc Kenna & Shroff, 1911 as cited by Nishida & Evenhuis, 2000). Jepson (1912) as cited by Nishida & Evenhuis (2000) believed that the rhinoceros beetle had been introduced in rubber seedlings from Sri Lanka to the areas of the Pacific Island in 1909.

There are a few invasion pathways or how the beetle spread to new locations. The rhinoceros beetle has been found in aircraft that carried tissue culture flasks from South East Asia, during nursery trade, transportations of organic material such as compost and sawdust heaps (Chandrika,2005), and by military activities (increased of sea traffic) during the second world war (Nishida & Evenhuis, 2000). The military activities play a major role in the spread of the beetle in Palau (Gressitt, 1953) and Vietnam (Hinckley, 1973). There are also a few abiotic factors that contribute in spreading this beetle such as water current (Chandrika, 2005) and typhoons (Hinckley, 1973)

Natural factors keep the beetle under control in its native range. Its introduction into island habitats without these natural control factors allows it to reproduce quickly and spread around the island to become a serious pest in invaded areas (Nishida & Evenhuis, 2000).

2.2 Economic importance

In oil palm and coconut plantations, the rhinoceros beetle becomes very important economically in the presence of coconut and oil palm logs or other suitable sites for larval feeding (Hinckley, 1973). The adults (male & female) are the destructive stage. They bore into the crown and young leaves of the palms to feed on tissue juice resulting in emerging leaves to be shortened, distorted and with wedge shape or “V” cuts in the fronds that unfurl (Wood, 1968b; Liaw & Ahmad, 1991).

Serious attack on sensitive oil palm leads to a setback in vegetative growth and eventually delays maturity (Chung *et al*., 1991). The effect of *O. rhinoceros* attack on younger oil palm is more severe compared to mature palms. The crushed fibers of palms are pushed outside the entrance holes, where it indicates the insect's presence (Wood, 1968b). The chewing marks of rhinoceros beetle may lead to break, droop and permanent holes on leaf petioles may cause the frond to break or snap easily by light winds (Kalidas, 2002)

In South East Asia, rhinoceros beetle is a serious pest of coconut causing an estimated 10% loss in crop yield. In India, Ramachandran *et al.*, (1963) reported a loss of 5.5% to 9.1% in yield due to beetle attack. In Malaysia approximately 25% of yield loss in the first two years of harvesting was due to rhinoceros beetle attack (Liaw & Ahmad, 1991). In 1999 the damage caused by rhinoceros beetle increased to more than a half as reported by Chung *et al*., (1999). According to Chung (2003), when the beetles attacked young palms it could result in a loss of 150 kg FFB (fresh fruit bunches) per palm per annum. The potential crop loss for 20 years is 3000kg (150 kg multiplied by 20 years). Desmier *et al*., (2001) reported that the growth of the palm is reduced by 30 cm and the reduction of yield in the first year of production is up to 59% (Nor Hisham *et al*., 2007). In Indonesia, the maturity of young oil palms attacked by *O.rhinoceros* will be delayed about one year and the percentage of young palm killed by the pest can reach 20% (Sudharto *et al*., 2001). More serious in loss yield up to 79% in the first year of production has been reported in Indonesia (PPKS, 1996).

Attacks by beetles may reduce yield and kill seedlings and may provide entry points for lethal secondary attacks by the palm weevil *Rhyncophorus schach* (L.) or invasion by pathogens (Wood, 1968a; Bedford, 1980; Howard, 2001). The phenomenon of ‘twin palm’ always occurs when the point of growth is divided into two sections because of continuing attacks by rhinoceros beetles on the same holes (Wood, 1968b). In that case, a new young branch of palms should be discarded or replanted. Repeated attacks would lead to the death of young and mature palms and these plants have to be replanted. Therefore it would increase the cost of maintenance the plantation.

Apart from coconut and oil palm, this beetle also attacks the date palm and other varieties of palms grown for ornamental purposes including *Raystonea regia, Livistonia chinensis, Chorypha umbraculifera* and *Raphia ruffia* (Gressitt, 1953; Bedford, 1980).

2.3 Morphology, biology, life cycle and behavior of rhinoceros beetle

The rhinoceros beetle is black or reddish black in colour and has a stout body (Hartley, 1977). The rhinoceros beetle is easily distinguished from other beetles because of the presence of cephalic horn at the anterior end of the head, which makes it look like a rhinoceros (Norman & Basri, 2004). The horn is longer in the male and shorter in the female (Howard *et al*., 2001). However, the males can be distinguished more easily from the females by examining the pygidium. The pygidium is bare in males but in females, fine hairs are present (Nirula, 1955). The clypeus of the beetle is bifurcate (divided into two branches) (Booth *et al.,* 1990). Its pronotum has a flattened excavation that is larger in males than in females. There are two teeth on the posterior margin of the pronotum and the elytra are distinctly punctured. This beetle also has a propygidium with a broad stridulatory band. The tibiae are armed with apical teeth. An apical tooth is located on the underside of the protibia while on the mesotibia and metatibia there are 2 apical teeth (Booth *et al.,* 1990).

The females of *O. rhinoceros* has been found to breed in various media such as heaps of rotting paddy straw and farm yard manure (Ghosh, 1923), cattle dung (Nirula, 1955; Kurian & Pillai, 1964; Monty, 1978), decayed *Pandanus* trunk (Gressit, 1953), decaying cocoa pod shells (Bedford, 1976a), decayed coconut log and decaying organic materials such as compost and saw dust (Bedford, 1976a; Bedford, 1980). *Oryctes rhinoceros* mate at the breeding sites (Zelazny, 1975). The females lay their eggs in the decomposing organic matter. The female digs in the organic matter and lays egg singly forming clusters of approximately 30 eggs. These egg clusters are secured by compressed organic matter around them, in a form of more or less oval “cocoons” (Hinckley, 1973). The immature *O. rhinoceros* are commonly found in decaying organic tissues such as coconut, oil palm and rubber logs or stumps. They can also occur in sawdust heaps and almost any other concentration of organic material such as cow dung, urea, compos and fertilizer (Wood, 1968b; Turner, 1973; Hinckley, 1973; Hartley, 1977).

The newly laid eggs are oval and later change to round shapes after a week. They take 4 to 13 days to hatch (Wood, 1968b; Hinckley, 1973). The eggs are whitish yellow in color (Wood, 1968b) and 3mm to 4mm long diameter size (Chandrika, 2005). Each female beetle can produce 3 to 4 clusters of eggs in its lifetime, each cluster containing 11 to 62 eggs (Gressit, 1953; Hinckley, 1973). The color of eggs changes to reddish yellow before hatching (Wood, 1968a). The size of egg produced by the female depends very much on the size of the female (Hinckly, 1973).

The larval stages of rhinoceros beetle are similar to other scarabaeids such as *Xylotrupes gideon, Scapenes australis, Trichogomohus faimeri, Oryces centaurus, Oryctodems* sp. and a few species in the families of Lucanidae and Cetoniidae (Barlow & Chew, 1970; Bedford, 1974). There are 3 larval stages or instars. These instars take about 72 to 120 days to complete before reaching the pupal stage (Howard *et al*., 2001). The mature larva is C-shaped with brown head capsule and three pairs of pro-legs (Chandrika, 2005). Based on Wood (1968b) Catley (1969) and Hinckey (1973) the first instar larva takes 10 to 14 days to complete its development and the size of the head capsule is 0.3mm. The second instar takes a little longer, from 12 to 18 days and the size of head capsule is 0.5cm. The third instar takes the longest time, from 90 to 120 days before reaching the pupal stage and the size of the head capsule is 0.9 cm.

Larvae in all instars are yellowish white in color. They can grow to 60 – 100mm or more (Wood, 1968a; Ooi, 1988). Given enough food, the third instar larva can complete its growth within 3 to 4 months (Catley, 1969). In total, the larval stage requires 80 to 200 days (3-6 months) to grow to pre pupa and pupa (Bedford, 1980).

The pre pupa is similar to the third instar larvae but it is inactive and its body shrunk or degenerated. This stage takes about 8 to 13 days (Wood, 1968a). The pupa stays in a cocoon made from soil or decomposed plant tissues (Howard *et al*., 2001) for about 11 to 20 days (Lever, 1979). Then the pupa molts to the adult, and the adult usually survives for more than 6 months (Gressit, 1953; Bedford, 1980; Khoo *et al.*, 1991).

The period from egg to adult ranges between 115 and 260 days (Norman, 2001). This range is dependent on the different substrates where the eggs are deposited (Bedford 1976b; Catley, 1969; Hurpin & Fresneau, 1973; Hinckley, 1973). At the right temperature and with good source of food, the life cycle is completed within 5 to 6 months (Schipper, 1976).

The larvae prefer habitats with low relative humidity and not very high temperature (Bedford, 1980; Hinckley, 1973). Dry conditions with low nutrients will delay the growth of rhinoceros beetle to 14 month and cause high mortality of the beetles (Catley, 1969; Hinckley, 1973).

The activity of the rhinoceros beetle increases during the wet season. Rainfall may have induced the beetles to search for moist places for breeding sites (Norman & Basri, 2004). Similar phenomenon occurs when night rainfall increases the capture in coconut log traps and likely indicates that the coconut log is suitable as a breeding substrate (Bedford, 1975; Zelazny & Alfiler, 1987). There is no significant relationship between moon phase and activity of *Oryctes rhinoceros* (Barlow & Chew, 1970; Bedford, 1975). Nevertheless, based on a study by Norman & Basri (2004), the activity of the male *O. rhinoceros* increases during the full moon phase. They suggest that the male beetle like to search for mate and food during the period of full moon.

The maximum flight recorded for adult *O. rhinoceros* is about 700m (Howard *et al*., 2001). However, Norman & Basri (2004) found that the beetles only flew approximately 19 m in a day or about 130 m in a week. The flight range of the beetle within replanting areas is restricted by high abundance of food and breeding sites (Norman & Basri, 2004).

2.4 Zero burning replanting

Oil palms reach the uneconomical stage 25-30 years after planting (Mohamad *et al.*, 1986). Then the standing palms are felled for replanting. The conventional clean felling and burning system is usually carried out. This technique is advantageous from the point of minimizing the rhinoceros beetle (*Oryctes rhinoceros*) attack and the risk of *Ganoderma boninense* (Pat) infection. In the coastal areas particularly in the West Coast of peninsular Malaysia this disease was reported to be serious (Mohd Hashim *et al.*, 1993).

Under the Environmental Quality Act (Clean Air Regulations) of 1978, open burning is not allowed. This practice causes air pollution as experienced in the last few years in peninsular Malaysia. Hazy weather condition was associated with open burning and forest fire (Mohd Hashim *et al.*, 1993). Open burning also has some effects on rainfall. In large replanting or clearing area, hot up droughts from the bare area tend to keep away light rainfall (Turner & Gillbanks, 1974).

Zero burning replanting is a practical and environmentally sound technique that has been adopted and implemented by Golden Hope Malaysia Sdn. Bhd. since 1989. The company was the first to introduce the technique to the plantation industry (Golden Hope, 2004). The zero burning replanting technique is practiced in which the old and uneconomical stand of oil palms and other crops are felled and shredded and left decomposed *in-situ* (Golden Hope, 2004). The zero burning technique allows replanting to be done without violating the Environmental Quality Act (Clean Air Regulations) of 1978. Besides being non-polluting, it also contributes positively towards efforts in minimizing global warming.

According to Golden Hope (2004), the zero burning technique offers the following benefits:

- It allows complete return of organic matter to the soil. This helps to preserve, restore and improve soil fertility and chemical as well as physical properties of the soil.
- The fallow period is reduced considerably because the new stand is planted simultaneously with felling or shredding operations.
- Felling or clearing will no longer dependant on the vagaries of weather. In the past, wet weather often delayed burning and thus replanting. Such delays are now avoided.
- In the absence of burning, the cost of land clearing is substantially cheaper.

The challenge in zero burning replanting is the outbreak of the rhinoceros beetle due to the presence of large quantities of decomposing biomass, which are ideal breeding grounds of the pest. The rotting oil palm trunks create an abundance of suitable breeding site for *Oryctes rhinoceros*, which pose problems to young and immature palms. Sometimes mature palms adjacent to an infested area may become seriously affected (Norman & Basri, 1997). Nevertheless, shredding of plant tissues and early establishment of leguminous cover crops such as *Mucuna bracteata* have been found to significantly reduce viability of breeding sites (Shaharudin & Stephen, 2000).

2.5 Integrated pest management (IPM) of *Oryctes rhinoceros*

The replanting programs have provided more breeding sites for *O. rhinoceros*. Infestations of *O. rhinoceros* causing severe damage in immature oil palms have been regularly reported especially in areas where they are under zero burning planting technique (FASB, 2003).

Integrated pest management (IPM) was developed to curb the problems caused by the rhinoceros beetle in oil palm plantations. IPM is essentially the utilization of all suitable techniques and methods of pest control in compatible as manner as possible to suppress pest levels below those causing economic injury and crop losses (Pedigo, 2002). This definition is very much similar to the FAO International Code of Conduct on the Distribution and Use of Pesticide (Article 2), defining IPM as “A pest management system that, in the context of the associated environment and the populations dynamic of the pest species, utilizes all suitable technique and methods and maintains the pest populations at levels below those causing economically unacceptable damages or losses”.

By using the IPM techniques, over dependence on any one method such as pesticide is avoided. The pest control is sustainable and yields encouraging results. This technique is also very cost effective and environmentally friendly (Lim, 2005). The IPM is not only used in the control of *O. rhinoceros* but for all pests in oil palm plantations such as bagworms, bunch moths and nettle caterpillars that feed on the leaves of the oil palm, rodents, *Ganoderma* and termites (Lim, 2005).

The main objective of IPM in oil palm plantations is to ensure that the delicate equilibrium between the destructive insect pest and the natural biological agents is always maintained (Yap, 2005). The keys to the success of using the concept of IPM are regular monitoring, early detections and speedy treatment when required (Lim, 2005). In IPM, three basic operational components require emphasis. They are prevention before pest outbreak occurs, observation during crops growth and intervention once the pest is infesting the crop (GCPF, 1998)

The intensified research into IPM has yielded encouraging results in control of insect and rodent pests in oil palms (Golden Hope, 2004). The IPM also has successfully and commercially been implemented (Ho & Teh, 2004). The components of the IPM encompass the integrated combinations of biological, cultural, physical and chemical control measures (Golden Hope, 2004; Yap, 2005).

2.6 Control of *Oryctes rhinoceros* in oil palm plantations

The rhinoceros beetle has become an important pest in oil palm plantations. Several management practices and controls are included in the integrated pest management to deal with outbreaks and to reduce the damage on the palms. This included mass trapping using pheromone traps, biological control, chemical control and practice good agricultural procedures such as planting cover crops and empty fruit bunches (EFB) management. The primary objectives of these approaches are to reduce losses from pest outbreaks and maintain the outbreaks below the economic injury level (EIL). The Insect Control Committee for Micronesia (ICCM) was established after the World War II to control the beetle (Anon., 1947)

2.6.1 Pheromone traps

Pheromones are chemicals that produced and released by insects or other organisms (Kratt, 2001) which influence the behavior of members of the same species (Campion, 1984). The pheromones can be divided into two different categories such as sex pheromones and aggregation pheromones. The sex pheromones are released by individual insects during mating and in most cases the females release them (Campion, 1984; Kratt, 2001). On the other hand, aggregation pheromones are produced and detected in both sexes. They give information about food sources as well as reproduction (Campion, 1984; Kratt, 2001).

The technique of using lures and traps for trapping the beetles was originally introduced by Hoyt (1963) in Western Africa. Ten years later Bedford (1973) tried it in Guinea. Hoyt (1963) created simple traps using metal containers and decomposed coconut log as a bait to attract the beetles while Bedford (1973) used a synthetic bait, ethyl dehydrokrisantemumate to replace the decomposed coconut logs and metal vane traps that were invented by Barber *et al.*, (1971).

Today a synthetic aggregation pheromone is available in the market (Hallet *et al.*, 1995). This pheromone, ethyl 4-metiloctanoate was reported 10 times more effective in controlling rhinoceros beetle as compared to ethyl dehydrokrisantemumate (Hallet *et al.*, 1995). This aggregation pheromone is packed in 4cm x 6cm membrane polymer sachet and weight approximately two grams. The pheromone sachet is placed on a metal vane and a plastic pail is hung under the metal vane. The beetles that are attracted to the pheromone fly towards the trap and hit the metal vane. Then, the beetles fall into the plastic pail.

In Malaysia, the pheromone trap was introduced in 1995 and marketed by Sime Darby Berhad and under trade name ‘P046 Sime RB Pheromone’. This pheromone is widely used in Malaysia for mass trapping and monitoring of rhinoceros beetle (Chung, 1997; Norman, 2001). Since its introduction in Malaysia, a few studies were conducted by Chung (1997) and Norman (2001) to evaluate the effectiveness of the pheromone. According to Chung (1997), the pheromone traps are effective in controlling rhinoceros beetle in newly replanted palm with high density beetles or during outbreaks. This technique also cost approximately 31% less and can reduce 86% of the labour cost compared to the conventional chemical control. Norman (2001) suggested that using the pheromone trap is also useful as a control method as it captures gravid females, which reflects the onset of breeding season. The recommended density of traps in oil palm plantation is 1 trap for every 2 hectares (Chung, 1997).

2.6.2 Biological control

Biological control is a method whereby natural enemies are used to control pests (Pedigo, 2002). This technique is environmentally friendly; furthermore insecticide usage can be reduced. A few biological organisms show potential in controlling the beetles such as predators, parasitoids, virus, bacteria and fungus.

Parasites such as the wasps, *Scolia ruficornis* from east Africa and *Scolia patricialis* var. *plebeja* from Malaya (Malaysia) were introduced from 1947 to 1950 to control this beetle in Micronesia. By 1952, the wasps failed to exert effective control and the palms continued to be attacked by the beetle (Nishida & Evenhuis, 2000). In 1974, Swain (1974) listed a few parasitoids and predators from Pacific Island. The most promising predators and parasitoids include Elateridae, Hesteridae and Carabidae (Order Coleoptera), Reduviidae (Hemiptera), Scoliidae (Hymenoptera), caterpillar and vertebrates (rats, squirrel, monkey and pig). Wood (1968b) reported that owl; *Tyto alba javanica* is one of the predators of the beetle. Hartley (1977) reported that termites predated this beetle in the egg stage.

The use of virus to control rhinoceros beetle is widely practiced in the Pacific Island, Indonesia and India (Zelzany, 1973; Bedford, 1976b; Bedford, 1981). The larva and adult rhinoceros beetle are exposed to entomophatogenic virus, *Baculovirus oryctes* (David, 1975). This virus also known as *Rhabdionvirus oryctes* (Huger, 1966). It was originally found in Malaysia and later introduced to other countries of the Pacific Island such as Fiji and Maldives. In these countries, the virus was used to control outbreaks of *O. rhinoceros* in coconut palms (Marschall, 1970; Young & Longworth, 1981; Marschall & Ioane, 1982; Zelazny *et al.*, 1992). Unfortunately, this virus was not effective in controlling *O. rhinoceros* due to interference by tropical storms that felled coconut trees and provided breeding sites for the beetle (Zelazny & Alfiler, 1987). Nevertheless, using virus is important as a technique in integrated pest management (IPM) in the plantations (Ho, 1996)

Several species of entomophatogenic bacteria have been identified as biological control agents of the larvae of *O. rhinoceros*. The bacteria include *Acinetobacter calcoaceticus* (Kanan *et al*., 1980), *Monocercomonoides oryctesae* and *Monocercomonoides qadrii* (Krishnamurthy & Sultana, 1977), *Bacillus thuringiensis* and *Bacillus popilliae* (Sundara-Babu *et al.*, 1971).

Metarhizium anisopliae is a greenish entomophatogenic fungus that has been reported to occur on approximately 200 species of insects including moth and butterflies, beetles, orthopterans and bugs (Bennett *et al*., 1997; Patchumuthu & Kamble, 2000). This fungus mostly attacks the larval stage of the beetle (Sundara-Babu *et al*., 1983). Black spots appear on the larval body to indicate the attack of the fungus. When the larva is dead, the color changes from white to greenish. The effectiveness of the fungus was not satisfactory due to low transmission and spreading rate of *M. anisopliae* on *O. rhinoceros* (Young, 1986; Jangi *et al.,* 1991). However, Tey & Ho (1995) reported that the population of *O. rhinoceros* dropped after being controlled by *M. anisopliae.* A study by Latch (1976) on *Beauveria bassiana* and *Beauvaria tenella* showed similar results to *M. anisopliae.*

2.6.3 Chemical control

Insecticide is a chemical that kills insects and plays a major role in controlling pests in agricultural productions (Pedigo, 2002). Insecticides have been classified according to mode of application or chemical compositions. Most of the major groups of modern insecticides are contact poisons. They are absorbed through the body wall when in contact with the body of insects (Pedigo, 2002). Common modern insecticides available in the market are from the major groups such as pyrethroids, organophosphates, chlorinated hydrocarbons, carbamates, neonicotinoids, phenylpyrazoles, pyrroles, pyrazoles, pyridazinones, insect growth regulators (IGRs) and repellents (Pedigo, 2002). Insecticide modes of action involve all the anatomical, physical and biochemical responses to a chemical, as well as its fate in the organism. Metabolic processes in insect are blocked by insecticide in three ways such as nerve poisons, muscles poisons and physical toxicants. Nevertheless, it depends on the compound of the insecticides (Pedigo, 2002).

Several insecticides have been used to control rhinoceros beetle such as lambda-cyhalothrin, cypermethrin, endosulfan, carbofuran (Toh & Brown, 1978; Ho & Toh, 1982; Chung *et al*., 1991; Ho, 1996) and naphthalene (repellent) (Gurmit Singh, 1987). Most of the insecticides applied to the palms are sprayed on the crown, spears and base of fronds that have been attacked by rhinoceros beetle. According to Sadakathulla & Ramachandran (1990), the most suitable place to apply insecticides is on the base of fronds.

O'Connor (1953) found that BHC (now known as HCH) and lindane was more toxic than dieldrin in controlling rhinoceros beetle in Fiji. The HCH and lindane is a wide spectrum insecticide and kills more insects (Pedigo, 2002). In another experiment by O'Connor (1953), he suggests that the powder of diazinon is more effective than BHC. Stelzer (1968) showed that diazinon and furadan are more effective as sprays compared to dieldrin and carbaryl. According to Ho & Toh (1982) and Toh & Brown (1978) the granule formulation of gamma-BHC, carbosulfan and carbofuran are the most efficacies and cost effective.

Chung *et al*., (1991) has evaluated 11 types of insecticides for controlling O.rhinoceros in nurseries and immature palms in plantations. His result showed that the insecticide lambda-cyhalothrin proved to be the most effective in reducing broken spears. Whereas insecticides such as carbofuran and cypermethrin were effective in reducing the holes in spears and fronds. Chung *et al*., (1991) also found that carbofuran was the cheapest among all the insecticides. However, Ho (1996) showed that carbofuran was not effective against rhinoceros beetle in zero burning replanting environments. In another study, Chung (1997) reported that spraying of mixed insecticides such as 1%

endosulfan, 0.1% lambda-cyhalothrin and 0.1% cypermethrin to the center and base of the spears can reduce the damages by rhinoceros beetle.

The placement of insecticides at the source of food for the beetles seemed to be more effective. Gurmit Singh (1987) reported that naphthalene controlled rhinoceros beetle up to 95% and reduced the level of damage to the 'acceptable' level when 5 to 8 naphthalene ball were placed at the palm spears every two weeks. In contrast, Ho (1996) showed that this technique is not suitable when the populations of beetles are high. Dhondt *et al*., (1976) reported that the juvenile hormone methoprene can be used to kill the pupae of the rhinoceros beetle. Methoprene is an IGR with good activity against many Diptera, Siphonaptera, Homoptera, Lepidoptera and Coleoptera.

2.6.4 Good agricultural practices (Cultural control)

According to Norman (2001), banning on open burning has provided large amount of breeding sites for rhinoceros beetle. Thus, cultural control such as planting cover crops, using appropriate planting methods and practicing good cleanliness of plantation areas should be adopted. The potential source of breeding sites such as empty fruit bunches (EFB) and decomposed palm oil trunk should be managed properly (Wood, 1968a). The use of cover crops such as *Mucuna bracteata* as a vegetative barrier can reduce the viability of breeding sites (Wood, 1968b; Shaharudin & Stephen, 2000). Tajudin *et al.*, (1993) suggested the removal of dead or decomposed palm by burying them.