EVALUATION OF SEVERAL CHEMICAL CONTROL APPROACHES AGAINST BAGWORM, *METISA PLANA* WALKER (LEPIDOPTERA: PSYCHIDAE) IN FELDA OIL PALM PLANTATIONS

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EVALUATION OF SEVERAL CHEMICAL CONTROL APPROACHES AGAINST BAGWORM, *METISA PLANA* WALKER (LEPIDOPTERA: PSYCHIDAE) IN FELDA OIL PALM PLANTATIONS

By

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بسم الله الرحمن الرحيم

In the name of Allah SWT, most Gracious, most Compassionate

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

LIST OF PLATES

Page

LIST OF APPENDICES

PENILAIAN BEBERAPA KAEDAH KAWALAN KIMIA BAGI KAWALAN ULAT BUNGKUS, *METISA PLANA* WALKER (LEPIDOPTERA: PSYCHIDAE) DI LADANG KELAPA SAWIT FELDA.

ABSTRAK

Dalam sektor perladangan sawit kawalan menggunakan racun kimia masih menjadi pilihan utama untuk mengawal serangga perosak. Dalam penyelidikan ini, beberapa siri kajian telah dijalankan bagi menilai tahap keberkesanan beberapa teknik aplikasi dan jenis racun serangga bagi kawalan *Metisa plana* di ladang sawit. Empat jenis racun kimia (trichorfon, lambda cyahothrin, cypermethrin EC & cypermethrin EW) dan racun biologi, *Bacillus thuringiensis* (Bt) telah diuji keberkesanannya bagi kawalan *M. plana* menggunakan kaedah semburan bawah pada pokok berumur 5 tahun di FELDA Besout 06. Secara amnya, didapati semua rawatan racun kimia memberi kawalan berkesan dan menurunkan populasi *M. plana* di bawah paras ambang ekonomi(< 5 larva/pelepah). Rawatan cypermethrin adalah rawatan yang paling berkesan membunuh *M. plana* sementara racun biologi, Bt adalah yang paling kurang berkesan. Racun kimia yang disembur dari bawah adalah berkesan mengawal *M. plana*. Namun, kaedah ini mempunyai produktiviti rendah dan ia tidak sesuai digunakan dikawasan serangan yang luas. Sebagai alternatf,, kajian lanjutan menilai keberkesanan racun biologi, *Bacillus thruingiensis* supsesis *kurstaki* (Btk) untuk mengawal *M. plana* telah dijalankan menggunakan kaedah semburan udara. Tiga dos rawatan (1L/ha, 2L/ha dan 3L/ha) telah diuji di kawasan serangan ulat bungkus, *M. plana* di FELDA Besout 02. Walau bagaimanapun, keputusan menunjukkan kawalan Btk terhadap, *M. plana* adalah tidak berkesan (P> 0.05) walaupun dos rawatan yang tinggi telah digunakan.. Kajian lanjutan menilai keberkesanan kaedah

suntikan batang menggunakan dua jenis racun sistemik, methamidophos dan monocrotophos telah dijalankan di kawasan pokok matang di FELDA Besout 06. Keputusan kajian telah menunjukkan kedua-dua bahan aktif tersebut sangat berkesan (P< 0.05) bagi kawalan *M. plana*, hanya dengan satu pusingan rawatan populasi perosak dapat dihapuskan. Tdak terdapat perbezaan keberkesanan bagi kedua-dua jenis bahan aktif pada P = 0.05 bagi kawalan perosak. Keputusan menunjukkan tanpa peningkatan dos rawatan, kawalan sangat berkesan dan ini membuktikan tiada kerintangan perosak terhadap racun tersebut walaupun ia telah digunakan sekian lama untuk mengawal perosak. Kaedah suntikan batang juga didapati mempunyai tahap produktif yang tinggi dan sesuai digunakan bagi kawalan serangan *M. plana* yang luas di kawasan pokok matang.

Kajian keberkesanan aplikasi racun sistemik methamidophos dan monocrotophos menggunakan teknik serapan akar telah dijalankan sebagai kaedah alternatif kepada suntikan batang dan semburan bawah bagi kawalan *M. plana*. Kajian ini telah dijalankan ladang FELDA Besout 03. Keputusan kajian menunjukkan rawatan racun sistemik menggunakan kaedah serapan akar adalah berkesan (P< 0.05) menurunkan populasi *M. plana* di bawah paras ambang ekonomi dengan hanya satu pusingan rawatan. Keputusan ini menunjukkan racun sistemik diserap dengan baik dari akar ke bahagian daun. Teknik serapan akar yang fleksibel boleh menjadi alternatif terbaik untuk kawalan *M. plana* dikawasan pokok muda dan pokok matang terutamanya dikawasan berbukit. Namun demikian, penambahbaikkan aspek alatan aplikasi yang digunapakai perlu diambil perhatian. Perkara ini penting bagi memastikan teknik serapan akar selamat kepada pekerja dan persekitaran

EVALUATION OF SEVERAL CHEMICAL CONTROL APPROACHES AGAINST BAGWORM, *METISA PLANA* (LEPIDOPTERA: PSYCHIDAE) IN FELDA OIL PALM PLANTATIONS

ABSTRACT

In oil palm plantations chemical control is still the principal means of reducing pest numbers when their population levels are high. In this study, a series of field trials investigating the efficacy of several application techniques for insecticides against bagworm, *Metisa plana*, were carried out in oil palm plantations. The efficacy of the ground spraying technique for four insecticides (trichorfon, lambda cyahothrin, cypermethrin EC and cypermethrin EW) as well as a bio insecticide, *Bacillus thuringiensis* (Bt), was investigated upon 5 year-old palms in FELDA Besout 06. In general, each insecticide provided satisfactory control against *M. plana*, and pest populations were reduced to below the economic threshold level (< 5 larvae/frond). Cypermethrin was the most effective treatment, whereas bio insecticide treatment was the least effective. While ground spraying was effective against *M. plana* in this study, this technique was not suitable for controlling a large-scale bagworm outbreaks due to its low productivity and small area coverage. As an alternative, the bio insecticide, *Bacillus thringiensis* subspecies *kurstaki* (Btk), was applied by using an aerial spraying technique and its efficacy assessed. Three dosages (1 L/ha, 2 L/ha and 3 L/ha) of commercially formulated Btk were tested in areas of high *M. plana* infestation in FELDA Besout 02. However, the treatment was not as effective as the chemical insecticides ($P > 0.05$), even at the highest dosage. Further efficacy assessments were carried out using a trunk injection technique for systemic insecticides methamidophos and monocrotophos, in mature palms in FELDA Besout

06. The results showed that both insecticides were highly effective ($P<0.05$) against *M. plana*, with the pest populations eradicated following a single application. No significant difference in effectiveness of methamidophos and monocrotophos was detected at $P = 0.05$. The results also showed that *M. plana* populations were susceptible to these insecticides with no increase of previously used dosages, indicating that although they have been used in the field for a long time, the pests have not developed resistance to them. The trunk injection technique has proven to be the most suitable technique to control large-scale bagworm outbreaks in mature oil palm plantations.

The efficacies of methamidophos and monocrotophos were further evaluated on young palms in FELDA Besout 03, using root absorption as an alternative method to trunk injection and spraying techniques. Results from this study showed that both insecticides were effective against pest populations using this technique ($P<0.05$), reducing them to below the economic threshold level. This indicates that these insecticides are efficiently trans-located from the roots to the foliage, and identifies this technique as a suitable alternative method for controlling *M. plana* in both young and mature palms, especially in hilly areas, as it is easy to implement. Further improvement and optimisation of this technique would minimise chemical contamination to the environment and ensure safer use, especially for the applicators.

CHAPTER ONE

GENERAL INTRODUCTION

1.1 FELDA oil palm cultivation

Federal Land Development Authority, better known as FELDA is the foremost land development agency in Malaysia established on July 1st 1956 under the Land Development Ordinance of 1955 (FELDA, 2007). The primary objectives of FELDA establishment are to develop forest land into productive agricultural areas and to evolve a progressive society having a better quality of life through resettlement of the rural poor (Tunku Shamsul & Lee, 1988). Today, after five decades of its establishment, FELDA has developed 480 new areas covering a total of 853,313 ha with plantation and settlements (Mohd Said, 2006). More than 600,000 ha of agricultural area under FELDA have been developed with oil palm as a major crop. Today FELDA has become the largest cultivator of oil palm in the world (FELDA, 2007).

To maintain the status as the biggest producer of palm oil in the world, FELDA is committed to produce sustainable palm oil through implementation of Good Agriculture Practices (GAP) based on safe and sustainable development principles and management, which comply with local safety standards, laws and regulations (FASSB, 2005). In its crop protection, the GAP concepts are practiced through the implementation of the Integrated Pests Management (IPM) (FASSB, 2005, Noor Hisham *et al.,* 2007). IPM is defined as a pest management system that utilises all suitable techniques in as compatible a manner as possible and maintains the pest populations at level below those causing economically unacceptable damage (FAO, 1968; Stern (1959). Wood (1971) proposed the idea of using IPM for the control of bagworm pest in which effective and selective insecticides were recommended to ensure that the pest was controlled while sparing the natural enemies for environmental friendly approach.

1.2 Malaysian oil palm industry and bagworms pest problem.

Oil palm, like all other crops, is susceptible to attack by several insect pests causing significant reductions in yields. Various injurious pests affecting the oil palms have been described by Hartley (1967) and Wood (1968). Of these, bagworms are one of the serious occasional insect pests (Wood *et al.,* 1974; Basri *et al.,* 1988; Basri, 1993; Eow, 2001; Howard *et al.,* 2001; Ho, 2002). They are called bagworms because they live in 'bags', which they carry on their bodies. Locally they are called 'ulat bungkus'.

The common species of bagworms that damage oil palm plantation in Malaysia are *Metisa plana* Walker, *Pteroma pendula* Joannis and *Mahasena corbetti* Tam (Woods, 1968; Hartley, 1967; Syed *et al.,* 1978; Sing, 1986, Basri *et al.,* 1988; Chung, 1988 and Hoong & Ho, 1991; Norman *et al.,* 1998). The most damaging species in peninsular Malaysia is *M. plana*, followed by *P. pendula* and *M. corbetti.* In Sabah and Sarawak, *M. corbetti* has been reported to be the most important, followed by *P. pendula* and *M. plana* (Basri *et al.,* 1988). More than one species could occur simultaneously during an outbreak in both young and old palm (Basri *et al*., 1988; Wan Ibrahim, 1992). Bagworms are voracious phytophagous pests and during an outbreak enormous amounts of photosynthetic leaf areas of oil palm are devoured and lost as the caterpillars complete their life cycle (Syed, 1978; Khoo *et al.*, 1991; Basri & Kegan, 1995; Ho, 2002). The bagworm, *M. plana* is a native pest that has become adapted to the introduced oil palm (Wood, 1976). Defoliation by bagworms adversely affects productivity of oil palm by reducing both number and size of fruit bunches (Wood *et al.*, 1973).

Economic losses caused by defoliators have been estimated by Basri (1993). Natural defoliation reduced about 10 -13 percent yield. However, a crop loss caused by *M. plana* could reach anywhere from 33-40 percent (Wood *et al.*, 1973). Nevertheless, the timely control pests in its early stages of development can significantly lower the cost of control while preventing any crop loss due to defoliation (Wood, 1968; Mackenzie, 1977; Noor Hisham *et al.*, 2004) Therefore, good understanding of biology and population management of on these organisms is very important for planters to ensure a balanced ecosystem which will reduce the chances of outbreak of pests in their plantation (Chung *et al*., 1995; Liew, 1999).

Management of insect pests in oil palm plantation today presents many challenges. The concept of environmental friendly management adopted by oil palm industry in Malaysia has totally changed the approach of any program involving pest control, particularly, in oil palm plantation (MPOB 2007). Through this concept, the use of chemicals is not just for spray and kills the pests but also involves evaluating the indirect effects especially to the non target organisms and the environment (FASSB, 2005; MPOB, 2007). According to Syed & Salleh (1991) insecticides are very potent weapons and their use has to be continued if man is to meet the ever increasing demand for agricultural produce. Their use must, however, be deliberate, selective and suitable to the environment. More importantly, correct application methods of suitable insecticides will ensure effective treatments with minimal impact to non target organisms. Furthermore the choice of control measure must be practical to suit the situation in the field (Basri *et al.,* 1989; Desmier de Chenon *et al.,* 1989).

1.3 *Metisa plana* infestation in FELDA

Noor Hisham *et al.,* (2002) reported that infestation of bagworm, *M. plana* in FELDA Gunung Besout complexes occurred since the 1980's. Today, the problem has become more serious with thousands of ha of oil palm being affected and the outbreaks are seemingly persistent each year (Noor Hisham *et al.,* 2004; 2007). Various control methods such as trunk injection technique using systemic insecticides, ground spraying and aerial spraying have been employed by many estates to control the bagworm infestation. However, most of their control programs reported poor results (PPPT, 2006). Several technical problems have been identified as very critical in obtaining good control of bagworms. Lack of knowledge on application methods and less information on the insecticides products especially the bio insecticides have been identified as the major factors. For these reasons together with human safety concerns, efforts have been focused on developing new techniques and new products by the management of FELDA (FASSB, 2005).

1.4 Objective of studies.

This study evaluated the efficacy of several type of insecticide application techniques namely ground spraying, aerial spraying, trunk injection and root absorption against *M. plana* infestation in FELDA oil palm plantation. Efficiency of each technique, cost of application and advantages and problem of each technique would be documented. The specific objectives of this research are as follows:-

1. To evaluate the efficacy of the ground spraying technique of four insecticides namely trichorfon, lambda cyahothrin, cypermethrin EC and cypermethrin EW and a bio insecticide, *Bacillus thuringiensis* (Bt) against *M. plana* on young oil palm.
2. To study the effectiveness of aerial application of *Bacillus thuringiensis* (Bt) supsp. *Kurstaki* to control of bagworm, *M. plana* in large scale infestation of oil palm plantation.
3. To investigate the efficacy of trunks injection technique of methamidophos and monocrotophos against bagworm, *M plana* in mature oil palm.
4. To study the efficacy of root absorption technique of methamidophos and monocrotophos for controlling *M. plana* in oil palm plantation.

The information gathered from these studies would contribute to the planning and controlling the bagworm in oil palm particularly in FELDA plantations. Subsequently, the yield losses caused by bagworm could be reduced and making the business more profitable.

CHAPTER TWO

LITERATURE REVIEW

2.1 Bagworm (Family: Psychidae)

Bagworms are small moths of the family Psychidae. The larvae construct cases out of silk and plants materials, sands, soil and lichen (Borror & White, 1970; Kalshoven, 1981; Robinson *et al.,* 1994). Cases of each species are very specific and useful for identification (Hartley, 1967). There are more than 60 species of bagworms known from Southeast Asia (Robinson *et al.,* 1994), of which 16 are recorded in Peninsular Malaysia, Sabah and Sarawak. They infest forest trees, shrubs, weeds, ornamental plants and cultivated crops (Norman *et al.,* 1995) such as oil palm, cocoa, cinchona, tea and coffee (Kalshoven, 1981).

The bagworms are pests in the immature stages. The larval stages are eruciform with well developed and scleritonized head and thoracic legs. They are characterized by the possession of cases, which they inhabit throughout their development (Davis, 1964). The bagworm begins to build its case as soon as it hatches. The tube-like bag opens at the anterior end to allow feeding and at posterior end to permit ejection of solid excrement (Kalshoven, 1981; Howard *et al.,* 2001). Neonatal larvae are known to either immediately crawl out of the posterior opening of the female bag onto the host plant or hang down a silk thread to be transported or ballooned away from their mother prior to feeding and bag constructions (Rhainds & Ho, 2002). As the larvae grow, they continually enlarge their cases. Bagworm larvae are generally polyphagus, some species eat lichen, while others prefer green leaves (Borror & White, 1970). The cases are attached and fixed to trees, rocks or fences except when feeding or moving on leaves (Davis, 1964).

Bagworms extend their heads from their mobile cases to devour the leaves of host plants, often leading to the damage of their hosts (Syed & Salleh, 1991; Basri & Kegan, 1995). Female bagworms have greater feeding requirements and longer larval development period than males (Basri & Kevan, 1995). The pupal stages are generally shorter for the females than males (Basri & Kevan, 1995; Rhainds *et al.*, 1998). Sexual dimorphism in pupae and bag morphology is very clear. Male pupae have all the normal characteristic of an obtect larval type namely, exhibiting eyes, antennae and wing sheaths and leg membranes (David, 1964; Borror & White, 1970; Robinson, *et al.*, 1994). Female pupae are larger, elongated vermiform and cylinder, lacking antennae and wing sheaths. The eyes are vestigial and the legs reduced to buds (Davis, 1964).

The adult males are small, dull colour and posses wings. Most species are strong fliers with well-developed wings and feathery antennae (Davis, 1964; Borror & White, 1970). They survive only long enough to reproduce due to under developed mouthparts that prevent them from feeding. Most of the wings have a thin covering of hairs with very few scales (Borror & White, 1970; Robinson *et al.*, 1994). They also have extensible abdomen for trotting the bags of females during copulation (Davis, 1964). The females are wingless and do not have legs. They lack antennae and eyes and without normal metamorphosis. They retain a wormlike appearance (Kalshoven, 1981) with vestigial mouthparts (Robinson *et al.*, 1994). Wingless females would remain in the pupal cases and lay eggs in their bags. Eggs are generally cream to pale yellow in colour, soft, oblong to barrel shaped, and less than 1 mm long depending on the species (Davis, 1964; Basri & Kevan, 1995).

2.2 Oil Palm and bagworm problem

Oil palms are tropical plants in the family of Palmae and consisting of two species. The African oil palm *Elaies guineensis* is native to Africa and better known as the African oil palm. Another species, American Oil Palm, *Elaies oleifera* or referred to *Elaeis melanococa* is native to central and South America (Hartley, 1967; Dennis, 1985; Moll, 1987; Gascon, *et al.,* 1989). *Elaies guineensis* is used for commercial planting while *E. oleifera* has no economic importance but could become useful for breeding purpose (Dennis, 1985; Moll, 1987; Gascon, *et al.*, 1989; Rajanaidu *et al.*, 2000).

The oil palm is a monoecious plant (Hartley, 1967; Moll, 1987; Dennis, 1985; Latiff, 2000). The plant has a single terminal growing point and grows up to 20 to 30 meters **(**Moll, 1987). Oil palm fronds can reach 7 meters long and consist of leaflets in rachis numbering 250-300 per leaf. Each leaf has short thorns at its base and about 250 leaflets in an irregular pattern on both sides of the petiole (Hartley, 1967; Gray, 1969)**.** Thus, these leaflets are not continuous like the tines of a feather. In fact, the irregular appearance of the frond is one of the characteristic features of this species (Latiff, 2000; Roslan & Hanif, 2004). With the practice of pruning to facilitate harvesting, 35-40 fronds are normally left on the palms (Hartley, 1967). Corley & Gray (1976) estimated the lamina area of a frond of a 10.5 year-old palm to be 102, 800 cm^2. This translates into a vast amount of leaf area for feeding of leaf eating pests in the monoculture environment of oil palm.

There are seven species of bagworms found in association with oil palm namely *M. plana M. corbetti, P. pendula*, *Brachycyttarus griseus*, *Manatha albipes, Amtissa* sp. and *Cryptothelea cardiophaga* (Norman *et al.,* 1995). Bagworms are occasional pests of oil palm in Malaysia, but they can cause serious damage during outbreak if not controlled and the attack can recur on both young and old palms (Turner & Gillbanks, 2003). The three common bagworm species in Malaysia are *M. plana*, *P. pendula* and *M. corbetti*. High prevalence of M. plana was reported in the Peninsular while M. corbetti was more injurious in Sabah and Sarawak (Woods, 1968; Hartley, 1967; Syed *et al.,* 1978; Sing, 1986, Basri *et al.,* 1988 and Chung, 1988).

The *M. plana* was first recorded in Malaysia in a garden palm on *Terminalia cattapa* in 1955 and never attacked oil palm (Wood, 1968). Before 1956, Khoo *et a*. (1991) reported that *M. plana* was not known to be problematic in Malaysian oil palm. However, soon after the pest has become very important. Similar development was observed in Indonesia, Hutauruk & Situmorang (1970) reported that *M. plana* existed in the field for a long time but never threatened the oil palm plantations. Only in late 1958 the pest has become serious and thousands of hectares oil palm plantations had been affected. Researchers claimed that the development of infestation was surmised due to the extensive use of broad spectrum residual contact insecticides (Wood, 1968; Basri *et al.,* 1988; Noor Hisham *et al.,* 2004). The infestation provided an excellent example of pest outbreaks that developed under suitable conditions in areas of extensive monoculture of oil palm plantation, once a balanced situation was disturbed (Wood, 1968). In FELDA, Noor Hisham *et al.* (2004) reported that *M. plana* has caused severe outbreaks especially in FELDA oil palm plantations in Besout and Trolak complexes in Sungkai Perak since 1980s. Various control methods have been employed to control the infestation. However, continues outbreaks occurred for the past 30 years causing large amount of losses (Noor Hisham *et al.*, 2007). The severity of attacks in that complexes had given considerable cause for concern and necessitated high expenditure on control measures (Liew, 1999; Noor Hisham *et al.*, 2004; 2007)

2.3 Biology and morfology of *Metisa plana*

Larvae of *M. plana* were eruciform with a well developed and sclerotized head, distinct prothorax, mesothorax and metathorax and 10 abdominal segments. Each segment of the thorax bore a pair of well developed, 5 segmented legs that ended in a sharp claw that served for locomotion and holding onto the leaf or substrate (Ho, 2002). Neonatal larvae emerged from the opening of the pupal bag and most of them would leave the mother's bag by ballooning on gossamer thread (Rhainds & Ho, 2002; Ho, 2002). The larval of *M. plana* feeds for about eight weeks after which pupation occurs. Advance larval stage (instars 5 to 7) are approximately 19 mm long (Rhainds, 2000; Rhainds & Ho, 2002 and Ho, 2002).

The larvae have a brown and white head capsule (Ho, 2002). These cases are composed of small pieces of leaf tissues. The case is augmented throughout larval development (Basri, 1993; Rhainds & Ho, 2002). The young caterpillars scrape the epidermis on upper surface of leaf whilst the more mature ones make holes in the oil palm leaf (Wood, 1968, Ho, 2002). Basri (1993) reported feeding behaviour of *M. plana* to change from scrapping to cutting after the 5th larval instar with instar 7 removing the greatest amount of tissue. In contrast, the study by Ho (2002) showed that instar 3 to instar 5 of *M. plana* scrape the leaf causing damages of leaf area at the average of 4.623 cm^2 or 0.03 gram dry weight of leaf in a complete life cycle. These badly damaged leaves soon dry up giving the lower and middle part of the crown its characteristic brown and scorching look (Basri, 1993; Norman *et al.*, 1995). In a severe outbreak the larvae tend to concentrate on the upper fronds but, since necrosis and damages occur gradually as new fronds are emerging in the top of the crown, the lower fronds may seem to be more severely damaged. The appearance of the characteristic 'shot holes' on newly opened fronds are danger signs that an outbreak would soon commences (Wood, 1968).

A study carried out by Ho (2002) demonstrated differences in composition of males and females instars in the immature of *M. plana*. He found that males have 5-6 instar stages while females have 6-7 instars. Meanwhile Wood in 1968 reported that only four instars occurred in both sexes. Nevertheless, Syed, (1978) found that there were 6 larval instars in both sexes. Similar to other species of bagworms, instar recognition is made by measuring the head capsule width of the larvae (Rhainds, 2000; Ho, 2002) However, in the field the measurement can be difficult because the leaves concealed in the bags. In this situation, bag length and bag morphology can become useful (Basri & Kevan, 1995). Several plant families are recorded as host plants for *M. plana*. They are *Pterocarpus indicus* (Leguminosae), *Coffea liberoca* (Rubiaceae), *Camellia sinensis* (Theaceae), *Cocos nucifera* (Palmae) and *Elaeis guineensis* (Palmae) (Robinson *et al.*, 1994). The *M. plana* usually attack mature palms, but young palms too are not spared (Wan Ibrahim, 1992). Usually the young palms are less infested because the fronds are not yet in contact with each other hence restrict dispersion of the pests (Wood, 1968; Wan Ibrahim, 1992).

Surviving caterpillars migrate to the underside of the leaves where they pupate in their cases. The pupae cases is sub-cylindrical up to 15 mm long, smooth-surfaced, with a hook shaped attachment to the leaf (Hartley, 1967; Chung, 1988, Khoo *et al*., 1991, Rhainds *et al.*, 1998). The female cases are larger than those of males (Rhainds *et al.*, 1998; Rhainds & Ho, 2002). Female's pupal cases are about 14.5 mm while male cases are 5.00 mm to 13.0 mm. The female pre-pupal and pupal period lasted 1-3 days and 2-8 days respectively. Meanwhile the male pre-pupal and pupal stages take 1-3 days and 8-18 days respectively depending on the environmental conditions (Ho, 2002).

The female adult assumes a form and size similar to that of the pupal case. It is maggot-like with a vestigial and lightly sclerotized head (Robinson, *et al.*, 1994). Females are wingless and spend their entire life cycle within the bags (Basri, 1993; Rhainds, 2000). The males or moths emerge on splitting the pupal shell and are ready for flight after the wings harden (Ho, 2002). Male adult wing span is up to 20 mm. Its scales in the cell are of uniform, long and almost hair – like, giving the wings an overall semi-transparent appearance (Robinson, *et al.*, 1994, Rhainds, 1999 and Ho, 2002).

Bagworms, including *M. plana*, have been reported to lay all their eggs immediately after mating (Rhainds, 2000). The female laid 100- 300 eggs in her bag (Wood, 1968). In a more recent study, Ho (2002) reported that fertilized females can produces 107 to

164 eggs in the laboratory condition and 121 to 201 eggs in the field. Eggs of *M. plana* are barrel shaped and pale to orange –yellow in colour with mean width and length range from 0.48-0.49 mm and 0.72-0.73 mm respectively. Mean incubation period of *M. plana* eggs are 6.5 to 8.4 days in field condition and 8.5 to 13.2 days in the laboratory condition (Ho, 2002).

Fertilized females lay their egg into the pupal case together with hair-like scales. Fertilized eggs in time showed clear signs of embryonic development otherwise they remain clear (Basri & Kegan, 1995; Ho, 2002). The eggs turn yellowish to black colour, signalling the emergence of larvae (Ho, 2002). The fertile eggs begin to hatch two or three weeks (Wood, 1968; Khoo *et al.*, 1991; Ho, 2002). An approximately compete life span of *M. plana* was reported to be little over 3 months (Wood, 1968 and Koo *et al*, 1991). Fed with oil palm leaves average total life cycle of *M. plana* fed with oil palm leaves was about 75 to 92 days in the field and laboratory conditions (Basri & Kegan, 1995 and Ho, 2002 – Figure 2.0). When the larvae were reared on alternative host, *Cassia* sp the males larvae took an average of 80 days and the females spent 113 days (Khoo *et al*., 1991) before turning to pupae. Syed (1978) also reported longer life cycle of the bagworm (107-168 days) living on Cassia sp.

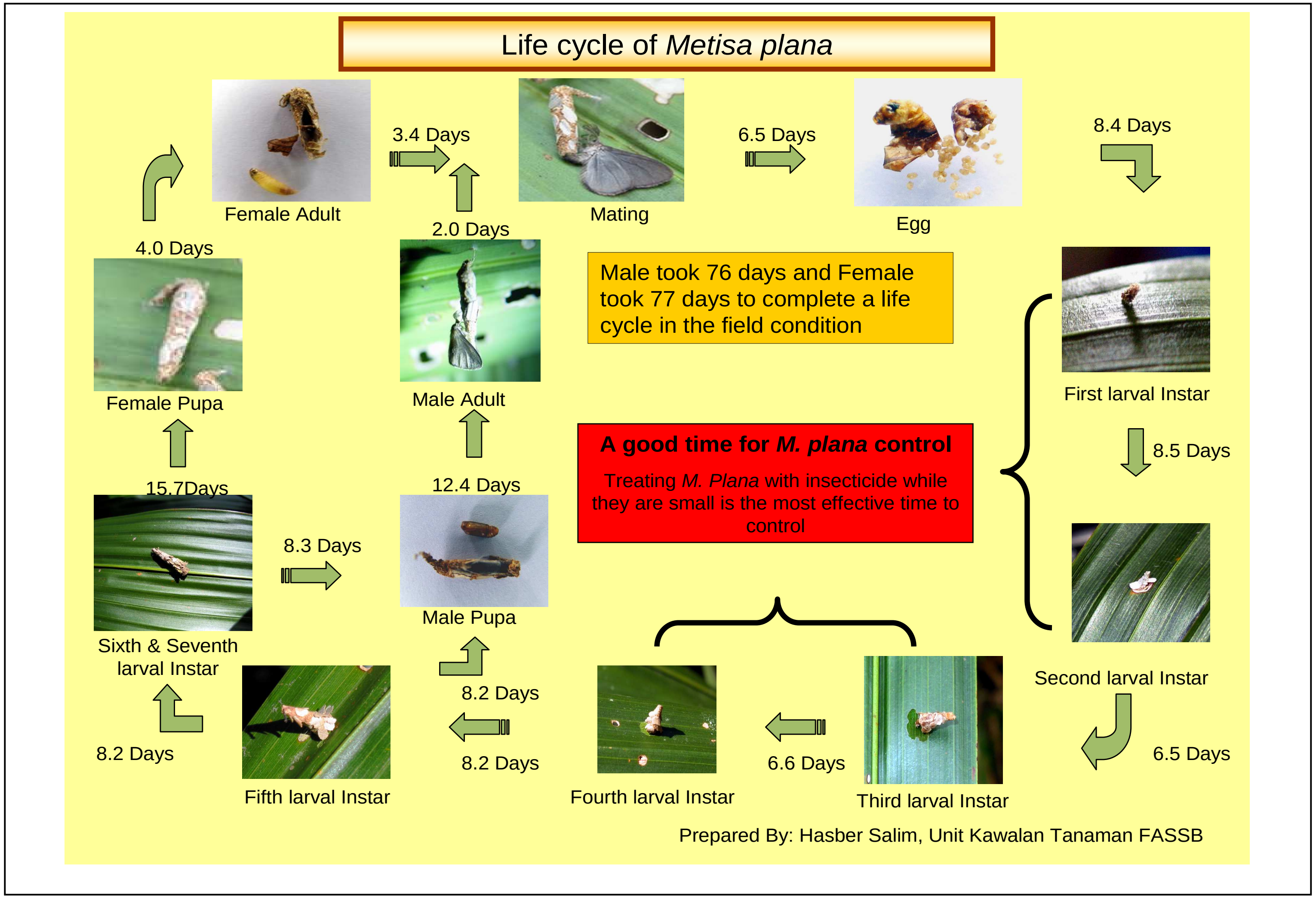

Figure 2.0**:** Life cycle of *Metisa plana* according to Basri & Kegan, 1995 and Ho, 2002

2.4 Population dynamics and managament of *Metisa plana* in oil palm plantation.

Usually *M. plana* population does not have economic impact in the production of oil palms. However, outbreaks of this pest occur occasionally when the environment is conducive for its population growth (Wood, 1968). The outbreak of *M. plana* in oil palms plantation is probably a result of complex interactions between biotic and abiotic factors. Factors such as dry weather, absence of ground cover, low incidence of natural enemies and road dust have been reported responsible for the occurrences of outbreaks (Wood, 1968; Basri, *et al*., 1988; Ho, 2002). Many researchers (Hartley, 1967; Mackenzie, 1976; Sipayung *et al.*, 1989) agreed that increases of *M. plana* outbreak in Malaysia were caused by excessive use of contact insecticides to control the bagworm and other pests thus killing its natural enemies.

Larvae of *M. plana* would remain on the same palm or frond where they hatched, but move to new hosts in response to high population pressure for their survival (Rhainds & Ho, 2002; Ho, 2002). Since the female is incapable of flying to distribute her eggs, the spread and dispersal of bagworms is entirely dependent on the larvae (Rhainds, 2000). Aggressive movement of young instars can ensure that they can disperse to far away areas and commence new infestations (Rhainds *et al.,* 1998; Rhainds, 2002 Rhainds & Ho, 2002) The spread of an infestation within an oil palm is mainly due to the caterpillars walking from palm to palm, either across fronds that are in contact with one another or on the ground. The major mode of dispersal to surrounding hosts involves ballooning by larvae that suspend themselves from silken thread to be wind –dispensed (Rhainds & Ho, 2002) or carried by plantation vehicles (Noor Hisham, *et al,* 2004).Therefore, the new infestation of bagworms normally occur in the adjacent plantations near to the main road. Normally, bagworms appear to eat for a while on one leaf and then move elsewhere (Rhainds, 2000; Ho, 2002)

Bagworms are difficult to control because their present are often unnoticed until they mature (Wood, 1968). Good surveillances on the extent of infestation and the stages of bagworm life cycle are very important information for halting the outbreaks. Thus, the implementation of a proper monitoring and surveillance (MSS) by establishing of Pest Monitoring System (PMS) is an important component for efficient control of bagworm (Chung *et al.*, 1995; Liew, 1999). The knowledge on the biology of the pests, recognition of individual species and its damage symptoms are important for early detection of infestation (Chung, 1998). More importantly is the acceptance by the management that the bagworm especially the *M. plana* is a serious pest of oil palm (Chung *et al.*, 1995).

According to Chung *et al.* (1995) the implementations of IPM control of bagworm relies heavily on the development of good MSS practiced by the planters. The PMS is useful to provide information on the pest presence and activity. It involves the ability to recognize the pest, its biology, its key natural enemies and damages the pest caused (Chung *et al.*, 1995; Liew, 1999; Noor Hisham *et al.*, 2007). The MSS can also help planters to determine the right time to control the pest (Noor Hisham *et al.*, 2007). Recently, due to increasing awareness of environmental safety, the biological control uses pests natural enemies has become the main focus by many estates. The biological control using pests natural enemies in maintaining the pest population density at a lower average than it would occur in their absence (Wood, 1968; Desmier de Chenon *et al.*, 1989). In oil palm plantation, the biological control of bagworm is enhanced by cultivation of nectariferous plants like *Euphorbia heterophylla*, *Cassia cobanens*is, *Antigonon leptopus* and *Turnera subulata* in and around infested fields (Basri *et al.*, 1999; Eow, 2001; Basri & Norman, 2002)

These beneficial plants encourage the establishment of parasitoid populations and predators of bagworms by providing their adults stages with nectar and shelters (Desmier de Chenon *et al.,* 1989; Basri *et al.,* 1989). However, the biology and life cycle of natural enemies of bagworm are little known although oil palm plantations have been inspected by many entomologists (Sipayung *et al*., 1989; Desmier de Chenon *et al.*, 1989; Basri *et al.*, 1989). Information on parasitoids and predators of bagworms especially *M. plana* and *M.corbetti* is still limited. Studies by Basri *et al.*, 1995 and Norman *et al.*, 1998; 2004 reported that *M. plana* are mainly parasitized by Hymenepteran parasitoids from family Braconidae, Eulophidae and Ichneumonidae. Usually programs of biological control are for long term control and their successes are only materialised after numerous attempts. Moreover, pest control by using natural enemies is not as popular as using pesticides (Wood, 1968; Sipayung *et al.,* 1989; Desmier de Chenon *et al.,* 1989; Basri *et al.,* 1989; Norman *et al.,* 2004).

2.5 Quantitative assessment of losses and economic threshold level of *Metisa plana* on oil palm plantation

During the pest outbreak, enormous amount of photosynthetic leaf areas are devoured as bagworms complete their life cycle (Davis, 1964; Syed & Salleh, 1991; Liau & Ahmad, 1995; Basri & Kegan 1995). The depletion in photosynthetic ability due to loss of foliage would result in severe yield loss in mature palms (Basri, 1993; Liau & Ahmad, 1995). Actually, the pests remain quite small and damage is only severe when they are present in extremely large numbers (Wood, 1968). Outbreaks of *M. plana* are known to severely defoliate leaf of oil palm. Defoliation by bagworm adversely affects productivity of oil palm by reducing both number and size of fruit bunches (Wood *et al.*, 1973). As reported by Liau & Ahmad (1995) substantial yield loses (30-76% over 2 years) occurred due to defoliation by bagworms. Moreover, according to Basri (1993) when the bagworm defoliation was in the range of 10-13 percent, crop loss of 33-40 percent could be expected.

In Sumatra, it has been estimated that the bagworm infestation ranging from slight to severe caused 10-25% yield reductions (Hutauruk & Situmarung, 1970). The cost of controlling the pest also contributed to the loss, consequently the monetary value involved was very high (Wood, 1968). The control expenditure is very much higher when insecticides are applied aerially. For example in 2004 FELDA Besout Complexes spent approximately RM 2 million for their first aerial spraying of triclorphon insecticide against bagworms in 1500 ha of infested areas (Nor Hisham *et al*, 2004).

The economic injury level (EIL) is an important IPM component which is defined as 'the lowest population density that causes economic damage' (Stem *et al.*, 1959). The economic threshold (ET) however is the population density at which control measures should be initiated to prevent an increasing population from reaching the EIL (Stem *et al.*, 1959; Wood, 1968). In Malaysia, the ET for *M. plana* in oil palm has been decided at 5 - 10 larvae per frond (Wood, 1971; Hoong & Hoh, 1992). From studies on bagworm's feeding studies, survivorship and nature of damages in the field, Basri (1993) suggested a wider range of threshold level of 7 to 47 larvae per frond. Higher threshold of 30-60 larvae per frond has been suggested for bagworm by IRHO (1991). However, Wood's threshold level of 10 larvae per frond is well accepted by the oil palm industry in Malaysia (Basri *et al.*, 1988)

2.6 Chemical insecticides and its application

In oil palm industry, chemical control is still the principal mean of controlling pests once the economic threshold level is reached. Insecticides are convenient to use and often provide quick reduction in the pest numbers (Wood, 1968; Chung, 1998). They are cheap and easy to handle, fast-acting and in most instances are very reliable especially for bagworm's infestation (Wood, 1968). Chemical insecticides have allowed satisfactory management of larger hectares of land areas by fewer individuals compared to physical and mechanical controls (Basri *et al*., 1988). However, due to the presence of plentiful natural enemies in the field, judicious insecticide treatment must be instituted to prevent decimation of beneficial organisms subsequently avoiding secondary or continuous outbreaks of pests (Turner a& Gillbanks, 2003)

Several types of insecticides have been found highly effective against bagworm in oil palm plantation when applied by using appropriate techniques (Wood, 1968; Chung, 1988). Commonly, several organophosphates, carbamates, and synthetic pyrethroids are recommended for use in Malaysian oil palm plantations (Chung, 1988, Chung 1998). The advantages of chemical control have been reported by many researchers (Wood, 1968; Hutauruk & Situmorang, 1970; Mackenzi, 1977; Noor Hisham *et al.* 2004) and it is generally agreed that trichlorfon is the most effective insecticides against bagworms. Based on a survey conducted by Basri *et al.* (1988) in 78 oil palm plantation in peninsular Malaysia reported that triclorphon is the most popular insecticide used to control bagworm in oil palm plantation. Nevertheless, insecticides from the synthetic pirethroid group mainly cypermethrin, cyflutrin and lambda cyhalothrin were recently preferable because they were much cheaper than triclorfon (Chung & Narendran, 1996; Chung, 1998).

The applications of insecticides to kill bagworms are very versatile depending on mode of action of the insecticides (Khoo *et al.,* 1983). Insecticides with contact action can be applied by various techniques of spraying such as ground and aerial spraying and fogging. The stomach poisons (those that must be ingested) can be applied by trunk injection and root absorption technique. Various types of spraying equipments for applying insecticides in the plantations are readily available in the market (Wood, 1968). Several types of chemical application techniques have been adopted in controlling bagworm infestation including ground spraying, aerial spraying, trunk injection (Hutauruk & Sipayung, 1978; Basri *et al.* 1988; Chung, 1988; Ang *et al*., 1998; Chung, 1998; Yap, 2000) and root absorption technique (Sinuraya *et al.,* 1989). Spraying technique is the most common practiced to apply contact poisons and biological insecticides in the field. In ground spraying a knapsack sprayer or a motorized knapsack mist-blower is used to spray oil palm seedlings in nurseries and young palms in newly planted field (Wood & Nesbit, 1969). A range of sprayer equipments are used for pesticide application in oil palm (Khoo *et al*., 1991). The choice of equipment is dependent on the age and height of palms (Basri *et al*., 1988). Lever-operated knapsack sprayers or mist blower are suitable and commonly used for young palms from one to three years old. The use of mini-micron portable mist-blowers adapted for shoulder mounting was employed to control caterpillar pest outbreaks in oil palm in Sabah (Wood & Nesbit, 1969). The semi-mechanised equipment or power sprayer is more suitable for more vigorous palms of four to six years old. The power sprayer is essentially meant for high volume spraying and very useful for spraying young palm especially those planted in low-lying soft ground and hilly terraces on slopes (Wood, 1968; Khoo *et al.,* 1991; Ho, 1997)). In some outbreaks, the spray gun attached to along bamboo / iron pole was used to spray bagworms or caterpillars on taller palms (Ho, 1997; Chung, 1998).

The air-blast or turbo-mizer sprayers were used to control palms of more than 40 feet high (Khoo *et. al.,* 1991). Three air-blast equipments namely, Hardi Combi 2™ Mist blower, Turbo-Mist™ Sprayer and Berthoud™ Mist blower, which are tractor mounted/driven equipments, were successfully evaluated for spraying of insecticides to control bagworm in mature palms on coastal flats (Chung, 1988). Besides the height of palms, other factors are also considered in the selecting of spraying equipments. These include the accessibility of the area to be sprayed, size of the area and cost of operation (Basri *et. al.,* 1988). Since spraying of insecticides directly expose the chemicals to environment, it risks non target organisms especially the beneficial species such as pollinators and natural enemies. The adverse effects could be reduced when applied by highly skilled operators with good knowledge on handling of chemicals (Khoo *et al.,* 1983; 1991). Aerial spraying was employed to apply insecticides for controlling pest outbreak over large areas as well as for tall palms (Wood, 1968; Wan Ibrahim & Leong 1977; Chung, 1988).

Systemic pesticides such as monocrotophos and methamidophos have been effectively used as trunk injection (Hutauruk & Sipayung, 1978; Basri *et al.,* 1988, Chung, 1988; Chung, 1998, Ang *et al.,* 1998; Yap, 2000) and root absorption techniques (Sinuraya *et al*, 1989). In these insecticides, both active ingredients still provided satisfactory control against bagworms although the chemicals have been used since mid 1970's (Wood *et al*, 1974;

Basri *et al.,* 1988). Selective insecticides suitable for use as sprays, trunk injection and root absorption technique for controlling bagworm in oil palm plantations in Malaysia are listed in Table 2.0.

The trunk injection technique was reported to provide good control of red palm weevil, *Rhynchophorus ferrugineus* on date palm. In India, Murphy & Briscoe (1999) found fenthion and carbaryl were very effective against the larvae of the weevil. A. very satisfactory control of the same weevil using monocrotophos insecticides was reported by Nirula (1956). The larvae of *R. ferrugineus* were effectively controlled using pirimicid injection on the trunk of the date palms (Frohlich & Rdoewald, 1970). Similarly, In Africa excellent controls of beetles were observed when several types systemic insecticides were applied by trunk injection technique (Azam & Razvi, 2000). This technique also provided good control when applied against non-beetle pest. Green date palm pit scale insect *Asterrolecanium phoenicis* in northern Sudan was satisfactory controlled using thiamethoxam and imidacloprid (Ahmed, 2007).

The trunk injection technique using systemic insecticides was very effective in controlling many pests on ornamental trees. For example, Gill *et al.* (1999), reported excellent control of lace bugs on hawthorn using imidacloprid and abamectrin. Infestation of Red Bark weevil on Elm trees was successfully reduced using systemic insecticides acephate (Orthene®) as documented by Booth & Howard (2007). Furthermore, this technique is very suitable for controlling pests of trees with hand trunks especially those of Palmae. Successful control of coconut stick insect, *Graeffea crouani and* red palm weevil on coconut were reported by Dharmaraju (1977) and Rao *et al*. (1973) respectively.

The insecticides usually used to spray bagworm are usually selective because they do not have adverse effects on the pest natural enemies (Wood, 1971). Similarly, insecticides that are used in trunk injection have some degree of selectivity because they do not affect free-flying natural enemies (Ho, 2002). However, heavily dependent on chemical control for long periods could eventually harm the non target organisms. It could also result in imbalance between pests and their natural enemies in the field and subsequently leads to occurrences of pest outbreaks (Hartley, 1967; Wood, 1968; Mackenzie, 1976; Barbosa & Schultz, 1987; Chung, 1988; Noor Hisham, *et al.*, 2004)

Table 2.0: The common insecticides recommended for controlling of bagworm infestation in oil palm.

Insecticdes	Application technique (dosage a.i g / ha)
Trichlorfon	Aerial spraying (1400g / ha - Noor Hisham *et al*, 2004) Aerial spraying (1700g / ha – Chung, 1988) Ground spraying (1368 g/ha – Chung, 1988)
Cypermethrin	Ground spraying (15 g/ha – Chung, 1988) Ground spraying (22.5 g/ha – Chung & Narendran, 1996) Ground spraying (25.0 g/ha – Ho, 2002)
Acephate	Ground spraying (500 g /ha – Chung, 1988; 1998 & Ho, 2002) Trunk injection (7.5 g /ha – Chung, 1998)
Lambda- Cyhalothrin	Ground spraying (7.5 g/ha – Chung 1988)
Fenvalerate	Ground spraying (23 g/ha – Chung 1998)
Diflubenzuron	Ground spraying (150 g/ha – Chung 1998) (120g/ha – Chung, 1988)
Bacillus Thuringiensis, strains *Kurtaski*	Aerial spraying (800 ml/ha Dipel ES – Halex, 2007)* Ground spraying (1-1.5 L/ha Dipel ES – Halex, 2007)* Ground spraying (650 g/ha WP – Chung, 1998)*
Monocrotophos	Trunk injection (10 ml/palm – Ho, 2002 & Chung, 1998) * Root absorption (10-30 ml / palm- Sinuraya *et al.*, 1989)*
Methamidophos	Trunk injection (10/ palm – Chung, 1998) * Root absorption (10-30 ml / palm- Sinuraya *et al.*, 1989)*

*Commercial product