

**A STUDY ON DAMAGE AND CONTROL OF  
ORYCTES RHINOCEROS L. (COLEOPTERA:  
SCRABAEIDAE) IN ZERO BURNING REPLANT  
OIL PALM AREAS OF FELDA LEPAR UTARA,  
PAHANG.**

**by**

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**Thesis submitted in fulfillment of the  
requirements for the degree of  
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## LIST OF ABBREVIATIONS

|       |                                       |
|-------|---------------------------------------|
| AP    | Aggregation pheromone                 |
| DxP   | Dura x Pisifera                       |
| EIL   | Economic injured level                |
| FASSB | Felda Agricultural Services Sdn. Bhd. |
| FELDA | Felda Land Development Authority      |
| FFB   | Fresh fruit bunches                   |
| FPSB  | Felda Plantations Sdn. Bhd.           |
| IPM   | Integrated pest management            |
| MAF   | Month after felling and chipping      |
| MBTW  | Mean beetle per trap per week         |
| PM    | Palm mature                           |
| RB    | Rhinoceros beetle                     |
| RCBD  | Randomize complete block design       |

**KAJIAN KEROSAKAN DAN KAWALAN KUMBANG BADAK, ORYCTES RHINOCEROS L. (COLEOPTERA: SCRABAEIDAE) DI KAWASAN TANAM SEMULA TANPA BAKAR, LADANG KELAPA SAWIT FELDA, LEPAR UTARA, PAHANG.**

**ABSTRAK**

Satu kajian kumbang badak telah dijalankan di ladang sawit FELDA Plantations Sdn. Bhd. Kompleks Lepar Utara, Pahang bertujuan mengenalpasti kesan serta impak pelaksanaan kerja tanpa bakar timbunan sisa batang sawit semasa aktiviti tebang, cincang dan longgok di kawasan tanam semula kelapa sawit. Kerosakan anak pokok sawit akibat serangan kumbang badak dinilai pada bahan tanaman anak benih yang berlainan, umur pokok yang berbeza dan keadaan topografi atau persekitaran kawasan tanaman yang berbeza, merangkumi kaki bukit, atas bukit berteres, tepi jalan utama, kawasan paya dan sempadan pokok matang. Tiada hubungkait yang jelas antara kerosakan pokok sawit dan perbezaan keadaan persekitaran tanaman ( $P > 0.05$ ). Didapati bahan tanaman tisu kultur yang berumur 0-1 tahun lebih kerap menerima serangan kumbang badak berbanding bahan tanaman benih D x P (Dura X Pisifera) pada umur yang sama.

Kajian kelimpahan kumbang badak dewasa di kawasan tanam semula dijalankan di ladang FELDA Lepar Utara 09, Lepar Utara 14 dan Lepar Utara 05 seluas 120 hektar selama 13 bulan dengan menggunakan perangkap feromon. Purata kumbang badak dewasa di tangkap per perangkap per minggu tertinggi adalah sebanyak 68.2 ekor di ladang FELDA Lepar Utara 14, pada 16 bulan selepas tebang dan cincang (16 BST)

(paras kecederaan ekonomi: 10 ekor kumbang dewasa/perangkap/minggu) manakala purata kumbang badak dewasa di tangkap per perangkap per minggu terendah dicatatkan sebanyak 6.1 ekor pada 22 BST di ladang FELDA Lepar Utara 14 (di bawah paras kecederaan ekonomi; kurang 10 ekor kumbang dewasa/perangkap/minggu). Didapati juga, jumlah curahan hujan bulanan tidak mempengaruhi aktiviti terbang dan penangkapan kumbang badak di ketiga-tiga ladang ( $P>0.05$ ).

Kemandirian dan kelimpahan populasi maksima bagi *O. rhinoceros* di dalam dua jenis keadaan berbeza longgokkan batang racik sawit iaitu A) tanpa bakar dan B) separa bakar di kawasan ladang tanam semula bagi tempoh bermula 3 sehingga 18 bulan selepas tebang dan cincang dikaji selama 16 bulan dalam keluasan lebih kurang 40 hektar tanam semula sawit. Populasi tertinggi bagi semua peringkat kumbang badak dalam kedua-dua jenis longgok batang sawit adalah pada 13 bulan selepas tebang (BST) dan ianya tiada dijumpai pada 3, 4 dan 5 BST. Larva instar ketiga mencatatkan densiti yang tinggi pada setiap bulan persampelan kecuali pada 3, 4 dan 5 BST. Tiada perbezaan jelas ( $P>0.05$ ) terhadap jumlah bilangan setiap peringkat kumbang badak pada longgokkan batang racik sawit yang berbeza (tanpa bakar dan separa bakar) sepanjang kajian kecuali pada peringkat larva instar pertama ( $P<0.05$ ). Peningkatan bilangan peringkat kumbang yang dijumpai dengan bulan selepas tebang menunjukkan terdapatnya perkaitan yang positif (ANOVA;  $F= 25.313$ ;  $df= 6$ ;  $P<0.05$ ). Kajian efikasi racun mengawal *Oryctes rhinoceros* dan kelecuman pucuk muda (fitotoksiti) lima rawatan insektisid (carbofuran 30gm, carbosulfan 3gm, 6gm and 12 gm and naftalena 30 gm) selama 20 minggu rawatan dilakukan terhadap bahan tanaman benih tisu kultur yang berumur satu setengah tahun

menggunakan rekabentuk blok rawak lengkap. Terdapat hubungkait positif ( $r=0.342$ ) ( $p<0.05$ ) penurunan kerosakan baru pelepah dan pucuk sawit selama tempoh 20 minggu rawatan. Racun karbamat carbosulfan 5% dengan dos rawatan 6 gram per pokok pada selangan sebulan merupakan rawatan terbaik dalam mengawal serangan kumbang badak. Maka, aktiviti pembakaran separa bakar sisa sawit di kawasan tanam semula sawit bagi pengurusan awal infestasi kumbang badak adalah tidak disarankan.

**A STUDY ON DAMAGE AND CONTROL OF ORYCTES RHINOCEROS L.  
(COLEOPTERA: SCRABAEIDAE) IN ZERO BURNING REPLANT OIL PALM  
AREAS OF FELDA LEPAR UTARA, PAHANG.**

**ABSTRACT**

A study on the implication of zero burning in the oil palm replanting program was carried out in FELDA Plantations Sdn. Bhd., Lepar Utara Complex, Pahang. Damages caused by rhinoceros beetles (RB) were assessed on different planting materials, palms of different ages, palms planted on various land topographies (hillside, hilltop, roadside, border to mature palm, swamp and valley) and various locations. Damages on oil palm trees in all topographies were not significantly different ( $p>0.05$ ). The 0 - 1 year tissue cultured plants have higher damages caused by RB as compared to D x P (Dura x Pisifera).

A survey on the abundance of adult beetles was carried in a replanted oil palm in estates of FELDA Lepar Utara 05, FELDA Lepar Utara 09, and FELDA Lepar Utara 14 of 0 - 3 years in approximately 120 hectares plot for 13 months using pheromone traps. High numbers of adult rhinoceros beetles were caught in traps between 10<sup>th</sup> and 38<sup>th</sup> month after felling (MAF) (EIL: 10 beetles/trap/week), and the beetle density started to decrease 39 MAF (below 10 beetles/trap/week). Rainfalls did not influence flying activities and number of beetles caught ( $p>0.05$ ) in the all traps locations. The abundance of *Oryctes rhinoceros* in the decomposing trunk on different stages of beetle namely eggs, larvae, prepupae, pupae and adult was carried out for 16 months period in approximately 40.00 hectares plot. Two types of breeding sites were selected, A: zero burning and B: partial

burning between 3 to 18 month after felling (MAF). Since 6<sup>th</sup> MAF, the populations of *O. rhinoceros* were collected in trunk chipped however the highest population detected at 13<sup>th</sup> MAF and no beetle was detected at 3, 4 and 5<sup>th</sup> MAF of both sites. The third instar larvae recorded as the dominant stage since the study was initiated except at 3, 4 and 5<sup>th</sup> MAF. The difference practices through zero burning or partial burning of trunk chipped did not influence ( $P>0.05$ ) the abundance of all beetle stages except for first instar larvae ( $p<0.05$ ). Statistically, it was found that population of *O. rhinoceros* positively significant due to the month after felling (ANOVA;  $F= 25.313$ ;  $df= 6$ ;  $p<0.05$ ).

Efficacy and phytotoxicity of three insecticides (carbofuran 30gm, carbosulfan 3gm, 6gm and 12 gm and naphthalene 30 gm) against *O. rhinoceros* were evaluated for 20 weeks on one and a half year tissue culture seedling (DxP) in zero burning oil palm replanting areas using a randomize complete block design (RCBD). There were significant differences ( $r=0.342$ ) ( $p<0.05$ ) of fresh damaged oil palm fronds and spears, 20 weeks after application. The result of this study showed that the usage of carbosulfan 5% applied at 6 grams per palm at the interval of two months was the most effective in controlling *O. rhinoceros* in newly planted oil palm areas as compared to the other insecticides. Partial burning is not recommended in the RB pest management in a replanting scheme because there was no different in the numbers of all stages of RB between the zero burning and partial burning plot.

## DEDICATIONS

To my beloved parents, brothers and sisters.

Not to forget, my lovely wife.

Thank you for your constant prayers.

To all my friends, thank you for your help.

# CHAPTER ONE

## GENERAL INTRODUCTIONS

### 1.1 Project descriptions

Federal Land Development Authority (FELDA) was established on July, 1<sup>st</sup> 1956 and started planting oil palm since 1961. The oil palm areas consists of 811,140 hectares comprising of FELDA Plantations Sdn. Bhd. (348,957.43 ha), FELDA Agricultural Services Sdn. Bhd. (11,442.62 ha), and FELDA settlers (450,955.05 ha). FELDA is committed to produce palm oil sustainably through the implementation of Good Agricultural Practices (GAP) (FELDA Agricultural Services Sdn. Bhd., 2005; Rosli, 2006).

Lepar Utara Complex is located in Pahang and is situated about 75 kilometers from Jerantut. It is considered a rural area and it is 100% planted with oil palm. The Lepar Utara Complex consists of six FELDA Plantations Sdn. Bhd. (FPSB) estates and five FELDA settler estates. The estates that have been chosen for this study are FPSB Lepar Utara 09, FPSB Lepar Utara 14 and FPSB Lepar Utara 05, which have been planted with the oil palms since 1983/1984. Lepar Utara Complex's first involvement in oil palm replanting programme is in the year 2001 and followed by Lepar Utara 09, Lepar Utara 14 and Lepar Utara 05 by the years 2002, 2003, 2004, 2005 and 2006 with the total area of 5,803.52 hectares being replanted (Table 1.1).

Table 1.1: The replanting programme in FELDA (FPSB) Lepar Utara Complex.

| <b>FPSB</b>       | <b>Phase</b> | <b>Year<br/>Replanting</b> | <b>Area<br/>(Hectare)</b> |
|-------------------|--------------|----------------------------|---------------------------|
| Lepar Utara 09    | *PM01E       | 2001/2002                  | 361.78                    |
| Lepar Utara 09    | PM01F        | 2001/2002                  | 190.00                    |
| Lepar Utara 09    | PM02J        | 2001/2002                  | 181.15                    |
| Lepar Utara 14    | PM01C        | 2001/2002                  | 494.49                    |
| Lepar Utara 14    | PM02D        | 2001/2002                  | 644.78                    |
| Lepar Utara 14    | PM02G        | 2002/2003                  | 353.39                    |
| Lepar Utara 14    | PM02G        | 2003/2004                  | 738.98                    |
| Lepar Utara 14    | PM03H        | 2003/2004                  | 394.77                    |
| Lepar Utara 14    | PM03I        | 2003/2004                  | 697.59                    |
| Lepar Utara 09    | PM04K        | 2004/2005                  | 344.95                    |
| Lepar Utara 05    | PM04I        | 2004/2005                  | 544.86                    |
| Lepar Utara 05    | PM05J        | 2005/2006                  | 478.35                    |
| Lepar Utara 05    | PM06K        | 2006/2007                  | 378.43                    |
| <b>TOTAL AREA</b> |              |                            | <b>5,803.52</b>           |

(Sources: Special Department of FPSB, Kuala Lumpur 2007). \* PM is for palm mature.

## 1.2 Study areas

The Fields are located at Complex of Lepar Utara which is approximately 65 km from Jerantut, Pahang. FELDA Lepar Utara 05, Lepar Utara 09 and Lepar Utara 14 were selected based on the history of the incidences with *Oryctes* beetles by surveys carried out by the FELDA estate staffs. These plantations were categorized inland area. Every plantations were managed by a manager, assisted by two assistant managers and approximately 8 to 9 field supervisors. Approximately 230 to 250 workers (mainly foreign) were employed to carry out various duties such as harvesting of oil palm fruits, weeding, palm planting, fertilizing, pesticide applications and others. All estates within the chosen locations were inspected for *Oryctes rhinoceros*. During the first inspection in Lepar Utara 09 in April 2004, the immature oil palms had heavy damages. Palms were detected with holes on rachis, dead spear and fan shaped fronds. These symptoms of damage on the oil palm were recognized and were similar to that stated by Chung (2004). Treatment or control methods were employed in the areas to overcome the problem included chemical control by cypermethrin active ingredient an interval of two weeks and manual hand picking.

The percentage areas of replanting program by FELDA Plantations Sdn. Bhd. since 2000 until 2007 is shown in Figure 1.1. While the locations of study areas are shown in Figure 1.2.

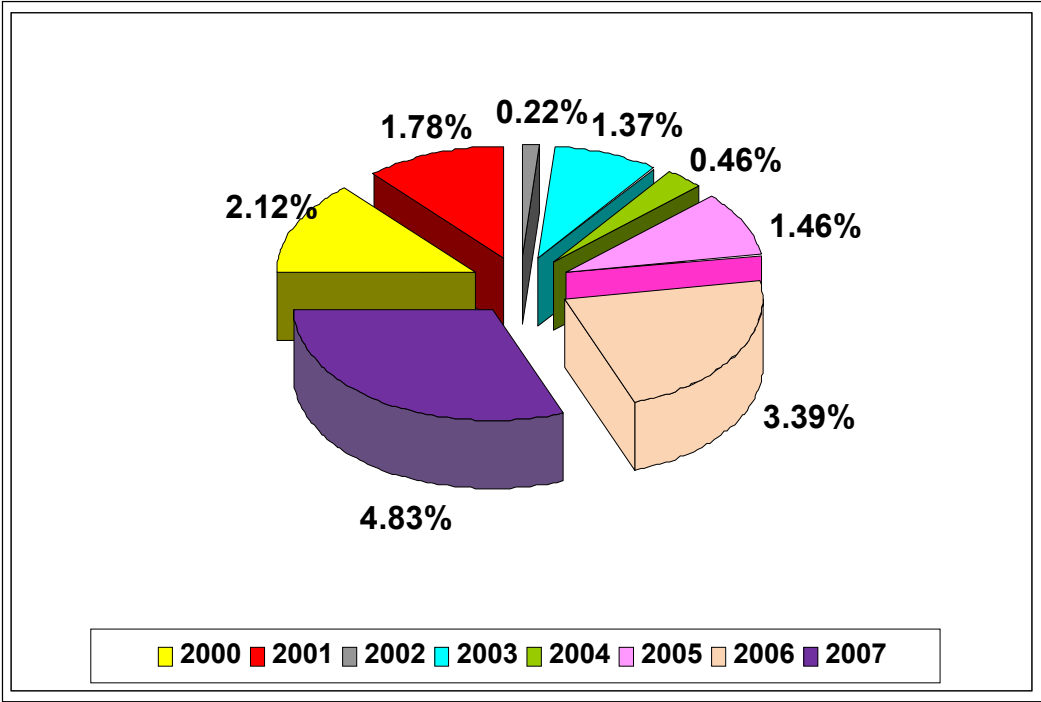


Figure 1.1: The percentage areas of oil palm replanted area in FELDA Plantations Sdn. Bhd. (FPSB) between 2000 to 2007. Note: Area total of FPSB are 348,957.43 hectares. (Sources: Special Department of FPSB, Kuala Lumpur 2007).

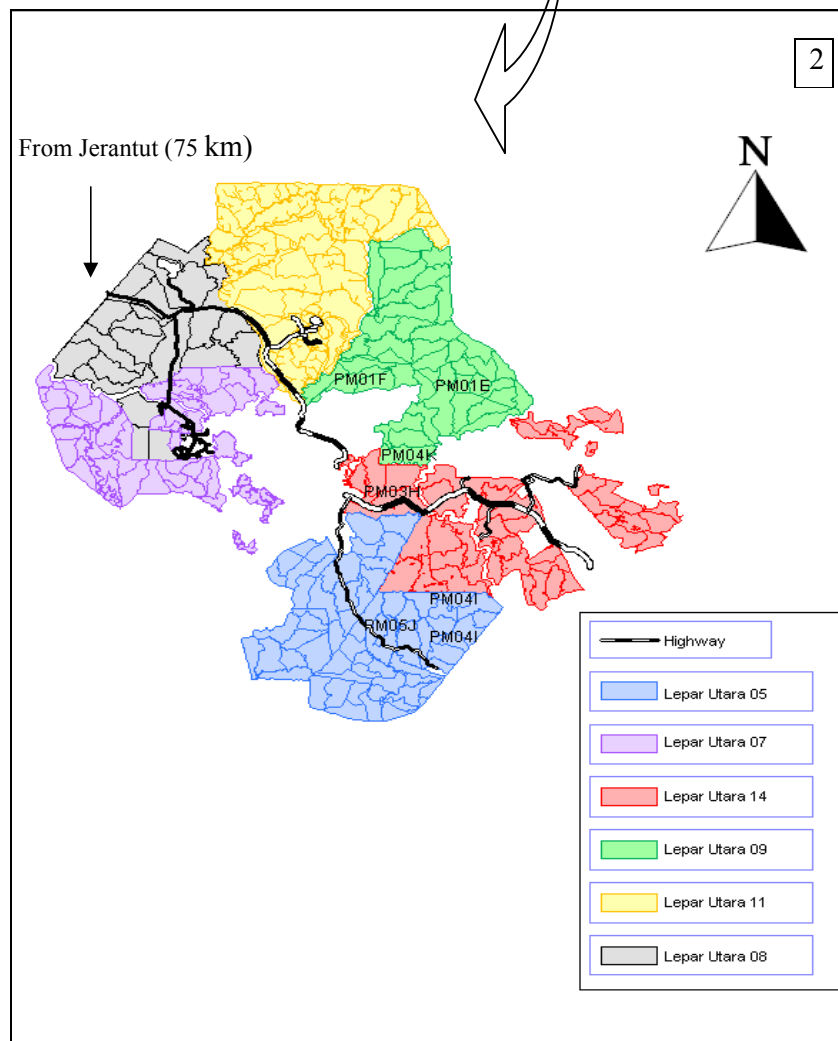
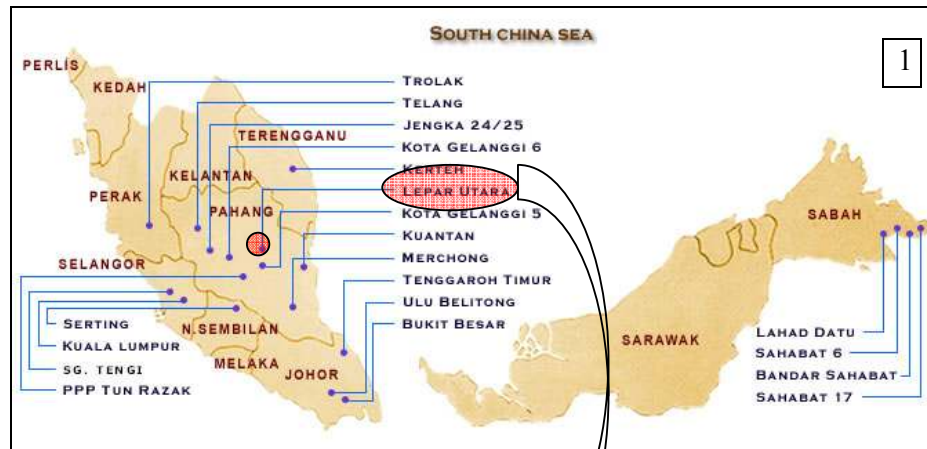


Figure 1.2: A map showing the Complex FPSB Lepar Utara, Pahang consisting of Lepar Utara 05, Lepar Utara 07, Lepar Utara 08, Lepar Utara 09, Lepar Utara 11 and Lepar Utara 14 (not in scale).(Source: Special Department of FPSB, Kuala Lumpur 2007).

### **1.3 FELDA: Oil palm replanting programme**

Annually, FELDA Plantations Sdn. Bhd. plans to replant oil palms between 16,000 to 17,000 hectares or 4.59% to 4.88% of its total areas. The new procedure and criteria for an area to be replanted are as follows:

- a) The age of standing palms must be above 22 year old.
- b) The yields are low ( below 17 tones/ha/year)
- c) The height of palms (must be over 40 feet and uneconomic to harvest), and
- d) Special cases (such as pest and disease case; *e.g.* basal stem rot beyond any control).

The zero burning replanting was implemented in FELDA, complying with the Environment Quality Act Of 1974 and the Environment Quality (Clean Air Regulations) Act of 1978. Zero burning preserved the valuable resources in environments, and prevents the excessive loading of nutrients in the soils and waterways (Hashim *et al.* 1993).

FELDA Plantations Sdn. Bhd. plans to replant 13,378.19 hectares in 2008 as permitted by Federal Land Development Authorities (FELDA) includes the opening of a new forest area. Furthermore, 2,541.84 hectares will be planted with tissue culture plants DxP and 10,863.15 hectares will be planted with DxP seedlings planting materials (Special Department FPSB, 2007).

#### 1.4 The oil palm industry

The oil palm (*Elaeis guineensis*, Jacq.) anatomically is similar to, and is grouped with the Cocos (*e.g.* coconut) and other genera in the family Palmae, a distinct group of monocotyledons (Tan, 1983). The oil palm tree (*E. guineensis*) is originated from West Africa where it grows wild and later developed into an agricultural crop. It was first introduced into Malaya in early 1875 as an ornamental plant (Arnot, 1963). The first commercial planting took place in Tennamaran Estate in Selangor around 1917, and it was the foundations of the vast oil palm plantations and palm oil industry in Malaysia (Tang, 1966).

The cultivation of oil palm increased rapidly in the early sixties under the government agricultural diversification program which reduced the country's economic dependence on rubber and tin. Later in the 1960s, the government introduced land settlement schemes (*e.g.* FELDA) for planting oil palm as a mean to eradicate poverty for the landless farmers and smallholders. The oil palm plantations in Malaysia are largely based on the estate management system and small holders scheme. Meanwhile, Sabri (2006) stated that early good agricultural practices of soil conservation, water management, effluent treatment and oil mill waste recycling, coupled with socio-economic provisions of utilities housing, medical facilities and welfare in oil palm plantations nevertheless forms a very sound foundation for sustainability. Pest management is one of the indicators of sustainability that has been identified as a guideline towards the development of good agricultural practice (GAP) (Unilever, 2005).

## **1.5 Integrated pest management (IPM) of rhinoceros beetles (RB).**

The existence of large oil palm estates profoundly modifies the environment from which was previously existed, resulting in one of the most dynamic features in oil palm cultivation, *i.e.* changes in the importance of individual pest species, together with the speed, sometimes seemingly swift, in which such changes can occur (Turner and Gilbank, 2003). Here, pest can be derived as all organisms within the crop environment that cause injury to the crop and are capable of reducing yield or quality (Norris *et al.* 2003). Thus, rhinoceros beetle is a major or a key pest of oil palm. The pest occurs routinely and will influence crop yield. The adult of *Oryctes rhinoceros* on immature and mature palms is a classic example of a key pest; the adult bored into the developing palm and each incidence either gave harmful effects to productivity or yield. If not controlled, they can cause huge crop losses.

When discussing about IPM, it is the interrelation with applied ecology. Pest management occurs within agricultural ecosystems, or agro-ecosystems, which consists the crop and its environment. By early 1970's, IPM was well accepted for crop protection (Lim, 2005). The implementation of IPM approach on oil palm had been described in detail by Wood (1984). Research on pest management occurs at each level of resolution, thereby providing the requisite understanding of the crop, the pests, the environment, and the management activities of people who allow the development of truly Integrated Pest Management (Norris *et al.* 2003). At the beginning of 2000, the pest management concept started to change radically. The Colombian Oil Palm Research Center started to not emphasize on the control of the pests, but they tried to prevent it through an adequate management of the oil palm

agriculture ecosystem (Pedro *et al.* 2003). These early experiences led to the development of integrated pest management (IPM) which involves the use of surveillance, census, monitoring and judicious use of selective pesticides (Chung & Sharma, 1999; Wood, 2004).

There are numerous definitions of pest management. The simple definition of pest management is the manipulation of pest population(s) so that they can no longer cause unacceptable losses to humans, is vague and does not capture the essence of the IPM. In RB problem, the control techniques include culture, genetic manipulation, biology, chemical, psychological, and mechanical ways which were introduced a long time ago to reduce the status of beetles to tolerable levels.

Figure 1.3 indicates an integrating concept called “The Pest Tetrahedron” which determines *O. rhinoceros* as a pest when these elements or components exist and operate. In this concept, the existing of rhinoceros beetles problem only occurs when the environment is suitable. No residue burning was evaluated. *In-situ* breeding sites (trunk chips heap) provided a suitable sites for beetle’s growth. When it comes to time, it may takes only five o six months to develop adults beetle (Norman, 2001) while palm planted will provided “a storage food” for them. As stated by Norman, (2001) that zero burning technique was suggested as the main factor for establishing *O. rhinoceros* population in the field of replanting. Natural controls, such as infection by naturally occurring pathogens or predators, may reduce the pest number in many situations. Integrated Pest Management (IPM), in utilizing the full use of biological control would be the best option to achieve environmentally sustainable oil palm production in facing the rhinoceros beetle threat (Jackson *et al.* 2003). Economic

Injury Level (EIL) indicates the level of beetles that would put the estates in an alert situation to manage the rhinoceros beetles. The General Equilibrium Position (GEP) provides a population's long-term average density. But, when the GEP is very high in some populations in relation to the crop, the environment, the time and the parasitoid or the predator, this initiates the abundance of *Oryctes* population in estates.

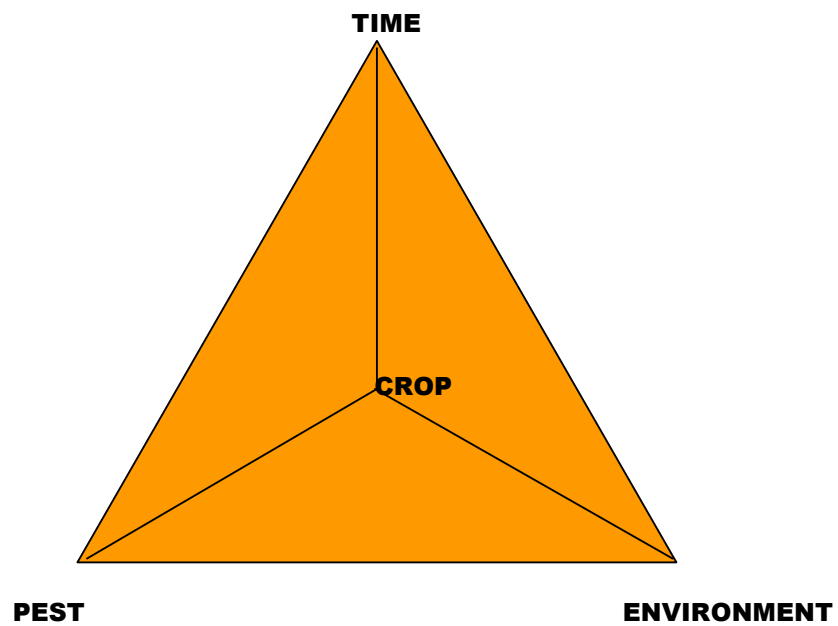


Figure 1.3: The pest tetrahedron concept for integrating the effects of pest organism, environment, time and host, as determinants of the status of the organism as a pest (Pedigo, 1991).

### 1.6.1 Research objectives

Knowledge on the ecology and biology are the main points for the researchers to take into consideration in managing the rhinoceros beetles (RB). Zero burning is an issue that causes the infestation of RB. Research findings of this study will enrich the process in providing new data, new information and methods towards the managing of the RB.

The objectives of this study are:

- i) To evaluate the damage caused by rhinoceros beetles (*O. rhinoceros*) in replanted oil palm in zero burning areas at FELDA Plantation Lepar Utara, Pahang in relation to the type of planting materials, ages of palms, location and topographies of the plantations.
- ii) To investigate the population dynamic of *O. rhinoceros* adults in immature oil palms for 14 months using pheromone traps in 40-hectare plots at Lepar utara 05, 09, and 14. The effects of abiotic factors, ages of replanted on the abundances of RB adults would be accessed.
- iii) To evaluate the effectiveness of six dosages of insecticides against *O. rhinoceros* in 1-2 years oil palm and its phytotoxicity to the tissue cultured planting materials.
- iv) To investigate the rotting age of palm chip (ages/times) in relation to the abundance and the life cycle of *O. rhinoceros* in a new replanted area in zero burning and partial burning areas.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Problems caused by rhinoceros beetle (RB) in replanting

Immature oil palms are attractive as host plants for a wide range of major pest species including many insects and vertebrates. Leaf eating caterpillars are capable of causing serious defoliation on both immature and mature palms while rats are often damaging immature palms by first chewing the fronds and then collapsing them and subsequently burrowing into the base.

The rhinoceros beetle, *Oryctes rhinoceros* is endemic in lowland areas of South East Asia. Rhinoceros beetle (RB) attacks and destroys the developing fronds and spears of oil palms. Prolonged and severe damages can result in delayed palm maturity (Chung *et al.* 1991). Adult feeding causes galleries at the base of unopened fronds. The galleries can be several dozen centimeters long (Jacquemard *et al.* 2002). In very young palms, the galleries retard the development or even kill the palm (Turner, 1981; Mariau, 2000). Within the oil palm replanting ecosystem, the study on the population and infestation levels of *O. rhinoceros* is fundamentally important in order to understand its relationship with the environmental factors and natural enemies (Norman, 2001).

In the 1960's, FELDA has started planting oil palm. In Malaysia, with the enforcement of zero burning technique by government during replanting, the population of the rhinoceros beetle increased due to the abundance of suitable breeding materials (Ramle *et al.* 2001). The larvae like many others of the subfamily Dynastinae, feed in heaps of decaying organic matter. When feeding is completed, the larvae become pupae and later emerge as adult beetles. Adults of rhinoceros beetles feed on the growing leaf tissue of palms. The incidence will bring disaster to the oil palm cultivation and if it becomes severe, palms can be dead. The main factor that contributes to the growing threat from rhinoceros beetles is the implementation of the zero burning environmental policy in the 1990's (Ho, 1996; Basri and Norman, 2000). Additionally, the heap of an empty oil palm fruit bunches (EFB) is an attractant and becomes a favourite breeding site for the beetle (Ramle *et al.* 2001; Wan Zaki *et al.* 2009).

During oil palm replanting, three common techniques that have been used; clean land clearing, underplanting (Turner and Gillbank, 1974) and trunk shred, and partial burning (McCulloch, 1982). The ground covers comprises of natural plants such as *Paspalum conjugatum*, *Nephrolepis biserrata*, *Hedyotis verticillata* and *Mikania micrantha* can completely cover the felled palm trunks at about six months after felling while the shredded trunk materials were completely covered by *Mucuna* sp. at approximately three months after partial burning (Samsudin *et al.* 1993). The mature palms were frequently attacked and even destroyed by RB. Pheromone traps were used as barrier along the blocks and is the best way to protect the palms. The same strategy was used to reduce the beetle population in old plantations before replanting (Norman, 2001). An oil palm

economic duration is between 25 to 30 years. After that, harvesting becomes difficult and less economic. At this age, it can grow up to 40 meters and ready to be replanted.

Nowadays, rhinoceros beetle (RB) has been the most important insect pest in oil palm plantation with trees less than four years especially in replanting areas where zero burning is practiced and mature palms on borders. At the same time, zero burning has provided a good breeding and foraging sites for the beetles. Damages by RB have prolonged effects to the palms because of boring activity through rachis or new spear and feeding of softer tissues in the crown region. In younger palms the effect of damage are much more severe. Attack by adult beetles may reduce 20 to 25% yield and kill the immature palms. Furthermore, they may provide entry points for lethal secondary attacks by the palm weevil or by pathogens.

Wood *et al.* (1973) reported that palms were killed in continuous repeated attack and severe damage in immature oil palm causes 40 to 50% reduction of yield for the next two year crops. The adult beetle attacks palm causing emerging leaves to be shortened and distorted with characteristic wedged-shaped appearance on the damaged fronds (Mat Amin, 2002). Unopened spear dieback or snapping, cluster or chewed materials close to frond bases, fan-shaped cutting on newly opened fronds, oval shape bore-holes on the rachis and petiole of fronds, snapping of newly opened fronds and little leaf complex on palms recovering from severe attack are symptoms of the damage by RB. Palms in replanting area are at risk as the decaying logs of the former stand of oil palms provide the breeding ground of the larvae, which develops in rotting organic material (Wood,

1968a). Replanting to replace old oil palm is profitable for the pest, because the insect develops in rotting oil palm stems left on the ground during land preparation (Samsudin *et al.* 1993; Sudharto *et al.* 2001; Kamarudin & Wahit, 1997).

Hashim *et al.* (1993) reported that the zero burning replanting technique is an environmentally sound practice which left the trunks to decompose in situ. Besides contributing to a clean environment, the zero burning replanting technique would replace soil organic matter, improves the physical and chemical properties of the soil and enhances its fertility. The ban on open burning of old palm biomass in replanting areas has resulted in very high of rhinoceros beetles population in the palm biomass and because the most serious pest in immature and young mature palms in Malaysia currently (Ooi *et al.* 2004). Beetles are attracted to organic matter in the early stages of decomposition, where female would lay eggs, then develops into feeding larvae. The beetles attacks the heart of the young palm, boring at the base of unopened leaves (spears) broken off newly emerging leaves, truncated or distorted them or even causing death to young palms (Wood, 1968a). Using a population beetle model, Barlow (2000) suggested that small patches of replanting would suffer from heavier attack than large replanting.

## **2.2 Biology and morphology of the rhinoceros beetles**

Beetles comprise the most species-rich insect order, Coleoptera. About 350,000 species have been described today, representing about 10% of the estimated actual amount (Francke & Dettner, 2005). Large numbers of valuable works published on the RB, morphology (Burton, 1971; Renou *et al.* 1998) and pest management (Toh and Brown, 1978; Ho and Toh 1982; Gurmit, 1987; Chung, 1997; Desmier *et al.* 2001; Norman, 2001; Ooi *et al.* 2004; Lim, 2005; Ramle *et al.* 2005 and Ramle *et al.* 2006). This beetle undergoes a holometabolous development with several larval instars, pupae (often poorly known), and completely transformed adults. The rhinoceros beetle belongs to the Family Scarabaeidae, Subfamily Dynastinae, Genus *Oryctes* and Species *rhinoceros*.

### **2.2.1 Family Scarabaeidae**

This is a very large family of about 2,000 genera and 20,000 species which are commonly referred as scarabs, chafers, and dung beetles. They vary in shape from round to elongated, but are usually not flattened, are glabrous and hairy, and occasionally bear scales. They are characterized by the formation of their antennae. The body length average is between 2.5 to 90.0mm. Most laparostict scarabaeidaes are dung feeders and are important agents in the recycling of the mammalian dung, especially that of the large herbivores. Many pleouristict scarabaeids are root feeders as larvae and leaf chafers as adults, although some adults feed only on pollen or nectar. A few pleuoristict scarabaeids develop, or have adults which feed in the nests of bees and ants. The root feeding larvae

of some species can become serious pests of crops and are known as white grubs, although this is actually applicable to all scarabaeid larvae (Wood, 1968a).

### **2.2.2 Subfamily Dynastinae**

This is a moderate sized subfamily with about 1,600 usually brown, rarely patterned species. The abdominal spiracles are situated in the sclerotized parts of the abdomen (pleurostict condition) and none of the three antennae of lamellae is densely pubescent with microseate. Meso- and metatarsal claws are usually of equal length, if not, then metatibiae with at most one apical spur. Labrum is usually membranous and not visible. Mandible expands at side and visible from above, even when closed (sometimes obscured by hair). Many species are sexually dimorphic in respect to the head and pronotum; the male bearing horns and/or deep excavations while the female either without, or with less strongly developed armature. Most dynastines feed as larvae on decaying organic matter, or on living plant material without doing any economic damage. A few however, have become pests, especially to palms and sugarcane (Wood, 1968a).

### **2.2.3 Eggs**

The eggs are yellowish-white, 3mm in diameter, and laid in rotting vegetative matter. Initially oval in shape, they then begin to swell about a week after being laid and hatches between 11 to 13 days (Wood, 1968a). Eggs are difficult to find because of the size and the physical condition. The larvae are usually yellowish-white in colour and may grow to about between 60 to 100mm long and more (Wood, 1968b; Ooi, 1988). Chung (2004) found that a female beetle produces an average of 60 to 100 eggs. Then, monthly

dissection of female beetles to count the number of large eggs was carried out and most female beetles (75 to 99%) were recorded to contain an average of 15.51 large eggs (range: 12.23 to 22.76).

#### **2.2.4 Larvae**

The larval stages look similar among the species within the Scarabaeid family (i.e. *Xylotrupes Gideon*, *Scapanes australis*, *Trichogomphus fairmarei*, *Orytes centaurus* and *Oryctoderus* sp.). The maximum head capsule is around 10.6 -11.4mm. The cranium is medium to dark brown, with numerous round pits, many of which bear minute setae. The thoracic spiracles are between 1.85 to 2.23mm long and 1.25 to 1.53mm wide. The respiratory plate has a maximum of 40 to 80 or more small round to oval holes along any diameter. The thoracic spiracles are larger than the abdominal spiracles, and the first abdominal spiracle is somewhat smaller than the succeeding spiracles (Bedford, 1974). A key to differentiate between the larval stages for the species is given by Bedford (1974). Lucanid and cetonid beetles, which often share the same breeding sites, may also be confused with the early instars of *O. rhinoceros* (Wood, 1968b).

#### **2.2.5 Prepupa and Pupa**

The prepupa is somewhat similar in appearance to the larval stage, except that it is shriveled, non-active and smaller than the final larval instar. Its cranium and head are non-functional at this time but still can make its own cocoon by body-reflection rhythms with decomposing materials surrounding them (soil, trunks etc.). The pupa is yellowish-

brown and measures up to 500mm long. It is segmented on the dorsal surface. The length of the protuberance on the anterior indicates the sex of the adult. A longer protuberance indicates a male and *vice versa*. It is shriveled in appearance and vibrates actively when is disturbed.

### **2.2.6 Adults**

In beetles, the front pair of wings is transformed into hardened wing covers under which the soft hind wings are folded when not in use. This hard cover provides protection which may be a major reason for the successful evolution of this largest order in the animal kingdom (Francke & Dettner, 2005). Earlier reports suggested the ability of the beetle to fly over considerable long distance (Nirula, 1955; Hinckley, 1973). But Norman *et al.* (1999) stated that, within a replanting area, the beetle was noted to be flying less than 12 metres per day likely due to the conducive environment, availability of food and breeding sites. The adults are stout looking, dark brown to black, shiny, 35-50 mm long and 20-23mm wide, with a prominent horn on the head (Wood, 1968b; Bedford, 1974). The male has a longer horn than the female but its rounded shiny terminal abdominal segment can differentiate the male more accurately while the female has a harrier ‘tail’ (Wood, 1968a). A strikingly similar but larger scarabaeid, *Oryctes gnu* (= *trituberculatus*), may be confused with the adult *O. rhinoceros* (Wood, 1968b). The difference is that there are three tubercles on the thoracic ridge for *O.rhinoceros* (Wood, 1968b).

### 2.3 Breeding sites

Many species of palms are suitable host plants for the RB. Although coconut palm appears to be the preferred host plant, 31 genera of palms were listed as host plants for the RB (Gressitt, 1953; Cumber, 1957) these include oil palms, nipah palms, nibong, sago palms, *etc.* Besides decaying oil palm trunks, the beetle also breeds in other decomposing materials, including coconut trunks, woods, sawdust, pandanus trunks, cocoa pod shells, cattle dung, paddy straw, rubber stumps, failed oil palm female inflorescence, leaf axils filled with humid organic wastes and empty oil palm fruit bunch heaps (Cumber, 1957; Barlow and Chew, 1970; Bedford, 1976a; Dhileepan, 1988). The problem is usually more serious in replants where the logs and stumps of previous coconut or oil palm stand have been windrowed to rot, providing sites for breeding. The under planting technique offers the advantages to RB where the poisoned trunks are left to decompose, and serves as suitable breeding sites for *O. rhinoceros* (Mohd and Chew, 1985) (Figure 2.1). The zero burning replanting and the disposal of empty fruit bunch (EFB) in wide scale have provided abundant on-site media for beetle breeding. Norman (2001) found that *O. rhinoceros* was still detected in the heaps up to more than two years (26 months after replanting). While Ho & Teh (2004) stated that during replanting in 'Zero Burning' plantation, it is a good practice to shred the old trunks into small pieces to accelerate decomposition of the potential breeding sites. Beetles were attracted by the volatile compounds produced through the decay of the organic matter, but also produce an aggregation pheromone, ethyl - 4 methyloctanoate, which can be used to trap beetles of both sexes (Jackson *et al.* 2003).



Figure 2.1: The under planting technique which is a suitable breeding site for RB when poisoned mature palms are rotting.

## 2.4 Life cycle

The life cycle of the rhinoceros beetle varies according to its habitat and environmental conditions. Duration of life stages is between 4.3 to 7.7 months from eggs to adult and is shown in Table 2.1 and Figure 2.2. Eggs needed between 6 to 8 days to hatch and 1<sup>st</sup> instar larvae needed between 10 to 21 days to become 2<sup>nd</sup> instar larvae. As for 3<sup>rd</sup> instar larvae, it needs a long period of growth, between 60 to 125 days. It is believed that, adult females obtain long days to survive with 274 days, compared to males with 192 days. Therefore, the period of 5 to 7 months are needed for larval development plus the further six weeks required for the maturation of adults gives a full life cycle of about 7 to 9 months when the larvae of rhinoceros beetle have developed in oil palm logs (Wood, 1968a). Dry climate or low nutritional conditions delays the larval development, which can be as long as 14 months, and give rise to smaller adults (Catley, 1969). The development cycle of the insect lasts around 4 to 5 months (Jacquemard *et al.* (2002). Adult beetles live long and with movements between feeding and breeding sites, a factor that has considerable effect on management strategies of the RB as a pest.

Table 2.1: Duration of life stages of *Oryctes rhinoceros* in oil palm\*.

| <b>STAGE</b>          | <b>RANGE<br/>(DAYS)</b> | <b>PERIOD<br/>(from oviposition of eggs)</b> | <b>SOURCE</b>                       |
|-----------------------|-------------------------|--|-------------------------------------|
| Egg- oval in shape    | 4 - 8                   | Up to 1 week                                 | Chung (2004)                        |
| Egg- round in shape   | 4 - 6                   | 1 - 2 weeks                                  | Chung (2004)                        |
| First instar larvae   | 10 - 21                 | 3 - 5 weeks                                  | Catley (1969)                       |
| Second instar larvae  | 12 - 21                 | 5 – 8 weeks                                  | Chung (2004) &<br>Catley (1969)     |
| Third instar larvae   | 60 - 125                | 3.2 – 6 months                               | Chung (2004)&<br>Catley (1969)      |
| Prepupa               | 7- 13                   | 3.4 – 6.5 months                             | Chung (2004) &<br>Bedford(1976a&b)) |
| Pupa                  | 20 - 28                 | 4.1 – 7.4 months                             | Chung (2004) &<br>Catley (1969)     |
| Adult (in pupae cell) | 8-10                    | 4.3 – 7.7 months                             | Bedford (1976a&b))                  |
| Adult female          | 274                     | –  | Hinckley (1973)                     |
| Adults male           | 192                     | –  | Hinckley (1973)                     |

\*(Based on Catley (1969), Chung (2004), Hinckley (1973) and Bedford (1976a&b))

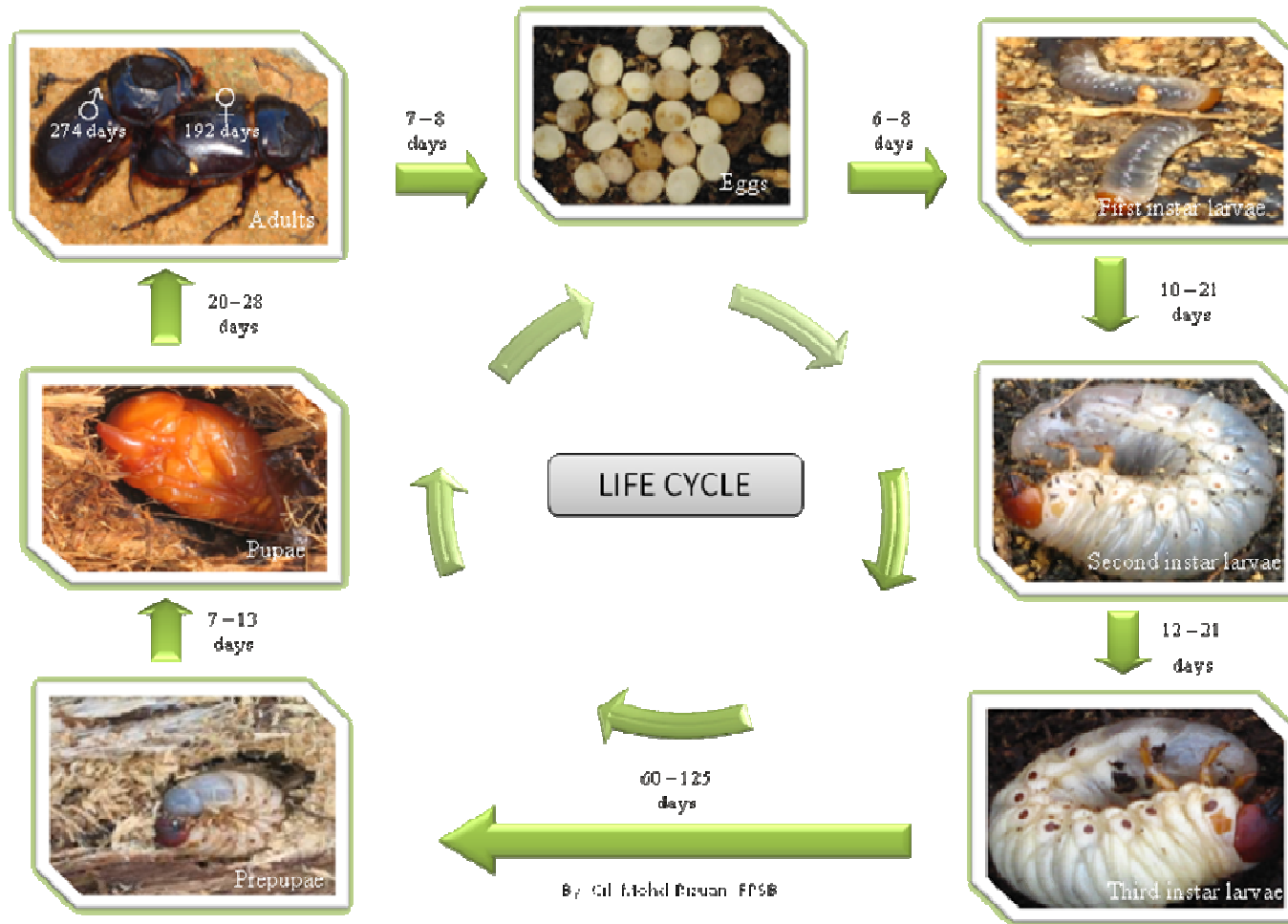


Figure 2.2 A complete life cycle of *Oryctes rhinoceros* in decomposing oil palm trunk.