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ROLE OF BENEFICIAL PLANTS IN IMPROVING PERFORMANCE OF PREDATORS OF OIL PALM BAGWORM

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By

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ROLE OF BENEFICIAL PLANTS IN IMPROVING PERFORMANCE OF PREDATORS OF OIL PALM BAGWORM

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Chairman : Associate Professor Nur Azura Adam, PhD
Faculty : Agriculture

The use of beneficial plants in the oil palm plantation is nature and food plant for insect predators widening year by year. This technique has been widely used in Malaysia. The effectiveness and advantages of this beneficial plant depends on several factors such as the presence of insects naturally, the existence of pests and abiotic factors. Research on the role of useful plants is critical to ensure and increase the effectiveness of natural enemies. The use of natural enemies as biological control agents against bagworms in palm plantation will be expanded. According to the Malaysian Palm Oil Board (MPOB), pest especially bagworms are becoming more common in Malaysia, still the effectiveness of the beneficial plants for protecting and food source for natural enemies in this country been carried out. In this study, the abundance and performance of predators against bagworm in palm plantations was done every month in three different oil palm fields. Sampling was performed using sweep nets of 30 cm diameter in three different localities; fields with cultivation of three beneficial plants namely *Antigonon leptopus, Cassia cobanensis* and *Turnera subulata*, single planting beneficial plants namely *Turnera* sp. and estate without beneficial plant. A total of 1,035 individuals of two species were found, namely *Cosmolestes picticeps* (n = 924) and *Sycanus dichotomus* (n = 111) both of Hemiptera order and Reduviidae family. They dominated the study areas that are practicing cultivation of three beneficial plants a significantly higher ($F = 21.75$; $p < 0.001$) and ($F = 32.21$, $p < 0.001$), compared to estate planting a single beneficial plant and without beneficial plant respectively. Fluctuations in insect predators correlated with rainfall and the presence of bagworm. Data showed that the sampling population, the adult insect predators found in the study area, with peaks identified particularly in May, June, July, September and October 2015 on estates that planting these three types of beneficial plants. *Antigonon leptopus, Cassia cobanensis* and *Turnera subulata* were the plants with potential to increase the number of predators in oil palm plantations. This was proved when bagworm outbreak incidences dropped on the planting of three species of beneficial plants than the other two regions. The population of predators, *C. picticeps* and *S. dichotomus* were not significantly correlated with rainfall parameters and bagworm. Studies showed that predation, tripled the number of bagworms where

Metisa plana eaten by adults *S. dichotomus* compared to *C. picticeps*. Furthermore, the reaction function *M. plana* on different densities of 2, 4, 6, 8 and 10 *S. dichotomus* showed the reaction function of type II, with 1.9, 3.4, 5, 6.4 and 8.1 individually rate than 0.9, 1.4, 2.1,1.9 and 2.3 of predation by *C. picticeps* rates. Therefore, based on the results obtained in this study, predators *S. dichotomus* can be used to control bagworm. The results showed a large number of adult *S. dichotomus* attracted to useful plants namely, *C. cobanensis* and *T. subulata* compared than most other plants, *A. leptopus, Asystasia intrusa, Euphorbia heterophylla* and *Ageratum conyzoides*. The study of the nutrient content in the flower nectars and six plants was carried out using the GS-MS method. Results showed that all plants contained volatile composition to attract insect predators. For the review on the role of useful plants, *T. subulata* was tested on different combination treatments where the comparison with the existence of *S. dichotomus*, oil palm trees, bagworms and *T. subulata* were implemented. The insect predators need shelter and food sources such as nectar and honey for a longer life span. This was evident when the cage has only insect predators, palm trees and *T. subulata*. There was no significant difference between the cage with *S. dichotomus*, oil palm trees, *T. subulata* and *M. plana*, life span of *S. dichotomus* male and female (30.40 and 30.84 days) as compared to male and female (31.08 and 31.72 days) respectively. The cultivation of the suggested beneficial plant in oil palm to maintain the abundance of natural enemies to control pests of oil palm leaves is of major concern.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

PERANAN TUMBUHAN BERMANFAAT DALAM MENINGKATKAN PRESTASI PEMANGSA PADA ULAT BUNGKUS POKOK SAWIT

Oleh

SYARI BIN JAMIAN

Januari 2017

Pengerusi : Profesor Madya Nur Azura Adam, PhD
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Penggunaan tanaman bermanfaat secara semulajadi dan sumber makanan kepada serangga pemangsa di kawasan penanaman sawit semakin meluas tahun demi tahun. Teknik ini telah digunakan secara meluas di Malaysia. Keberkesanan dan kebaikan tanaman bermanfaat ini bergantung kepada beberapa faktor seperti kehadiran serangga semulajadi, kewujudan serangga perosak dan faktor abiotik. Sehubungan dengan itu, kajian peranan tumbuhan bermanfaat menjadi sangat penting bagi menjamin kehadiran dan penambahan keberkesanan musuh semulajadi secara terus menerus. Tambahan pula, musuh semulajadi merupakan agen kawalan biologi terhadap perosak ulat bungkus di kawasan penanaman sawit. Walau bagaimanapun, penggunaan musuh semulajadi di Malaysia untuk mengawal populasi ulat bungkus akan diperluaskan. Terutamanya, pendedahan ilmu pengetahuan terhadap kepentingan tanaman bermanfaat kepada peladang dan estet masih rendah. Mengikut laporan dari Lembaga Minyak Sawit Malaysia (LMSM) menyatakan perosak ulat bungkus ini semakin menular di Malaysia, keberkesanan tanaman bermanfaat bagi melindungi musuh semulajadi di negara ini masih kurang dijalankan. Kajian kepelbagaian dan kelimpahan musuh semulajadi ulat bungkus di ladang sawit dilakukan setiap bulan di tiga ladang sawit yang berlainan. Persampelan dilakukan dengan menggunakan jaring rama – rama berdiameter 30 cm pada tiga lokaliti yang berlainan, ladang dengan penanaman tiga jenis tanaman bermanfaat iaitu *Antigonon leptopus, Cassia cobanensis* dan *Turnera subulata*, ladang yang hanya menanam sejenis tanaman bermanfaat iaitu *Turnera* sp. dan ladang yang tiada menanam tanaman bermanfaat. Sejumlah 1,035 individu dan dua spesies berjaya ditemui. *Cosmolestes picticeps* (n = 924) dan *Sycanus dichotomus* (n = 111) kedua – duanya dari Order Hemiptera dan Famili Reduviidae mendominasi di kawasan kajian yang mengamalkan penanaman tiga jenis tanaman bermanfaat (F = 21.75; p<0.001) dan (F = 32.21, p< 0.001) berbanding penanaman satu jenis dan tiada tanaman bermanfaat. Perubahan turun naik serangga pemangsa berhubung kait dengan taburan hujan, hari hujan dan kehadiran ulat bungkus. Data persampelan populasi menunjukkan bahawa, serangga pemangsa dewasa ditemui dalam kawasan kajian di tiga ladang sawit, mempunyai tiga puncak populasi jelas yang terdapat dalam bulan Mei, Jun, Julai, September and Oktober 2015

pada ladang yang menanam tiga jenis tanaman bermanfaat. *Antigonon leptopus, Cassia cobanensis* dan *Turnera subulata* merupakan tanaman bermanfaat yang berpotensi menambahkan bilangan musuh semulajadi di ladang sawit. Ini dibuktikan apabila didapati pengurangan serangan ulat bungkus pada kawasan penanaman tiga jenis tanaman bermanfaat berbanding dua kawasan yang lain. Populasi pemangsa, *C. picticeps* dan *S. dichotomus* tidak mempunyai hubungan yang signifikan dengan parameter cuaca dan ulat bungkus. Kajian pemangsaan menunjukkan bahawa, bilangan tiga kali ganda lebih banyak ulat bungkus, *Metisa plana* di makan oleh dewasa, *S. dichotomus* berbanding *C. picticeps*. Tambahan pula, tindak balas fungsi *M. plana* untuk ketumpatan yang berbeza iaitu 2,4,6,8,dan 10 *S. dichotomus* menunjukkan tindak balas berfungsi jenis II, dengan 1.9, 3.4, 5, 6.4 dan 8.1 kadar serangan berbanding 0.9,1.4,2.1,1.9 dan 2.3 kadar serangan oleh *C. picticeps*. Oleh itu, berdasarkan keputusan yang diperolehi dalam kajian ini, pemangsa *S. dichotomus* boleh digunakan untuk mengawal ulat bungkus. Keputusan kajian pilihan menunjukkan sejumlah besar dewasa *S. dichotomus* tertarik kepada tanaman bermanfaat seperti, *C. cobanensis* dan *T. subulata* berbanding tanaman yang lain iaitu *A. leptopus, Asystasia intrusa, Euphorbia heterophylla* dan *Ageratum conyzoides*. Kajian terhadap kandungan nutrien dalam bunga dan nektar bagi keenam – enam tanaman telah dijalankan dengan menggunakan kaedah GS-MS. Keputusan menunjukkan semua tanaman mempunyai komposisi mudah meruap untuk menarik perhatian serangga pemangsa. Kajian peranan tanaman bermanfaat, *T. subulata* telah diuji pada perlakuan yang berbeza. Perbandingan dengan kewujudan serangga pemangsa, pokok sawit, kehadiran perosak dan *T. subulata* dilaksanakan. Hasil kajian mendapati serangga pemangsa memerlukan tempat perlindungan dan sumber makanan seperti nektar dan madu untuk memanjangkan jangka hayatnya. Ini terbukti apabila sangkar yang hanya mempunyai serangga pemangsa, pokok sawit dan *T. subulata* tiada perbezaan bererti dengan sangkar yang mempunyai serangga pemangsa, pokok sawit, *T. subulata* dan perosak *M. plana* iaitu jantan dan betina (30.40 dan 30.84 hari) berbanding jantan dan betina (31.08 dan 31.72 hari) masing – masing. Akhirnya penanaman tanaman bermanfaat amat dicadangkan dalam kawasan penanaman sawit bagi mengekalkan kelimpahan musuh semulajadi bagi mengawal perosak daun sawit.

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I certify that a Thesis Examination Committee has met on 23 January 2017 to conduct the final examination of Syari Jamian on his thesis entitled "Role of Beneficial Plants in Improving Performance of Predators of Oil Palm Bagworm" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

The oil palm (*Elaeis guineensis* Jacq.) is a native of Africa and was first introduced into Southeast Asia in 1848 when it was planted at Bogor Botanical Garden, Indonesia (Hartley, 1977). In 1875, this crop was brought to Malaysia from Bogor as an ornamental plant (Arnott, 1963). To date, oil palm has become one of the most important plantation crops in Malaysia to where it occupies more than five million hectares of total overall land in this country (MPOB, 2012). The Malaysian's oil palm industry has shown stellar performance in mostly the key performance indicators, namely price of palm oil products, crude palm oil production, and imports/exports volume as well as revenue. Export earnings from palm oil, palm kernel oil and other associated products in 2014 have reached a record of RM 63.36 billion with an increase of 3.7% against RM61.36 billion achieved in 2013 although, total exports of oil palm products declined by 2.5% to 25.07 million tonnes in 2014 from 25.70 million tonnes exported in 2013 (MPOB, 2015). The crop also plays a significant role in socio-economic development of rural areas by providing employment and raising the income level.

Due to the need for crop diversification, the oil palm growth was expanded in the late 1950s and by 1960s, 54,700 hectarage (ha) of these crops have been planted. Indeed, the amount dramatically increased to 1,482,399 ha in 1985. By 2014, a 5,392,235 ha of Malaysia's land area is covered by oil palm, making it the primary agricultural crop of the country and Malaysia has since become among the top exporters of crude palm oil worldwide (MPOB, 2015). However, oil palms are hosts for a large numbers of pests as most of these crops are planted in contiguous large areas, which provide a mono-crop situation that is ideal for a gradual explosion of pest population. These pests include insects, particularly beetles and caterpillars, some mites and vertebrates, especially rats, some large mammals and birds. Pests problem are of critical importance because their existence will reduce production and product quality, and to control them would involve high input costs. Most pests are capable of causing damage indirectly or directly via vectors or carriers of disease-causing bacteria or viruses that could threaten the oil palm industry. Therefore, the knowledge and experience on pests affected oil palm crops in Malaysia is important to face invasion of various pests and the multi-effective approaches to manage them. For record, information on the pest spectrum in oil palm in Southeast Asia is available in Wood, (1968, 1971a, 1976), Tiong, (1982), Hoong and Hoh, (1992), Norman and Basri, (2007, 2010) and Ho et al., (2011).

1.2 Problem statement

With the increasing rate of oil palm expansion, insect pest infestation such as bagworms (*Metisa plana* Walker and *Pteroma pendula* Joannis), nettle caterpillars

(*Setora nitens*), and the rhinoceros beetle (*Oryctes* spp.) in oil palm plantation has become a primary concern among stakeholders (Foster et al., 2011). Bagworms have been recognized as the most destructive insect pest in oil palm plantation of Peninsular Malaysia (Basri et al., 2001; Rhainds et al., 2002; Norman and Basri, 2010). Infestations cause leaf defoliation from early instar larvae and become worse as larvae grow. Larger populations cause extensive damage and infestations become more intense in oil palm monocultures (Ho, 2002). The use of less environmentally-friendly control methods such as chemical pesticides has proven to be ineffective as it improves pest resistance and eliminates beneficial insects such as pollinators and predators (Cheong et al., 2010). Predatory insects are known to be an excellent tool for the biological control of insect pests (Pimentel et al., 1992; Cardinale et al., 2003; Fazal et al., 2012). Insects such as parasitoids and hemipterans serve an important role in regulating bagworm and caterpillar populations in oil palm plantations (Basri et al., 1995; Norman and Basri, 2007; Cheong et al., 2010). Currently, six hemipteran species are reported as potential predatory insects in oil palm plantations in Peninsular Malaysia, namely *Cosmolestes picticeps* (Yusdayati, 2008), *Callimerus arcufer* (Basri et al., 1996), *Sycanus dichotomus* (Jamian et al., 2011), *Andrallus spinidens*, *Platynopus melachantus* and *Cantheconidea furcellata* (Khoo and Chan, 2000).

By introducing flowering plants that are commonly planted at the edges of oil palm plantations to presumably improve performance of insect predators. Alas, there is no research evidence that shows the effects of beneficial plants on the abundance and survivorship of insect predators as potential biocontrol agents in oil palm plantation. Basri et al. (1995) reported that the important role of parasitoids in regulating bagworms numbers, and their populations were depend on the availability of shelter and food sources e.g. nectar provided by beneficial plants in the oil palm ecosystem. These plants was found to prolong the life span of the adult parasitoid (Basri et al., 1999). Meanwhile, (Norman and Basri, 2007) disclosed that in 2005, three oil palm agencies have fully adopted the technology of planting beneficial plants to control bagworm and nettle caterpillar. Four species of plants are considered to be beneficial for leaf eating and bagworm control which are *Cassia cobanensis* (*C. cobanensis*), *Crotalaria usaramoensis* (*C. usaramoensis*), *Asystasia gangetica* (*A. gangetica*) and *Euphorbia heterophylla* (*E. heterophylla*) (Norman and Basri, 2010). However, *A. gangetica* is a pestiferous weed and is not recommended to be propagated. Ho (2002) had also quantitatively evaluated the effects of several beneficial plants in field caged trials such as *C. cobanensis* and *E. heterophylla* that are almost equal in terms of attracting parasitoids in the field. Interestingly, *C. cobanensis* has a competitive edge in that it is easier to propagate and does not need to be continually replanted every three months than *E. heterophylla* (Norman and Basri, 2010).

1.3 Significant of the study

Biological control of bagworm has been implemented but the results have not been satisfying since it is not based on thorough knowledge of the biology and ecology of the bagworms. Considering the importance of bagworms as a major pest in oil palm plantations and the lack of updated evidence on its predator, this study is a jump start to evaluate the performance of potential predators as biocontrol agents on beneficial plants in oil palm**.**

1.4 The objectives of the study

The main objective was to study the role of beneficial plants in improving the performance of predators of oil palm plantation. Specifically to achieve this, the study were:

1. to effect of beneficial plants on the abundance and population fluctuation of predatory insects.
2. to determine the beneficial plants mostly suitable for selected predator species.
3. to study the effect of different host plants on the performance of predators.

CHAPTER 2

LITERATURE REVIEW

2.1 Leaf-eating caterpillars and economic losses caused by bagworms to the oil palm

A wide range of insect pests attack oil palms in Malaysia, and the frequency of outbreaks has increased quite considerably in recent years (Wood, 1968). Nevertheless, these is no general incidence of continuing "chronic" infestation by any insect pest; instead irregular and spasmodic outbreak occur. Terms of outbreaks are usually restricted to a single location, and there is no tendency for the same pest to increase in several oil palm areas, even adjacent ones, at the same time. Other purposes, outbreaks of the latter type develop very rapidly and are referred to as "explosions" (Wood, 1968). Anyone who has seen the consequences of an explosive increase of, for example, leaf-eating caterpillars.

Leaf eating caterpillars such as bagworms (Psychidae) and nettle caterpillars (Limacodidae) are among the most critical pests of oil palm (Wood, 1968; Cock et al., 1987; Basri et al., 1988; Basri and Norman, 2000; Ho, 2002; Norman, 2002). Eight species and two genera of bagworms commonly associated with oil palm in Malaysia are *Pteroma pendula*, *Metisa plana*, *Mahasena corbetti*, *Brachycyttarus griseus* Joannis, *Manatha albipes* Moore, *Amatissa cuprea* Moore, *Cryptothelea cardiophaga* Westwood, *Dappula tertia* Templeton, *Pteroma* sp. and *Clania* sp., with the first three species being the most common and problematic (Sankaran, 1970; Syed and Shah, 1977; Norman, 1994; Robinson, 1994). Out of these three species, *M. plana* and *P. pendula* were reported to be troublesome in Peninsular Malaysia with *M. plana* is more damaging while *M. corbetti* is the main bagworm pest in Sabah and Sarawak (Basri et al., 1988).

Crop loss from even moderate defoliation brought by bagworm can be severed, where a decline of 33-40% on yield was once reported (Wood, 1973; Basri et al., 1995). According to Basri et al. (1988), the reported total area of bagworm outbreaks between 1981 to early 1985 was 37,102 hectares, of which 27,941 hectares were in Peninsular Malaysia, 8,975 hectares in Sabah and 186 hectares in Sarawak. They also described the total area affected by bagworms constituted 20.8% of total area of oil palm estates with outbreak records. Chung (1998) pointed that outbreak of the bagworm *M. corbetti* occurred over a large area in Sandakan, Sabah during 1997 and 1998. Before 1956, *P. pendula* was reported to exist in small population with moderate damages in small areas with the absence of *M. plana* (Tinker, 2003). Years after, *M. plana* and *P. pendula* are the most common bagworms attacking oil palm in Perak, Johor and Sabah (Norman and Basri, 2007), while *M. corbetti* is the main bagworm pest in Sabah and Sarawak (Basri et al., 1988). In addition, Ho et al. (2011) showed that infestation by the bagworms *M. plana* and *P. pendula* covered 63,955 hectares of 69 estates managed by Golden Hope Plantation Berhad in Peninsular Malaysia in the year 2000 either in single or mixed species.

It is somewhat surprising that insect pests are not a continuing problem since an oil palm estate or smallholders in Malaysia would appear to be an environment extremely suitable for pest increases. The warm and humid climate is ideal for insect development and the large areas planted solely with a single perennial plant present conditions in which one would expect regular multiplication and spread of oil palm pests (Wood, 1968). Weather conditions sometimes appear to have a direct effect, but there is no evidence that such effects follow any regular seasonal trend. Nor Ahya et al. (2012) and Cheong et al. (2010) agreed that bagworms and natural enemies populations were not correlated with weather parameters. Hovewer, many researchers agreed heavy rains will normally cause considerable reductions in the infestation of bagworms, but there is no recorded.

2.2 Chemical control of bagworms

The use of pesticides can be a reliable and cost effective for pest control. However, various side effects of chemical control have been reported worldwide including resurgence of pest population, development of resistance and abundance of residue in the environment. These effects have led to a much greater appreciation of non-chemical arsenals and the need to integrate different control technique (Chung, 1998). This is even more relevant with current understanding and knowledge of ecology of insect pests and their natural enemies in oil palm plantations. Frequently, the benefits of natural enemies are not realized until their activity is disrupted by the use of insecticides, which sometimes is more severe on beneficial insects than rather the pests (Wood, 1971). Reiterated application of insecticides also resulted in pesticides resistance or the destruction of natural enemies (Khoo et al., 1991).

Fogging insecticide is a potential technique that is as effective as the spraying technique (Figure 2.1). The suitability and effectiveness of portable thermal fogging and mist-blower application of *Bacillus thurigiensis* (BT) against *M. plana* in less than 12 years old oil palm, spraying using knapsack can be done (Chung, 1989). Mistblower is used to ensure that the chemical reaches the foliage of trees in oil palm between the ages of one to four years. When the palm trees extended up to eight meters and above, spray within machine can be used to control the bagworms attack (Norman, 2005) (Figure 2.2). Bio-control of bagworms using BT must be applied at the right time since it works well only on young bagworms.

Figure 2.1 : A fogging device which sometimes been used in oil palms against caterpillars or bagworms.

Figure 2.2 : Tractor-drawn and powered air-blast sprayer in use in six year old oil palms, on flat terrain.

2.3 Biological control of leaf-eating caterpillars of oil palm

Biological control is defined as the action of parasites, predators or pathogens in maintaining another organism's population density at a lower average than in their absence (Debach, 1964). Natural enemies are left to multiply, matured and to control insect pests capable of killing pests (Fauziah et al., 2000). Leaf-eating caterpillars of oil palms are normally kept under control by natural enemies, which include predatory bugs, parasites, fungal and viral pathogens (Chung et al., 1995). The biological control methods employed in Sabah encompass the release of parasites, predators and viruses. Outbreak of nettle caterpillars, *Darna trima* in oil palm plantation have been effectively controlled by spraying them with an aqueous suspension of triturated virus infected with *D. trima* larvae (Tiong, 1982; Norman and Basri, 1992). A total of six primary parasitoid and predators against *M. plana* have been recorded together with hemipteran species that attacked bagworms (Basri and Kevan, 1995; Norman and Basri, 2010). An entomopathogen, *Beauveria bassiana* isolated from the insect pests in oil palm revealed that it could infect *M. plana* through the integument and respiratory system. In the absence of natural control, these pests are capable of rapid buildup and can cause severe defoliation (Ramlah and Jalani, 1993; Ramlee *et al*., 1996).

2.4 Natural enemies of pest insects

Classical biological control involves the exploring or searching of natural enemies in native homes where they can be found exerting an important regulatory pressure upon pests (Yusof, 1987). Good natural enemies not only act as a substantial mortality factor and thereby limit or reduce (control) the pest population size, but they tend to stabilize both the pest density aside from their own density (Huffaker et al., 1971). In context of biological control, natural enemies are referred to parasites and predators, in which they are better known as entomophagous, and pathogens as entomogenous. A predatory insect, *S. dichotomus* owns characteristic by sucking the body fluids from a nettle caterpillar or insect pests through its proboscis (Fig. 2.3). Natural enemies can play an important role in limiting potential pest populations. When a non-toxic control method is used, natural enemies are more likely to survive and reduce the numbers and damage of potential pest species (Farehan et al., 2013).

Figure 2.3 : The predatory insect, *Sycanus dichotomus* fed on nettle caterpillar using stylet.

The potential of biological control was first demonstrated in Malaysia circa 1940 by introduction of *Isyndus* sp. to control *Helopeltis* sp. (Jangi et al., 1991). Since then, the success rate of classical biological control attempts has remained low, approximately at 10% (Gurr et al., 2000). These scenarios were due to lack of attention paid to the requirements of the natural enemies in the field that might contribute to the poor success rate (Gurr and Wratten, 1999). To resolve these problems, the use of conservation biological control and other habitat manipulation techniques to fulfill the requirements of natural enemies in agro-ecosystems were later introduced (Berndt et al., 2002). These techniques can also be expended to improve the success of classical biological control attempts (Gurr and Wratten, 1999).

Pests are tiny fraction of insect species that occasionally attack resources and caused serious damage. The first record of the use of predatory insects by man is known originated from the ancient Chinese, where an ant species, *Oecophylla smaragdina* found in citrus trees was used to control caterpillars and beetles (Clausen, 1956). Sometimes, the natural control of a pest in a particular region can be improved by importing an insect enemy which attacks it in some other part of the world. In general, the natural control of most Malaysian oil palm pests is good, and outbreaks are associated with disturbances which would be equally likely to occur if new insect enemies were imported. Two importants have been made in connection with *Oryctes rhinoceros* (Wood, 1968).

2.5 Predation

Predation is a way of life among predatory insects. The predatory process can sometimes be quantified and explained in relatively fine detail for particular predator/prey interactions, where extrapolation from laboratory to field conditions are necessary for uncontrolled factors e.g. weather and prey dynamics (New, 1991). Evans (1982) pointed out that predatory insect species often occurred at relatively low densities and are known as groups that are difficult and challenging in terms of field studies. Most of progressive works done in understanding their biology come from laboratory studies, particularly on the taxa that are important as predators of crop pests. The ability of introduced predator insects to survive and successfully seek out their prey is basic to the success of a biological pest control program. Van den Bosch (1973) reviewed requisites of introduced biological control agents with particular emphasis upon their adaptability to new environment. Logical early steps in the consideration of new or imported predator species are studies of their life history and feeding habits (Greene, 1973). Later studies should determine their ability to survive in the field, predation potential, functional response, or changes in the number of prey consumed by individual predator insects (Solomon, 1949). The latter is especially important in inundative release programs.

2.6 Important groups of predators

The orders of insects containing predatory species are Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, Neuroptera and Odonata (Debach, 1964; Khoo et al., 1991; New, 1991). The Hemiptera is largely phytophagous, with various families of predaceous species such as Miridae, Reduviidae, Pentatomidae and Anthocoridae (Nayar et al., 1976; New, 1991; Khoo, 1992). One subfamily of the large terrestrial group Reduviidae, the Assassin appears not to 'capture' prey, where the bugs merely walk up slowly to potential prey items mainly caterpillars and bagworms and by piercing them with a stylet without further elaboration (De Chenon, 1989; Syari, 2010). Apart from its feeding behavior, *S. dichotomus* plays a significant role in the biological control program in oil palm. With its longer rostrum compared to other hemipteran predators, it can successfully attack the bigger late instar bagworms and other larger sized oil palm caterpillars (Zulkefli, 1996).

2.7 Asopin and assassin bug

Assassin bug are predatory shield bugs feeding on other insects (Kalshoven, 1981). Among the predators of leaf eating caterpillars and bagworm in oil palm plantations, the predators are more interesting due to their activity both at nymphal and adult stages, their ability to find prey and their importance as predators over caterpillars and bagworms (Sipayung et al., 1992; Norman et al., 1998). They prefer soft-bodied prey such as phytophagous caterpillars and beetles' larvae (Kalshoven, 1981). In Reduviidae and Pentatomidae family, all species of the subfamily Assassin and Asopine are known as predators (Kalshoven, 1981; De Chenon, 1989; Sipayung et al., 1989). The species *S. dichotomus*, *Eocanthecona* sp., *Canthecodidae* sp. and *P. melacanthus* are frequently feed on nearly all caterpillar groups for example Limacodidae, Lymantriidae, Noctuidae, Notodontidae and Geometriidaebut (De

Chenon, 1989; Sipayung et al., 1989,1992; Norman and Basri, 1992; Teh, 1996; Jamian et al., 2011).

2.7.1 Description

Sycanus is a genus of assassin bug with many species that are found in the African and Asian region with seventy-six species have been acknowledged around the world (Putshkov and Putshkov, 1985,1996; Maldano-Capriles, 1990; Ishikawa et al., 2007). There are several species of these bugs namely *Sycanus affinis* Reuter, *Sycanus albofasciatus* Bergroth, *Sycanus ater*, *Sycanus atrocoerulens* Signoret, *Sycanus bifidus*, *Sycanus collaris, Sycanus croceovittatus* Dohrn, *Sycanus dubius* Paiva, *Sycanus falleni* Stal, *Sycanus galbanus* Distant, *Sycanus indagator* Stal, *Sycanus inermis* Distant, *Sycanus pyrrhomelas* Walker, *Sycanus reclinatus* Stal Dorn, *Sycanus rubicratus* Stal, *Sycanus ventralis* Distant, *Sycanus versicolor* Dohrn and *Sycanus vividus* Distant (Distant, 1904). Apart from that, *Sycanus* species are large sized important potential biological control agents in agricultural and forestry systems (Liu et al., 2012).

In Malaysia, *S. dichotomus* is a large genus of the reduviid subfamily Reduviidae, which comprise the other hemipteran predators. Adults *S. dichotomus* are normally dark-brown in color. Other characteristics of *S. dichotomus* are the posterior prenatal lobe is weakly tumid in the middle near the posterior margin; the scutellar spine being erect, short and rounded at the thorax; each femurs consist of two incomplete black annulations, and the abdominal contains five dot white color with weakly extended dorsal.

2.7.2 Distribution

The assassin bugs (Hemiptera: Reduviidae) are important group of predators found in oil palm plantations of Southeast Asia (Wood, 1968,1976; Sankaran and Syed, 1972; Tiong, 1979). Among the Reduviids, *S. dichotomus* is the most common species found feeding on the larvae of nettle caterpillars such *as Darna* spp. and *Setothosea asigna* and also the bagworms, *Mahasena corbetti* (DeChenon et al., 1989; Singh, 1992; Norman et al., 1998). The same genus of these bugs known as *S. aurantiacus* and *S. colaris* has been encountered in Indonesia as biocontrol agents for insect pests in plantation forestry (Ishikawa et al., 2007; Budi et al., 2008). Other predaceous species, *C. furcellata* had been discovered in South India, Thailand, Taiwan, Indonesia and Malaysia (Nayar et al., 1976; Kalshoven, 1981; Napompeth, 1982; Sipayung et al., 1989,1992; Suasa-ard, 1989; Hoong and Hoh, 1992; Teh, 1996). According to Nayar et al. (1976), the species *A. spinidens* is widely distributed in the Malay Archipelago, Fiji, Tahiti, East Africa, Mexico, Pakistan and India. Meanwhile, *P. melacanthus* is a common species found in oil palm plantation in Sumatra and Irian Jaya located in Indonesia (Sipayung et al., 1992).

2.7.3 Biology

Biological studies have indicated that the female adults of *S. dichotomus* are generally larger than the males (Zulkefli et al., 2004; Syari, 2010; Ibrahim and Mohd Fairuz, 2011). The eggs of *S. dichotomus* hatched after 13 to 18 days with each clusters consist of 3 to 143 eggs (Syari et al., 2013). This assassin bug has five nymphal instar and its development from egg to adult takes around 118 to 130 days feeds with *Corcyra cephalonica* and *Plutella xylostella* while 76 days with *Tenebrio molitor* (Zulkefli et al., 2004; Syari, 2010).

2.7.4 Predatory habit

Assassin bugs attack slow-moving insects not equipped to defend themselves (Usharani et al., 1994). The method of attack also differs from that adopted by other predaceous Hemiptera, e.g. Reduviidae which use their anterior legs to seize the prey and later insert stylet into the soft integument. Normally, direct insert of the stylet into any part of the prey consists of soft-bodied lepidopterous larvae, where the insects are paralyzed by injection of fluid following sucked dry (Lamp, 1974; Kalshoven, 1981; Suasa-ard, 1989; New, 1991; Usharani et al., 1994). The rostrum of these bugs is more prehensile than that of the plant-sucking species (Kalshoven, 1981; Dolling, 1987). Furthermore, the nymphs of these bugs are gregarious and they might feed together on a single prey (Kalshoven, 1981; Dolling, 1987; Sipayung et al., 1989). Among the Reduviids, *S. dichotomus* is the most common species found feeding on the larvae of nettle caterpillars such as *Darna* spp. and *Sethotosea asigna* as well as the bagworms *Mahasena corbetti* (DeChenon et al., 1989; Singh, 1992; Norman et al., 1998). Based on results from DeChenon et al. (1989), *S. dichotomus* is not a suitable biocontrol candidate since it is generally less effective due to its slow-feeding habit and a long handling time. However, a study carried out by Syari et al. (2010) on predatory efficiency of *S. dichotomus* showed that the adult predator killed twice a number of bagworms, hitherto killed by *Platynopus melacanthus* Biosdural (Hemiptera: Pentatomidae). In addition, having a longer rostrum compared to other bagworm predators offers *S. dichotomus* the ability to attack bigger late instar bagworms and presumably other larger oil palm caterpillars (Ibrahim and Mohd Fairuz, 2011).

2.8 Plant that attract beneficial insects

All insects depend on plants, either directly or indirectly (predators and parasites feed on plant-eating forms) for sustenance (Headstrom, 1963). Plant-eating insects feed on all parts of plants such as bud, flower, leaf, stem, root, fruit and seed as well as their secretions e.g. sap, pollen, nectar, and other juices. Generally, this association between insects and plants are essential as an exchange of pollen and nectar. In other words, the insects visit the flowers to obtain their nectar and in return pollinating the flowers.

The bagworms are opportunistic pests which could multiply to create outbreak proportions in a conducive environment. The larvae feed on foliage and tear off bits of oil palm leaflets to make their bags, thus causing skeletonisation and desiccation of infested palms. Primary accounts of bagworm outbreaks in oil palm inevitably attribute to excessive ground vegetation and weed removal as a causative factor (Mackenzie, 1977; Teh, 1996). Previously, wide range of weeds and under-storey plants have been associated with the encouragement of bagworm natural enemies activity (Tiong, 1982). Plant species capable of attracting natural enemies usually produce nectar and their flowers consist of an open structure allowing easy access to the pollen. A study by Norman and Basri (2007) reported that out of 332 estate respondents with bagworms infestation, only 66% of the estates were planted with beneficial plants such as *Cassia cobanensis, Turnera subulata, Antigonon leptopus* and *Eurphorbia heterophylla* to control the leaf-eating pests. Teh (1996) has described *Echthromorpha agrestoria* Swederus, a pupal parasitoid of *Mahasena corbetti*, was found alive on *Euphorbia geniculata* Ortega and *E. prunifolia* Jacq. The same effect was observed in experiments using *Asystasia intrusa* Bl., *Ageratum conyzoides* L., *Cleome rutidosperma* DC, *Euphorbia heterophylla* L., *E. hirta* L., *Cassia cobanensis* (Britton) Lundell, *Crotaria usaramoensis* Baker, *Hedyotis corymbosa* (L.) Lamk. and *H. verticillata* Lam. on selected parasitoids (Basri et al., 1999). Out of these beneficial plants, *C. cobanensis* provided the best results where longevity of parasitoids being comparable with individuals fed on diluted honey. Meanwhile, Khoo and Chan (2000) demonstrated the benefits of *A. leptopus* as a food resource for the insect predator, *Andrallus spinidens* (F.) with nymphs developed faster than its control, after addition of this plant to the mealworms. The adult longevity was also increased even in the absence of the mealworms.

Numerous evidence on the association between beneficial plants and natural enemies have been reported. Earlier findings by Ho and Teh (1997) described the large scale establishment of *E. heterophylla* for the enhancement of predators and parasitiods in oil palm plantations. On the other hand, Syed and Shah (1977) and Tiong (1982) disclosed results that intensive use of herbicides which killing *E. geniculata* and *E. prunifolium* resulted in the outbreak of *P. pendula* and *Setothosea asigna*. Moreover, Singh (1992) reported attempts made by planters to encourage the growth of beneficial plants along road edges, non-harvesting avenues and in vacant points within a field. These encouraging efforts need to be reinforced by direct evidence on the usefulness of various plants as beneficial.

2.8.1 *Turnera subulata* Smith

The *Turnera subulata* is a species of flowering plant that is native to Tropical America, but has been widely naturalized outside its native range including South-east Asia (Short, 2011). It is commonly cultivated as a garden flower where there are about 120 species in the genus *Turnera* (Short, 2011). In the world of medicine, *T. subulata* is a medicinal plant used as an herbal remedy for coughs and bronchitis (Chai and Wong, 2012) . This plant is pollinated by a variety of insects e.g. the bee species *Protomeliturga turnerae*, *Trigona spinipes, Frieseomelitta deoderleinii* and *Plebeia flavocinta*, the butterflies species such as *Nisoniades macarius* and *Urbanus dorantes*, and the beetle *Pristimerus calcaratus* (Schlindwein and Medeiros, 2006). In Malaysia, *T. subulata* is usually planted along the roadside of an oil palm estate to attract insect pollinators (Figure 2.4).

Figure 2.4 : *Turnera subulata*, among beneficial plants that is mostly easy to establish.

2.8.2 *Cassia cobanensis* (Britton) Lundell

The *Cassia cobanensis* (Britton) Lundell (Family: Leguminosae) is a leguminous crop that can be planted using seeds or vegetative propagation. It forms a small to medium shrub of about 0.6-0.9 m in height at maturity. The leaves are 2.5-3.8 cm long, oblong to oblong elliptic in shape, with fine hairs. It has a gland at the base of the leaf, which emits nectar. The flower is normally yellow-orange and composite. The seeds are in pods of about 8 cm long. It requires minimal maintenance, except at the early stage of establishment. It grows well in the open land, and therefore is suitable for planting along the roadside and drains where sunlight is sufficient. An example of the field planting by the roadside of a mature oil palm block is shown in Figure 2.5.

Figure 2.5 : *Cassia cobanensis* is a perennial nectariferous plant.

The effect of *C. cobanensis* can only be expected after about a year, when the bagworm parasitoid begins to establish themselves with the plant (Basri and Norman, 2002). The benefits of this plant in supporting the life span of parasitoids were indicated by low population of *M. plana* after its establishment (Basri et al., 2001). The species of bagworm parasitoids which normally visited *C. cobanensis* are *Brachymeria lugubris, Dolichogenidea metesae, Eurytoma sp., B. lasus, B. carinata, Goryphus bunoh, Elasmus sp., Paraphylax varius, Pediobius imbrues* and *P. anomalus* (Basri and Norman, 2002). *Cassia cobanensis* is a good nectar-producing plant which attracts a wide range of parasitoids that are associated with bagworms, with no current observational study has been conducted on the biodiversity of insect predators in the crop.

2.8.3 *Antigonon leptopus* Hook. & Arn.

The *Antigonon leptopus* is a fast-growing climbing vine that holds via tendrils and able to reach up to 25 ft or more in length. It has a cordate or heart-shaped and occasionally triangular leaves from 2½ to 7½ cm long (Figure 2.6). The flowers are borne in panicles and clustered along the rachis producing pink or white flowers from spring to autumn. This plant forms underground tubers and large rootstocks, is a prolific seed producer with seeds floating on water as well as fruit and seeds that are often eaten and spread by a wide range of animals for example pigs, raccoons and birds. The tubers will re-sprout if it is cut back or damaged by frost. *Antigonon leptopus* is documented as an invasive species of natural areas but is greatly recommended for a large scale establishment in oil palm plantations (Raju, 2001; Ernst and Ketner, 2007; Norman and Basri, 2007; Pichardo, 2009).

Figure 2.6 : *Antigonon leptopus* grows best on trellising metal support.

CHAPTER 3

THE EFFECT OF BENEFICIAL PLANTS ON THE ABUNDANCE AND POPULATION FLUCTUATION OF PREDATORY INSECTS

3.1 Introduction

Metisa plana Walker (*M. plana*) and *Pteroma pendula* Joannis (*P. pendula*), or known commonly as bagworms are the most destructive pests affecting oil palm in Peninsular Malaysia. The damage caused by these pests was mainly through feeding on leaves of the oil palms prior to monoculture environment (Norman and Basri, 1992; Ho, 2002; Norman and Basri, 2010; Cheong et al., 2010). Earlier population studies on bagworms complexes in oil palm crops and their enemies in Peninsular Malaysia were carried out on 69 oil palm estates managed by Golden Hope Plantation Berhad and in Hutan Melintang district (Cheong et al., 2010; Ho et al., 2011).

The use of chemical pesticides has proven to be ineffective as they promote pest resistance and eliminates beneficial insects such as pollinators and predatory insects (Cheong et al., 2010). Generally, insects are vital component of ecosystem where they involved in various biological controls, pollination, decomposition and herbivory processes (Fazal et al., 2012). Insects such as parasitoids and hemipterans serve an important role in regulating bagworm and caterpillar populations in oil palm plantations (Basri et al., 1995; Norman and Basri 2007; Cheong et al., 2010). Currently, six species of hemipteran with the possibility of acting as predator insects have been identified in oil palm plantations in Malaysia, namely *Cosmolestes picticeps* (Yusdayati, 2008), *Callimerus arcufer* (Basri et al., 1996), *Sycanus dichotomus* (Jamian et al., 2011), *Andrallus spinidens*, *Platynopus melachantus* and *Cantheconidea furcellata* (Khoo and Chan, 2000).

Integrated pest management (IPM) is a series of essential strategies which provide a long-term preventation of pests while limiting environmental damage (Kogan, 1998).. IPM systems keep pest populations below damaging levels via insects or other animal and plant management tactics with minimal environmental impacts (Romoser and Stoffolano, 1998; Wood, 2002). Successful implementation of IPM systems in oil palm plantation has been reported by Caudwell (2000). The idea of planting beneficial plants such as *Turnera subulata, Antigonon leptopus* and *Cassia cobanensis* to sustain natural enemies is well-received by planters and is actively being implemented. Numerous experiments showed that the presence of flowers in agro-ecosystem could increase the abundance of natural enemies (Wratten et al., 2002). Up to the present time, seven hymenopteran and one hemipteran family on beneficial plants have been identified (Yusdayati et al., 2014). In addition, *C. cobanensis* was suggested to sustain the population of natural enemies for long term control of bagworms (Norman and Basri, 2010). The flowering plants of *C. cobanensis, Crotalaria usaramoensis, Asystasia gangetica* and *Euphorbia heterophylla* were proven to prolong the life span of adult parasitoids in the laboratory (Basri et al., 1999). A study by Ho (2003) thus confirmed that *C. cobanensis* and *E. heterophylla* were almost equal in terms of attracting natural enemies in the field. The abundance and distribution of predator insects are regulated by several biotic and abiotic factors and their interaction. Among abiotic factors, temperature, rainfall and humidity stand out as the most important ones constraining abundance and distribution of insect.

Based on personal observation and reviews by researchers, it is well understood that insect predators highly significant in controlling bagworm and caterpillars (Basri et al., 1995; Norman and Basri, 2007). Presently, flowering plants are planted at the edges of oil palm plantations to improve the performance of insect predators. Still, there is no evidence proving these plants could improve the performance of insect predators as potential biocontrol agents in oil palm plantation.

Maintenance of predatory insect populations as biological control agents requires assessment of habitat quality to distinguish with characteristics support higher populations of predatory insects. Thus, the objectives of this study are; 1) To compare the abundance of predators in different oil palm plantations areas, and 2) To determine the relationship between the predators, abiotic factors and bagworms.

3.2 Materials and methods

3.2.1 Study sites

The study was conducted from April 2014 to March 2015 (12 month) in three pesticide-free oil palm plantation areas which were divided into three categories; 1) With three types of beneficial plants (*T. subulata, C. cobanensis and A. leptopus*) in Bukit Talang Estate (BTE, 4,428 ha) in the state of Selangor (N 03^0 23’ 58.4”, E 101^0 18’ 94.2”) (Figure 3.1); 2) with single beneficial plant, *Turnera urmifolia* in Bukit Senorang Estate (BSE, 1,628.10 ha) in the state of Pahang (N 03^0 07’ 04.3”, E 102^0 24’ 48.0”) (Figure 3.2) and 3) Without beneficial plant in South East Pahang Estate (SEP, 1,618.7 ha) in the state of Pahang (N 03^0 05’ 23.5”, E 102^0 24’ 53.7”) (Figure 3.3). All respective plantation areas are monitored by the estate management (Figure 3.4). The location of beneficial plants planted along the main road of oil palm plantations. Plantations were defined as large-scale oil palm cultivation areas covering more than 50 ha each, and were managed by private businesses (Azhar et al., 2011). This plantation area is equipped with modern facilities and infrastructure such as paved roads, perimeter fences, worker settlements and mills (Jambari et al., 2012).

Figure 3.1 : Fully-adopted planting technology of beneficial plants in Bukit Talang Estate, Selangor.

Figure 3.2 : Single beneficial plants for pest control purposed in Bukit Senorang Estate, Pahang.

Figure 3.3 : South East Pahang Estate in Pahang without any beneficial plants.

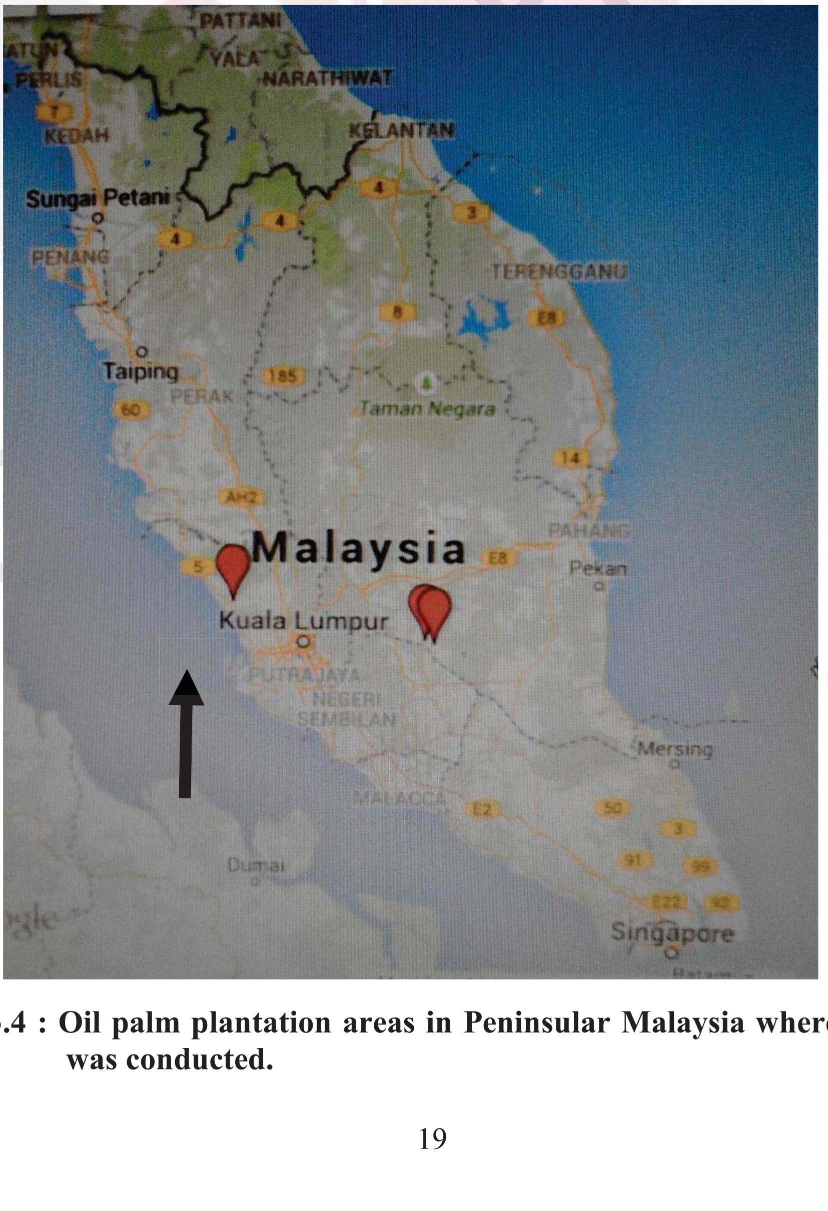

Figure 3.4 : Oil palm plantation areas in Peninsular Malaysia where the study was conducted.

3.2.2 Insect sampling

Sampling was conducted in every month during a clear day (without rains or heavy clouds) from 0700 to 1100 h and were resumed at 1600 to 1900 h with the used of straight line- transect. Sampling on predator insects species was carried out using sweep net and visual sampling technique. A total of 20 transects were set up from each sides. Each transect is 50 m apart to ensure observation of independence of predator insects. The corresponded predator species were identified and the number of each species was recorded. The predators were identified using keys as described by Norman et al. (1998).

3.2.3 Bagworms sampling

Sampling was performed on 20 identified palms (5-7 harvester's path) from each sites that were previously marked. Fronds number 17 (Ho, 2002) of each marked trees were cut using a cutter where the leaflets were collected, together with bagworm larvae and pupae. Numbers of bagworm larvae and pupae were recorded. Identification of each species was carried out according to protocols provided by Malaysian Palm Oil Board (2002) and Norman et al. (1998*)*. Twelve month of rainfalls were also obtained using a rain gauge from the weather station located in the field.

3.2.4 Population fluctuation study

The bagworm, predator insects and rainfall were recorded for 12 month. For bagworm, twenty plots were randomly selected for each estate for study. Each plot , two palms were randomly selected in the fifth to seventh row off the road side and these palms were marked with plastic tape. The bagworm was placed inside a small plastic bag and marked. The specimens were sorted out in the field. Sampling adult predator insects were using sweep net. Sweep netting was standardized using a set number of back-and-forth sweeps (between 10 to 20) approximately 1 m in length taken every other pace while walking at a consistent speed through the beneficial plants or vegetation (Ausden and Drake, 2006). Monthly rainfalls were also obtained using a rain gauge from the weather station located in the field.

3.3 Data analysis

3.3.1 Abundance of predatory insect

The abundance data (predators and bagworms) were transformed to squareroot (Sqrt) prior to inferential analysis for comparison of abundance of predators on three sites of oil palm plantations. To test for the interaction between number of predators and estates the data were analyzed by using two-way ANOVA test. The least significant difference (LSD) at 0.05% level of probability was used to separate the means.

3.3.2 Population fluctuation of predatory insect

To estimated population fluctuation of predators and bagworms were determined started from April 2014 to March 2015 (12 month) in three pesticide-free oil palm plantation areas. The total number of predators and bagworms per sampling visit against time and total monthly rainfall parameters were recorded. The total number of predators and bagworms were correlated with monthly rainfall parameters obtained subjected to using Pearson Correlation analysis at 0.05% significance level.

3.4 Result and discussion

3.4.1 Abundance of predatory insects populations

A total of 1,035 individuals from two species of predatory insects, namely *Cosmolestes picticeps* (n = 924) (Figure 3.5). and *Sycanus dichotomus* (n = 111) (Figure 3.6) were recorded. As expected, mean abundance of *C. picticeps* was significantly higher (F = 21.75; p<0.001) in with three types of beneficial plants sites (67.08 ± 6.41 individuals) than single-planting and without beneficial plant sites (8.42 ± 0.62 individuals and 1.50 ± 0.19 individuals, respectively (Figure 3.7). Likewise, significant number of *S. dichotomus* was found in with three types of beneficial plants sites (F = 32.21, p< 0.001) (9.25 ± 2.25 individuals), compared to the single planting and without beneficial plant sites (Figure 3.8).

Figure 3.5 : An adult assassin bug, *Cosmolestes picticeps* on *Cassia cobanensis* leaf.

Figure 3.6 : *Sycanus dichotomus* is a predatory bug found in oil palm plantation.

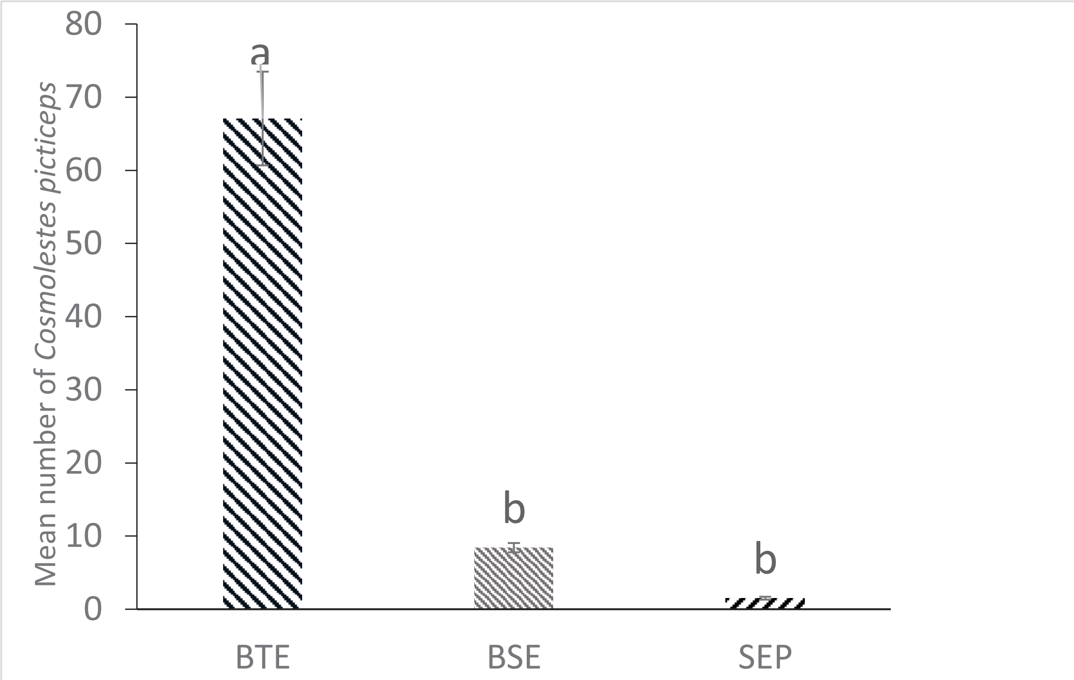

Figure 3.7 : Abundance of *Cosmolestes picticeps* in three oil palm plantations located in Peninsular Malaysia

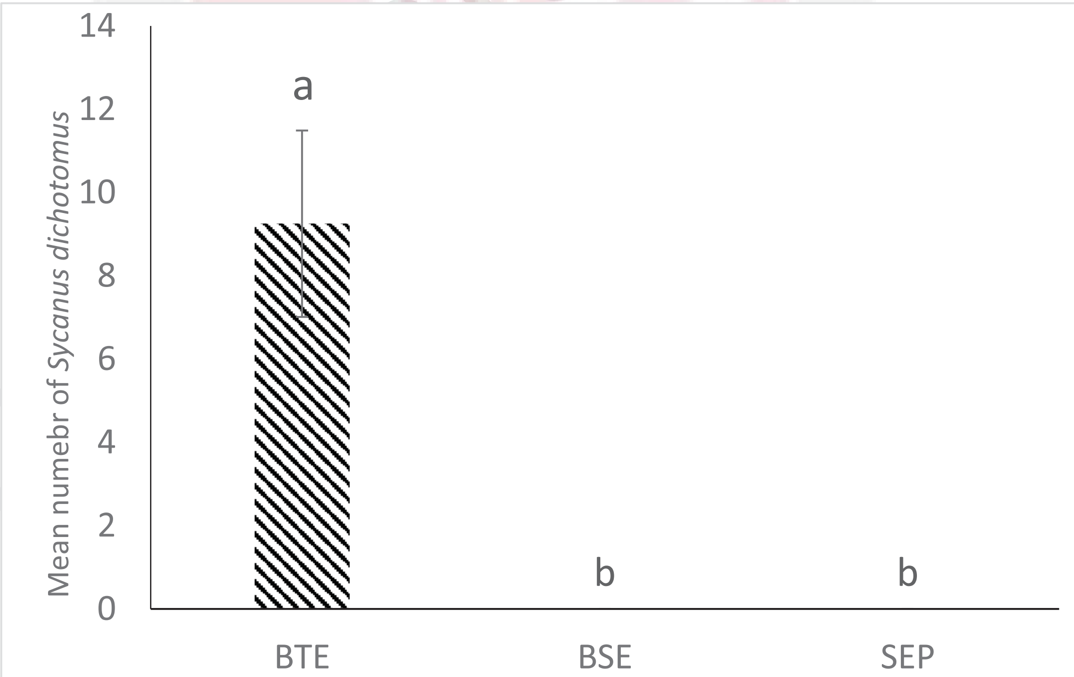

Figure 3.8 : Abundance of *Sycanus dichotomus* in three oil palm plantations located in Peninsular Malaysia.

Earlier findings on studies of natural enemies on beneficial plants by Yusdayati et al. (2014) reported similar results, however the number of *S. dichotomus* and *C. picticeps* found on beneficial plants was low. The studies also discovered the predators; *Turnera spp., C. cobanensis* and *A. leptopus* in selected host plants of oil palm plantation (Yusdayati et al., 2014). These host plants provide refuges and food for the natural enemies. The result revealed that by planting various beneficial plants in oil palm plantations, the oil palm management would be less dependent on chemical pesticides to control bagworm populations. Although the usage of insecticides (monocrotophos, methamidaphos and cypermethrin) have been reported to be successful in controlling pest (Wood and Nesbit, 1969; Chung, 1989), the extensive usage of chemical will also disturb natural enemies population and in turn encourage pests resurgent that can lead to pest outbreak (Leena and Hazem, 2011). Otherwise some beneficial plants are not perennial species (e.g. *C. cobanensis*), these plants require continuous replanting and alternative food plants (e.g. *Turnera* spp.) should be planted as well during the absence of the annual species (Yusdayati et al., 2014). Furthermore, a previous study by Norman and Basri (2010) on interaction of the bagworm and its natural enemies in oil palm plantation disclosed the existence of predatory insects on *C. cobanensis*. The study also reported the abundant of other predatory insects, *C. picticeps* and *S. dichotomus* in with three types of beneficial plants site.

3.4.2 Population fluctuations of predator insects, bagworms and rainfall volume

Population fluctuation of predatory insects in relation to rainfall and bagworms are shown in Figure 3.8, Figure 3.9, and Figure 3.10. *Cosmolestes picticeps* adults were found on all sampling dates in three oil palm plantations but *S. dichotomus* was only found in Bukit Talang Estate. A one-year observation revealed relative abundance of predators and bagworms at three oil palm plantations. Based on our results, the presence of predators in Bukit Talang Estate was consistently present, however there are fluctuation every month. During April 2014 to March 2015, two population peaks of predators were identified particularly in (May and June) and (Sept and Oct) while the lowest population was in November to December (Figure 3.8). An expected, the abundance of predators in areas with single planting beneficial plant (BSE) and without beneficial plants (SEP) consisted a low number of predators. This is because the results from Bukit Senorang Estate and South East Pahang Estate recorded the only existence of the predator *C. picticeps*, present in consistently low (8.42 ± 0.62 individuals (BSE) and 1.50 ± 0.19 individuals (SEP)) numbers during every month (Figure 3.9 and Figure 3.10) compared to Bukit Talang Estate (67.08 ± 6.41 individuals).

Our results further disclosed that the *M. plana* bagworm populations fluctuated throughout the year in these three oil palm plantations. Bukit Talang Estate recorded two months the highest numbers of *M. plana* larvae, which were in April (45 individuals) and June (46 individuals). However, Bukit Senorang Estate recorded three months the highest numbers of bagworms in January, February and March 2015 (248, 241 and 261 individuals) repectively. While, South East Pahang Estate recorded two months the highest numbers of these larvae in January, February and March 2015 (330, 130 and 318 individuals) respectively.

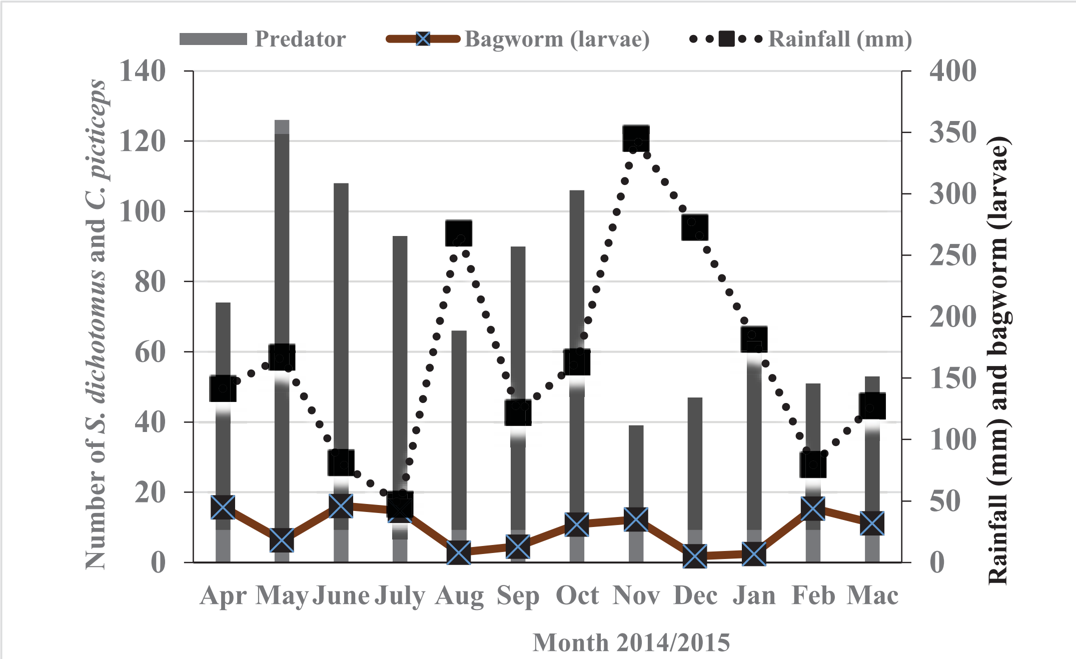

Figure 3.8 : Graph of monthly population of bagworm *M. plana*, its predators (*S. dichotomus and C. picticeps*) and rainfall volume at Bukit Talang Estate in Selangor.

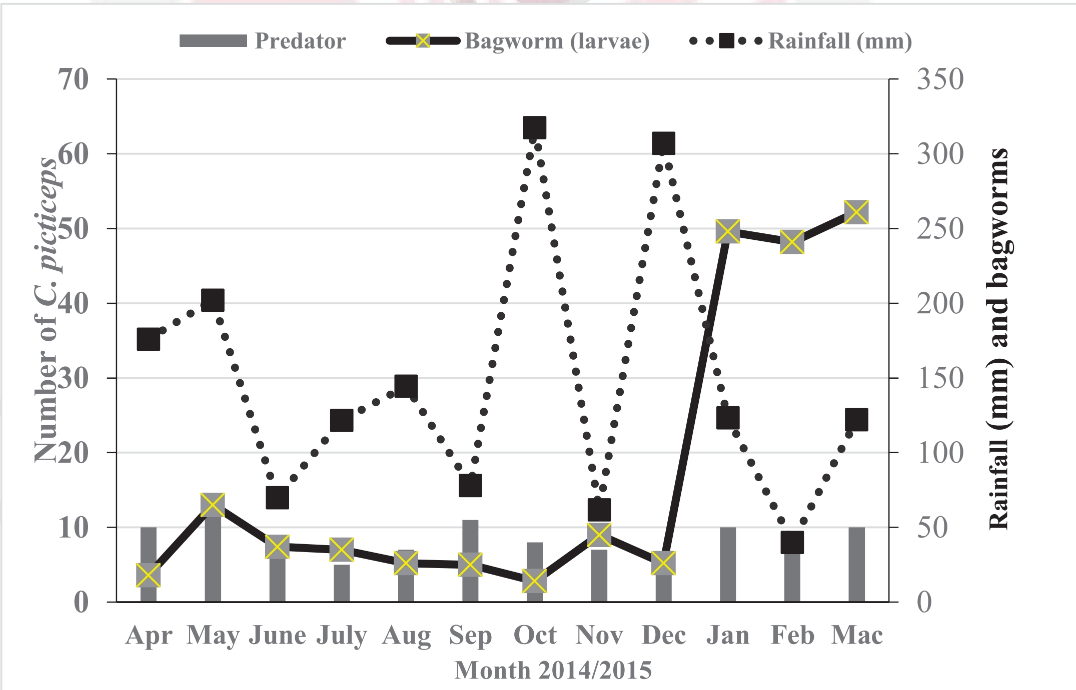

Figure 3.9 : Graph of monthly population of bagworm *M. plana*, its predators (*C. picticeps*) and rainfall volume at Bukit Senorang Estate in Pahang.

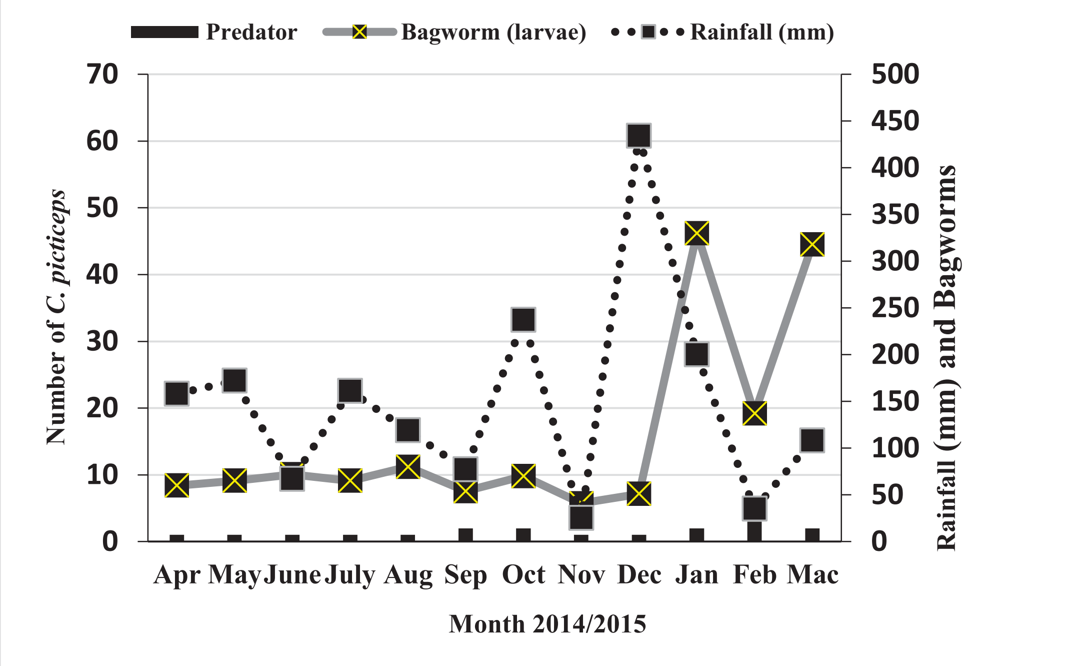

Figure 3.10 : Graph of monthly population of bagworm *M. plana*, its predators (*C. picticeps*), and rainfall volume at South East Pahang Estate in Pahang.

The correlation analysis showed that *C. picticeps* and *S. dichotomus* population are not significantly correlated with rainfall parameters and bagworms at all estate namely Bukit Talang Estate, Bukit Senorang Estate and South East Pahang Estate (Table 3.1).

Table 3.1 : Correlation of predators, rainfall parameters and bagworms.

Predators/Estate	Correlation with rainfall and bagworm *(α = 0.05)*	
	Rainfall	Bagworms
<u>Bukit Talang Estate (BTE)</u>		
Cosmolestes picticeps	0.070 (- 0.541)	0.211 (- 0.389)
Sycanus dichotomus	0.541 (- 0.196)	0.251 (-0.360)
<u>Bukit Senorang Estate (BSE)</u>		
Cosmolestes picticeps	0.872 (- 0.052)	0.511 (-0.210)
<u>South East Pahang (SEP)</u>		
Cosmolestes picticeps	0.273 (-0.344)	0.273 (-0.496)

Description: Number in brackets = correlation coeffision value (r). Correlation column shows probability (P) value: * = significant at α= 0.05; ns = not significant at α= 0.05

Population fluctuation of natural enemies in oil palm plantation has been studied by a lot of researchers. Based on a study by Nor Ahya et al. (2012), natural enemies was reported to be high in April, July and August 2011 in the oil palm plantation of Hutan Melintang, Perak. Yusdayati et al. (2014) latter revealed that greater number of natural enemies was recorded in Felda Plantation, Besout 6, Sungkai, Perak during December 2005. Meanwhile, Norman and Basri (2010) reported the presence of peaks populations of natural enemies on oil palm in June, October and December 2006 at Telok Intan, Perak. Nevertheless, Cheong et al. (2010) described a high mortality of bagworms initiated by predators during March to November 2006 in Hutan Melintang oil palm plantation located in Perak.

We discovered population of two predators (*C. picticeps and S. dichotomus*) in Bukit Talang Estate, in which these populations were fluctuated throughout the duration of our study, and were generally higher during the dry season (February to July annually) compared to rainy or wet season (August to January annually). Our results were supported by former research reported by Aneni et al. (2014), which demonstrated population of natural enemies was found fluctuated due to seasonal conditions. This is important to enhance the use pest control strategies based on interactions between natural enemies, insect pest and abiotic factor should be understanding.

On the other hand, outbreaks of bagworms population are reported to be the most common during January to March 2015 in Bukit Senorang Estate and South East Pahang Estate. This scenario might suggest that these estates perhaps are not totally aware of the importance to planting beneficial plants. For example Bukit Senorang Estate area is known to planting single beneficial plant such as *T. urmifolia* and without beneficial plant in South East Pahang Estate. Our study clearly suggest the role of beneficial plants in reducing the occurrence of bagworms in oil palm plantations via the propagation of natural enemies (Norman and Basri, 2007).

Beneficial plant plays a critical role for host plants to maintain the existence of predators in oil palm plantations. However, there is still no correlation between weather parameters and bagworms infestation. Results showed that high numbers of bagworm larvae incidence being washed-out by rain drops on frequent rainy days per month could affect bagworm population. Hence, the results showed there is no significant correlation between rainfall over the monthly annual incidence of bagworms infestation. The result of this study confirmed the finding obtained by (Chung and Sim, 1991) where recorded building up of bagworm infestations occurred in relatively high rainfall period and not necessarily in dry months. Cheong et al. (2010) also observed that there was no significant relationship between bagworms and rainfall. Although observation of bagworm infestations in Malaysia were often associated with low rainfall or drought although this association has not been statistically established (Basri et al., 1988; Syed and Shah, 1992; Hoong and Hoh, 1992). Moreover, according to Nor Ahya et al. (2012), bagworms resting under oil palm leaflets did provide protection from rain drops. Our results could become the reason on why rainfall has been reported to be unreliable in predicting outbreaks since all bagworm species was formerly assumed to have similar response against rainfall (Chung, 1998).

Our over a year period observation between populations of predators and weather parameters revealed no significant relationship. Therefore, other factors could be responsible for the fluctuation of predator populations in the study areas. One such factor could be the form of the shelter offered by beneficial plants, which dew-dropped the plants early in the morning. Our visual observation also demonstrated the predators resting under beneficial plants and sucking water from the plant (Figure 3.11). Since water management is one of the most critical aspects in oil palm plantations (Jamian et al., 2016), rainfalls are indeed important for their sustenance in support to water suppliant. Oil palm plants need a lot of water to ensure an outstanding quality, growth and fruit yield, thus an unstable supply of water could create unnecessary stress to the trees and adversely affect their productivity.

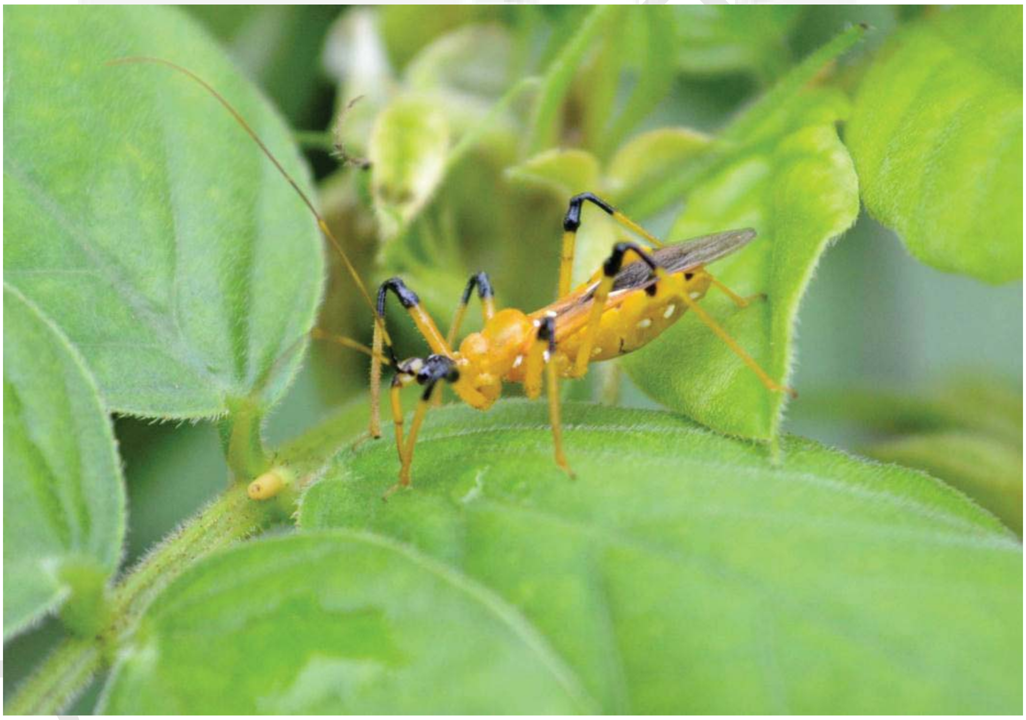

Figure 3.11 *: Cosmolestes picticeps* sucking water on *Cassia cobanensis*.

3.5 Conclusion

Our study revealed the abundance of predators is dependent to host population of the bagworms. Due to the negligible numbers of bagworms host in sites the field, the activities of insect predators shifted mainly to beneficial plants along the roadside. Our results indicated that the abundances of *C. picticeps* and *S. dichotomus* increased with the richness of beneficial plants. These findings are consistent to other research reported that beneficial flowering plants, such as *C. cobanensis* and *T. subulata* are able to attract natural enemies of bagworms. These host plants provide refuges and nectar for natural enemies. By planting various beneficial plants in oil palm plantations, oil palm growers would be less dependent on chemical pesticides to control bagworm populations. As some of the beneficial plants are not perennial species (e.g. *C. cobanensis*), these plants require continuous replanting and alternative host plants (e.g. *T. subulata*) to be planted during the absence of annual species. Studies on predators performance (functional response) could provide insights into the behavior or interactions of the predators in relation to their host.

CHAPTER 4

THE FUNCTIONAL RESPONSE OF TWO PREDATORY INSECTS FED ON BAGWORM, *METISA PLANA* WALKER

4.1 Introduction

The biological control studies of the psychidae, *M. plana* using predators have been reported by researchers worldwide (Norman et al., 1998; Sipayung et al., 1992; Tiong, 1981; Basri et al., 1995; Cheong et al., 2010). Based on previous findings, two predators; *S. dichotomus* and *C. picticeps* were found to be existed. Apparently, the potential of a predator can be evaluated under laboratory condition in which it could provide a better idea on the efficacy of the predators. The efficacy of a predator immensely depends on its ability to locate the accurate hosts size within the crops habitats (Zulkefli et al., 2004).

The functional response of a predator is the key factor in population dynamics of predator-prey systems, where it can be used to determine whether a predator is able to regulate the density of its prey (Murdoch and Oaten, 1975; Schenk and Bacher, 2002). For this to become realistic, functional response must show density dependence, e.g. the predator must response to higher prey densities by consuming and increasing proportion of the prey available over the range of prey densities. These functional response curves are classified as Type II, and are characterized by their sigmoid shapes when plotting the number of prey items eaten by the predators against the number of prey available (Holling's, 1965). Interestingly, the reduviid *S. dichotomus* has been described as an effective predator attacking many species of lepidopteran larvae, with the potential as biological control agent (Norman et al., 1998). Nevertheless, *C. picticeps* was reported of depicting a cannibal behavior (Azlina and Tey, 2011).

Sycanus dichotomus has been reported as effective attacks many species of lepidopteran larvae, this reduviid may have the potential for biological control (Norman et al., 1998). However, the predator, *C. picticeps* was reported from previous chapter more abundance in oil palm plantation. On purpose, the functional response of two predatory insects attack on bagworm were be conducted. The objectives of this study to compare the functional response of two species of predators.

4.2 Materials and Methods

4.2.1 Rearing the predators

The study was conducted inside a controlled environment room (insectary laboratory) at Ladang 2, UPM (day temperature 27 $\pm$ 1^{0}C, night temperature 24 $\pm$ 1^{0}C, light: darkness 12:12 and humidity 60% - 80% RH). All predators were reared in plastic cages (35 x 28 x 20 cm) with each cages contained a pair of adult predators. An alternative prey, the mealworm was supplied daily.

The eggs were later collected from the surface of the cages and kept in different plastic cages in a controlled environment room. Upon hatching, the first instar nymphs were fed with honey in small petri dishes. On the second day of hatching, the first instar nymphs were transferred and kept in groups in small plastic cups (5 cm height x 11 cm diameter). The cups were checked every one or two days, while the prey and water were replenished when necessary. The F1 adults of each species from each cage were subsequently used to generate more colonies of the predators.

4.2.2 Functional response of predators

A total of 50 adult individuals of each insect species (*S. dichotomus and C. picticeps*) were used. Five different treatment or insect densities (2, 4, 6, 8 and 10) of the third instar from *M. plana* were used. For each densities the prey were separated into cylindrical plastic cages (10 cm height x 12 cm diameter). Individuals predators were starved for 24 h prior experiment. The experiment was performed in ten replicates with 24 h duration. After 24 h, the remaining of the killed larvae (prey) were counted, and the percentages of the prey consumed were calculated.

4.3 Data analysis

The behavioral response of the predator to the prey density was expressed by fitting the Holling's equation to the data using the following formula:

$$Ne = \frac{aNT}{1 + aNTh}$$

Ne = number of prey consumed by the predator
a = attack rate of a predator
N = original number of prey offered to predator at the beginning of the experiment
T = total exposure time in the experiment
Th = handling time for each prey attacked

All statistical analyses were conducted in Minitab version 17.0 statistical software.

4.4 Result and discussion

Functional responses of *S. dichotomus* and *C. picticeps* to different densities of the third instars of *M. plana* are shown in figure 4.1 and figure 4.2. The average number of *M. plana* larva fed by *S. dichotomus* was increasing, while for *C. picticeps* fed on *M. plana*, the average number keeps increasing and decreasing back and forth until the rate reached an upper plateau with mounting in prey densities during 24 hours of exposure period (Figure 4.1).

In figure 4.2, we revealed the functional responses on the number of prey consumed by two predators over the prey density. The graph showed that as the prey density increased, the number of prey consumed by the predators was equally accumulating. When the density of *M. plana* was increased from 2 to 10 larvae, the number of prey consumed by *S. dichotomus* increased regularly upward. For instance, when the number of *M. plana* prey was increased from 2 to 6 and from 8 to 10, number of the prey consumed by *C. picticeps* also increasing from 0.9 to 2.1 and from 1.9 to 2.3, respectively. The rate of consumption of the *C. picticeps* predator might become gradually lessen after the prey density was about 6 and above, in line with results reported by Azlina and Tey (2011) disclosing *C. picticeps* possessed an immense cannibalism characteristic. Effectiveness of *S. dichotomus* and *C. picticeps* in suppressing Psychidae populations under laboratory conditions has been inconsistence. For instance, predation of *S. dichotomus* on rates ranging up to 73.33% while *C. picticeps* only 18.9% predation on bagworms (Azlina and Tey, 2011).

Nevertheless, the values of predation by 3^{rd} nymphal instars observed in the present study under insectary condition (27 ± 1^0C and 80% RH) are similar to those obtained by Fahmi (2013), who studied effectiveness of *S. dichotomus* on *Spodoptera exigua* at same temperatures, he reported a predation rate of 84% from 10 larvae. Similar results have been obtained for other species of the family Reduviidae. According to Greene and Shepard (1974), who studied functional response of *S. indigator* on *Pseudoplusia includens* in laboratory conditions reported only 48.5% of the predators were able to successfully find the cabbage looper. Those authors found that the number prey consumption by *S. dichotomus* were suitable at room temperatures than at other temperatures studied. Idris and Grafius (1998) found that the temperature high did not increase *Diadegma insulare* flight activity in the field and when low temperature the females seemed not active than males.

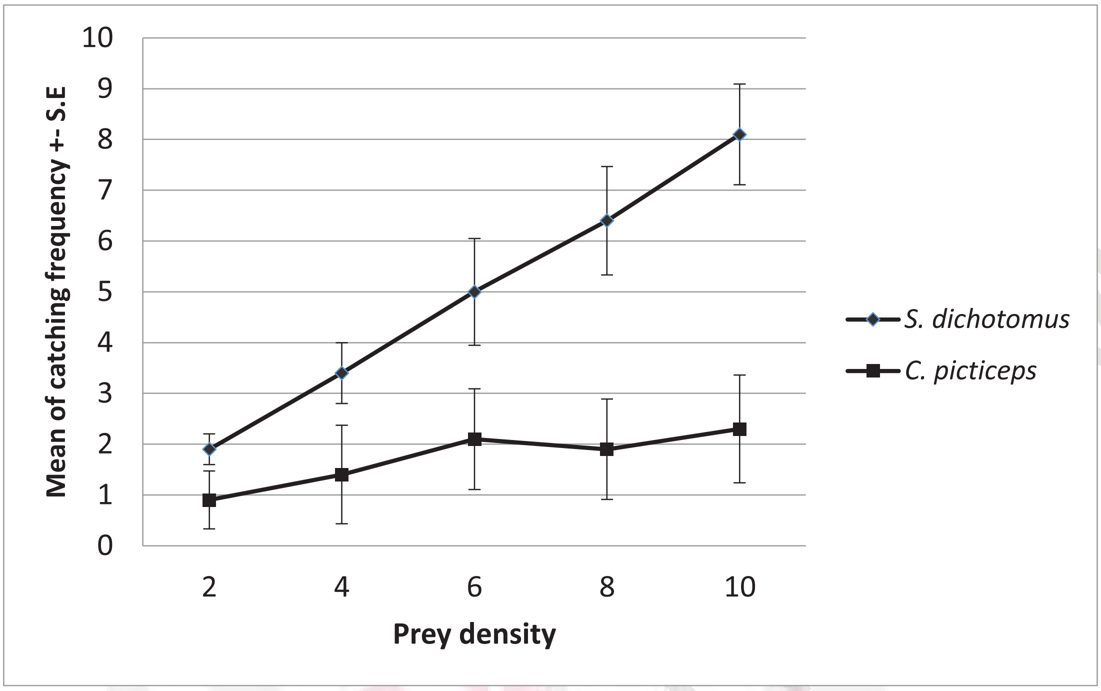

Figure 4.1 : Mean number of *M. plana* larva fed by two predatory insects in relation to prey density.

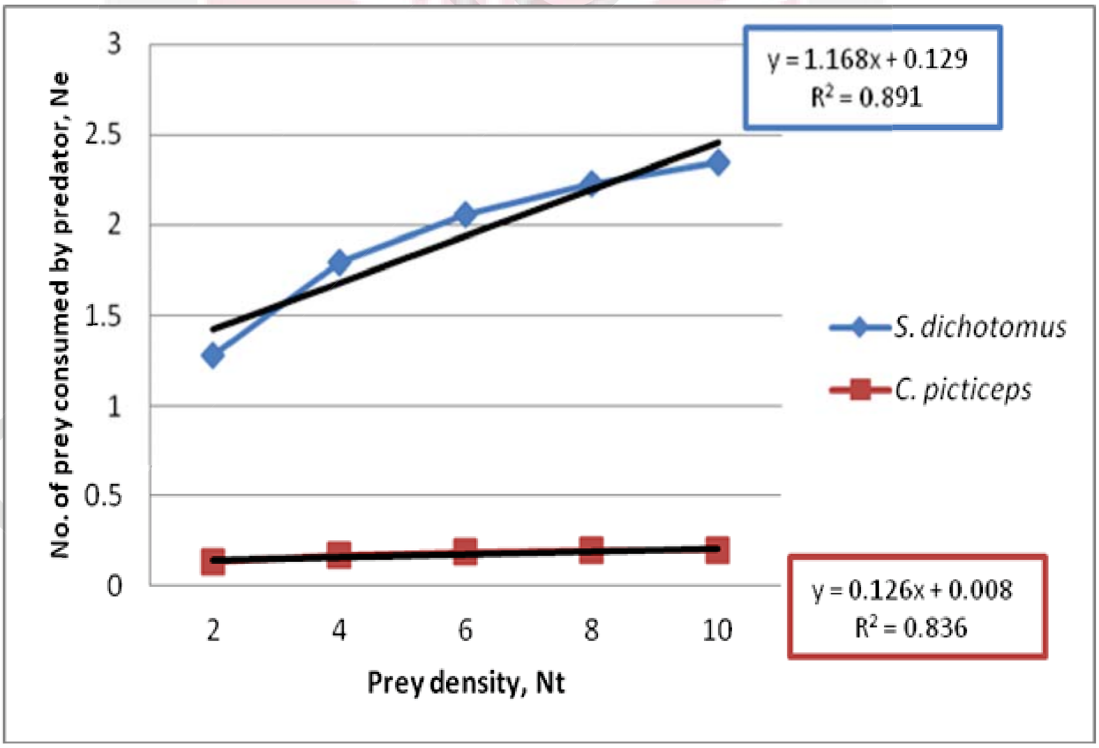

Figure 4.2 : Mean number of *M. plana* consumed by two predatory insects, Ne vs. prey density, Nt.

In the present study, the accelerated increased of *M. plana* attacked by predators in relation to the density of the host best-fitted the description of a Type II functional response. Type II functional response is known to increase on individual rate of attacks on host, where an increasing of host density is common for the predators (Holling, 1965; Schenk and Bacher, 2002). The fact that there is a specific amount of handling time (T_h) associated with each prey item consumed or attacked generates invariant to the density of the prey (N). While prey items are easier to find as their density increased, handling time per prey items consumed or attacked is reported by the ratio of total available searching time to handling time (T/T_h).

Type II functional response has been reported previously for a number of insect predators in laboratory experiments (Schenk and Bacher, 2002). Type of functional response of natural enemies undeniably affected by biotic and abiotic factors such as host plant, temperature, rainfall as well as type and growth stage of prey or host (Mohaghegh et al., 2001). Pervez and Omkar (2005), showed the functional response of three coccinellid predators *Cheilomenes sexmaculata, Coccinella transversalis* and *Propylea dissecta* (Coleoptera: Coccinellidae) to be type II when fed on two different prey species, *Aphis craccivora* and *Myzus persicae* (Hemiptera: Aphididae). While (Sahayaraj et al., 2015), in a laboratory experiment reported that, *Rhynocoris kumarii* (Hemiptera: Reduviidae) demonstrated a Holling's type II functional response, when fed with cotton mealy bug, *Phenacoccus solenopsis* (Hemiptera: Pseudococidae).

Although natural enemies which demonstrate type III functional response are generally regarded as efficient biocontrol agents (Pervez and Omkar, 2005), ecologist normally showed a lot of the natural enemies that have been successfully released as biocontrol agents exhibit type II functional response on their prey/host (Timms et al., 2008; Yingfang and Fadamiro, 2010). Furthermore, the magnitude of functional responses are determined with the attack rate and handling time of the insect predators.

Therefore, the number of prey densities attacked by the predators increased towards handling time as the results fitted Type II functional response. Based on Figure 4.1, the mean number started to taper off when the prey density reaches the maximum number. Hitherto, Syari (2010) reported the ability of *S. dichotomus* fed on *M. plana* larvae in both field and laboratory conditions values of 12.5 and 8.2 individuals, respectively. Meanwhile, the effectiveness of *C. picticeps* to consume *M. plana* in laboratory condition values of three individuals (Azlina and Tey, 2011). It fits the Type II functional response which stated before. It begins to taper off when the prey density reaches the maximum number. It can be point out that predators may have limitations in addition to handling time in field situations, and caution that functional response determined in the laboratory may differ in maximum consumption rates, and even in the shape of the response curve, from those observed in the field.

4.5 Conclusion

Data obtained from our study indicated *S. dichotomus* was the most fed on *M. plana* compared to *C. picticeps*, where the comsumption rate may consistent up to 80% in contrast with *C. picticeps* with only between 23 to 45%. Type II functional response exhibited by the predators displayed a negative density-dependent mortality in *M. plana* larvae population. Nevertheless, we should be aware this functional response was measured in insectary, so the observed pattern may be an experimental artifact and not reflecting the true effect of predators on its host population in the field. The results attained from our study demonstrated the vital potential of *S. dichotomus* in regulating the population of *M. plana* larvae, and may contribute to the establishment of a biological control program in different oil palm regions of Malaysia. Next chapter only focusing on its predators, *S. dichotomus*.

CHAPTER 5

BENEFICIAL PLANT MOST SUITABLE FOR *SYCANUS DICHOTOMUS*, PREDATOR OF THE BAGWORM

5.1 Introduction

Conservation and distribution of natural enemies of insects (predators and parasitoids) in oil palm plantation can help suppress pests while pollinators can increase crop yields. Many beneficial insects rely on beneficial plants for nectar and pollen or shelter (Yusdayati, 2014). Plants commonly recommended to provide these resources are non-native annuals such as *Turnera subulata, Antigonon leptopus* and *Cassia cobanensis* to sustain natural enemies are well received by planters and is actively being implemented (Norman and Basri, 2007). Some plants are especially good at attracting pest, predator and parasitoid. Beneficial plants can be important in providing alternative food (nectar and pollen) and habitat for beneficial insects (Basri et al., 1995). Michigan University reported that predatory insect attracting plants saved American farmers an estimated USD4.6 billion in year 2011 on insecticides (http://nativeplants.msu.edu/). Many predator insects, pest and parasites use flower nectar as a source of energy while they search for prey (Yusdayati et al., 2014).

Currently, bagworms are being controlled using various insecticides available in the world. Trunk injection technique are most popular to control pest using monocrotophos and methamiphos chemical in palms aged six years old and above in FELDA plantations (Noor Hisham and Sukri, 2004). Although the usage of insecticides is successful to controlling pests (Wood and Nesbit, 1969; Singh, 1976; Chung, 1988), extensive usage will also annihilate natural enemy population and in turn encourage pests resurgent that can lead to pest outbreak (Leena and Hazem, 2011). Noor Farehan et al. (2013) reported three insecticides, namely, cypermethrin, deltamethrin and trichlorfon are the chemical that causes high mortality percent against insect predators. The idea of planting beneficial plants to sustain natural enemies are well received by planters and is actively being implemented. Some researcher agreed, most natural enemies (predators and parasitoids) of bagworm available life on beneficial plants (Ho et al., 2003; Norman and Basri, 2010; Yusdayati et al., 2014). Strategic use of flowering plants to increase plant biodiversity in a targeted manner can very well provide natural enemies with shelter and food source to enhance biological control and reduce dependence on chemical pesticides. Therefore, the propagation and abundance of natural enemies depend strongly on availability of suitable beneficial plants as sources of nectar (Norman and Basri, 2010). Some beneficial plants were adopted in oil palm plantation such as *T. subulata, C. cobanensis* and *A. leptopus* have been found to provide food and shelter to many natural enemies particularly predators and parasitoids (Ho, 2002).

Predator insects and parasitoid needs the plants and flowers that provide moisture, shelter, alternative prey and immediate nutrition from nectar and pollen. Floral nectar composition is central to understanding a species pollination system and relationship with potential pollination vectors (Heil, 2011). Different groups of animals differ in their physiology and nutritive requirements, therefore the composition of sugars and amino acids in nectar is usually highly correlated with the specific nutritive requirements of a flower's pollinators (Gonzalez-Teuber and M. Heil, 2009). One aspect of habitat manipulation is the addition of floral resources to agroecosystem to provide additional food for beneficial insects, potentially enhanching their fitness and efficacy. Nutrients in the form of nectar and pollen namely carbohydrate- rich nectar provides energy, and pollen, which is often ingested with nectar, may provide nutrients for egg production in some species (Jervis et al., 1996) and longevity of parasitiod (Basri et al., 1999). But beneficial plants are not a magic bullet or quick fix, however a flower may attract a beneficial insects through chemicals it releasen plants. Liu et al. (2013) reported floral nectar on *Mucuna sempervirens* produces various composition such as sugar, proteins, phenolic, hydrogen peroxide and aromatic compounds. Whilst, the flowering plants namely *C. cobanensis, Crotalaria usaramoensis, Asystasia gangetica* and *Euphorbia heterophylla* containing composition nectar such as sucrose, fructose and glucose (Basri et al., 1999).

Many predators and parasitoids are attracted to flowering plants, where they obtain pollen and nectar that help increase their longevity and ability to lay eggs. Pollen and nectar not only provide this energy, but also serve as an alternative food when pests are scarce. However, there is no research evidence that shows the suitable of beneficial plants in improving the performance of insect predators as potential biocontrol agents in oil palm plantation.

Therefore, the aims of this study are 1) to investigate the efficiency of various beneficial plants towards the activities of *S. dichotomus*. 2) To evaluate the nectar content of a number of different type of plants.

5.2 Materials and methods

The experiment was carried out under a controlled environment in the glasshouse of the Faculty of Agriculture, Universiti Putra Malaysia (UPM), Selangor. The glasshouse had 12:12 h day:night photoperiod and a 21 – 36^{0}C temperature range. Six types of plant were used in the experiment namely *T. subulata, A. leptopus* and *C. cobanensis*, *Asystasia intrusa, Euphorbia heterphylla* and *Ageratum conyzoides*. Experiment were devided into two categories, no choice and choice.

5.2.1 No choice experiment

The plants were placed in a cage size (40 x 40 x 60 cm) (Figure 5.1). The sides and the top are made of transparent perspex and the base is made of wood. The front of the cage is converted into a door with a dimension of 40 x 60 cm to facilitate access into the cage that is for introducing the various plants into the cage prior to the start of the experiment and for cleaning the cage. A hole of 20 cm diameter is made at the left and right sides, and on the door, to facilitate introduction of the predator insects. To prevent escape of insect predator, the holes are equipped with a sleeve of muslin cloth that can be folded. To diffuse the light coming from the ceiling, the top of the cage were covered with a layer of clean plain white paper. Five pair of predatory insects and six types of plants in the different place were introduced in each cages. The parameters observed were

i. Number of predatory insects feeding nectar or resting on any parts of the plants. The observation was run from 9.00-11.00 am per day for 4 consecutive days
ii. Number of eggs laying.

The experiment was replicated ten times.

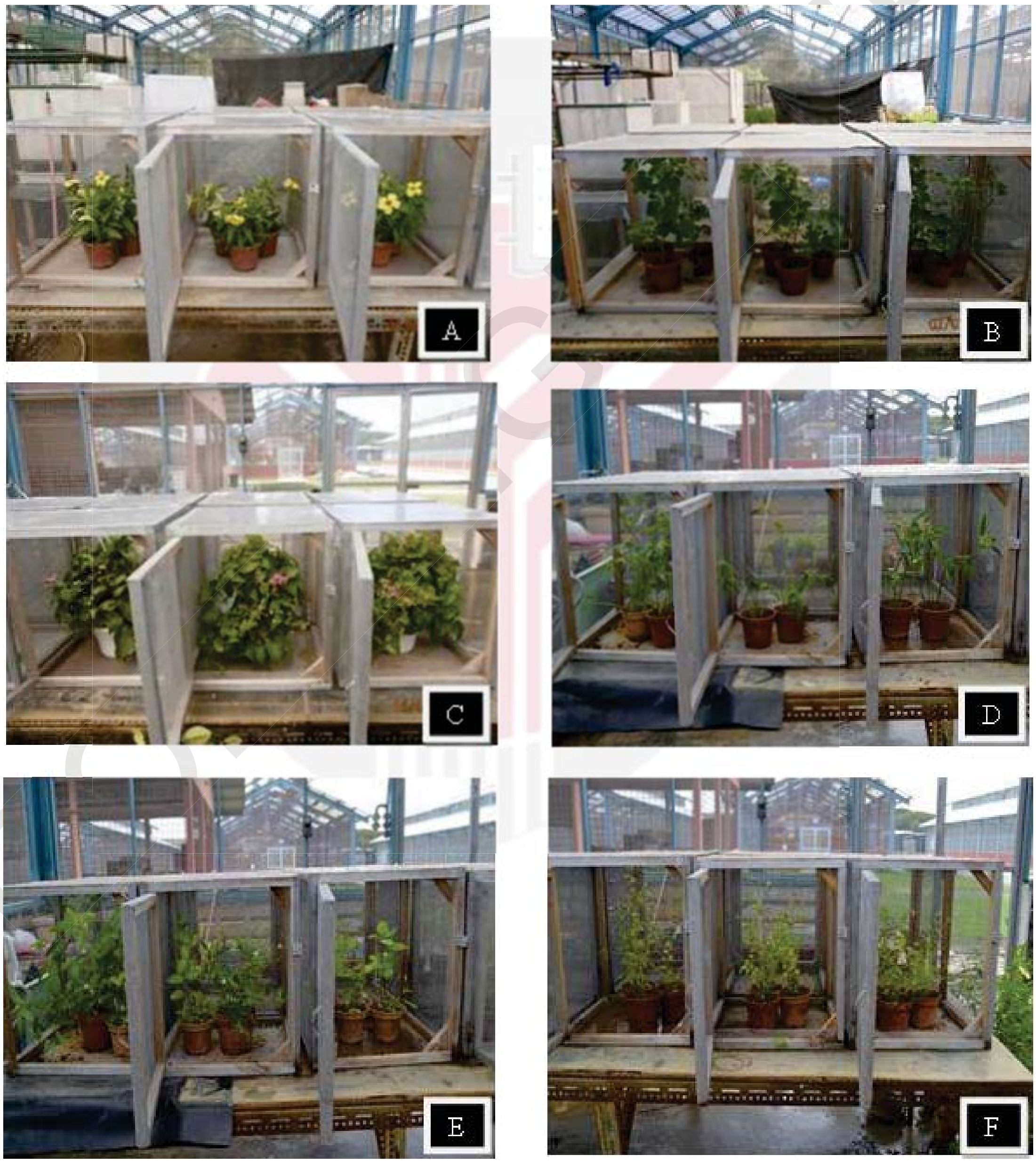

Figure 5.1 : Demographic of plants, *T. subulata* (A), *C. cobanensis* (B), *A. leptopus* (C), *E. heterophylla* (D), *A. intrusa* (E), and *A. conyzoides* (F).

5.2.2 Choice experiment

The plants were placed in a large cages size (100 x 100 x 170 cm). The front of the cage is converted into two doors with a dimension of 37.5 x 45cm to facilitate access into the cage that is for introducing the various plants into the cage prior to the start of the experiment and for cleaning the cage. Five pair of predatory insects and six types of plants were introduced in the same cage. The parameters observed were

i. Number of predator insects feeding nectar or on any parts of the plants. The observation was run from 9.00-11.00 am per day for 4 consecutive days
ii. Number of eggs laying.

The experiment was replicated ten times.

5.2.3 Nectar content in beneficial plants

Fresh nectar and pollen was collected in May 2015 from six plants in the Ladang 2 and Glasshouse, Universiti Putra Malaysia using a pipette and autoclaved tips. A wick was used to collect nectar from 10 flowers of each *T. subulata, A. leptopus, C. cobanensis, A. intrusa, E. heterophylla* and *A. conyzoides*. As described by Liu et al. (2013). Nectar and pollen from sample were extracted with *n*-hexane and shaken at room temperature for one hour. The mixture was then centrifuged at 12,000g for 30 min at 4°C. The oils were dried (anhydr. Na_2SO_4), concentrated under a stream of N2, and subjected directly to either GC (Trace EC Ultra, column:0.25 mm x 30m (TG-5MS) with temperature programming 80 to 350°C at 3°C/min, or to GC-MS (TSQ Quantum XLS(Trace EC Ultra, column:0.25 mm x 30m (TG-5MS) analysis under the following conditions: electron-impact (EI) mode (70 eV), constant current 1.0 ml/min, and temperature programming from 80 to 240°C at 3°C/min. Identification of volatile compounds was performed using X Calibur 2.1 software for Windows. Peak identification was made by comparing retention times and the mass spectra of eluting compounds to those in the NIST/Wiley database.

5.3 Data analysis

Data sets collected on containers test of choice and no choice experiment were subjected to analysis of variance using computer software (MINITAB 14.0 for windows) statistical package. Treatments with significant differences were compared at P = 0.05 level of probability using Tukey's test.

5.4 Results and discussion

5.4.1 Number of predator insects

In the no choice test, the duration of exposure to different plants had a pronounced effect on cumulative mean number of adult predators. Highest number of adult predators were observed on *Turnera subulata*, *Antigonon leptopus* and *Cassia* *cobanensis* throughout the 4 days exposure time (Table 5.1) . The number of adult predators at 2 days exposure times were significantly highest (P<0.001) on *Turnera subulata* (3.7 individuals), *Cassia cobanensis* (3.3 individuals) and *Antigonon leptopus* (2.6 individuals) compared to other plants in the treatments. However, we observed a declined in the number of predators in those plants at day 3 of exposure. While at day 4, *Turnera subulata* showed the highest numbers of predators among *Antigonon leptopus* and *Cassia cobanensis*. The number of predators on the weed plants ranging from 1.8 to 2.8 (*Asystasia intrusa, Euphorbia heterophylla* and *Ageratum conyzoides*) were significantly lower compared to the other three plants with the exception in day 3, throughout the study. These result are agreement with Yusdayati et al. (2014) who observed diversity and distribution of natural enemies populations on beneficial plants (*C. cobanensis* and *Turnera* spp*.)* while Norman and Basri (2010) reported that parasitoids and predators are the most abundant on *C. cobanensis*. However, Ho et al. (2003) reported that the number of parasitoid activity in the field increases with the presence of *E. heterophylla* and *C. cobanensis* the field.

Table 5.1 : Mean number of adult predators in no choice study at different exposure times

Treatment/Exposure Time	Day 1	Day 2	Day 3	Day 4
Cassia cobanensis	0.0 ± 0.00^{a}	3.3 ± 0.9 ^{ab}	2.7 ± 0.68^{a}	2.8 ± 1.55^{ab}
Antigonon leptopus	0.0 ± 0.00^{a}	2.6 ± 1.08^{abc}	2.5 ± 1.08^{a}	3.2 ± 1.48^{ab}
Turnera subulata	0.0 ± 0.00^{a}	3.7 ± 1.40^{a}	3.3 ± 0.68^{a}	4.1 ± 1.20^{a}
Asystasia intrusa	0.0 ± 0.00^{a}	2.2 ± 0.79^{bc}	2.8 ± 1.48^{a}	2.1 ± 0.88^{b}
Euphorbia heterophylla	0.0 ± 0.0^{a}	1.8 ± 1.03^{c}	2.2 ± 1.40^{a}	2.1 ± 1.10^{b}
Ageratum conyzoides	0.0 ± 0.00^{a}	2.2 ± 0.79^{bc}	2.1 ± 0.88^{a}	2.6 ± 1.08^{ab}

Means in the column with same letters are not significantly different at P = 0.05 level of probability according to Tukey's test.

The same result was obtained from the choice study where the exposure to different plants in choice study had a pronounced effect on cumulative mean number of adult predators. The highest number of adult predators were observed on *Turnera subulata* and *Cassia cobanensis* throughout the 4 days exposure times (Table 5.2). In this study, we observed the presence of predators after 2 days on the *Turnera subulata* (3.0 individuals), *Antigonon leptopus* (3.0 individuals) and *Cassia cobanensis* (2.1 individuals) and were significantly higher than the weed plants. Although the number of predators declined at day 3 and 4, the *T. subulata* and *C. cobanensis* remained the highest with 2.2 and 2.3 number of predators respectively. Meanwhile on *A. leptopus* significant declined were observed in the number of predators and were lower compared to the weed plants from day 3 and 4 in this study.

Table 5.2 : Mean number of adult predators in choice study at different exposure times.

Treatment/Exposure Time	Day 1	Day 2	Day 3	Day 4
Cassia cobanensis	0.0 ± 0.00[a]	2.1 ± 0.32[b]	2.3 ± 0.95[b]	2.0 ± 1.16[b]
Antigonon leptopus	0.0 ± 0.00[a]	3.0 ± 0.48[a]	0.5 ± 0.71[a]	0.0 ± 0.00[a]
Turnera subulata	0.0 ± 0.00[a]	3.0 ± 1.50[b]	2.2 ± 1.03[b]	2.0 ± 0.67[b]
Asystasia intrusa	0.0 ± 0.00[a]	0.0 ± 0.00[a]	0.2 ± 0.42[a]	0.4 ± 0.52[a]
Euphorbia heterophylla	0.0 ± 0.00[a]	0.4 ± 0.52[a]	0.8 ± 0.79[a]	0.8 ± 0.42[a]
Ageratum conyzoides	0.0 ± 0.00[a]	0.2 ± 0.42[a]	0.0 ± 0.00[a]	0.4 ± 0.52[a]

Means in the column with same letters are not significantly different at P = 0.05 level of probability according to Tukey's test.

Many predatory insect and parasitoid fed on nonprey foods such as pollen and nectar (Hoffman and Frodsham, 1993; Hickman and Wratten, 1996; Kroon, 2009). Predators may be attracted to host from the allelochemical part when released into the environment. Host colour and shape can be important in plant characteristic visual features and in predators that are day flying, although visually mediated responses are usually relatively unspecific (Bernays and Chapman, 1994). Many experiment have shown that presence of flowers in an agroecosystem can increase the abundance of natural enemies. Our results suggest that predators show strong attractant against beneficial plant, *T. subulata*. Our findings are similar to those of Yusdayati (2008), who reported that the *Turnera* and *C. cobanensis* are more favored by natural enemies compared to others plant. Chaney (1998) reported, the numbers of beneficial insects increased in lettuce in the presence of a range of flowers spesies. Leafroller parasitoids, *Dolichogenidea tasmanica* (Cameron) were found in yellow sticky trap increased in number when buckwheat flowers were present in an apple orchad (Irvin et al., 2000) and a vineyard (Berndt et al., 2002).

Our study is the first to investigate the attractance of predatory insects to beneficial plants namely *T. subulata, A. leptopus* and *C. cobanensis* and three ground vegetation covers, the *A. intrusa, E. heterphylla* and *A. conyzoides*. Ho et al. (2003) carried out comprehensive trials to evaluate the efficacy of range of beneficial plants and the result showed three groups of plants species namely *C. cobanensis, A. leptopus* and *T. subulata* were found to be the most effective to attracting natural enemies. In addition, *E. heterphylla* which also give effectiveness of insects but was not favoured for planting because difficulty in establishment and short life cycle of the plant (Ho et al., 2003) and *C. cobanensis* produce flowers only once a year (Basri et al., 1999). The best preference plant is *Turnera* than most other plants. Schlindwein and Medeiros (2006) reported that the flowers of *T. subulata* can attracted insects of 28 species. Similarly, Barret (1978) lists as many as 13 species of insects as flower visitors on *T.*

urmifolia. In the studied case, *S. dichotomus* indeed is very attracted to *T. subulata*. This shows the importance of the *Turnera* as shelter and nectar sources for *S. dichotomus*, and suggests planting because the plants set flowers throughout the year.

5.4.2 Number of egg laying

In both no choice and choice test, there was no egg produce. Even *S. dichotomus* get food source of pollen, but it is not enough because *S. dichotomus* to a large-sized of predator insect. Nutrients, including essential nutrients namely protein & amino acis, lipids, vitamins and mineral are vital to enhance or optimize growth, development and reproduction. Besides that, Wäckers et al. (2007) describes that plant provides food sources because of their direct role in plant-insect interactions and important for a broad range of adult insects. Lu et al. (2014) reported pollen enhances longevity, fecundity and other physiological functions of many insect. Similarly, Eubanks and Styrsky (2005) shown to significantly increase the fecundity of predatory insects feed on pollen. Additionally, when the predators, *Amblyseius cucumeris* was fed on an apple and Lycopodium pollen mix the survival and longevity increased but when supplied only with water, the female failed to produce eggs (Zhi, 2006). This is also true for parasitoids where they feed on nectar and pollen for survival and egg maturation (Vollhardt et al., 2010).

5.4.3 Structural elucidation unknown compound using GC-MS

In this study, gas chromatography–mass spectrometry (GC-MS) was used to determine the number of compounds in the beneficial plants extracts. Based on the results of the earlier study, extracts of six plants namely *T. subulata, C. cobanensis, A. leptopus, A. intrusa, E. heterophylla and A. conyzoides* were selected for further study because they were contained high concentration of volatile compounds. Our result showed, between 88 - 92 volatile compounds were identified in the nectar and pollen using GC/MS by comparing retention times and the mass spectra of eluting compounds to those in the NIST/Wiley database. These quantification identified compounds accounted for 100% of the total volatiles (Table 5.3). Additional compounds were detected at retention times as shown in Figure 5.2. They were grouped into four major classes (alkane, alcohol, carboxylic acid and carboxylate ester) based on their biosynthetic origins. None of these three classes were dominant in six plants. Tholl et al. (2004) reported terpenoids compound are generally thought to be insect attractants. In six plants, the terpenoids containing volatile compounds were detected.

Several compounds have been identified in intact host plants nectars (sucrose, fructose and glucose) (Basri et al., 1999). In this study, the major constituents include Trimethyl-3,4-methylenedioxychromane, Phenol,4,6-di(1,1-dimethylethyl)-2-methyl, and 2H-1-Benzopyran,6,7-dimethoxy-2,2-dimethyl- (48.45%). The minor constituents include: n-Hexadecanoic acid, Dodecanoic acid, 3-hydroxy-, and Octadecanoic acid, 2-(2-hydroxyethoxy) ethyl ester (0.45%). Host plants volatiles attracted the predatory insects, while carboxylic acids (Buchmann and Buchmann, 1981), lipids (Baker and Baker, 1975) and other organic compounds are also present in floral nectar. Water, present in nectar is also important to nectarivores (Willmer, 1986). Smilanick et al. (1978) reported on field tests indicate that acetaldehyde, ethyl acetate and ethyl alcohol are the principal attractants of *Carpopilus hemipterus* (Coleoptera: Nitidulidae) in California.

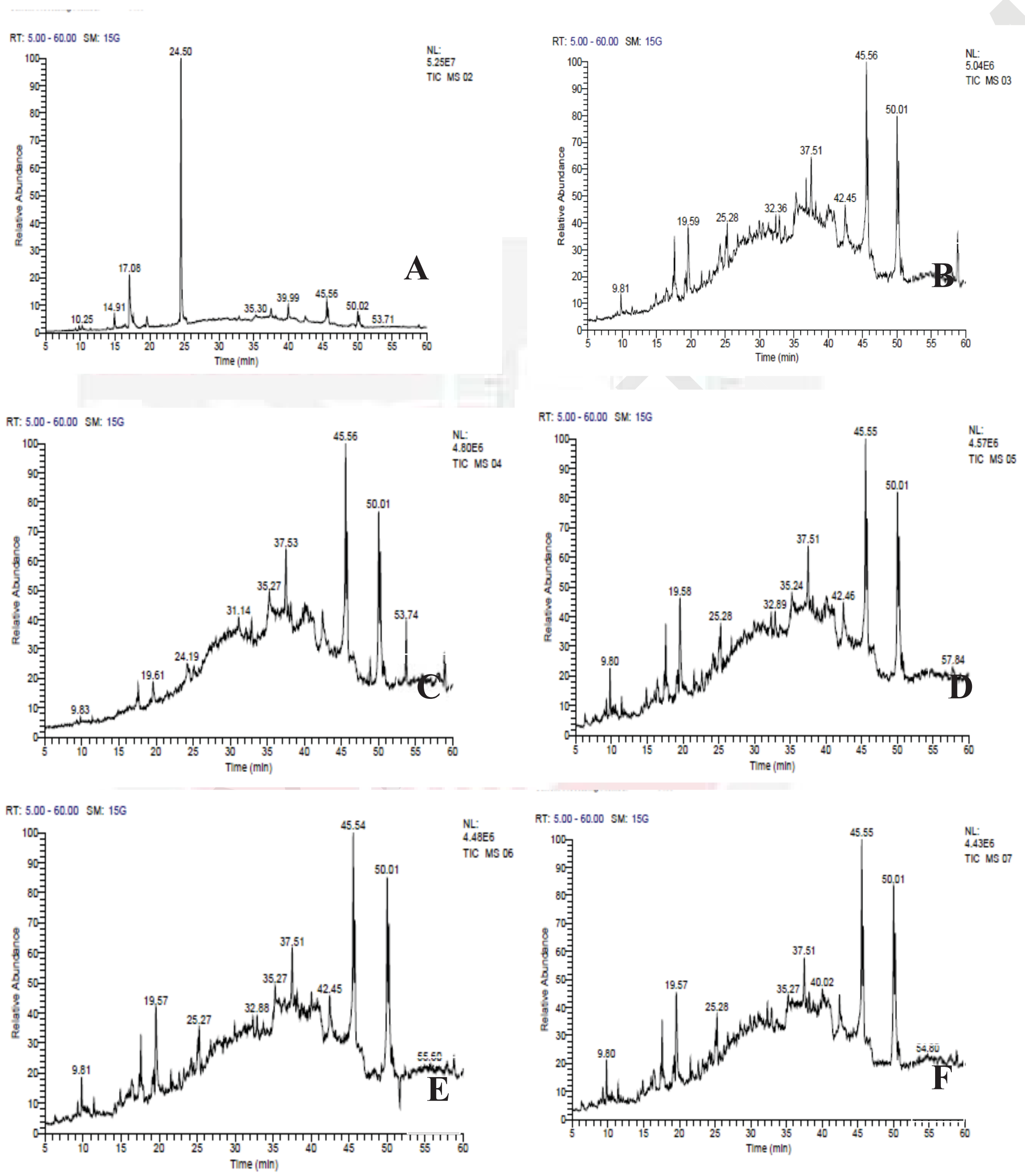

Figure 5.2 : Chromatogram peak of plants namely *Ageratum conyzoides* (A), *Asystasia intrusa* (B), *Turnera subulata* (C), *Cassia cobanensis* (D), *Euphorbia heterophylla* (E), *Antigonon leptopus* (F).

Table 5.3 : Composition of host plants floral volatiles from six cultivars by GC-MS.

	Compounds	Number of compounds					
		AC	AI	TS	CC	EH	AL
1	Alcohol	10	12	15	15	18	11
2	Carboxylate ester	12	19	9	19	14	22
3	Alkane	14	21	15	25	30	17
4	Alkene	13	3	5	5	4	7
5	Carboxylic acid	19	25	28	12	19	19
6	Alkyne	1	1	3	1	1	3
7	Aldehye	2	1	1	1	0	1
8	Amine	2	1	0	1	1	1
9	Carboxylate salt	0	2	0	0	0	0
10	Ester	2	0	0	0	0	0
11	Ether	0	0	0	1	0	1
12	Ketone	4	1	2	3	2	3
13	Organosilicone	2	1	1	0	0	1
14	Salt	5	2	10	8	1	2
15	Unknown	2	0	1	1	0	2
	TOTAL	**88**	**89**	**90**	**92**	**90**	**90**

AC - *Ageratum conyzoides*
AI - *Asystasia intrusa*
TS - *Turnera subulata*
CC - *Cassia cobanensis*
EH - *Euphorbia heterophylla*
AL - *Antigonon leptopus*

Volatile compounds mediate many interactions between organisms, including plant response to pathogen infection (Shulaev et al., 1997), plant-parasitoid signaling in response to herbivory (Turlings et al., 1990) and plant-pollinator communication during flowering. As pollinator attractants, volatiles are important cues that help insects locate flowers and signal the presence of food or mates (Knudsen et al., 1993). In this study, these beneficial plants found very useful plants to insects as a shelter, find food, eggs and mating. Plants synthesize and emit a large variety of volatile organic compounds with terpenoids, fatty acids and derivatives as the dominant classes. Floral scent composition of a plant is thought to have evolved partly from adaptations towards the olfactory requirements of efficient pollinators. Some volatiles are probably common to almost all plants while others are specific to only one or a few related taxa (Visser, 1986; Pichersky and Gershenzon, 2002). Plant odour specificity is achieved by a characteristic ratio of the constituent chemical compounds, which are generally distributed among the plant species (Visser, 1986). Anthers and pollen release distinctive odours (Blight et al., 1995; Barkman, 2003). Floral volatiles are formed via plant biosynthetic pathways. The rapid progress in elucidating the biosynthetic pathways, enzymes and genes involved in the formation of plant volatiles allows their physiological activity and function to be rigorously investigated at the molecular and biochemical levels. Floral volatiles act as attractants for species-specific pollinators. However, the volatiles emitted from the vegetative parts, especially those released after herbivory, protect plants by deterring herbivores and/ or attracting the enemies of herbivores (Pichersky and Gershenzon, 2002). Most of the floral fragrance compounds are terpenoids, simple aromatics, amines and hydrocarbons. The most common floral fragrance compounds are monoterpenes (Vickery and Vickery, 1981; Williams and Whitten, 1983).

There are many suggestion in the use of beneficial plants for the improvement in quality of natural enemies or beneficial insects (van Emden, 1963; Altieri and Whitcomb, 1980; Tiong, 1982). Many researchers study the parasitoid relationship with plants, while little research on predatory insects with plants. Leius (1967) reported on Umbelliferea species have carbohydrates content that essential in the normal fecundity and longevity of three Icheumonid species. Meanwhile, (Wolcott, 1941) reported that the succesful establishment of the introduced parasitoid, *Larra americana* to control cricket depended on the presence of two weeds, *Borreria verticillata* and *Hyptis atrorubens* as these plants provided the nectar for the adult wasps in Puerto Rico. However, In Malaysia there are lacking data on plants floral volatile studies have been reported to date.

5.5 Conclusion

Predatory insects have been known to respond to plant volatile. Our result indicated that the volatile from *T. subulata*, *C. cobanensis*, and *A. leptopus* attract *S. dichotomus* adults in cages experiment. To our knowledge, there are few reports on the response of *S. dichotomus* to different plant volatiles. Both sexes of the predator insect highly preferred the odors emanating from *T. subulata* followed by *C. cobanensis*, and *A. leptopus*. These results show relationship between beneficial plants (*T. subulata*, *C. cobanensis* and *A. leptopus)* and ground vegetation cover (*A. conyzoides, A. intrusa* and *E. heterophylla*) against insect predators depends on the number of floral volatiles produced by plants. The next experiment (Chapter 6) used *T. subulata* as the host plant based on the results (no choice test and choice test) as highest numbers of predator insects were attracted to *T. subulata* than other plants. Although *C. cobanensis* showed the same result, it produces flowers once a year and *A. leptopus* is a perennial vine and climbing plants while other plants known as a plant that grows naturally in the oil palm cultivation.

CHAPTER 6

THE PERFORMANCE OF *SYCANUS DICHOTOMUS* ON COMBINATION OF PLANT HOST AND PREY

6.1 Introduction

Conservation biological control enhances biological control efficacy by providing nectar, pollen, shelter, mating, lay eggs, hatching and/or alternative prey to biological control agent. It is a fast-growing sub-discipline of biological control, with notable recent successes (Wratten et al., 2002) . The provision of floral nectar to insect predators can enhance longevity from 18.6 and 20.6 days (male and female) in the presence of water only to 34.5 and 32.7 days (male and female), but no eggs produced. Insects recognize nectar and pollen which provide them nutritional needs. The flowers in return advertise insects that fit their needs (Pichersky and Gershenzon, 2002). Flowers attract insects from various distances through the interplaying of visual and chemical stimuli, which by virtue of their species-specific patterns allowing insects to discriminate flowers of different species (Menzel, 1985). Moreover, the plant volatiles, together with few other compounds act as determinants in insect-plant interactions (Dobson, 1994). In this study, *T. subulata* as the most suitable beneficial plant for predatory insect. Out of six plants species studied, *T. subulata* is the most preferred based on earlier results obtained (Chapter 5).

The important of Hemipteran predators in regulating population of pest species have been acknowledged for years (Grant et al., 1985). Several studies were designed to scrutinize quantitative assessment on the action of predatory insects in pest populations. This niche of investigation is amongs the most difficult yet challenging facets of biological control since information on insect-flowers interaction and performance of predatory insects are lacking in Malaysia. Therefore, in this chapter, the study was come out with the objective to evaluate the effects of using different plant hosts and prey on the predators' performance.

6.2 Materials and methods

6.2.1 Study sites

The study was conducted in the glasshouse, Faculty of Agriculture, Universiti Putra Malaysia. The in-house environmental conditions were at 28-31^{0}C with relative humidity of 70-80%. The predatory insects were placed within clear cages of 150 cm x 100 cm x 100cm in size (Figure 6.1). To prevent the predators from escaping, each door was built in small sizes (50 cm x 100 cm). Tap water was sprayed at regular intervals through the cage top with a squeeze bottle to form fine water droplets on the plant foliage from which the predators will drink. There were three types of combination (treatment) involved in the experiment were:

Treatment A: 10 months old oil palm, 5 pairs of *S. dichotomus*, beneficial plant (*Turnera subulata*) and 4th instar larvae of *M. plana* as a prey.

Treatment B: 10 months old oil palm, 5 pairs of *S. dichotomus* and beneficial plant (*Turnera subulata*).

Treatment C: 10 months old oil palm, 5 pairs of *S. dichotomus* and 4th instar larvae of *M. plana* as a prey.

Observation was done daily (0700 to 1100 h and 1600 to 1800 h) until the death of the last *S. dichotomus*. Water and prey were replenished when necessary. The eggs were collected from surface of the cages and kept in a different plastic cylindrical container in a controlled environment room (insectary lab). Upon hatching, the first instar nymphs were given moist cotton wool placed in a small petri dish. The number of hatching was precisely recorded.

Succeeding parameters were determined:

i. Longevity of adult *S. dichotomus*
ii. numbers of eggs and
iii. numbers of eggs hatching until death.

The method of study involves the predators against the different containers with five replicates.

Figure 6.1 : *Sycanus dichotomus* in cages for different host experiments

6.3 Data analysis

Experiments were replicated three times with 10 individuals in each treatment for each replications. Samples were first described as means and standard errors. Data were done using one way (ANOVA) to compare the longevity of adult *S. dichotomus*, numbers of eggs and numbers of eggs hatching until death except gender ratio using Minitab 17.0 software. Where statistical differences existed between the data sets ($P<0.05$), Tukey's test were used to separated the differing means.

6.4 Results and discussion

6.4.1 Longevity of adult predators

The development period for adults *S. dichotomus* fed on the three categories of food sources were examined (Table 6.1). Statistical analysis revealed significant differences ($p < 0.001$) of the mean longevity within these treatments. In treatment A the male and female adults of *S. dichotomus* had a longer life span (31.08 ± 1.31 and 31.72 ± 1.32 days), followed by treatment B of 30.40 ± 1.33 and 30.84 ± 1.23 days, while treatment C had the shortest life span of 17.44 ± 1.18 and 20.04 ± 1.01 days, all for male and female, respectively. This shows that the with the availability of *M. plana* as a food. However, inconstent results was also described by Zulkefli et al. (2004) where the mean longevity of adult stage of *S. dichotomus* was at 63.99 and 61.86 days for male and female when fed with *Corcyra cephalonica* in a laboratory condition (Zulkefli et al., 2004). In additional Nurul Hidayah and Norman (2016) reported three food categories given had relatively supported the growth and development of *S.*

dichotomus whereas mean life span of *S. dichotomus* of 180.6 + 8.31 days when fed on *Tenebrio molitor*. Syari et al. (2011) disclosed that the mean development time of adult stages of *S. dichotomus* fed on *Tenebrio molitor* were 93.10 and 61.40 days for male and female, respectively. The life span was longer in these previous researches might due to the fact that both experiments were conducted in laboratory condition. On the contrary, our study involved experiment in field condition with combination of oil palm plantation environment, the presence of beneficial plants and bagworms, which represents the cycle of biological control.

Table 6.1 : Longevity of adult of *Sycanus dichotomus* reared on three different treatments.

Treatment	*Life span of predators (days)*								Result
	n	Male	±	S.E	n	Female	+	S.E	
A (Oil palm + predators + beneficial plant + *M. plana)*	25	31.08	±	1.31	25	31.72	±	1.32	ns
B (Oil palm + predators + beneficial plant)	25	30.40	±	1.33	25	30.84	±	1.23	ns
C (Oil palm + predators + *M. plana*	25	17.44	±	1.18	25	20.04	±	1.01	**

Notes:
n = number of samples
S.E = standard error
n.s. = not significant
** = significant at 1% level

6.4.2 Numbers of eggs and hatching

Observations of egg production by *S. dichotomus* on three treatments were recorded. Table 6.2 showed highly significant ($p < 0.001$) differences of *S. dichotomus* producing number of eggs in three different treatments. In treatment A, a highly significant ($p < 0.001$) difference on the duration of the incubation period was attained compared to other treatments. Likewise a significant higher numbers of eggs hatching in treatment A was obtained compared to treatment B and C.

Table 6.2 : Mean number of *Sycanus dichotomus* eggs, hatching (day) and fecundity in three different treatments.

Treatment	No. of eggs			Hatching (day)			Fecundity		
	Mean	±	S.E.	Mean	±	S.E	Mean	±	S.E
A (Oil palm + predators + beneficial plant + *M. plana)*	0.92	±	0.06a	16.5	±	0.88a	89.4	±	3.34a
B (Oil palm + predators + beneficial plant)	0.00	±	0.00	0.00	±	0.00	0.00	±	0.00
C (Oil palm + predators + *M. plana*	0.32	±	0.09b	14.8	±	0.53b	60.9	±	3.17b

Means followed by same letters within same column are not significantly different at P=0.05 level of probability according to Tukey's test.

With regards to treatment A and C, the eggs were laid in clusters and cemented to each other at surface of the cages, or under the leaves of oil palm but treatment B no egg produce. In female insect, reproduction generally involves producing yolky eggs, mating and then laying fertilized eggs. In the common of reproduction by yolked eggs, female insects accumulate large amounts of macronutrien, especially protein and fat (Wheeler, 2009). Kalushkov and Hodek (2004) shown that food quality affects the developmental period as well as affecting the reproductive performance of the adults. The study shown the eggs masses were brown and always in a precise *chevron* vertical pattern, but with oblique rows (Figure 6.2). Our results disclosed that female *S. dichotomus* laid three or five batches of eggs during its lifetime and all of the eggs (71 to 120 eggs per cluster) hatched in the same day. The incubation period was 11 to 25 days. Zulkefli et al. (2004) stated the female laid three batches of eggs where they hatched after 11 to 39 days, with each cluster having 15 to 119 eggs. Meanwhile, Jamian et al. (2011) reported that female *S. dichotomus* produced one to four batches of eggs during its lifetime with mean of eggs period was 16.2 days and the range of hatch-ability was between 46.6 and 77.6 eggs. Similarly, Muhamad Fahmi (2013) reported the female produced up to four batches of eggs during its lifetime, with 11 to 20 days incubation period and 50 to 176 eggs in each cluster. However, Ambrose (1999) described that the fecundity of *S. affanis* was 372 eggs/female*, S. pyrrhomelas* 86.80 with eggs/female and *S. versicolor* with 68.9 eggs/female.

Figure 6.2 : Egg of *Sycanus dichotomus*.

The study findings have improved understanding of predatory insects and their role for keeping oil palm plantations low economic injured level from bagworm. Our finding provide new insights into how to maintain predatory insects levels through insect-plant interactions. The addition of *T. subulata* species is the best practices because can improve buffer strips as habitats for predatory insects. Similarly, Yusdayati et al. (2014) shown the importance of *Turnera* spp and *C. cobanensis* on host plants to support high abundance and diversity of natural enemies.

6.5 Conclusion

In this study, the performance of *S. dichotomus* was assessed in three different situations inside cages. Our findings revealed that *S. dichotomus* preferred the combination on beneficial plant and bagworm treatment terms of life span, produced eggs and fecundity. Results indicated the killing potential of *S. dichotomus* on *M. plana* was higher than that of other predators as previously reported, and the possible usage of *S. dichotomus* as an effective biocontrol agent of oil palm bagworm was also discussed. However, we should bear in mind that, the performance was measured in field cages, as well as the observed prey killed, attracted to beneficial plant and number of eggs produced showed that it could perform better in an open field. Our results demonstrated the forefront and excellent performance of *S. dichotomus* in combination treatment that will contribute to the establishment of a biological control program for *M. plana* as a component of IPM, in different management systems of oil palm in Malaysia.

CHAPTER 7

SUMMARY, GENERAL CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

In this thesis, we have reported results that provided the abundances of predatory insect in oil palm plantations in Peninsular Malaysia. Although there were previous studies on beneficial insect in oil palm plantation in Malaysia, none use related to insect predators. Therefore, our study was established with the following specific objectives; 1) to determine the species and abundance of predators in different types of beneficial plants; 2) to determine the beneficial plants mostly suitable for selected predator species; 3) to evaluate the nectar content of a number of different types of plants species; 4) to determine the host plant preference of *S. dichotomus* and 5) to study the performance of *S. dichotomus* on combination of plant host and prey.

Predatory insect of the family Reduviidae are important beneficial insects on various economic crops in the tropic. Within the Reduviidae family, the genus *Sycanus* and *Cosmolestes* are known as a natural control of bagworms on oil palm plantation and the species *S. dichotomus* regarded as the most important. *Cosmolestes picticeps* are commonly found in most oil palm plantation areas, but *S. dichotomus* are the most efficient in feeding on bagworm. Yusdayati et al. (2014) and Norman and Basri (2010) found the existence of these insect in oil palm plantations in Malaysia, while Budi et al. (2008) reported the application of *Sycanus colaris* as a biological agent for insect pests in plantation forestry in Indonesia.

To develop strategy for management of the pest, an ecological study was undertaken in other to obtain information that can be used for developing improved and sustainable strategies. The present results suggest that *C. picticeps* can be used as a biological agent to control bagworm populations in oil palm plantations, but *S. dichotomus* has no or little potential for such ecosystem service. In order to maintain predatory insect populations at steady numbers in oil palm plantations, the key habitat quality characteristics should be considered by growers. Norman and Basri (2007) agreed on the application of beneficial plants in enhancing the population of natural enemies for controlling pests in estates that planted them.

Number of individual in a population continuously change with time and space, thus population fluctuations are known based on the amplitude and frequency of the fluctuation, it may be stable, irruptive or cyclic. The abundances of predatory insect and their density fluctuations in this study implied that there were many prey species for *Sycanus* and *Cosmolestes*. In this present study, population fluctuations of predatory insects investigated in pesticide-free oil palm indicated that in Bukit Talang Estate, the predatory insects population fluctuated in a stable manner in study areas planted with three type of beneficial plants (*T. subulata, C. cobanensis and A. leptopus*). Meanwhile, two other estates revealed limited fluctuation on predatory insect population. Results on interaction between predatory insects population with prey and weather condition within these three oil palm plantations showed only two predator species were identified. Predators population and bagworms were not correlated with weather parameters. The number of predators were relatively low, bagworm-dependant and their populations could have been adversely affected by other factors. Thus, we suggested a long-run time scale study to be conducted considering all microclimatic and abiotic parameters such as water stress, height of beneficial plants, age of oil palm and coverage ground vegetation in order to understand in depth. The relationship between beneficial plants, host and predators.

Understanding the relationship between predator and prey is a central goal in ecology. Among significant components of predator-prey relationship is the predator's rate of feeding upon prey. The feeding rate describes the transfer of biomass between trophic level and the dynamic coupling between predator abundance and prey abundance (e.g., Lotka, 1925). The description of a predator's instantaneous or *per capita* feeding rate, Ne, as a number of prey consumed by the predator, N, is the classic definition of a predator's "functional response" (Holling, 1959). One type of functional response derived by Holling (1959) was "Type II" which described the average feeding rate of a predatory insects when they spent certain times searching for prey and in each searching process did capture the prey item (i.e., handling time). Our findings revealed that *S. dichotomus* indeed, a predator preferentially hunt for prey. Based on a study by Schenk and Bacher (2002), the functional response Type II was frequently found in laboratory or field cage studies when only a single species was offered. However, laboratory studies do not take into account the alternative prey prior in field studies. Therefore, the prevalence of Type II functional responses found under restricted conditions may overestimate their occurrences and importance in nature. Thus, we recommended the determination of functional responses on not strictly polyphagous predators, most of which are attacking different prey species in the oil palm plantation.

In Chapter 5, we came out with a hypothesis that beneficial plants are the most suitable for our selected predator species. We also evaluated the nectar content of different types of beneficial plants. We had conjectured the hypothesis since whatever the attracted predatory insects on beneficial plants and important of nectar as a source of energy while they searching for prey. A previous study showed *C. cobanensis* and *Turnera* spp. were equally preferred by predatory insects in FELDA Besout 6 oil palm plantation, thus finding the predators were seen to be more prominent on ferns and beneficial plants (Norman and Basri, 2010; Yusdayati et al., 2014). To address this hypothesis, we performed a choice study to observe the best preferred plant for predators activity such as feeding nectar and prone to/lean, and a no choice study to determine the life span and ability to lay eggs of predatory insects which fed on nectar and pollen of selected host plants.

The GC-MS analysis of the pollen and nectar extracts of six potential plants disclosed that only three plants could be regarded as beneficial. We also discovered that the method used for determination of unknown compound was a simple, suitable and rapid procedure. Gas chromatography–mass spectrometry was used to measure the content of volatile compounds in plants. The results showed only three species shown beneficial effects, with the most notable was *T. subulata*, followed by *C. cobanensis* and *A. leptopus*. However, with the exception of *T. subulata*, the planting of these beneficial plants mostly attractted predators (after 48 hours) and increased their life spans (male and female insects can live for 34.5 and 32.7 days), and such practices might enhance effectiveness the natural biological control. Plants such as *A. intrusa, E. heterophylla* and *A. conyzoides* could as wild plants, therefore not regarded as beneficial. Nevertheless, the searching for beneficial plants is still to be continued for these types of predators where *T. subulata* could be major considered for this purpose.

In Chapter 6, we were determined to study the effect of different hosts on the performance of predators. The experiments involved different treatments to ensure these plants are useful for insects and relevance for bagworms attacks on an oil palm plantation. The concept was that once these predators were attracted to the plants, they would obtain the alternative food, fed on bagworm, increase their life spans and ability to lay eggs as well as survival. Beneficial plants were used since predators can survive even when pests are rare and when there is always something to eat. When pest populations are flaring up, the predators usually the first to respond and help providing some controls. The contribution and role of beneficial plants in enhancing the population of predators for controlling the pest were shown by a clear reduction in bagworm infestation in estates that planted them (Norman and Basri, 2007).

The effect of beneficial plants in sustaining predators for long-term control of the pest should not be overlooked. In Chapter 6, we also decided to study the affinity of beneficial plants, oil palm and predatory insects. The advantage of useful beneficial plants was in fact contributes to insect survivorship, not at the lay eggs. The presence of the prey is pivotal to ensure the survival of insect predators. Our study described the duration of the adult stages of *S. dichotomus* consuming *M. plana* as a prey. We revealed that the mean adult durations took over a month for predators with beneficial plants, or beneficial plants and bagworms treatment. On the contrary, Norman (1996, unpublished) found that the duration of *S. dichotomus* with unbagged bagworm larvae took about 126.4 days to becoming adult.

Earlier publications reported that *S. dichotomus* lived under covered crops therefore their populations tend to become restricted to young palm. Observations done during our study showed that this predator laid eggs on the oil palm leaflets, making it easier to find its prey on the higher fronds (DeChenon et al., 1989). We did observe that cannibalism was common among the adults and nymphs. Result also indicated they sometime preferred cannibalizing than to feed on their preys. Zulkefli et al. (2004) suggested this problem can be avoided if the predators are separated individually, but not economical for mass rearing technique. The information on survivorship and fecundity of *S. dichotomus* is useful for a further study on biological control of bagworm in oil palm.

For any management strategy to succeed particularly if using more than one strategy such as cultural and biological controls, it is crucial to have details information on demographic background of the pest, and how it interacts with environment, predators and hosts. All these factors must also be judged in the context of economic injury level. With regards to *S. dichotomus*, our findings including its abundance, population fluctuation in relation to environment factors, behavior in relation to its host and killing efficiency would be advantageous to improve strategies for the pest integrated management. The way to accomplish this synthesis is to incorporate biological control into IPM systems, completing the research required to deploy alternative control tactics and providing expertise for their implementations. Based on our findings, we recommended future researches to be carried out as the followings:

Studies on the abundance and affinity of natural enemies on beneficial plants need to be conducted, particularly in other management estates and smallholdings, to better understand the other natural enemies species in oil palm areas.

As suggested by Norman and Basri (2007), the adoption of beneficial plants should be fully utilized on oil palm. Thus, continuous data on planting beneficial plants in oil palm is important as nectar sources from certain species of flowering plants for the establishment of a specific beneficial insect. In order to use natural predatory insects as biological control of pest populations, the maintenance of local habitat complexity and farmland biodiversity in plantation management as well as IPM. Stakeholders should manage oil palm plantations so that the plantations become more favourable of biological control agents such as predatory insects.

In general, our study has added to in depth understanding on nectar and pollen compositions. The analysis of nectar and pollen compositions revealed interesting results, particularly on exceptionally high volatile compounds content in the nectar and pollen, and the presence of potentially attracted the predators. The specific functions and other composition of the nectar components identified in this study are highly recommended further investigation for future research.

REFERENCES

Altieri, M. A. and Whitcomb W. H. 1980. Predacious and herbivorous arthropods associatied with comphorweed (Heterotheca subaxillaris Lamb.) in north Florida. Journal Georgia Entomology Society 15(3): 290-299.

Ambrose, D. P. 1999. Assassin Bugs., USA: C.W. Science Publisher.

Aneni, T. I., Aisagbonhi, C. I., Iloba, B. N., Adaigbe, V. C. and Ogbebor, C. O. 2014. Influence of weather factors on seasonal population dynamics of *Coelaenomenodera elaeidis* (Coleoptera: Chrysomelidae) and its natural enemies in NIFOR, Nigeria. American Journal of Plant Sciences 5: 42-47.

Arnott, G. W. 1963. The Malaysian oil palm and the analysis of its products. Division of Agriculture.

Ausden, M. and Drake, M. 2006. Invertebrates. Ecological cencus techniques (ed. W.J. Sutherland), pp. 225. Cambridge University Press. United Kingdom.

Azhar, B., Lindenmayer, D.B., Wood, J., Fischer, J., Manning, A., McElhinny, C. and Zakaria, M. 2011. The conservation value of oil palm plantation estates, smallholdings and logged peat swamp forest for birds. Forest Ecology and Management, 62. 2306-2315.

Azlina, Z. and Tey, C. C. 2011. Killing efficiency of selected insect predator species against bagworm, *Metisa plana*. Proceeding of the PIPOC 2011 International Palm Oil Congress (Agriculture, Biotechnology & Sustainability), Kuala Lumpur.

Baker, H. G. and Baker, I. 1975. Studies of nectar constitution and pollinator plant co-evolution. . In: Animal and Plant Co-evolution. R. P. H. e. Gilbert L.E. Austin, Texas, University of Texas Press: pp100-140.

Barkman, T. J. 2003. Evidence for positive selection on the floral scent gene Isoeugenol-O- methyl transferase. Molecul Biology Evolution. 20: 168-172.

Barret, S. C. H. 1978. Heterostyly in a tropical weed: the reproductive biology of the *Turnera ulmifolia* complex (Turneraceae). Can. J. *Bot.* 56: 1713-1725.

Basri, M. W., Abdul, H. H. and Masijan, Z. 1988. Bagworms (Lepidoptera: Psychidae) of oil palms in Malaysia. No. 23. PORIM Occasional Paper No. 23.

Basri, M. W. and Kevan, P. G. 1995. Life history and feeding behaviour of oil palm bagworm *Metisa plana* Walker (Lepidoptera: Psychidae). *Elaeis* 7(1): 18-34.

Basri, M. W. and Norman, K. 2000. Insect pest, pollinator and barn owl. Advances in Oil Palm Research. Yusof Basiron *et. al.*, Malaysian Palm Oil Board.: 466-541.

Basri, M. W. and Norman, K. 2002. *Cassia cobanensis* as a beneficial plant for sustenance of parasitoid in bagworm control. MPOB information series No. 132.

Basri, M. W., Norman, K. and Hamdan, A. B. 1995. Natural enemies of bagworms, *Metisa plana* (Lepidoptera: Psychidae) and their impact on host population regulation. Crop Protection 14(8): 637-645.

Basri, M. W., Norman, K..and Othman, A. 2001. Field impact of beneficial plants on the parasitism levels of the bagworm, *Metisa plana* (Lepidoptera: Psychidae). Proceedings of agricultural conference 2001 international palm oil congress "cutting-edge technologies for sustained competitiveness", Malaysian Palm Oil Board.

Basri, M. W., Ramlah Ali, A. S., Moslim, R. and Arshad, O. 1996. Biological efficacy of three commercial products of *Bacillus thuringiensis* for the control of bagworms, *Metisa plana* and *Mahasena corbetti* (Lepidoptera: Psychidae) on oil palm. 1996 PORIM international palm oil congress. Competitiveness for the 21st Century, Kuala Lumpur, Palm Oil Research Institute of Malaysia.

Basri, M. W., Siburat, S., Ravigedari, S. and Othman, A. 1999. Beneficial plants for the natural enemies of the bagworm in oil palm plantations. Proceeding of the 1999 PORIM international palm oil congress : "Emerging technologies and opportunities in the next millennium". Kuala Lumpur, Palm Oil Research Institute of Malaysia.

Bernays, E. A. and Chapman, R. F. 1994. Host-Plant Selection by Phytophagous Insects., Chapman & Hall, New York.

Berndt, L. A., Wratten, S. D. and Hassan, P. 2002. Effects of buckwheat flowers on leafroller (Lepidoptera: Tortricidae) parasitoids in New Zealand vineyard. Agricultural and Forest Entomology 4: 39-45.

Blight, M. M., Pickett, J. A., Ryan, K., Wadhiam, J. and Woodack, K. 1995. Recognition of oilseed rape volatiles by pollen beetles *Meligethes* spp: electrophysiological and chemical studies. In. Proc. 9th Int. Rapeseed Congr. Vol. III, Cambridge University Press.

Buchmann, S. L. and Buchmann, M. D. 1981. Anthecology of *Mouriri myrtilloides* (Melastomatacea: Memecyleae) an oil flower in Panama. Biotropical (Reproductive Botany Supplement) 13: 7-24.

Budi, T., Gafur, A., Nasution, A. and Golani, G. D. 2008. Application of *Sycanus colaris* as biological agent for insect pests in plantation forestry, Indonesia, Publication Research and Development Forestry.

Caudwell, R.W. 2000. The successful developmet and implementation of an integrated pest management system for oil palm in Papua New Guinea. Integrated Pest Management Reviews, 5,297-301.

Cardinale, B. J., Harvey, C. T., Gross, K. and Ives, A. R. 2003. Biodiversity and biocontrol: emergent impacts of a multi-enemy assemblage on pest suppression and crop yield in an agro-ecosystem. Ecology Letters. 6: 857-865.

Chai, T. T. and Wong, F. C. 2012. Whole-plant profiling of total phenolic and flavonoid contents, antioxidant capacity and nitric oxide scavenging capacity of *Turnera subulata*. Journal of Medicinal Plants Research 6: 1730-1735.

Chaney, W. E. 1998. Biological control of aphids in lettuce using in-field insectaries. Enhancing Biological Control: Habitat Management to Promote Natural Enemies of Agricultural Pests, Berkeley, California, USA, University of California Press.

Cheong, Y. L., Sajap, A. S., Hafidzi, M. N., Omar. D. and Abood, F. 2010. Outbreaks of bagworms and their natural enemies in an oil palm, *Elaeis guineensis*, plantation, at Hutan Melintang, Perak, Malaysia. Journal of Entomology 7(3): 141-151.

Chung, G. F. 1988. Spraying and trunk injection of oil palm for pest control. In National Seminar on Oil Palm/Palm Oil: Current Development, PORIM, Kuala Lumpur.

Chung, G. F. 1989. Spraying and trunk injection of oil palm for pest control. The Planter: 500-524.

Chung, G. F. 1998. Strategies and methods for the management of leaf-eating caterpillars of oil palm. The Planter 74: 531-558.

Chung, G. F. and Sim, S. C. 1991. Bagworm Cencus and Control: A Case Study. Kuala Lumpur, PORIM: 433-442.

Chung, G. F., Sim, S. C., Hon, K. M. and Ramli, K. 1995. Monitoring and surveillance system for integrated pest management of leaf-eating caterpillar in oil palm. The Planter 71: 253-263.

Clausen, C. P. 1956. Biological control of insect pest in the continental United States.

Cock, M. J. W., Godfray, H. C. J. and Holloway, J. D. 1987. Slug and nettle caterpillars. The biology, taxonomy and control of the Limacodidae of economic importance on oil palms in South-east Asia, Wallingford, U.K: C.A.B. International.

Corley R. H. V. and Tinker, P. B. 2003. The Oil Palm. Oxford UK, Blackwell Science.

De Chenon, R. D., Sipayung, A. and Sudharto, P. S. 1989. The importance of natural enemies on leaf-eating caterpillars in oil palm plantations in Sumatra, Indonesia- Uses and Possibilities. Proceeding of the 1989 palm oil development conference module 11 - Agriculture, Kuala Lumpur, Palm Oil Research Institute of Malaysia.

Debach, P. 1964. Biological Control of Insect Pests and Weeds. London, Chapman and Hall.

DeChenon, R. D., Sipayung, A. and Sudharto, P. S. 1989. The importance of natural enemies on leaf-eating caterpillars in oil palm plantations in Sumatra, Indonesia- Uses and Possibilities. Proceeding of the 1989 palm oil development conference module 11 - Agriculture, Kuala Lumpur, Palm Oil Research Institute of Malaysia.

Distant, W. L. 1904. Fauna of British India. Rhychota., London: Taylor and Francis.

Dobson, H. E. M. 1994. Floral Volatiles in Insect Biology. In: Insect Plant Interactions, 5th Edn. B. E. A. (ed.). Boca Raton, CRC Press: 47-81.

Dolling, W. R. 1987. A summary of the hemiptera recorded as predators of Southeast Asia Limacodidae. Slug and nettle caterpillars. M. J. W. e. a. Cock. Wallingford, CAB International: 197-198.

Ernst, J. J. and Ketner, P. 2007. Final Report: Corallita pilot project: St. Eustatius, Netherlands Antilles. St. Eustatius, Netherlands Antilles, Published by the authors: 38.

Eubanks, M. D. and Styrsky, J. D. 2005. Effects of plant feeding on the performance of omnivorous "predators". Plant Provided Foods for Carnivorous Insects. P. C. J. v. R. J. B. e. F.L Wackers, Cambridge University Press, Cambridge 148-177.

Evans, E. W. 1982. Feeding specialization in predator insects: hunting and attack behaviour of two stink bugs species (Hemiptera: Pentatomidae). American Middle Nature 108: 96-103.

Fauziah, I., Rahman, S. A. and Aziz, A. M. 2000. Pengurusan Serangga Perosak. Panduan pengeluaran sayur-sayuran, Institut Penyelidikan dan Kemajuan Pertanian Malaysia (MARDI). Kementerian Pertanian Malaysia: 89-96.

Fazal, S., Manzoor, F. and Abdul-Satar, A. 2012. Impact of abiotic factors on insect diversity of at Lawrence Garden, Lahore. Pakistan Journal of Science 64: 127-135.

Foster, W. A., Snaddon, J. L., Turner, E. C., Fayle, T. M., Cockerill, T. D., Ellwood, M. D. F., Broad, G. R., Chung, A. Y. C., Eggleton, C., Khen, C. V. and Y. K.M. (2011). Establishing the evidence base for maintaining biodiversity and ecosystem function for oil palm landscapes in South East Asia. Philosophical Transaction of the Royal Society 366: 3277-3291.

Gonzalez-Teuber, M. and Heil, M. 2009. Nectar chemistry is tailored for both attraction of mutualists and protection from exploiters. Plant Signal Behav. 4(9): 809-813.

Grant, J. F., McWhorter R. E. and Shepard, M. 1985. Influence of soybean looper density on predation by *Lebia analis*. J. Agric. Entomol.

Greene, G. L. 1973. Biology of a predator, *Sycanus indagator* (Stal). Life history and feeding habits. Florida Entomology 56: 255-267.

Greene, G. L. and Shepard, M. 1974. Biological studies of the predator, *Sycanus Indigator*; Field survival and predation potential. The Florida Entomologist 57(1): 33-38.

Gurr, G. M., Barlow, N. D., Memmot, J., Wratten, S. D. and Greathead, D. J. 2000. A history of methodological, theoretical and empirical approaches to biological control. biological Control: Measures of Success. G. M. a. S. D. W. e. In Gurr, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Gurr, G. M. and Wratten, S. D. 1999. Integrated biological control: a proposal for enhancing success in biological control. International Journal of Pest Management 45(2): 81-84.

Hartley, C. W. S. 1977. The Oil Palm. London, Longman.

Headstrom, R. 1963. Adventures with insects, Philadelphia : J. B. Lippincott Company.

Heil, M. 2011. Nectar: generation, regulation and ecological functions. Trend Plant Sci., 16(4): 191-200.

Hickman, J. M. and Wratten, S. D. 1996. Use of *Phacelia tanacetifolia* strips to enhance biological control of aphids by hoverfly larvae in cereal fields. Journal of Economic Entomology 89: 832-840.

Ho, C. T. 2002. Ecological studies on *Pteroma pendula* Joannis and *Metisa plana* Walker (Lepidoptera:Psychidae) towards improved integrated management of infestations in oil palm, University Putra Malaysia. Ph.D. Thesis.

Ho, C. T., Ibrahim, Y. and Khoo, K. C. 2011. Infestations by the bagworms *Metisa plana* and *Pteroma pendula* for the period 1986-2000 in major oil palm estates managed by golden hope plantation berhad in Peninsular Malaysia. Journal of Oil Palm Research 23: 1040-1050.

Ho, C. T., Khoo, K. C., Ibrahim, Y. and Omar, D. 2003. Comparative Studies on the Use of beneficial Plants for Natural Suppression of Bagworm Infestations in Oil Palm. Proceedings of the PIPOC 2003 International Palm Oil Congress (Agriculture), Kuala Lumpur, Palm Oil Research Institute of Malaysia.

Ho, C. T. and Teh, C. L. 1997. Integrated pest management in plantation crops in Malaysia : Challenges and realities. Proceedings of the 1997 international planters conference "Plantation management for the 21st century, The Incorperated Kuala Lumpur: Society of Planters.

Hoffman, M. P. and Frodsham, A. C. 1993. Natural Enemies of Vegetable Pest Insects. Ithaca, New York, Cornell Cooperative Extension Publications.

Holling, C. S. 1965. The functional response of predators to prey density and its role in mimicry and population regulation. Memoirs of Entomological Society of Canada 45: 1-60.

Hoong, H. W. and Hoh, C. K. Y. 1992. Major pest of oil palm and their occurrence in Sabah. The Planters 68: 193-210.

Huffaker, C. B., P. S. Messenger and P. Debach 1971. The natural enemy component in natural control and the theory of biological control. Biological Control. C. Huffaker, Plenum Press. New York.: 16-67.

Idris, A.G. and Grafius, E. 1998. Diurnal flight activity of Diadegma insulare (Hymenoptera: Ichneumonidae), a parasitoid of the diamondback moth (Lepidoptera: Plutellidae), in the field. Enviromental Entomology 27(2):406-414.

Ibrahim, Y. and Mohd Fairuz, O. 2011. Demographic parameters and reproductive performance of the assassin bug *Sycanus dichotomus* Stal. fed on mealworm *Tenebrio molitor*. Journal of Oil Palm Research 23: 974-978.

Irvin, N. A., Wratten, S. D. and Frampton, C. M. 2000. Understory management for the enhancement of the leafroller parasitoid *Dolichogenidea tasmanica* (Cameron) in orchads at Canterbury, New Zealand. Hymenoptera: Evolution, Biodiversity and Biological Control, CSIRO Publishing Collingwood, Victoria, Australia.

Ishikawa, T., Toriumi, W., Susila, W. and Okajima, S. 2007. *Sycanus aurantiacus* (Hemiptera: Heteroptera: Reduviidae), a new harpactorine species from Bali, Indonesia, with brief notes on its biology. Zootaxa 1615: 21-27.

Jambari, A., Badrul, A., NorLaili, I., Syari, J., Arnina, H., Puan, C .L., Hafidzi, M. N., Ebil, Y. and. Zakaria. M. 2012. Avian Biodiversity and Conservation in Malaysian Palm Oil Production Lands. Journal of Oil Palm Research 24: 1277-1286.

Jamian, S., Ahmad, N., Ghazali, A., Zakaria, A. and Azhar, B. 2017. Impacts of two species of predatory Reduviidae on bagworms in oil palm plantations. Insect Science 24:285-294

Jamian, S., Muhamad, R., Norman, K. and Idris, A. B. 2011. Pemeliharaan *Sycanus dichotomus* Stal. (Hemiptera: Reduviidae) Serangga Pemangsa Ulat Bungkus Tanaman Sawit, *Metisa plana* (Lepidoptera: Psychidae) Walker di Makmal. Sains Malaysiana 40(10): 1129-1137.

Jangi, M. S., Ibrahim, A. G., Liau, S. S., Lim, G. S., Lim, G. T., Mohamed, M. S. and Ooi, P. A. C. 1991. Biological control in Malaysia: insect and other pest., Kuala Lumpur: MARDI.

Jervis, M. A., Kidd, N. A. C. and Heimpel, G. E. 1996. Parasitiod adult feeding behaviour and biocontrol - a review. Biocontrol News and Information 17(1): 11-26.

Kalshoven, L. G. E. 1981. Pests of crops in Indonesia, P. T. Ichhtiar Baru-Van Hoeve, Jakarta.

Kalushkov, P. and Hodek, I. 2004. The effects of thirteen species of aphids on some life history parameters of the ladybird *Coccinella septempunctata*. Bio Control, 49: 21-32.

Khoo, K. C. 1992. Manipulating predators for biological control with special reference to the tropics. Proceedings of the Biological Control Session 3rd International Conference of Plant Protection in the Tropics, Kuala Lumpur, Malaysian Plant Protection Society.

Khoo, K. C. and Chan, Y. C. 2000. The Honolulu creeper, *Antigonon leptopus*, as a supplementary food resource for the predatory bug *Andrallus spinidens* (Hemiptera: Pentatomidae, Asopine). Plant health 2000 conference on crop protection and biotechnolgy toward improved plant health, Kuala Lumpur, Malaysian Plant Protection Society.

Khoo, K. C., Ooi, P. A. C. and Ho, C. T. 1991. Crop Pests and Their Management in Malaysia. Kuala Lumpur: Tropical press.

Knudsen, J. T., Tollsten, L. and Bergström, G. 1993. Floral scents, a checklist of volatile compounds isolated by headspace techniques. Phytochemistry 33: 253-280.

Kroon, H. 2009. Biology of *Lilioceris lilii* (Coleoptera: Chrysomelidae) and the occurrence of their parasitoids in Sweden, Swedish University of Agricultural Sciences, Alnarp. Master thesis: 21-25.

Lamp, K. P. 1974. Economic Entomology in the Tropics. London, Academics Press.

Leena, A. I. and Hazem, S. H. 2011. Bioresidual Effect of Two Insecticides on Melon Aphids *Aphiss gossypii* Glover (Homoptera: Aphididae) and its Parasitoid *Aphidius colemani* Verick (Hymenoptera: Brachonidae). American-Eurasian Journal of Agriculture and Environmental Science, 11(2): 228-236.

Leius, K. 1967. Influence of wild flowers on parasitism of tent caterpillar and codling moth. Canadian Entomologist 99: 444-446.

Liu, H., Li, H., Yu, C., Tadauchi, O., and Cai, W. 2012. Taxanomic and Bionomic Notes on *Sycanus sichuanensis* Hsiao (Hemiptera: Reduviidae: Harpactorinae). J. Fac. Agr. Kyushu Univ. 57(1): 73-77.

Liu. T., Amin, S., Hong-guang. Zha, Mohsin, M. and Ishtiaq, M. 2013. Floral nectar composition of an outcrossing bean species *Mucuna sempervirens* Hemsl (Fabaceae). Pak. K. Bot. 45(6): 2079-2084.

Lu. Z. X., Zhu, P., Geoff, M. G., Zheng, X. S., Read, D. M. Y., Heong, K.L., Yang, Y. J. And Xu, H. X. 2014. Mechanisms for flowering plants to benefit arthropod natural enemies of insect pests: Prospects for enhanced use in agriculture. Insect Science 21: 1-12.

Lotka, A. J. 1925. Elements of physical biology. William and Wilkins, Baltimore, MD, USA

Mackenzie, R. 1977. Observations on the control of some leaf-eating pests in oil palms. International development in oil palm, Kuala Lumpur, The Incorperated Society of Planters.

Maldano-Capriles, J. 1990. Systematic Catalogue of the Reduviidae of the World (Insecta:Heteroptera). A special edition of Caribbean Journal of Science: 694.

Menzel, R. 1985. Learning in honey bees, in an ecological and behavioral context. In: Experimental Behavioral Ecology. L. M. Holldobler B. Stuttgart, Fischer G. Publishers: 55-74.

Mohaghegh, J., De Clercq, P. and Tirry, L. 2001. Functional response of the predators, *Podisus maculiventris* (Say) and *Podisus nigrispinus* (Dallas) (Heteroptera: Pentatomidae) to the beet armyworm, *Spodoptera exigua* (Hubner) (Lepidoptera: Noctuidae): Effect of temperature. Journal of Applied Entomology 125: 131-134.

MPOB, 2012. "http;mpob.gov.my/images/overview/Overview of Industry 2011.pdf."

MPOB, 2015. "http;mpob.gov.my/images/overview/Overview of Industry 2015.pdf."

Muhamad Fahmi, M. H. 2013. Potensi serangga pemangsa, *Sycanus dichotomus* (Hemiptera: Reduviidae) sebagai agen kawalan biologi ke atas ulat bungkus, *Metisa plana* (Lepidoptera: Psychidae) di kawasan kelapa sawit, Universiti Kebangsaan Malaysia. Master Sains.

Murdoch, W. W. and Oaten, A. 1975. Predation and population stability. Advances in Ecological Research 9: 1-131.

Napompeth, B. 1982. Biological control research and development in Thailand. Proceeding of the international conference on plant protection in the tropics, Kuala Lumpur, Malaysian Plant Protection Society.

Nayar, K. K., Ananthakrishan, T. N. and David, B. V. 1976. General and Applied Entomology. New Delhi, Tata McGraw-Hill Publishing Company Limited.

New, T. R. 1991. Insect as Predators. New South Wales, The New South Wales University press.

Noor Farehan, I., Syarafina, R. & Idris, A. B. 2013. Toxicity of Three Insecticides on the predator of Oil Palm Leaf-Eater Pests *Sycanus dichotomus* Stal. (Hemiptera: Reduviidae). Journal of Entomology 6(1): 11-19.

Noor Hisham, H. and Sukri, T. B. 2004. Ancaman serangan ulat pemakan daun yang berterusan di ladang sawit.

Nor Ahya, M., Muhamad, R. and Nur Azura, A. 2012. Relationship between bagworm *Pteroma pendula* Joannis (Lepidoptera: Psycidae) populations, parasitoids, and weather parameters in oil palm plantation. Journal of Agriculture Science 4(12): 13- 17.

Norman, K. 2005. Tahukah anda: menangani serangan merebak ulat bungkus di ladang sawit. Peladang Sawit 30/2005: 8-15.

Norman, K. and Basri, M. W. 1992. A survey of current status and control of nettle caterpillars (Lepidoptera: Limacodidae) in Malaysia (1981-1990). PORIM Occasional Paper No. 27.

Norman, K. and Basri, M. W. 2007. Status of common oil palm insect pest in relation to technology adoption. The Planter 83: 371-385.

Norman, K. and Basri, M. W. 2010. Interactions of the bagworm, *Pteroma pendula* (Lepidoptera: Phsycidae), and its natural enemies in an oil palm plantation in Perak. Journal of Oil Palm Research 22: 758-764.

Norman, K., Basri, M. W. and Zulkefli, M. 1998. Handbook of Common Parasitoid and Predator Associated with Bagworm and Nettle Caterpillars in Oil Palm Plantation. Bangi: PORIM, .

Norman, K., Robinson, G. and Basri, M. W. 1994. Common bagworm pests (Lepidoptera: Psychidae) of oil palm in Malaysia with notes on related South-East Asian species. Malayan Nature Journal 48: 93-123.

Norman, K. and Basri, M. W. 2002. A diagnostic tool for the identification of parasitoids and predators for bagworm and nettle caterpillars in oil palm, MPOB information series. No. 134.

Pervez, A. and Omkar. 2005. Functional responses of coccinellid predators: An illustration of a logistic approach. Journal of Insect Science. 5(5): 125-131.

Pichardo, J. S. and Vibrans, H. 2009. "*Antigonon leptopus*. Malezas de Me´xico. http://www.conabio.gob.mx/malezasdemexico/polygonaceae/antigonon-leptopus/fichas/pagina1.htm. ." Retrieved October 20, 2010.

Pichersky, E. and Gershenzon, J. 2002. The formation and function of plant volatiles: perfumes for pollination attraction and defence. Curr. Opin. Plant Biol. 53: 237-243.

Pimentel, D., Stachow, U., Takacs D., Brubaker W., Dumas A., Meaney J., O'Neil J., Onsi E. and Corzilius D. 1992. Conserving biological diversity in agricultural/forestry systems. Science 42: 354-362.

Putshkov, V. G. and Putshkov, P. V. 1985. A Catalogue of Assassin-bug Genera of the World (Heteroptera, Reduviidae). Viniti, Moskva.

Putshkov, V. G. and Putshkov, P. V. 1996. Family Reduviidae Latreille, 1807, assassin-bug. In "Catalogue of the Heteroptera of the Palaearctic Region, Volume 2, Cimicomorpha I". E. B. A. a. C. Rieger. The Netherlands Entomology Society, Amsterdam: 148-265.

Raju, A. J. S., Raju, V. K., Victor, P. and Naidu, S. A. 2001. Floral ecology, breeding system and pollination in *Antigonon leptopus* L. (Polygonaceae). Plant Species Biol. 16: 159-164.

Ramlah, A. A. S. and Jalani, B. S. 1993. Viral control of oil palm insects pests. MPOB Information Series 26.

Ramlee, M., Ramlah, A. A. S. and Basri, M. W. 1996. Histopathology of *Metisa plana* (Lepidoptera:Psycidae) infected with *Beauveria bassina* (Deuteromycitina:Hypomycetes). Elaeis 8: 10-19.

Rhainds, M., Gries, G. and Ho, C. T. 2002. Dispersal by bagworm larvae, *Metisa plana*: effects of population density, larval sex, and host plant attributes. Ecological Entomology 27: 204-212.

Robinson, G. S., Tuck, K. R. and Shaffer, M. 1994. A Field Guide to the Smaller Moths of South-East Asia. Malaysian Nature society.

Sahayaraj, K., Kumar, V. and Avery, P. B. 2015. Functional response of *Rhynocoris kumarii* (Hemiptera: Reduviidae) to different population densities of *Phenacoccus solenopsis* (Hemiptera: Pseudococidae) recorded in the laboratory. European Journal of Entomology 112(1): 69-74.

Sankaran, T. 1970. The oil palm bagworms of Sabah and the possibilities of their biological control. PANS 16: 43-55.

Sankaran, T. and Syed, R. A. 1972. The natural enemies of bagworms on oil palms in Sabah, East Malaysia. Pacific Insect 14: 57-71.

Schenk, D. and Bacher, S. 2002. Functional response of a generalist insect predator to one of its prey species in the field. Journal of Animal Ecology 71: 524-531.

Schlindwein, C. and Medeiros, P. C. R. 2006. Pollination in *Turnera subulata* (Turneraceae): Unilateral reproductive dependence of the narrowly oligolectic bee *Protomeliturga turnerae* (Hymenoptera, Andrenidae). Flora 201: 178-188.

Short, P. 2011. Turneracea. Flora of the Darwin Region, Northern Territory Herbarium,. I. D. C. P.S. Short. Palmerston, Australia. 1: 1-2.

Shulaev, V., Silverman, P. and Raskin, I. 1997. Airborne signaling, by methyl salicylate in plant pathogen resistance. Nature 385: 718-721.

Singh, G. 1992. Management of oil palm pests and disease in Malaysia in 2000. Pest management and the environment in 2000. A. Aziz, Kadar, S.A & Barlon, H.S: 195-212.

Singh, S. 1976. The Use of Electrical Drills fore More Efficient Trunk Injection against Bagworms in Oil Palms. The Planter 62: 53-57.

Sipayung, A., De Chenon, R. D. and Sudharto, P. S. 1989. Natural enemies of leaf-eating Lepidoptera in the oil palm plantation, North Sumatra. Biological control of pest in tropical agriculture ecosystem. S. e. a. Sosromarsono, BIOTROP Special Publication. No. 36: 99-121.

Sipayung, A., De Chenon, R. D. and Sudharto, P. S. 1992. Study of the *Eocanthecona-Contheconidae* (Hemiptera: Pentatomidae) Asopin predator complex in Indonesia. Journal Plant Protection Tropics 9(1): 85-103.

Siti Nurulhidayah, A and Norman, K. 2016. Growth and longevity of the insect predator, *Sycanus dichotomus* STAL. (Hemiptera: Reduviidae) fed on live insect larvae. Journal of Oil Palm Research 28(4) 471-478.

Smilanick, J. M., Ehler, L. E. and Birch, M. C. 1978. Attraction of *Carpophilus* Spp. (Coleoptera: Nitidulidae) to volatile compounds present in figs I. . J. Chem. Ecol 4(6): 701-707.

Solomon, M. E. 1949. The natural control of animal populations. Journal Animal Ecology 18: 1-35.

Suasa-ard, W. 1989. Utilization of *Eocanthecona furcellata* (Wolff) (Hemiptera: Pentatomidae) for augmentative biological control of castor bean semilooper, *Ophiusa janata* (L.) (Lepidoptera: Noctuidae), in Thailand. Biological Control of Pests on Tropical Agricultural Ecosystems. S. S. e. al., BIOTROP Special Publication. No. 36: 191-201.

Syari, J. 2010. Pemeliharaan Serangga Pemangsa, *Sycanus dichotomus* Stal. (Hemiptera: Reduviidae) dan Keberkesanannya terhadap *Metisa plana* Walker (Lepidoptera: Psychidae), National University of Malaysia. Thesis. M. Sc. (Zoology).

Syari, J., Muhamad, R., Norman, K. & Idris, A. B. 2010. Feeding Behavior and Predatory Efficiency of Assassin Bug, *Sycanus dichotomus* Stal. on Oil Palm Bagworm, *Metisa plana* Walker. Malaysian Applied Biology Journal 39(2): 55-60.

Syari, J., R. Muhamad, K. Norman and A. B. Idris. 2013. Effects of two alternative insect prey on the performance of the predatory insect, *Sycanus dichotomus* (Hemiptera: Reduviidae). Postgraduate Symposium on Plant Protection 2013, UNITEN, Bangi. Selangor

Syed, R. A. and Shah, S. 1977. Some important aspects of insect pest management in oil palm estates in Sabah, Malaysia. International development in oil palm, Kuala Lumpur, The Incorperated Society of Planters.

Teh, C. L. 1996. Integrated pest management of leaf-eating caterpillars of oil palm in Sabah. The Planter 72: 395-405.

Tholl. D., Chen, F., Gershenzon, J. and Pichersky, E. 2004. Arabidopsis thaliana, a model system for investigating volatile terpene biosynthesis, regulation and function. In: Secondary Metabolism in Model System. J. T. Remoe. Amsterdam, Elsevier: pp. 1-18.

Timms, J. E., Oliver, T. H., Straw, N. A. and Leather, S. R. 2008. The effects of host plant on the coccinellid functional response: Is the conifer specialist *Aphidecta obliterate* (L.) (Coleoptera: Coccinellidae) better adapted to spruce than the generalist *Adalia bipunctata* (L.) (Coleoptera: Coccinellidae). Biological Control 47: 273-281.

Tiong, R. H. C. 1979. Some predators and parasites of *Mahasena corbetti* (Tams) and *Thosea asigna* (Moore) in Sarawak. The Planter 55: 279-289.

Tiong, R. H. C. 1982. Oil palm pests in Sarawak and the use of natural enemies to control them. Proceeding international conference plant protection in tropics. pp 363-372.

Turlings, T. C. J., Tumlinson, J. H. and Lewis, W. J. 1990. Exploitation of herbivore induced plant odors by host seeking parasitic wasps. Science 250: 1251-1253.

Usharani, P., Wakamura, S. and Asaoka, K. 1994. Rostral tip appendages in carnivous stink bug, *Eocanthecona furcellata* (Wolff) (Heteroptera: Pentatomidae). J. Ent. Res. 18(3): 199-202.

Van den Bosch, R. and Messenger, P.S. 1973. Biological Control. London, Intext Education Publication.

Van Emden, H. F. 1963. Observations of the effects of flowers on the activity of parasitic Hymenoptera. Entomologist's Monthly Magazine. 98: 265-270.

Vickery, M. L. and Vickery, B. 1981. Secondary Metabolism. London, Macmillan Press.

Visser, J. H. 1986. Host odor perception in phytophagous insects. Ann. Rev. Entomol. 31: 121-124.

Vollhardt, I. M. G., Bianchi, F. J. J. A., Wäckers, F. L., Thies, C. and Tscharntke, T. 2010. Spatial distribution of flower vs. honeydew resources in cereal fields may affect aphid parasitism. Biological Control 53: 204-213.

Wäckers, F. L., Romeis, J. and Rijn, P. V. 2007. Nectar and Pollen Feeding by Insect Herbivores and Implications for Multitrophic Interactions. Annual Review of Entomology 52: 301-323.

Wheeler, D. E. 2009. Reproduction, Female In encyclopedia of insects (Vincent H. R. and Ring T.C., eds.). Elsevier, U. S., 880-882

Williams, N. and Whitten, W. M. 1983. Orchid floral fragrances and male euglossine bees: methods and advances in last sesquidecades. Biological Bulletin 164: 355-395.

Willmer, P. 1986. Foraging patterns and water balance: problems of optimization for a xerophilic bee, *Chalicodoma sicula*. J. Anim. Ecol. 55: 941-962.

Wolcott, G. N. 1941. The establishment in Puerto Rico of *Larra americana* Saussure. J. Econ. Entomol 34: 53-56.

Wood, B. J. 1968. Pest of Oil Palm in Malaysia and Their Control. The Incorporated Society of Planter.

Wood, B. J. 1971a. Development of integrated control programmes for pest of tropical perennial crops in Malaysia. Biological Control. C. B. Huffakers, New York: Plenum Press: 422-457.

Wood, B. J. 1971b. The importance of ecological studies to pest control in Malaysia plantation. PANS 17: 411-416.

Wood, B. J. 1976. Insects pests in South East Asia. oil palm research. R. H. V. Corley, Hardon, J.J & Wood, B.J., Amsterdam: Elsevier: 347-368.

Wood, B. J., Corley, R.H.V. and Goh, K.H. 1973. Studies on the effect of pest damage on oil palm yield. Advances in oil palm cultivation. R. L. E. Wastie, D.A. Kuala Lumpur, The Incorporated Society of Planters: 360-379.

Wood, B. J. and Nesbit, D. P. 1969. Caterpillar Outbreaks on Oil Palms in Eastern Sabah. The Planter 45: 285-299.

Wratten, S., Berndt, L., Gurr, G., Tylianakis, J., Fernando, P., and Didham, R. 2002. Adding floral diversity to enhance parasitoid fitness and efficacy. 1st International Symposium on Biological Control of Arthropods.

Yingfang, X. and Fadamiro, H. Y. 2010. Functional responses and prey-stage preferences of three species of predacious mites (Acari: Phytoseiidae) on citrus red mite, *Panonychus citri* (Acari: Tetranychidae). Biological Control. 53: 345-352.

Yusdayati, R. 2008. Biological and ecological aspects of bagworms (Lepidoptera: Psychidae) in Ladang FELDA, Sungkai, Perak emphasizing on increasing efficiency of natural enemies through planting of beneficial plants, Universiti Sains Malaysia. Master Thesis.

Yusdayati, R., Md Rawi, C. S., Ahmad, A. H. and Hamid, N. H. 2014. Diversity and distribution of natural enemies (predators and parasitoids) of bagworms (Lepidoptera: Psycidae) on selected host plants in an oil palm plantation. The Planter 90(1055): 91-101.

Yusof, M. H. 1987. Biological control: the natural way to fight crop pests. Newsletter Malaysia Plant Protection Society. Kuala Lumpur. 11: 51-52.

Zhi, J. R. 2006. Effect of pollens on *Amblyseius cucumeris*. Hubei Agricultural Sciences 45: 200-202.

Zulkefli, M. 1996. The effect of selected insecticides on the oil palm bagworm *Metisa plana* Walker (Lepidoptera: Psychidae) and predatory bug *Cantheconidea* sp. (Hemiptera: Pentatomidae). Serdang, University Pertanian Malaysia. B. Sc. Thesis.

Zulkefli, M., Norman, K.and Basri, M. W. 2004. Life cycle of *Sycanus dichotomus* (Hemiptera: Reduviidae) - A common predator of bagworm in oil palm. Journal of Oil Palm Research 16(2): 50-56.

APPENDICES

Appendix 1 : Composition of host plants floral volatiles from six cultivars by hydrodistillation Relative amounts (%).

Peak No.	Rt (min)	Compounds	AC	AI	TS	CC	EH	AL
			Relative amounts (%)					
		Alkane						
	9.29	Hexane, 4-ethyl-2-methyl-	-	-	-	1.33	-	-
	9.29	Heptane, 4-azido-	-	-	-	1.33	-	-
	9.8	1-Iodo-2-methylnonane	-	-	-	2.75	-	-
	9.8	Decane, 2,4-dimethyl-	-	-	-	2.75	-	-
	9.8	2-Bromononane	-	-	-	-	1.85	2.46
	9.8	Decane, 2,9-dimethyl-	-	-	-	-	1.85	-
	9.8	Octane, 2,7-dimethyl-	-	-	-	-	1.85	-
	9.8	Decane, 1-iodo-	-	-	-	-	-	2.46
	9.81	Tetradecane, 1-iodo-	0.76	-	-	-	-	2.46
	9.81	Decane, 2,4,6-trimethyl-	0.76	-	-	2.75	-	-
	9.81	Decane, 2-methyl-	0.76	-	-	-	-	-
	11.43	Octane	-	-	-	1.29	-	-
	11.43	Decane, 2,3,5,8-tetramethyl-	-	-	-	1.29	-	-
	11.43	Hexane, 2,3,4-trimethyl-	-	-	-	1.29	-	-
	14.89	3-Trifluoroacetoxy-6-ethyldecane	-	-	-	1.42	-	-
	14.89	Oxirane, [(tetradecyloxy)methyl]-	-	-	-	1.42	-	-
	14.9	Oxirane, (2-methylbutyl)-	-	1.19	-	-	-	-
	16.41	1-Iodo-2-methylnonane	-	-	-	-	1.45	-
	16.41	Octane, 2-methyl-	-	-	-	-	1.45	-
	16.46	Octadecane, 6-methyl-	1.12	-	-	-	-	-
	17.41	Decane, 2,4,6-trimethyl-	-	1.62	-	-	-	-
	17.42	Heptadecane, 2,6,10,14-tetramethyl-	-	-	-	-	1.72	-
	17.42	Tetradecane, 1-iodo-	-	-	-	-	1.72	-
	17.43	Tridecane, 6-propyl-	-	-	-	1.99	-	-
	17.43	Undecane, 6-ethyl-	-	-	-	1.99	-	-
	17.43	2,3-Dimethyldecane	-	-	-	1.99	-	-
	17.6	Octane, 3-ethyl-2,7-dimethyl-	-	-	-	3.88	-	-
	17.6	Undecane, 2,10-dimethyl-	-	-	-	3.88	-	-
	17.6	Tridecane, 6-methyl-	-	-	-	-	3.17	-
	17.6	Undecane, 4-methyl-	-	-	-	-	3.17	3.72

17.6	Octane, 6-ethyl-2-methyl-	-	-	-	-	3.17	-
17.6	Tridecane, 4,8-dimethyl-	-	-	-	-	-	3.72
17.61	Decane, 2-methyl-	-	3.56	-	-	-	-
17.61	2,6-Dimethyldecane	-	3.56	-	-	-	-
17.61	Decane, 2,4,6-trimethyl-	-	3.56	-	-	-	-
17.61	Tetradecane, 1-iodo-	-	-	1.61	3.88	-	-
17.61	Decane, 5-ethyl-5-methyl-	-	-	1.61	-	-	-
17.61	1-Iodoundecane	-	-	1.61	-	-	-
17.62	1-Iodo-2-methylundecane	1.02	-	-	-	-	-
17.69	Heptadecane, 2,6-dimethyl-	-	-	-	-	1.75	-
17.69	Decane, 2,9-dimethyl-	-	-	-	-	1.75	-
19.1	Octane, 1-(ethenylthio)-	-	1.34	-	-	-	-
19.27	Octane, 1,1'-oxybis-	-	-	-	1.37	-	-
19.28	Octane, 2-methyl-	-	-	-	-	-	1.55
19.28	Tetradecane, 1-iodo-	-	-	-	-	-	1.55
19.29	Hexadecane, 7,9-dimethyl-	0.49	-	-	-	-	-
19.29	Tetradecane, 1-iodo-	0.49	-	-	-	-	-
19.29	1-Iodo-2-methylnonane	-	1.25	-	-	-	-
19.29	2-Bromononane	-	1.25	-	-	-	-
21.55	Nonane, 4-ethyl-5-methyl-	-	-	-	1.28	-	-
21.85	2-Trifluoroacetoxypentadecane	-	-	-	1.38	-	-
21.85	5-Tridecene, (Z)-	-	-	-	1.38	-	-
22.66	3-Cyclopropylcarbonyloxydodecane	-	-	-	1.81	-	-
22.66	4-Cyclopropylcarbonyloxydodecane	-	-	-	1.81	-	-
22.67	Octane, 2,4,6-trimethyl-	-	-	-	-	-	1.53
22.67	Undecane, 4,7-dimethyl-	-	-	-	-	-	1.53
22.67	Decane, 3,7-dimethyl-	-	-	-	-	-	1.53
22.69	Tetradecane, 1-fluoro-	-	1.43	-	-	-	-
23.27	Heptane, 2,5-dimethyl-	-	-	-	-	-	1.76
24.19	Oxirane, [(tetradecyloxy)methyl]-	-	-	2.45	-	-	-
24.24	2-Trifluoroacetoxypentadecane	0.66	-	-	-	-	-
24.26	1,2:4,5:9,10-Triepoxydecane	-	-	-	-	1.57	-
24.5	Trimethyl-3,4-methylenedioxychromane	48.45	-	-	-	-	-
24.51	Pentadecane, 1-bromo-	-	-	1.21	-	-	-
25.09	Pentadecane, 2-methyl-	-	-	-	-	1.84	-
25.09	Heptadecane, 9-hexyl-	-	-	-	-	1.84	-
25.09	Eicosane, 3-methyl-	-	-	-	-	1.84	-
25.1	Octadecane, 6-methyl-	-	-	-	-	-	2.34
25.11	Tetradecane, 1-iodo-	-	2.72	-	-	-	-
25.11	Dodecanoic acid, 2-penten-1-yl ester	-	2.72	-	-	-	-
25.27	Decane, 2,4,6-trimethyl-	-	-	-	-	2.55	-
25.27	Decane, 2,3,5,8-tetramethyl-	-	-	-	-	2.55	-
25.27	Heptadecane, 2,6-dimethyl-	-	-	-	-	2.55	-
25.28	Octadecane, 6-methyl-	-	2.62	-	2.72	-	-
25.28	Dodecane, 5,8-diethyl-	-	2.62	-	-	-	-

28.05	4-Methyl(pentamethylene)silyloxypentadecane	-	-	-	-	1.79	-
32.36	Dodecane, 5,8-diethyl-	-	1.51	-	-	-	-
37.51	Oxirane, [(tetradecyloxy)methyl]-	-	4.82	-	-	-	-
37.51	2-Heptafluorobutyroxypentadecane	-	-	-	4.83	3.81	-
37.51	5-Tridecene, (Z)-	-	-	-	-	3.81	-
37.51	5-Tetradecene, (Z)-	-	-	-	-	3.81	-
37.54	4-Heptafluorobutyroxytridecane	2.6	-	-	-	-	-
40.02	3-Heptafluorobutyroxytetradecane	-	1.5	-	-	-	-
40.02	3-Heptafluorobutyroxypentadecane	-	1.5	-	-	-	-
40.84	3-Trifluoroacetoxytetradecane	-	-	1.6	-	-	-
40.89	Oxirane, [(tetradecyloxy)methyl]-	-	-	-	-	-	2.04
40.89	2-Trifluoroacetoxytetradecane	-	-	-	-	-	2.04
40.89	4-Trifluoroacetoxytetradecane	-	-	-	-	-	2.04
41.17	4-Trifluoroacetoxypentadecane	-	-	-	-	-	1.67
41.26	Decane, 1-(ethenyloxy)-	-	-	2.84	-	-	-
42.47	1,6-Bis(2-propyn-1-yloxy)hexane	-	-	4.52	-	-	-
45.55	Cyclotetracosane	-	-	-	-	11.92	12.34
45.56	4-Trifluoroacetoxyhexadecane	4.62	12.99	-	-	-	-
46.69	Bicyclo[3.1.1]heptane,2,6,6-trimethyl-	-	-	-	-	1.36	-
45.77	Cyclotetracosane	2.34	-	-	-	-	-
45.77	2-Heptafluorobutyroxypentadecane	-	-	6.75	-	-	-
51.78	Dodecane, 1-cyclopentyl-4-(3-cyclopentylpropy l)-	-	-	-	-	1.32	-
51.78	Eicosane, 2-cyclohexyl-	-	-	-	-	1.32	-
53.74	Heptadecane, 9-octyl-	-	-	4.15	-	-	-
53.74	Heneicosane, 11-(1-ethylpropyl)-	-	-	4.15	-	-	-
53.74	Eicosane, 7-hexyl-	-	-	4.15	-	-	-
55.83	3-Methyl(pentamethylene)silyloxypentadecane	-	-	1.16	-	-	-
55.85	Dodecane, 5,8-diethyl-	-	-	2.97	-	-	-
55.85	Decane, 2,6,7-trimethyl-	-	-	2.97	-	-	-
57.84	trans-5,6-Epoxydecane	-	-	-	1.62	-	-
58.8	Dodecane, 5,8-diethyl-	-	-	-	-	1.61	-
58.8	Undecane, 5-ethyl-	-	-	-	-	1.61	-
58.8	Octadecane, 6-methyl-	-	-	-	-	1.61	-
58.83	Heptadecane, 9-octyl-	-	4.48	-	-	-	-
58.83	Heptadecane, 9-hexyl-	-	4.48	-	-	-	-
58.83	Octadecane, 6-methyl-	-	4.48	-	-	-	-
58.84	Heptane, 2,3,5-trimethyl-	0.78	-	-	-	-	-
58.84	Undecane, 2,3-dimethyl-	0.78	-	-	-	-	-
	Alkene						
10.25	Myrcenylacetat	1.11	-	-	-	-	-
14.00	Z,Z,Z-4,6,9-Nonadecatriene	0.47	-	-	-	-	-
14.00	Z,Z,Z-1,4,6,9-Nonadecatetraene	0.47	-	-	-	-	-
14.91	(E)-á-Famesene	2.94	-	-	-	-	-

14.91	1,6,10-Dodecatriene,7,11-dimethyl-3-methylene	2.94	-	-	-	-	-
14.91	cis-á-Farnesene	2.94	-	-	-	-	-
17.08	Precocene I	11.01	-	-	-	-	-
23.27	2,4,6,8-Tetramethyl-1-undecene	-	-	-	-	-	1.76
24.19	2-Methyl-E-7-hexadecene	-	-	-	2.77	-	-
24.24	2-Undecene, (Z)-	0.66	-	-	-	-	-
24.24	4-Tridecene, (Z)-	0.66	-	-	-	-	-
25.12	2,4,6,8-Tetramethyl-1-undecene	0.77	-	-	-	-	-
37.54	2-Methyl-Z-7-hexadecene	2.6	-	-	-	-	-
39.79	5-Tridecene, (Z)-	-	-	-	1.35	-	-
40.84	2-Methyl-7-nonadecene	-	-	1.6	-	-	-
42.43	1-Cyclohexylnonene	-	-	-	-	-	3.07
42.47	4-Nonene, 5-nitro-	-	-	4.52	-	-	-
45.55	10-Heneicosene (c,t)	-	-	-	-	11.92	12.34
45.55	1-Pentadecene, 2-methyl-	-	-	-	12.21	-	-
45.56	cis-2-Methyl-7-octadecene	4.62	-	-	-	-	-
45.56	10-Heneicosene (c,t)	4.62	12.99	15.88	-	-	-
45.56	cis-2-Methyl-7-octadecene	-	12.99	15.88	-	-	-
45.56	5-Eicosene, (E)-	-	-	15.88	-	-	-
45.77	2-Methyl-Z-7-hexadecene	-	6.16	-	-	-	-
45.76	cis-2-Methyl-7-octadecene	-	-	-	6.51	-	6.87
45.76	9-Nonadecene	-	-	-	6.51	-	-
45.76	1-Dodecene	-	-	-	-	5.7	-
45.76	2-Tridecene, (Z)-	-	-	-	-	5.7	-
45.76	1-Pentadecene, 2-methyl-	-	-	-	-	-	6.87
50.24	E-1,9-Tetradecadiene	-	-	-	-	8.08	-
58.84	1-Hexene, 3,5,5-trimethyl-	-	-	-	-	-	1.29
58.84	2-Undecene, 4,5-dimethyl-	-	-	-	-	-	1.29
	Alkyne						
46.63	7-Hexadecyne	-	-	2.17	-	-	-
50.01	11-Hexacosyne	-	-	12.6	-	-	-
50.01	1-Heptadecyne	-	-	-	-	-	13.66
50.01	1-Octadecyne	-	-	-	-	-	13.66
50.02	11-Hexacosyne	3.59	-	-	-	-	-
50.24	1-Heptadecyne	-	-	-	-	-	9.43
50.25	11-Hexacosyne	-	7.27	9.24	-	-	-
	Alcohol						
10.25	Cyclohexanol, 2-methyl-3-(1-methylethenyl)-acetate	1.11	-	-	-	-	-
14.9	(S)-3,4-Dimethylpentanol	-	1.19				
19.29	1-Decanol, 2,2-dimethyl-	0.49	-	-	-	-	-
19.57	Phenol, 2,4-bis(1,1-dimethylethyl)	-	-	-	6.9	5.79	6.61
19.57	Phenol, 2,6-bis(1,1-dimethylethyl)-	-	-	-	6.9	5.79	6.61
19.57	Phenol, 3,5-bis(1,1-dimethylethyl)-	-	-	-	6.9	5.79	6.61
19.59	Phenol, 2,6-bis(1,1-dimethylethyl)-	2.61	5.63	-	-	-	-

19.59	Phenol, 2,4-bis(1,1-dimethylethyl)-	2.61	5.63	-	-	-	-
19.59	Phenol, 3,5-bis(1,1-dimethylethyl)-	2.61	5.63	-	-	-	-
19.61	Phenol, 2,4-bis(1,1-dimethylethyl)	-	-	1.6	-	-	-
19.61	Phenol, 2,6-bis(1,1-dimethylethyl)-	-	-	1.6	-	-	-
19.61	Phenol, 3,5-bis(1,1-dimethylethyl)-	-	-	1.6	-	-	-
22.66	2-Decen-1-ol	-	-	-	1.81	-	-
23.27	2-Nitrohept-2-en-1-ol	-	-	-		-	1.76
24.19	1,3-Propanediol, 2-dodecyl	-	-	-	2.77	-	-
24.50	Phenol,4,6-di(1,1-dimethylethyl)-2-methyl-	48.45	-	-	-	-	-
35.27	Estra-1,3,5(10)-trien-17á-ol	-	-	-	-	4.12	-
40.05	11-Methyldodecanol	-	-	-	-	1.81	-
40.08	2-Nitrohept-2-en-1-ol	-	-	-	2.47	-	-
41.26	2-Methyl-1-undecanol	-	-	2.84	-	-	-
42.43	2-Pentadecyn-1-ol	-	-	-	-	-	3.07
42.47	Z-10-Pentadecen-1-ol	-	-	4.52	-	-	-
45.55	Hexadecen-1-ol, trans-9-	-	-	-	12.21	11.92	-
45.55	1,3-Propanediol, 2-dodecyl	-	-	-	12.21	-	12.34
45.76	2-Hexyl-1-octanol	-	-	-	6.51	-	-
45.76	2-Undecanethiol, 2-methyl-	-	-	-	-	5.7	-
45.76	Hexadecen-1-ol, trans-9-	-	-	-	-	-	6.87
45.77	1-Dodecanol, 3,7,11-trimethyl-	-	-	6.75	-	-	-
45.77	2-Hexyl-1-octanol	-	-	6.75	-	-	-
46.26	11-Tridecen-1-ol	-	-	1.15	-	-	-
46.52	Z-2-Dodecenol	-	1.25	-	-	-	-
46.52	2-Decen-1-ol	-	1.25	-	-	-	-
46.52	2-Decen-1-ol, (E)-	-	1.25	-	-	-	-
46.63	3-Decyn-2-ol	-	-	2.17	-	-	-
46.69	cis-9,10-Epoxyoctadecan-1-ol	-	-	-	1.58	-	-
46.69	11-Tridecen-1-ol	-	-	-	-	1.36	-
46.69	(2,4,6-Trimethylcyclohexyl) methanol	-	-	-	-	1.36	-
46.69	2-Decen-1-ol 3752315	-	-	-	-	-	1.95
46.69	1,1-Dodecanediol, diacetate	-	-	-	-	-	1.95
46.78	cis-9,10-Epoxyoctadecan-1-ol	-	-	1.78	-	-	-
50.01	Eicosen-1-ol, cis-9-	-	11.76	12.6	-	13.74	-
50.01	E-2-Octadecadecen-1-ol	-	11.76		-	-	-
50.01	E-11-Hexadecen-1-ol	-	11.76	12.6	11.53	-	-
50.01	1,15-Pentadecanediol	-	-	-	11.53	-	-
50.01	E,Z-2,13-Octadecadien-1-ol	-	-	-	-	13.74	-
50.01	18-Nonadecen-1-ol	-	-	-	11.53	13.74	-
50.01	(Z)6-Pentadecen-1-ol	-	-	-	-	-	13.66
50.02	Eicosen-1-ol, cis-9-	3.59	-	-	-	-	-
50.02	(Z)6-Pentadecen-1-ol	3.59	-	-	-	-	-
50.24	E-2-Octadecadecen-1-ol	-	-	-	-	8.08	-
50.24	cis-7-Tetradecen-1-ol	-	-	-	-	8.08	-
50.24	11-Hexadecen-1-ol, (Z)-	-	-	-	-	-	9.43
50.25	E-2-Tetradecen-1-ol	2.38	-	-	-	-	-

50.25	E,Z-2,13-Octadecadien-1-ol	2.38	-	9.24	-	-	-
50.25	Z-10-Pentadecen-1-ol	-	7.27	-	-	-	-
50.25	18-Nonadecen-1-ol	-	7.27	-	-	-	-
50.25	11-Hexacosyne	-	-	-	8.98	-	-
50.25	E-11-Hexadecen-1-ol	-	-	-	8.98	-	-
51.46	Cyclohexanemethanol, 4-methyl-, cis-	-	-	-	-	3.59	-
51.46	3-Octen-1-ol	-	-	-	-	3.59	-
51.46	2-Octen-1-ol, (E)-	-	-	-	-	3.59	-
51.78	E-3-Pentadecen-2-ol	-	-	-	-	1.32	-
55.83	1,2-Cyclopentanediol, 3-methyl-	-	-	1.16	-	-	-
57.92	2-Octen-1-ol	-	-	1.49	-	-	-
	Aldehye						
14.00	Lilac aldehyde C	0.47	-	-	-	-	-
14.89	2-Nonenal, (Z)-	-	-	-	1.42	-	-
38.20	2-Nonenal, (Z)-	-	-	2.32	-	-	-
42.43	2-Dodecenal, (E)-	-	-	-	-	-	3.07
45.77	E-14-Hexadecenal	-	6.16	-	-	-	-
49.15	9-Octadecenal	0.69	-	-	-	-	-
	Amine						
16.41	Hydroxylamine, O-decyl-	-	-	-	-	-	2.24
17.41	Hydroxylamine, O-decyl-	-	1.62	-	-	-	-
17.69	Hydroxylamine, O-decyl-	-	-	-	-	1.75	-
25.12	Hydroxylamine, O-decyl-	0.77	-	-	-	-	-
25.28	Hydroxylamine, O-decyl-	-	-	-	2.72	-	-
25.3	Hydroxylamine, O-decyl-	0.75	-	-	-	-	-
	Carboxylic acid						
16.41	3-t-Butyl-hexanedioic acid	-	-	-	2.22	-	-
19.1	Pentanoic acid, 4-methyl-	-	1.34	-	-	-	-
21.85	11-(2-Cyclopenten-1-yl)undecanoic acid, (+)-	-		-	1.38	-	-
22.69	n-Hexadecanoic acid	-	1.43	-	-	-	-
22.69	4-Methyloctanoic acid	-	1.43	-	-	-	-
23.26	4-Methyloctanoic acid	-	-	-	1.38	-	-
24.19	11-(2-Cyclopenten-1-yl)undecanoic acid,	-	-	2.45	-	-	-
24.26	Cyclopentaneundecanoic acid	-	-	-	-	1.57	-
24.51	Adenosine, 1,2-dihydro-2-oxo-	-	-	1.21	-	-	-
24.51	3-Heptenoic acid	-	-	1.21	-	-	-
25.11	n-Hexadecanoic acid	-	-	1.25	-	-	-
25.11	4-Methyloctanoic acid	-	-	1.25	-	-	-
27.72	Cyclopentaneundecanoic acid	-	-	-	-	1.33	-
27.72	11-(2-Cyclopenten-1-yl)undecanoic acid, (+)-	-	-	-	-	1.33	-
27.72	n-Hexadecanoic acid	-	-	-	-	1.33	-
28.05	Tridecanoic acid	-	-	-	-	1.79	-
28.05	n-Hexadecanoic acid	-	-	-	-	1.79	-
28.09	n-Hexadecanoic acid	-	-	1.69	-	-	-

28.09	Cyclopentaneundecanoic acid	-	-	1.69	-	-	-
28.52	n-Hexadecanoic acid	-	-	-	-	-	1.29
28.52	Pentadecanoic acid	-	-	-	-	-	1.29
28.52	Tetradecanoic acid	-	-	-	-	-	1.29
28.53	n-Hexadecanoic acid	-	1.46	-	-	-	-
28.53	Decanoic acid, 3-methyl-	-	1.46	-	-	-	-
29.17	n-Hexadecanoic acid	0.47	-	-	-	-	-
29.17	Eicosanoic acid	0.47	-	-	-	-	-
29.17	Cyclopentaneundecanoic acid	0.47	-	-	-	-	-
29.91	n-Hexadecanoic acid	-	1.64	-	-	-	1.95
29.91	Cyclopentaneundecanoic acid	-	1.64	-	-	-	1.95
29.94	Cyclopentaneundecanoic acid	-		-	-	1.49	-
30.49	4-Methyloctanoic acid	-	1.81	-	-	-	-
30.49	n-Hexadecanoic acid	-	1.81	-	-	-	-
30.49	Cyclopentaneundecanoic acid	-	1.81	-	-	-	-
31.14	Cyclopentaneundecanoic acid	-	-	1.45	-	-	-
31.14	n-Hexadecanoic acid	-	-	1.45	-	-	-
31.14	E-11-Tetradecenoic acid	-	-	1.45	-	-	-
31.3	n-Hexadecanoic acid	-	1.98	-	-	-	-
31.3	Dodecanoic acid, 3-hydroxy-	-	1.98	-	-	-	-
32.13	n-Hexadecanoic acid	-	-	1.2	-	-	-
32.13	Oleic Acid	-	-	1.2	-	-	-
32.13	Cyclopentaneundecanoic acid	-	-	1.2	-	-	-
32.34	n-Hexadecanoic acid	-	-	-	-	-	1.36
32.34	Cyclopentaneundecanoic acid	-	-	-	-	-	1.36
32.35	n-Hexadecanoic acid	0.45	-	-	-	1.89	-
32.35	Dodecanoic acid, 3-hydroxy-	0.45	-	-	-	-	-
32.36	Tridecanoic acid	-	1.51	-	-	-	-
32.36	Pentadecanoic acid	-	1.51	-	-	-	-
32.88	n-Hexadecanoic acid	-	2.63	-	-	-	-
32.88	Tridecanoic acid	-	2.63	-	-	-	-
32.89	n-Hexadecanoic acid	-	-	-	2.34	-	2.16
32.89	Tridecanoic acid	-	-	-	2.34	-	-
32.89	Decanoic acid, 3-methyl-	-	-	-	-	-	2.16
32.89	Nonanoic acid	-	-	-	-	-	2.16
33.66	n-Hexadecanoic acid	-	1.41	-	-	-	-
34.98	n-Hexadecanoic acid	0.52	-	-	-	-	-
34.98	Eicosanoic acid	0.52	-	-	-	-	-
34.98	Octadecanoic acid	0.52	-	-	-	-	-
35.24	n-Hexadecanoic acid	-	-	-	1.87	-	-
35.24	Cyclopentaneundecanoic acid	-	-	-	1.87	-	-
35.24	Oleic Acid	-	-	-	1.87	-	-
35.26	Cyclopentaneundecanoic acid	-	-	-	-	-	2.53
35.26	Oleic Acid	-	-	-	-	-	2.53
35.27	n-Hexadecanoic acid	-	-	3.64	-	4.12	-
35.27	Cyclopentaneundecanoic acid	-	-	3.64	-	4.12	-

35.27	Tetradecanoic acid	-	-	3.64	-	-	-
35.29	n-Hexadecanoic acid	1.48	-	-	-	-	-
35.29	Tridecanoic acid	1.48	-	-	-	-	-
35.3	n-Hexadecanoic acid	-	3.02	-	-	-	-
35.3	Eicosanoic acid	-	3.02	-	-	-	-
35.47	n-Hexadecanoic acid	-	-	-	-	3.43	-
35.47	Tetradecanoic acid	-	-	-	-	3.43	-
35.47	Tridecanoic acid	-	-	-	-	3.43	-
36.51	n-Hexadecanoic acid	-	-	-	-	1.51	-
36.78	Eicosanoic acid	-	1.41	-	-	-	-
37.51	n-Hexadecanoic acid	-	4.82	-	-	-	4.11
37.51	Cyclopentaneundecanoic acid	-	-	-	-	-	4.11
37.53	Oleic Acid	-	-	6.23	-	-	-
37.53	Cyclopentaneundecanoic acid	-	-	6.23	-	-	-
38.17	Oleic Acid	-	-	-	-	1.27	1.38
38.19	Oleic Acid	0.65	-	-	-	-	-
38.19	Cyclopentaneundecanoic acid	0.65	-	-	-	-	-
38.2	Oleic Acid	-	-	2.32	-	-	-
38.2	E-11-Tetradecenoic acid	-	-	2.32	-	-	-
39.8	n-Hexadecanoic acid	-	-	1.18	-	-	-
39.8	Oleic Acid	-	-	1.18	-	-	-
40.02	Z-8-Methyl-9-tetradecenoic acid	-	-	-	-	-	1.4
40.05	Hexadecanoic acid	-	-	-	-	1.81	-
40.07	Oleic Acid	-	-	1.28	-	-	-
40.07	E-11-Tetradecenoic acid	-	-	1.28	-	-	-
40.08	Cyclopentaneundecanoic acid	-	-	-	2.47	-	-
40.25	n-Hexadecanoic acid	-	-	1.16	-	-	-
40.83	Oleic Acid	-	2.34	-	-	-	-
41.17	Oleic Acid	-	-	-	-	2.28	1.67
41.17	Cyclopentaneundecanoic acid	-	-	-	-	-	1.67
41.17	11-(2-Cyclopenten-1-yl)undecanoic acid	-	-	-	-	-	1.67
41.26	n-Hexadecanoic acid	-	-	2.84	-	-	-
42.45	cis-13-Octadecenoic acid	-	4.23	-	-	-	-
42.45	Oleic Acid	-	-	-	3.55	4.59	-
42.45	Z-8-Methyl-9-tetradecenoic acid	-	-	-	3.55	-	-
42.45	cis-Vaccenic acid	-	-	-	-	4.59	-
42.46	Oleic Acid	1.68	-	-	-	-	-
42.46	Hexadecenoic acid, Z-11-	1.68	-	-	-	-	-
42.74	Oleic Acid	0.48	-	-	-	-	-
42.74	cis-Vaccenic acid	0.48	-	-	-	-	-
46.78	cis-10-Nonadecenoic acid	-	-	1.78	-	-	-
49.15	Dodecanoic acid, 3-hydroxy-	0.69	-	-	-	-	-
49.15	Eicosanoic acid	0.69	-	-	-	-	-
49.45	Octadecanoic acid	0.94	-	-	-	-	-
55.83	Stearic acid hydrazide	-	-	1.16	-	-	-
57.84	Cyclooctaneacetic acid, 2-oxo-	-	-	-	1.62	-	-

57.87	Hexadecanoic acid, 1-(hydroxymethyl)-1,2-ethanediyl	-	1.47	-	-	-	-
57.87	n-Hexadecanoic acid	-	1.47	-	-	-	-
	Carboxylate ester						
9.28	Propanoic acid, 2-methyl-,2-ethyl-1-propyl-1,3-propanediyl ester	-	-	-	-	-	1.56
9.28	Oxalic acid, allyl hexyl ester	-	-	-	-	-	1.56
9.28	Oxalic acid, allyl pentyl ester	-	-	-	-	-	1.56
9.29	Oxalic acid, allyl nonyl ester	-	-	-	1.33	-	-
11.42	Oxalic acid, allyl nonyl ester	-	-	-	-	-	1.26
11.42	Oxalic acid, allyl octyl ester	-	-	-	-	-	1.26
16.41	Oxalic acid, hexyl neopentyl ester	-	-	-	-	1.45	-
16.41	Oxalic acid, allyl nonyl ester	-	-	-	-	-	2.24
16.41	Oxalic acid, decyl propyl ester	-	-	-	-	-	2.24
19.27	Oxalic acid, allyl octyl ester	-	-	-	1.37	-	-
17.41	Oxalic acid, allyl nonyl ester	-	1.62	-	-	-	-
17.43	Oxalic acid, monoamide, n-propyl,pentadecyl ester	-	-	-	-	-	1.86
17.43	Oxalic acid, monoamide, n-propyl,tridecyl ester	-	-	-	-	-	1.86
17.6	Oxalic acid, allyl nonyl ester	-	-	-	-	-	3.72
17.62	Oxalic acid, allyl nonyl ester	1.02	-	-	-	-	-
19.1	Cyclopentaneundecanoic acid, methyl ester	-	1.34	-	-	-	-
19.28	Heptanoic acid, 2-methyl-2-butyl ester	-	-	-	-	-	1.55
19.29	Propanoic acid, 2-methyl-, 2-ethyl-1-propyl-1,3-propanediyl ester	-	1.25	-	-	-	-
21.55	Oxalic acid, allyl heptyl ester	-	-	-	1.28	-	-
23.26	Dodecanoic acid, 2-penten-1-yl ester	-	-	-	1.38	-	-
24.19	Oxalic acid, allyl hexyl ester	-	-	2.45	-	-	-
24.25	Oxalic acid, allyl tridecyl ester	-	3.51	-	-	-	-
24.25	Oxalic acid, allyl octadecyl ester	-	3.51	-	-	-	-
24.25	Propanoic acid, 2-methyl-, 2-ethylhexyl ester	-	3.51	-	-	-	-
25.1	Dodecanoic acid, cyclohexyl ester	-	-	-	2.7	-	-
25.1	Valeric acid, 4-tridecyl ester	-	-	-	2.7	-	-
25.1	Valeric acid, 4-pentadecyl ester	-	-	-	2.7	-	-
25.11	Oxalic acid, allyl nonyl ester	-	2.72	-	-	-	-
25.28	Methoxyacetic acid, 2-tetradecyl ester	-	2.62	-	-	-	-
25.28	Valeric acid, 4-tridecyl ester	-	-	-	2.72	-	3.17
25.28	Valeric acid, 3-tridecyl ester	-	-	-	-	-	3.17
25.28	Oxalic acid, allyl decyl ester	-	-	-	-	-	3.17
25.3	Oxalic acid, allyl nonyl ester	0.75	-	-	-	-	-
25.3	Oxalic acid, dodecyl hexyl ester	0.75	-	-	-	-	-
26.79	Oxalic acid, allyl nonyl ester	-	-	-	-	-	1.4
26.79	Methoxyacetic acid, 4-tridecyl ester	-	-	-	-	-	1.4
28.09	9-Octadecenoic acid (Z)-, hexyl ester	-	-	1.69	-	-	-
28.53	10-Undecenoic acid, octyl ester	-	1.46	-	-	-	-
29.94	9-Octadecenoic acid (Z)-, hexyl ester	-	-	-	-	1.49	-

29.94	2-Octadecenoic acid, methyl ester	-	-	-	-	1.49	-
31.3	9-Octadecenoic acid (Z)-, hexyl ester	-	1.98	-	-	-	-
32.34	Oxalic acid, cyclobutyl decyl ester	-	-	-	-	-	1.36
32.35	Octadecanoic acid, 2-(2-hydroxyethoxy)ethyl ester	0.45	-	-	-	-	-
32.35	Oxalic acid, allyl octadecyl ester	-	-	-	-	1.89	-
32.35	Oxalic acid, allyl tridecyl ester	-	-	-	-	1.89	-
32.36	Dodecanoic acid, 2-penten-1-yl ester	-	-	-	2.72	-	-
32.36	Oxalic acid, allyl decyl ester	-	-	-	2.72	-	-
32.36	Oxalic acid, allyl octadecyl ester	-	-	-	2.72	-	-
32.88	Tridecanoic acid, 12-methyl-, methyl ester	-	2.63	-	-	-	-
32.88	Cyclopentaneundecanoic acid, methyl ester	-	-	1.94	-	1.7	-
32.88	Cyclopentaneundecanoic acid, 2-undecyl-, methyl ester, trans-	-	-	1.94	-	-	-
32.88	Octadecanoic acid, 2-(2-hydroxyethoxy)ethyl ester	-	-	1.94	-	-	-
32.88	11-Octadecenoic acid, methyl ester	-	-	-	-	1.7	-
32.88	16-Octadecenoic acid, methyl ester	-	-	-	-	1.7	-
32.89	Tetradecanoic acid, 12-methyl-,methyl ester	-	-	-	2.34	-	-
32.9	Cyclopentaneundecanoic acid,methyl ester	1.43	-	-	-	-	-
32.9	Tetradecanoic acid, 12-methyl-,methyl ester	1.43	-	-	-	-	-
32.9	Cyclopropanepentanoic acid,2-undecyl-, methyl ester, trans-	1.43	-	-	-	-	-
35.26	4-Fluoro-1-methyl-5-carboxylic acid, ethyl(ester)	-	-	-	-	-	2.53
35.29	Hexadecanoic acid, 1,1-dimethylethyl ester	1.48	-	-	-	-	-
36.51	4-Fluoro-1-methyl-5-carboxylic acid, ethyl(ester)	-	-	-	-	1.51	-
36.78	Oxiraneundecanoic acid, 3-pentyl-,methyl ester, trans-	-	1.41	-	-	-	-
37.51	Oxalic acid, allyl pentadecyl ester	-	4.82	-	-	-	-
37.51	9-Octadecenoic acid (Z)-, hexyl ester	-	-	-	4.83	-	-
37.51	Oxalic acid, allyl decyl ester	-	-	-	-	-	4.11
38.17	9-Octadecenoic acid (Z)-, hexyl ester	-	-	-	-	1.27	-
38.17	11-Octadecenoic acid, methyl ester	-	-	-	-	1.27	1.38
38.17	6-Octadecenoic acid, methyl ester	-	-	-	-	-	1.38
38.19	9-Octadecenoic acid (Z)-, hexyl ester	0.65	-	-	-	-	-
40.05	9-Octadecenoic acid (Z)-, hexyl ester	-	-	-	-	1.81	-
40.08	10-Undecenoic acid, octyl ester	-	-	-	2.47	-	-
40.25	Oxalic acid, allyl hexadecyl ester	-	-	1.16	-	-	-
40.83	Oxalic acid, allyl decyl ester	-	2.34	-	-	-	-
40.83	Oxalic acid, allyl tridecyl ester	-	2.34	-	-	-	-
40.84	Oxalic acid, allyl undecyl ester	-	-	-	1.26	-	-
40.84	Oxalic acid, allyl dodecyl ester	-	-	-	1.26	-	-
41.17	Oxalic acid, allyl undecyl ester	-	-	-	-	2.28	-
41.17	Oxalic acid, allyl dodecyl ester	-	-	-	-	-	-
42.45	9-Octadecenoic acid (Z)-, hexyl ester	-	4.23	-	-	4.59	-
42.45	11-Octadecenoic acid, methyl ester	-	4.23	-	-	-	-
45.77	Oxalic acid, allyl dodecyl ester	2.34	-	-	-	-	-

45.77	Bromoacetic acid, tetradecyl ester	2.34	-	-	-	-	-
45.77	Oxalic acid, allyl tridecyl ester	-	6.16	-	-	-	-
46.69	13-Docosenoic acid, methyl ester	-	-	-	1.58	-	-
46.69	Myristic acid, 9-hexadecenyl ester,(Z)-	-	-	-	1.58	-	-
48.86	Valeric acid, 3-tridecyl ester	-	-	1.5	-	-	-
57.84	Sulfurous acid, 2-propyl heptyl ester	-	-	-	1.62	-	-
57.87	Octadecanoic acid, 2-(octadecyloxy)ethyl ester	-	1.47	-		-	-
57.92	Hexadecanoic acid, 4-nitrophenyl ester	-	-	1.49	-	-	-
58.84	Oxalic acid, octyl propyl ester	0.78	-	-	-	-	-
58.84	Pentanoic acid, 1,1-dimethylpropyl ester	-	-	-	-	-	1.29
58.85	Sulfurous acid, 2-ethylhexyl tetradecyl ester	-	-	2.97	-	-	-
	Carboxylate salt						
35.3	l-(+)-Ascorbic acid 2,6-dihexadecanoate	-	3.02	-	-	-	-
36.78	l-(+)-Ascorbic acid 2,6-dihexadecanoate	-	1.41	-	-	-	-
	Ester						
42.46	9-Octadecenoic acid (Z)-, hexyl ester	1.68	-	-	-	-	-
42.74	9-Octadecenoic acid (Z)-, hexyl ester	0.48	-	-	-	-	-
	Ether						
19.27	Ether, 6-methylheptyl vinyl	-	-	-	1.37	-	-
25.1	Ether, 6-methylheptyl vinyl	-	-	-	-	-	2.34
	Ketone						
16.41	Piperazine-3,5-dione, 1-tetradecanoyl-	-	-	-	2.22	-	-
16.46	Cyclopenta[c]furo[3',2':4,5]furo[2,3-h][1]benzopyran-11(1H)-one,2,3,6a,9a-tetrahydro-1,3-dihydroxy-4-methoxy-	1.12	-	-	-	-	-
17.08	Benzo[c]furanone,3,3,4,7-tetramethyl-	11.01	-	-	-	-	-
17.42	2-Butanone, 3,4-epoxy-3-ethyl-	-	-	-	-	1.72	-
17.43	3-Heptanone, 2-methyl-	-	-	-	-	-	1.86
23.26	one,2,3,6a,9a-tetrahydro-1,3-dihydroxy-4-methoxy-	-	-	-	1.38	-	-
24.19	Octan-2-one, 3,6-dimethyl-	-	-	2.45	-	-	-
24.26	Octan-2-one, 3,6-dimethyl-	-	-	-	-	1.57	-
26.79	2-Bromononane	-	-	-	-	-	1.4
33.66	9,9-Dimethoxybicyclo[3.3.1]nona-2,4-dione	-	1.41	-	-	-	-
37.54	1,1,1-Trifluoroheptadecen-2-one	2.6		-	-	-	-
39.79	Ethanone, 1-(1,2,2,3-tetramethylcyclopentyl)-,(1R-cis)-	-	-	-	1.35	-	-
39.99	3á-Acetoxy-17á-methyl-16-d-homoa ndrosten-17a-one	2.76	-	-	-	-	-
40.02	9,9-Dimethoxybicyclo[3.3.1]nona-2,4-dione	-	-	-	-	-	1.4
48.86	9,9-Dimethoxybicyclo[3.3.1]nona-2,4-dione	-	-	1.5	-	-	-
	Organosilicone						
14.9	Silane, trichlorodocosyl-	-	1.19	-	-	-	-
25.1	Silane, trichlorodocosyl-	-	-	-	-	-	2.34
39.99	Silane, dimethyloctyloxyoctyloxy	2.76	-	-	-	-	-
39.99	Silane, dimethyl(2-ethylhexyloxy)octyloxy-	2.76	-	-	-	-	-
48.86	Silane, trichlorodocosyl-	-	-	1.5	-	-	-

	Salt						
10.25	Dihydrocarvyl acetate	1.11	-	-	-	-	-
16.41	Allyl nonanoate	-	-	-	2.22	-	-
16.46	Nonanoyl chloride	1.12	-	-		-	-
17.62	1-Octadecanesulphonyl chloride	1.02	-	-		-	-
21.55	Isobutyl nitrite	-	-	-	1.28	-	-
24.19	Z-10-Tetradecen-1-ol acetate	-	-	-	2.77	-	-
26.79	7-Methyl-Z-tetradecen-1-ol acetate	-	-	-	-	-	1.4
33.66	Z-10-Tetradecen-1-ol acetate	-	1.41	-	-	-	-
36.51	Z-10-Tetradecen-1-ol acetate	-	-	-	-	1.51	-
37.51	Z-10-Tetradecen-1-ol acetate	-	-	-	4.83	-	-
37.53	Z-10-Tetradecen-1-ol acetate	-	-	6.23	-	-	-
39.79	Z-10-Tetradecen-1-ol acetate	-	-	-	1.35	-	-
39.8	Z-10-Tetradecen-1-ol acetate	-	-	1.18	-	-	-
40.02	Z-10-Tetradecen-1-ol acetate	-	1.5		-	-	1.4
40.07	Z-10-Tetradecen-1-ol acetate	-	-	1.28	-	-	-
40.25	Z-10-Tetradecen-1-ol acetate	-	-	1.16	-	-	-
40.84	Z-10-Tetradecen-1-ol acetate	-	-	1.6	1.26	-	-
42.45	Z-10-Tetradecen-1-ol acetate	-	-		3.55	-	-
46.26	9-Tetradecen-1-ol, acetate, (E)-	-	-	1.15	-	-	-
46.26	Z-10-Tetradecen-1-ol acetate	-	-	1.15	-	-	-
46.63	(S)(+)-Z-13-Methyl-11-pentadecen-1-ol acetate	-	-	2.17	-	-	-
46.78	9-Methyl-Z,Z-10,12-hexadecadien-1-ol acetate	-	-	1.78	-	-	-
49.45	Tetrabutyl titanate	0.94	-	-	-	-	-
49.45	7-Methyl-Z-tetradecen-1-ol acetate	0.94	-	-	-	-	-
50.25	Z-9-Hexadecen-1-ol acetate	-	-	-	8.98	-	-
57.92	Tetrabutyl titanate	-	-	1.49	-	-	-
	Unknown						
11.42	1,6:3,4-Dianhydro-2-O-acetyl-á-d-talopyranose	-	-	-	-	-	1.26
17.08	2,2'-Ethylidenebis(5-methylfuran)	11.01	-	-	-	-	-
23.26	Cyclopenta[c]furo[3',2':4,5]furo[2,3-h][1]benzopyran-11(1H)-	-	-	-	1.38	-	-
24.5	2H-1-Benzopyran,6,7-dimethoxy-2,2-dimethyl-	48.45	-	-	-	-	-
48.86	1,1'-Bicyclopentyl, 2-hexadecyl-	-	-	1.5	-	-	-
50.24	1,1'-Bicyclopentyl, 2-hexadecyl-	-	-	-	-	-	9.43

Components > 1 % in bold; superscript refer to method of identification: a-retention time, mass spectrometry and co elution used to confirm identity of compounds, b-mass spectrometry used to identity of compounds, c-mass spectrometry and retention time used to confirm identity, - not detected and tr-trace amounts.

BIODATA OF STUDENT

Syari bin Jamian was born on October 6th, 1981 in Kota Tinggi, Johor. He completed his formal education with Sijil Pelajaran Malaysia (SPM) in Sekolah Menengah Kebangsaan Teknik, Johor Bahru, Johor (SMTJB). In 1999, he persued his study in Diploma of Agriculture program at Universiti Putra Malaysia, Serdang. Two years after that, he continued his undergradute degree in Bachelor Science Bioindustry at UPM and graduated in November 2004.

He was employed as a Research Officer in the Biology Department, Malaysian Palm Oil Board (MPOB) from 1 June 2005 until 31 August 2005. In September 2006, he enrolled as a full-time candidate for persuing the study in Master of Science (Zoology) at Faculty of Science and Technology, Universiti Kebangsaan Malaysia (UKM), Bangi with Professor Dr. Idris Abd Ghani as his supervisor. His research project entitle *Pemeliharaan Serangga Pemangsa, Sycanus dichotomus Stal. (Hemiptera: Reduviidae) dan Keberkesanannya terhadap Metisa plana Walker (Lepidoptera: Psychidae)*.

Syari later enrolled as a Ph.D (Entomology) candidate in Department of Plant Protection, Faculty of Agriculture, UPM since September 2011 until present under the supervision of Associate Prof. Dr. Nur Azura Adam.

LIST OF PUBLICATIONS

Journals

Jamian, Syari., Ahmad, Norhisham., Ghazali, Amal., Zakaria, Azlina., and Azhar, Badrul., 2017. Impacts of two species of predatory Reduviidae on bagworms in oil palm plantations. Insect Science.24: 285-294.

Badrul Azhar, Chong Leong Puan, Najjib Aziz, Muhammad Sainuddin, Nurfatin Adila, Sohaimi Samsuddin, Siti Asmah, Muhamad Syafiq, Syafiq A. Razak, Ahmad Hafizuddin, Ainil Hawa, and **Syari Jamian**. 2015. Effects of in situ habitat quality and landscape characteristics in the oil palm agricultural matrix on tropical understory birds, fruit bats and butterflies. Biodiversity and Conservation Journal 24:3125–3144.

Nur Azura Adam, Rita Muhamad Awang and **Syari Jamian.** 2013. True Transformer**.** In Nature's Yield And Wonders of Art. University Putra Malaysia. 2: 64 – 67.

Posters and Proceedings

Syari Jamian, Nur Azura Adam, Badrul Azhar, Hafidzi Mohd Noor, Rita Muhamad**.** 2016. Relationship between bagworm and predatory insect species in oil palm plantations of Peninsular Malaysia. *In 9th International Conference on Plant Protection in the Tropics (ICPPT)* 3-5 Aug 2016 Hilton Hotel, Sarawak pp 34-37.

Syari Jamian, Nur Azura Adam and Rita Muhamad. 2014. Importance of Predatory Insects on Beneficial Plants in Oil Palm Plantation. *In International Conference Postgraduate Education* 17-18 Dec 2014 Main Hall UTeM, Melaka.

Syari, J., Manjeri, G. and Muhamad, R. 2013. Assassin bug, *Sycanus dichotomus* Stal.; An answer to reduce bagworm (*Metisa plana*) populations in oil palm plantations. *in Malaysia International Commodity Conference and Showcase 2013*. 24 – 27 Oct 2013. Malaysia Agro Exposition Park Serdang (MAEPS), Selangor.

Syari, **J.,** Muhamad, R., Nur Azura**,** A., Norman, K. and Idris, A.B. 2013. Effects of two alternative insect prey on the performance of the predatory insect, *Sycanus dichotomus* (Hemiptera: Reduviidae). pp. 41 in Postgraduate Symposium on Plant Protection 2013. Bangi. Selangor

Award and Honors

Research University Grant Scheme from UPM for Biological Control research from September 2012 to 31 August 2014 (24 month).

Skim Latihan Akademik Bumiputera from Ministry of Education, Government of Malaysia from August 2011 until August 2015.

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