RELATIONSHIP OF OIL PALM INFLORESCENCE AND EVALUATION OF SEVERAL INSECTICIDES ON *Tirathaba mundella* Walker (LEPIDOPTERA: PYRALIDAE) AND *Elaeidobius kamerunicus* Faust (COLEOPTERA: CURCULIONIDAE)

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by

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"So verily, with the hardship, there is relief"

Quran 94: 5

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LIST OF ABBREVIATIONS

A	Floral part (spathe)
Ach	Acetylcholine
AChE	Acetylcholinesterase
B	Female inflorescence pre-anthesis
BBCH	Biologische Bundesantalt, Bundessortenamt und Chemische Industrie
BD	Banting *dura*
C	Female inflorescence at-anthesis
CPO	Crude palm oils
D	Female inflorescence post-anthesis
DAA	Day after application
DDT	Dichlorodiphenyltrichloroethane
DxP	Dura x Pisifera = Tenera
E	Young bunch
EIL	Economy injury level
ENH	Young bunch with new frass and high infestation
ETL	Economy threshold level
F	Middle bunch
FFB	fresh fruit bunch
G	Old bunch
GABA	Gamma-Aminobutyric acid (γ-Aminobutyric acid)
K	Potassium
L	Low infestation

M	Medium infestation
N	Nitrogen / New frass
nAChR	Nicotinic acetylcholine receptor
O	Old frass
P&D	Pest and disease
RyRs	Ryanodine
VGM	Vegetative growth measurement
X	No frass/ No infestation

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HUBUNGAN BUNGA KELAPA SAWIT DAN PENILAIAN BEBERAPA JENIS RACUN SERANGGA TERHADAP *Tirathaba mundella* Walker (LEPIDOPTERA: PYRALIDAE) DAN *Elaeidobius kamerunicus* Faust (COLEOPTERA: CURCULIONIDAE)

ABSTRAK

Pokok kelapa sawit, (*Elaies guineensis* Jacq.) dari keluarga Palmae berasal dari Afrika Barat dan telah dibawa masuk ke Malaysia oleh Kolonial British. Ia kini dikenali sebagai "tanaman emas" dan telah menjadi salah satu daripada tumbuhan penghasil minyak yang paling penting di dunia. Bunga dan tandan kelapa sawit adalah diet penting kepada dua serangga, ulat pengorek buah, *Tirathaba mundella* Walker dan kumbang pendebungaan, *Elaeidobius kamerunicus*. Faust *Tirathaba.mundella* menyebabkan 50% kerosakan terhadap buah tandan segar (FFB) manakala *E. kamerunicus* merupakan pendebunga penting. Objektif kajian ini ialah: (1) untuk mencari hubungan antara peringkat bunga dan tandan kelapa sawit dengan *T. mundella* dan *E. kamerunicus*, (2) untuk mencari keberkesanan dan sisa kesan daripada beberapa racun serangga terhadap populasi *T. mundella* dan (3) untuk menentukan kesan daripada beberapa racun serangga terhadap populasi *E. kamerunicus*. Dengan menggunakan Biologische Bundesantalt, Bundessortenamt und Chemische Industrie atau skala BBCH, peringkat bunga dan tandan kelapa sawit telah dijelaskan dan digunakan untuk kajian lanjut mengenai kedua-dua serangga. Keputusan menunjukkan bahawa tandan kecil (E) dengan frass baru (N) dan serangan tinggi (H) mempunyai bilangan larva *T. mundella* yang tertinggi. Lokasi yang mempunyai jumlah tandan busuk yang tinggi mempunyai serangan dan kiraan larva *T. mundella* yang tinggi. Selain itu, lokasi dengan jumlah tandan busuk yang tinggi juga mempunyai jumlah bunga jantan yang rendah. Kedua-dua keputusan menunjukkan

bahawa pendebungaan yang lebih rendah menyebabkan serangan *T. mundella* meningkat sekali gus meningkatkan jumlah tandan busuk. Masa yang diambil untuk bunga jantan untuk melengkapkan perkembangan adalah kira-kira 9 hari. Kajian mendapati bahawa populasi kumbang pendebungaan adalah paling banyak pada masa kemuncak pembungaan. Chlorantraniliprole mempunyai keberkesanan dan kesan sisa yang tertinggi terhadap serangan baru dan kiraan larva *T. mundella*. Selain itu, chlorantraniliprole juga mempunyai kesan yang sama seperti *Bacillus thuringiensis* kurstaki (Bt) iaitu menyebabkan kesan yang paling rendah terhadap populasi dewasa *E. kamerunicus*.

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ABSTRACT

Oil palm plant, (*Elaies guineensis* Jacq.*)* from family Palmae was originated from the West Africa and was brought into Malaysia by British Colony. It is now known as the "golden crop" and have become one of the most important oil producing plants in the world. Oil palm inflorescences and bunches are important diet for two insects, the fruit bunch moth, *Tirathaba mundella* and the pollinating weevil, *Elaeidobius kamerunicus*. *T. mundella* cause 50 % loses of fresh fruit bunch (FFB) while *E. kamerunicus* is an important pollinator. The objectives of this study are: (1) to find the relationship between the oil palm inflorescences and bunches stage with *T. mundella* and *E. kamerunicus*, (2) to find the efficacy and residual effect of several insecticides towards the *T. mundella* population and (3) to determine the effect of several insecticides towards the *E. kamerunicus* population. By using Biologische Bundesantalt, Bundessortenamt und Chemische Industrie or BBCH scale, the oil palm inflorescences and bunches stage were described and used for further study on both insects. The results show that the young bunch (E) with new frass (N) and high infestation (H) have the highest count of larvae. Location with high rotten bunches are having high *T. mundella* infestation and larvae count. Besides, location with high rotten bunches also had low male inflorescence. Both results show that lower pollination which caused *T. mundella* infestation to increase thus increasing the rotten bunches count. The time taken for male inflorescence to complete their development was approximately 9 days. The study found that pollinating weevil populations were most abundant during peak anthesis time. Chlorantraniliprole had the highest efficacy

and residual effect towards *T. mundella* new infestation and larvae count. Beside, chlorantraniliprole also had similar effect as *Bacillus thuringiensis* kurstaki (Bt) which caused the least detrimental effect towards *E. kamerunicus* adult populations.

CHAPTER 1: INTRODUCTION

Elaeis guineensis (Palmae: Arecaceae) was originated from the West Africa and was brought into Malaysia by British Colony. It is now known as the "golden crop" and have become one of the most important oil producing plants in the world. One hectare of oil palm plantation is able to produce 10 times more oil than other oilseed crops (Abdullah, 2011). Its optimal production period are between 10- 15 years and it can last long up to 20 years. Oil palm seeds were converted into refined palm oil through many process like hydrolysis and oxidation. The liquid fraction, oil palm olein is commonly used as cooking oil in the tropical regions compared to other oils like groundnut and sunflower (Kusum et al., 2011).

The importance of palm oil caused the peat soil to be converted into oil palm plantation. Oil palm cultivated on peat was estimated at 666 038 ha (13 %) (Wahid et al., 2010). Oil palms on peat were already in their 3rd generation (MPOB, 2012). Peat soil or Histosols is the soil that are made up with more than 50cm depth of organic matter. It is originated from swamp, bog or river that had been accumulated with organic matter.

In Malaysia, oil palm is effectively pollinated by an introduced weevil, *Elaeidobius kamerunicus* Faust (Coleoptera: Curculionidae) (Syed et al., 1982). Good pollination required 15 to 30 weevils per inflorescence and 4000 to 30000 weevils per hectare depending on male anthesis stage (Wahid and Kamarudin, 1997). The fluctuation of weevil populations increased during dry season, however pollinating efficiency is not affected because wind and other insects also play the role in pollinating the inflorescence (Wahid and Kamarudin, 1997). Introduction of pollinating weevil in 1981 had increased the fresh fruit bunch (FFB) of oil palm up to

30 %. Increasing in FFB can be obstructed by the pest that infested the oil palm such as *Tirathaba mundella*, leaf eating caterpillar and rhinoceros beetle.

One of the most important pests affecting the FFB quantity and quality is *Tirathaba mundella* (Lepidoptera: Pyralidae). It is known as the fruit bunch moth or inflorescence moth. Presently, this pest was reported to cause serious problem on oil palms planted on peat soil (Lim et al, 2012). Their life cycle is about 1 month. The damage symptoms are indicated by the presence of faeces or frass on the fruit or inflorescences (Wood & Ng, 1974). Other symptoms that occur once the infestation become worst are the premature abortion of the oil palm fruit, delayed spathes opening and yellowing of spadices of the oil palm inflorescences (Lim, 2012). *T. mundella* damaging symptoms and level of infestation is established through the monitoring method and the routine sampling of FFB grading (Lim et al., 2012). Cultural control method is usually done before the infestation occurred. Conducting biological control measures will avoid destroying beneficial pollinators such as pollinating weevil and thrip.

Recent study showed that broad spectrum chemical insecticide, cypermethrin, also kill the oil palm pollinator, *Elaeidobius kamerunicus* and the fruit bunch moth natural enemies, earwig. On the other hand, study has shown that *Bacillus thuringiensis* (Bt) variety Kurstaki produced the best performance against fruit bunch moth (Lim, 2012). The problems arise about Bt is that it does not have long shelf life and lifespan, it need certified individual to operate and besides it does not last long in the field condition. So this research will evaluate and select the best insecticide against *Tirathaba mundella* under lab and field condition.

The overall objectives of this study are (1) to determine the relationship between the female oil palm bunch phenology with the *Tirathaba mundella* new infestation and larvae count, (2) to determine the relationship between the male oil palm inflorescence phenology with the *Elaeidobius kamerunicus* adult count, (3) to evaluate the insecticides that have the best efficacy and residual effect towards the *T. mundella* population and caused the least detrimental effect towards the *E. kamerunicus* population.

CHAPTER 2: LITERATURE REVIEW

2.1.1 Oil palm and their importance

The first commercial scale planting of oil palm in Malaysia was founded in 1917, the Tennamaran Estate in Selangor (Jagoe, 1952; Basiron, 2007). It is now known as the “golden crop” and have become one of the most important oil producing plants in the world and grown in 16 countries across tropic region (Wahid et al., 2005).

Nowadays, the world has increased their demand towards the palm oil. Fresh fruit bunch (FFB) contain 25 % of oil and 5 % of kernel. Oil palm seeds are converted into refined palm oil through many process like hydrolysis and oxidation. Indonesia and Malaysia are the main world’s palm oil producers while the other countries include Thailand, Columbia and Nigeria. Palm oil is used in a wide variety of food products such as cooking oil, shortenings and margarine. Palm kernel oil is a raw material used in the production of non-food products which include soaps, detergents, toiletries, cosmetics and candles. Palm oil is increasingly being used as biofuel although its primary use remains for food (Basiron, 2007).

2.1.2 Biology of oil palm

Oil palm is a monoecious plant, having both male and female on one palm. It has pinnate leaf and is considered the best producer of oil in the world. The vegetative components of a mature palm are the roots, trunk or stem and foliage (Turner and Gillbanks, 2003). The palm bunch comprises of compacted fruitlets that weigh from 10 to 25 kg with 1000 to 3000 of fruitlets. Their fruitlet shape is mostly spherical or elongated. Fruitlets are purple black when unripe and turned to orange black when ripe (Corley and Tinker, 2003). The fruitlets consist of soft outer mesocarp, the shell endocarp and the hard inner kernel (seed). Oil palm can grow more than 10 meter and replanting is done when it reaches 20 to 25 years old (Corley and Tinker, 2003; Legros et al., 2009). Oil palm growth and production depended on the vegetative dry matter production because of the conversion of carbon into oil (bunch) required vegetative parts that have efficient photosynthesis such as leaves (Corley, 1973).

After years of generation selection during 1920s, Deli *dura* rise in Malaysia and Indonesia as it have heritable characters. Further breeding and selection give rise to more variety population such as Elmina (E), Dumpy E206, Banting *dura* (BD), Johore Labis *dura* (JLD) and Ulu Remis *dura* (URD) (Din, 2009).

Tenera/Pisifera was introduced into Malaysia in 1957 by Harrison & Crossfield (now Sime Darby) and Department of Agricultural (DOA) of Peninsular Malaysia. *Tenera* variety was obtained by combining both *dura* and *pisifera* which is known as Yangambi population. After that, through breeding and selection, it evolved into AVROS pisifera. La Me population obtained from developing oil palm plant material from palm groves

Oil palm phenology or stage scale was well described from previous study by Hormaza et al. (2012) using the BBCH scale (Biologische Bundesantalt, Bundessortenamt und Chemische Industrie) as the references. BBCH scale was established by Zadoks et al. (1974) to standardise the growth of plants by giving a decimal number for each specific growth stage. Under BBCH scale, oil palm has three growth stages comprised of germination and emergence (stage 0), leaf development (stage 1) and stem elongation (stage 3) while reproductive growth comprised of four stages: inflorescence emergence (stage 5), flowering (stage 6), fruit growth (stage 7) and fruit ripening (stage 8). Last phenology is leaf senescence (stage 9). Total time taken from inflorescence emergence to fruit ripening is around 519 days, the longest period is during inflorescence emergence (Forero et al., 2012).

2.1.3 Oil palm inflorescence and bunch phenology

Forero et al. (2012) stated that inflorescence sexes were unable to be identified during principle stage 5 because during this stage the prophyll and peduncular bract were still covered the inflorescence completely. Once the inflorescence reached 90 % of its final size (stage 509), the prophyll is torned apart completely while the peduncular bract had a slight torn, during this stage, the inflorescence sexes can be determined.

Both male and female inflorescences undergo principle stage 6: flowering. Both of them have the same stages which are: pre-anthesis I (stage 601), pre-anthesis II (stage 602), pre-anthesis III (stage 603), at-anthesis (stage 607) and post-anthesis (stage 609). All the stages were differentiated based on the characteristic of peduncular bract that disintegrate through all these processes.

Cik Mohd Rizuan et al., (2013) stated briefly that male inflorescence at-anthesis can be differentiated into 4 distinct stages of ¼, ½, ¾ and full at-anthesis. Further study on this matter is important because of the close relationship between the at-anthesis male inflorescence and the pollinators of oil palm specifically the pollinating weevil, *E. kamerunicus*.

2.1.4 Acreage of oil palm planted in Malaysia

Nowadays, Malaysia and Indonesia are producing 85% of world oil palm in 2016 (USDA-FAS, 2016). Peninsular Malaysia has about 2 million hectares of oil palm plantation and East Malaysia (Sabah and Sarawak) comprised of 1.7 million hectares thus making a total of 3.7 million hectares of oil palm cultivation. Table 2.1 shows the acreage of oil palm planted in the different states in Malaysia.

Table 2.1: Acreage of oil palm planted in the different states of Malaysia

State	**1980**	**1990**	**1995**	**2000**
	Ha (%)	Ha (%)	Ha (%)	Ha (%)
Johor	288,883 (27.0)	532,866 (26.3)	587,686 (23.1)	634,716 (18.8)
Kedah	11,211 (1.1)	29,296 (1.4)	37,166 (1.5)	57,375 (1.7)
Kelantan	18,238 (1.7)	60,490 (3.0)	70,834 (2.8)	72,065 (2.1)
Melaka	12,184 (1.1)	26,856 (1.3)	36,278 (1.4)	43,859 (1.3)
N. Sembilan	49,337 (4.6)	86,523 (4.3)	103,887 (4.1)	123,343 (3.7)
Pahang	276,464 (25.8)	439,663 (21.7)	498,417 (19.6)	514,709 (15.2)
P. Pinang	8,116 (0.8)	14,149 (0.7)	15,174 (0.6)	14,665 (0.5)
Perak	122,610 (11.5)	236,385 (11.6)	265,427 (10.5)	303,533 (9.0)
Selangor	100,875 (9.4)	149,489 (7.4)	148,242 (5.8)	1,325,467 (4.0)
Terengganu	67,589 (6.3)	122,781 (6.0)	140,060 (5.5)	145,767 (4.3)
P. Malaysia	**955,507 (89.3)**	**1,698,498 (83.7)**	**1,903,171 (74.9)**	**2,045,500 (60.6)**
Sabah	90,000 (8.4)	276,171 (13.6)	518,133 (20.4)	1,000,777 (29.6)
Sarawak	24,000 (2.3)	54,795 (2.7)	118,783 (4.7)	330,387 (9.8)
E. Malaysia	114,000 (10.7)	330,966 (16.3)	636,916 (25.1)	1,331,164 (39.4)
MALAYSIA	**1,069,507 (100.0)**	**2,029,464 (100.0)**	**2,540,087 (100.0)**	**3,376,664 (100.0)**

Source: Teoh, 2000; PORLA

Fertile soil in the coastal areas is suitable to grow oil palm in Peninsular Malaysia. In Sabah, majority of oil palm plantations were from forest land or converted crop land especially from cocoa. In Sarawak, the oil palms are planted mostly on hilly areas of Bintulu division. There were 2.5 million of hectares that were suitable for agricultural purposes with the areas mainly from hill, steep terrain or peat swamps. From that total, 1.5 million hectares was under peat soil with 89% was accounted as deep peat (Hai et al., 2001).

Manuring of oil palm generally depend on the type of soil where they are planted. Goh (2005) stated that oil palm planted on clay soil need the least amount of ammonium sulphate (1.59 kg/palm/year) and rock phosphate (1.14 kg/palm/year) whereas the oil palm planted on sandy loam, silty clay, organic clay, shallow peat and deep peat need literally large amount of ammonium sulphate (2.73 kg/palm/year) and rock phosphate (1.82 kg/palm/year). Apart from that, both clay soil and deep peat need high amount of potassium (3.64 kg/palm/year). Nutrient fixation and release in soil are basically associated with the soil pH so maintaining soil pH between 3.5 to 5.5 pH is crucial for the oil palm plant in order to get the best FFB yield (Goh, 2005; Lim et al., 2012).

2.1.5 Oil palm planted on peat soil

Increasing demands and shortage of mineral land for oil palm plantation have been overcome by converting peat land for oil palm plantation and nearly 25% of all oil palm plantations right now are cultivated on peatlands (Sheil et al., 2009; Tan et al., 2009). Peat soil or Histosols is the soil that are made up with more than 50cm depth of organic matter. The peat soil condition occurred when the deposition of organic matter is more than the decomposition process. The soil always low in pH as such it is acidic in nature. The soil contained water log that can last for 3 month if a long drought had occurred (Lim et al., 2012). The decomposing rate is reduced because of the high water level that prevent aerobic decomposition of the plant materials (Andriesse, 1988).

In term of pests, both peat and mineral soils have the same set of pests but on peat, the pest's infestation occurred earlier and outbreak became more frequently (Lim et al, 2012). Mutert & Fairhurst (1999) predicted that oil palm grow on peat soil can produce higher yield compared to palms grow on the mineral soil. The FFB yield can produce up to 25.6 tonnes of crude palm oils (CPO), 6 tonnes higher than the mineral soil.

Oil palm is grown by monoculture practice, and is known as monoculture crop. Extensive monoculture have developed more pests, weeds and diseases to exploit these unnatural environment of the monoculture: single crops, higher nutrient uptake and mostly genetically the same (Altieri and Nicholls, 2005). This problem can be solved by repairing and restoring community homeostasis through addition or enhancement of biodiversity (Altieri and Nicholls, 2005). One of the well-known process to repair the community homeostasis is the introduction of the beneficial insects. Beneficial insects are differentiated into some roles that benefit to nature and human (Van Huis et al., 2013). Benefits to nature are differentiated into several roles such as pollinators (bees), predators (rove beetles), parasitoids (parasitic wasps) and waste biodegradation (dung beetles) (Pickett, 1998) while benefit to human are differentiated into valuable products (honey from bees), medicals (propolis from bees), technology and engineering (silk thread from silk worm and termite hills). Predators, parasitoids and pathogens are grouped under natural enemies of pests (Howard et al., 2002). In term of oil palm industry, only pests, pollinators, predators and parasitoids are importance to state.

2.1.6 Pollinators of Oil Palm

Pollinators are insects that assist in pollination of plant reproductive organs. Pollination can be differentiated into 2: biotic (insects) or abiotic (wind) (Pellmyr et al., 1991). Most plant reproductive organs were designed to closely associate with the insects: having colourful petals, odour, sticky pollen and produce honey (Harborne, 1993). In oil palm pollination, a recent study shown that there are around 15 insects that visit on oil palm inflorescence. Apart from that, only 4 species of insects that visit both male and female inflorescences which are pollinating weevil, earwig, honeybee and moth (Sambathkumar and Ranjith, 2013). List of insect visitors on oil palm inflorescence is shown on Table 2.2.

Pollinating weevil was the most predominant and the best mechanism in pollinating the oil palm inflorescences (Sambathkumar and Ranjith, 2013). Wind also play a role in pollination with the ability to carry pollen up to 30 meters (Tandon et al., 2001). In Malaysia, oil palm is effectively pollinated by pollinating weevil, *Elaeidobius kamerunicus* Faust (Coleoptera: Curculionidae). It was introduced in 1981 (Syed et al., 1982) from West Africa and South America (Howard et al., 2002).

Table 2.2: Insect visitor on oil palm inflorescence

No.	**Insect**	**Order: Family**	**Visit on inflorescence**	
			Male	Female
1	African oil palm weevil (*Elaeidobius kamerunicus)*	Coleopteran: Curculionidae	Yes	Yes
2	Earwig	Dermaptera: Forficulidae	Yes	Yes
3	Moth	Lepidoptera: Cosmopterigidae	Yes	Yes
4	Leaf caterpillar (*Elymnias* sp.)	Lepidoptera: Nymphalidae	Yes	No
5	Citrus butterfly (*Papilio* sp.)	Lepidoptera: Papilionidae	Yes	No
6	Butterfly – yellow (*Eurema hecabe*)	Lepidoptera: Pieridae	Yes	No
7	Indian honey bee (*Apis cerana indica*)	Hymenoptera: Apidae	Yes	Yes
8	Dammer bee *Trigona iridipennis*)	Hymenoptera: Meliponidae	Yes	No
9	Black ant (*Camponotus* sp.)	Hymenoptera: Formicidae	No	Yes
10	Leaf cutter bee (*Megachile* sp.)	Hymenoptera: Megachilidae	Yes	No
11	Cuckoo wasp	Hymenoptera: Chrysididae	Yes	No
12	Carpenter bee (*Xylocopa* sp.)	Hymenoptera: Xylocopidae	Yes	No
13	Giant hornet (*Vespa* sp.)	Hymenoptera: Vespidae	Yes	No
14	Mealy bug	Hemipteran: Pseudococcidae	No	Yes

	(*Paracoccus marginatus*)			
15	Hover fly	Diptera: Syrphidae	Yes	No

Source: Sambathkumar and Ranjith, 2013

2.1.7 Predators and parasitoids of oil palm pests

Predators regulate ecosystem by feeding on many preys. Some predators are considered as stenophagous and another one as polyphagous. There was no evidence on monophagous predators (Petráková et al., 2015). Stenophagous predators are considered to consume a few closely related prey like spiders of the Ammoxenidae family that preys specifically on termite (Pekár and Toft, 2015). Whereas polyphagous predators are consuming a range of preys like rove beetle preys on vast range of arthropods and plants (Weisser et al., 1999).

In oil palm, there are several types of predators that feed on the pests of oil palm. Predators are found mostly from Coleoptera (Staphylinidae, Carabidae and Coccinellidae), Neuroptera (Chrysophidae), Diptera (Syrphidae) and Heteroptera (Pentatomidae and Miridae) (Howard et al., 2002). Ants like *Oecophylla smaragdina* was said can be a control agent against *Tirathaba* sp. (Lim, 2012). *Sycanus dichotomus*, *Cosmolestes picticeps* and *Callimerus arcufer* were said to prey on lepidopteran larvae like *Setora nitens*, *Pteroma pedula* and *Sethotosea asigna* (Kamarudin & Wahid, 2010; Jamian et al., 2015).

Parasitoids are the insects that their larvae feed on or inside the arthropod host, which killed the host in the process. Parasitoids comprised nearly 600,000 species worldwide (Heraty, 2009). Mostly parasitoids were from Orders of Hymenoptera, Diptera, Strepsiptera and Lepidoptera. Parasitoids can be classified as ectoparasitoids and endoparasitoids. Ectoparasitoid larvae developed outside the host body while endoparasite the another way around (Howard et al., 2002). Endoparasite wasp also oviposit other component like venom fluid alongside the egg to facilitate their progeny development (Werren et al., 2010; Asgari and Rivers, 2011). Solitary parasitoids lay single egg per host while gregarious parasitoids lay many. They were some events like superparatism and multiparasitism that refer to a host was being parasitized by multiple parasitoids from the same or different species.

There are many parasitoids that parasitized the pest of oil palm. *Spinaria spinator, Apanteles aluella*, *Systropus roepkei* and *Brachimeria lasus* had been proved to be an effective parasitoid to lepidopteran especially nettle caterpillar such as *Setora nitens* and *Sethothosea asigna*. The braconid, *Apanteles tirathabae* parasitizes young *Tirathaba* sp. larvae (Hinckley, 1964).

2.1.8 Pests of oil palm

Oil palm has many pests (insects and mammals) (Howard et al., 2002). Pests are classified: (1) key pests are perennial pests that can cause severe damage and having inadequate natural enemies, (2) occasional pests can cause sporadic economic damage if their biological control have been disrupted and (3) induced or potential pests can cause potential damage if environmental control are disrupted by change in agricultural practice. Important pests are differentiated into 2 categories: vertebrate and invertebrate (Turner and Gillbanks, 2003).

Important pests of oil palm are *Tirathaba mundella*, termite, leaf eating caterpillar, rat and rhinoceros beetle (Lim et al., 2012). *T. mundella* is fruit borer. Their life cycle is about 1 month. Adult lay eggs upon the damaged inflorescence, after about 5 days later, the emerging caterpillar bore into the spadices of the inflorescence. Highly infested bunch will rot before reaching the ripening stage (premature abortive) (Turner and Gillbanks, 2003; Lim et al., 2012). The larvae has 5 instars and will continue eating for about 2 weeks. *T. mundella* late instar is brownish black in colour and soon turn into pupae at bunch surface for about a week. Heavy infestation of *T. mundella* reduce the production of fresh fruit bunch (FFB) by more than 50 % (Lim, 2012). Usages of bio pesticide Bt, *Bacillus thuringiensis* have been reported to show remarkable result than endosulfan in suppressing these pests (Lim, 2012).

There is one species of termite that attacks living oil palm plants, especially when planted on peat soils. It is known as *Coptotermes* sp. which attacks oil palm plants as early as seven to eight month old. It causes three to five percent of death on the immature oil palm plants. In mature palms (10 years old), it can cause more than 50 % death if no proper management was taken. The recommended chemical for termite control is fipronil (5.0 % a.i.) at 2.5 ml product per 5 liters of water (Lim et al., 2012).

Leaf eating caterpillar such as bagworm, nettle caterpillar and hairy caterpillar can cause outbreak when the condition is favourable. They are known as defoliators. Their population is usually stabilized by parasitoids such as *Spinaria spinator*. Crop can losses 50 % of foliage at 30 to 40 % infestation rate in eight years oil palms. Chemical control for young palms (1 – 6 years) is by spraying 0.005% cypermethrin at fortnightly intervals on the infested canopy until new infestations clear off. When mist-blowers are used, the concentration is increased to 0.01 %. Biological control can be done by increasing the beneficial plants associate with parasitoids (Ariffin and Basri, 2000).

Rats are important vertebrate pests in oil palm plantations on peat. They cause damage in both mature and immature plantings. On mature palms, rats feed on loose fruits and developing fruit bunches (Turner and Gillbanks, 2003). They also attack the inflorescences. Crop losses due to rat damage were estimated at 7-10% if not properly controlled. Rats can be control by using toxic baits and barn owl, *Tyto alba* (Lim et al., 2012).

The rhinoceros beetle (*Oryctes rhinoceros*) is an important insect pest of immature oil palms on peat. It is known as trunk borer. The beetles breed in rotting woody materials, in trunks of oil palm in the field at the time of felling (Turner and Gillbanks, 2003). In the Riau, Indonesia, rhinoceros beetles in peat areas often migrated from the nearby coconut plantations (Lim et al., 2012). If control measures are not applied quickly on immature palms, repeated attacks will lead to palm death, arising from direct damage to the meristematic tissue. Monthly census is important for newly planted palms in areas with high rhinoceros beetle population. On mature palms, severe attacks will result in reduction of leaf area and subsequently lead to pronounce male cycle and lower yields.

Table 2.3 shows the economy threshold level (ETL) of several known pests that are associated with the oil palm.

Table 2.3: Economic threshold of important pests of oil palm

No.	Common name (infested part)	Scientific name	Economic threshold	Reference
1	Bagworm (leaves)	*Metisa plana*	10 larvae/frond	Wood (1971)
		Pteroma pendula	30-60 larvae/frond	IRHO (1991)
		Metisa plana	8-47 larvae/frond	Basri (1993)
		Mahasena corbetti	5 larvae/frond	Wood (1971)
2	Nettle caterpillar (leaves)	*Darna trima*	10 larvae/frond	Wood (1971)
			30-60 larvae/frond	IRHO (1991)
		Setora nitens	5-10 larvae/frond	IRHO (1991)
		Darna diducta	10-20 larvae/frond	IRHO (1991)
		Setothosea asigna	5 larvae/frond	Hoong and Hoh (1992)
3	Rhinoceros beetle (crown/ leaves)	*Oryctes rhinoceros*	10% palms with damage	Wood (1968)
			3-5 adults/Ha (traps)	IRHO (1991)
4	Bunch moth (inflorescence/bunch)	*Tirathaba rufivena*	30% of the palms with at least one bunch >50% attacked in young plantings and 60% in older plantings	IRHO (1991)
5	Cockchafer	*Adoretus*	5-10 adults/palm	IRHO (1991)
		Apogonia	10-20 adults/palm	IRHO (1991)
6	Rat (bunch)	*Rattus* spp.	< 20% bait acceptance	Wood (1968)
			5% bunch with damage	Basri & Norman (2000)

Source: Ariffin & Basri (2000)

2.2.1 *Tirathaba mundella*

Nowadays, *Tirathaba mundella*, the fruit bunch moth has become widespread and increasingly severe in both Malaysia and Indonesia (Turner and Gillbanks, 2003). Short life cycle and peat soil condition are conducive to *T. mundella* population which reduced the oil palm yield by more than 50% if no proper management and control are taken (Lim et al., 2012). Adult lay eggs upon the damaged inflorescence and five days later, the emerging caterpillar will then bore into spadices of the inflorescence. *T. mundella* have five instars and will continue eating for about 2 weeks. The caterpillar's late instar is brownish black in colour and soon will form pupae for about a week.

They usually pupate at bunch surface. The pupae stay in cocoons of silken thread and then emerge as adults. Both sexes of adults have wings and some reports said they are practically sexual dimorphism (Chan et al., 1973). Worst affected palms usually occurred in newly planting area, but older planting can also be badly infested and more difficult to treat (Turner and Gillbanks, 2003).

2.2.2 Biology of *Tirathaba mundella*

Based on previous studies, female adult *Tirathaba mundella* can lay eggs from 30 to 50 eggs within three days (Riana, 2000). Female lay white eggs at the fibrous sheath of the flower spike. Through time, the eggs will turn yellow, orange and black when it hatched (Howard et al., 2002). All 5 stages of the larvae took between 14 to 19 days to complete and the total life cycle of *T. mundella* is between 26 to 34 days. Figure 1 shows the life cycle of *Tirathaba* sp. (Riana, 2000). Table 2.4 explains the detail of the life cycle of *T. mundella* (Riana, 2000).

Pupae is enclosed in a silken thread and takes 10 to 14 days before reaching adult stage (Chan et al., 1973). Adults are practically different between genders, as male moths have smaller size wings, visible male genitalia part and thinner abdomen than female moths (Riana, 2000).

Peak activity of *Tirathaba mundella* adult male for mating is at 12 a.m. (Sasaerila et al., 2002) and the extracted pheromone from these males has a compound that resemble vanillin (Sasaerila et al., 2003). Unlike other lepidopteran that can be caught on light trap, *T. mundella* moths were not flying towards light (Paine, 1994).

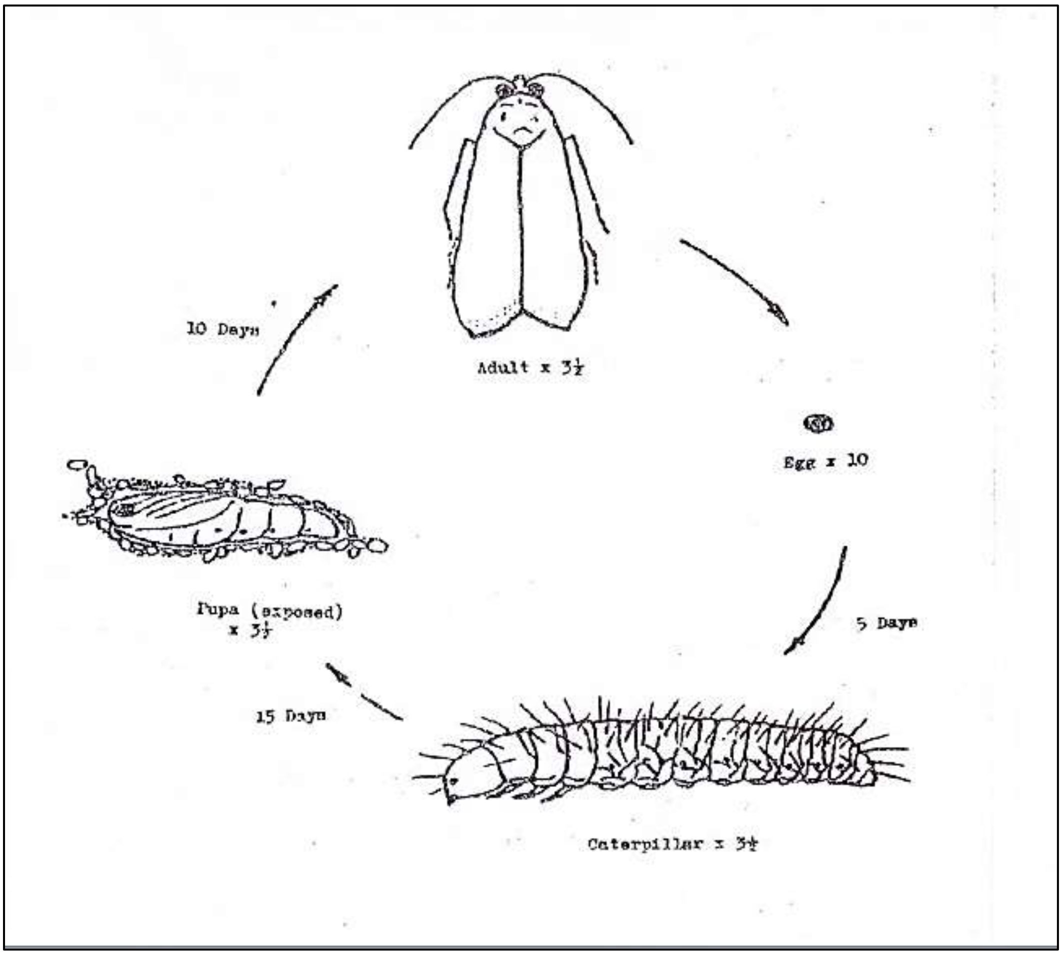

Figure 2.1: Life cycle of *T. mundella* (Riana, 2000)

Table 2.4: Detail diagram of *Tirathaba mundella* life cycle done by Riana (2000)

Stage	**Morphology** Measurement (mm)	Colour	Shape	**Activity**	**Development period (day)**
Egg	• 0.50 – 1.00	• White at first and orange during hatched	• Round and scale	• -	• 3 – 4
Larvae					
• **Instar 1**	• 1.00 – 2.00	• Brownish white	• Hairless cruciform	• Does not eat	• 3 – 4
• **Instar 2**	• 5.00 – 6.00	• Brown	• Hairy cruciform	• Eat	• 4 – 5
• **Instar 3**	• 9.00 – 10.00	• Brownish black	• Hairy cruciform	• Eat	• 2 – 5
• **Instar 4**	• 16.00 – 18.00	• Blackish brown	• Hairy cruciform	• Eat	• 4 – 5
• **Instar 5**	• 12.00 – 15.00	• Blackish brown dorsal with greyish brown ventral	• Hairy cruciform	• Does not eat	• 1
Pupae	• 10.00 – 12.00	• Brown	• Obtect	• -	• 7 – 8
Adult					
• **Male**	• 11.00 – 12.00	• Blackish brown dorsal with greyish brown ventral	• Triangular shape, slim abdomen, scale wings	• Nocturnal	• 3 – 4
• **Female**	• 14.00 – 15.00	• Blackish brown dorsal with greyish brown ventral and orange striped abdomen	• Triangular shape, broad abdomen, scale wings	• Nocturnal	• 3 – 4

2.2.3 Identification of *Tirathaba mundella*

Tirathaba mundella (order Lepidoptera; family Pyralidae) are one of the most diverse species worldwide (Mutanen et al., 2010). Pyralidae can be differentiated from Crambidae by their forewing veins, sclerotized costad, bullae tympani and uncus arm of male genitalia (Regier et al., 2013). Subfamily Gallerinae is described as lack of gnathos (Munroe 1972; Arenberger et al., 2001), dorsum of thorax and abdomen with prominent median ridge (Solis, 2007). There were several pests under this subfamily included *T. mundella*, rice moth, *Corcyra cephalonica* and worldwide stored product pest, *Paralipsa* sp. Under the genus *Tirathaba*, Hampson (1917) has stated 17 species which are *T. acrocausta, T. trichogramma, T. complexa, T. irrufatella, T. pseudocomplana, T. mundella, T. ignivena, T. rufivena, T. maculifera, T. fuscistriata, T. purpurella, T. grandinotella, T. semifoedalis, T. parasitica, T. haematella, T. unicolorella* and *T. nitidalis*.

Only two species of *Tirathaba* has been recorded responsible for infestation of oil palm in Malaysia and Indonesia; *T. mundella* and *T.rufivena*. Susanto (2011) differentiated these two species through their forewing coloration, where by *T. mundella* is greenish and *T. rufivena* is greyish. However, Mariau (2001) has stated that *T. rufivena* is the same species to *T. mundella*, *T. fructivora*, *T. complexa* and *Mucialla rufivena*. Turner and Gillbanks (2003) combined both species together as fruit bunch moth. Molecular technique done by Yaakop and Manaf (2015) showed that *T. rufivena* and *T. mundella* are different species.

Other important *Tirathaba* species are *T. trichogramma* which is associated with the premature nut-fall in Fiji (Hinckley, 1964) and *T. complexa* that is known as Greater coconut spike moth (Godfray, 1985).

2.2.4 Population and distribution of *Tirathaba mundella*

Plants from the family Palmae are considered as the host for *Tirathaba mundella* population. *T. rufivena* and *T. mundella* were considered as pests for coconut, areca nut and oil palm (Corbett, 1931; Wood & Ng, 1974; Gallego and Abad, 1985; Basri et al., 1994; Huang et al., 2008; Lim, 2012). *Tirathaba* incidence were reported in India, Philippines, Malaysia and Indonesia. *T. mundella* is infesting oil palm plantation in Indonesia and Sarawak, Malaysia (Lim et al., 2012). *T. mundella* incidences were recorded in various FELDA plantations especially in immature areas located in Johor, Negeri Sembilan, Selangor and Perak (Wood and Ng, 1974).

2.2.5 Control on *Tirathaba mundella*

Samples of 20 bunches per 100 acres are proven to give a reasonable and producible guide to the actual state of infestation. The economic threshold (ET) of *Tirathaba mundella* infestation on oil palm is 3-5 larvae per fruit bunch (Wood & Ng, 1974). Young oil palm usually had heavier infestation because of their more compacted crown and their inflorescences tends to remain within the sheath than matured palm (Howard et al., 2002).

Cultural control method is usually carried out before the infestation occurred. All the ripened, rotten and unproductive (ablated) fruits are harvested and kept away from the plantation as this method has decrease the *Tirathaba mundella* population (Wahid et al., 1991).

Biological control is about using predators, parasitoids or pathogens to control pests (Ponnamma, 2001). *Tirathaba mundella* may be regulated by natural predators, especially earwigs, *Chelisoches moris* and Kerengga ants, *Oecophylla smaragdina* (Lim et al., 2012). The braconid, *Apanteles tirathabae* is a host specific parasitoid that only parasitized young larvae of *T. mundella* (Corbett, 1930). This braconid may in turn be parasitized by any of four hyperparasitoids: *Aphanogmus manilae* (Ceraphronidae), *Irichohalticella tirithabae* (Chalcidae), *Perilampus* sp. (Perilampidae) and *Eurytoma* sp. (Eurytomidae). *Telenomus tirathabae* (Scelionidae) is an egg parasitoid. *Venturia palmaris* (Ichneumonidae) is a solitary parasitoid that