SUSTAINABLE CONTROL OF BAGWORM (*LEPIDOPTERA: PSYCHIDAE*) IN OIL PALM PLANTATION: A REVIEW PAPER

Muhamad Nasarudin Sulaiman
Faculty of Plantation and Agrotechnology
Universiti Teknologi MARA
96400 Mukah, Sarawak, Malaysia
Email: nasarudinsulaiman@uitm.edu.my

Muhamad Syukrie Abu Talip
Faculty of Plantation and Agrotechnology
Universiti Teknologi MARA
96400 Mukah, Sarawak, Malaysia
Email: muhd_syukri@uitm.edu.my

ABSTRACT

The oil palm industry is a key economic agriculture activity to contribute to Malaysia Gross Domestic Product (GDP). In 2019, it was reported that oil palm GDP was about RM38 Billion or 38% of the agricultural sector in Malaysia. However, the substantial yield reduction due to pest attacks are becoming main threats in the oil palm industry. The bagworm (Lepidoptera: Psychidae) is one important leaf eating pest that could cause severe leaf damage and yield losses up 43% without a proper treatment as stated by Malaysia Oil Palm Board (MPOB) in 2016. Integrated pest management (IPM) has been suggested in pest control measures by integrating various techniques such as biological controls, cultural controls, and chemical controls. Insect natural enemies consist of predators as a biological control agent that capture and feed on bagworm thus reducing the infestation outbreaks. The establishment of ground vegetation flowers such as beneficial plants able to increase the insect natural enemies' population as a part of cultural controls. The presence of beneficial plants would provide nectar as a food source for predators. Chemical controls have been identified as an effective measure to reduce the incidence of bagworm in oil palm estate. The application of insecticides through Trunk Injection (TI) and aerial spraying are fast-acting to reduce the larval population of bagworm. The investigation of pheromone traps was carried out for trapping of male bagworm moths thus reducing the subsequent population of larvae due to reducing chances of mating. This paper deliberates on controlling the bagworm population through integrated pest management (IPM) that ensures sustainable control of bagworm in oil palm plantation.

Key words: *Bagworm, IPM, biological controls, cultural controls, chemical controls, sustainable control*

INTRODUCTION

Oil palm plantation has been expanding to the highest yielding vegetable oil crop per unit area (Murphy, 2009). In Malaysia, oil palm (*Elaeis guineensis*) is a major agriculture sector contributing to Malaysia Gross Domestic Product (GDP). However, the detrimental effects to the oil palm industry due to the emergence of various pests thus become a loss to the annual oil palm production (Yap, 2005). According to Wood (1971) and Corley and Tinker (2003) that insufficiency of predators as natural enemies in the environment is related to the existence of pests in oil palm plantations. In addition, the declining natural enemies' diversity in poor habitat of agroecosystems lead to the pest outbreak (Kruess and Tscharntke, 1994; With *et al.*, 2002). Basri *et al.* (1995) has reported that the existence of parasitoids has significance as a biological control to regulate bagworm population. The initiative of increasing the population of parasitoids and predators can be done by establishment of recommended beneficial plants to supply nectar as a food source for them. It has been confirmed by Basri *et al.* (1995) that the life span of adult parasitoids and predators in the laboratory with sufficient food supply. Gazhali *et al.* (2016) and Ashraf *et al.* (2018) have reported the decreasing of arthropod biodiversity due to monoculture oil palm of oil palm that caused damage to the foliage. According to Basri and Kevan (1993), a moderate defoliation of about 10%-13%. However, further defoliation is about 33% - 40% may cause crop loss in oil palm plantations. Ecological functions in agroecosystems such as pollination and biological control are affected due to poor biodiversity in oil palm plantations (Feintrenie *et al.*, 2010).

The bagworms are one of the major leaf-eating pests yield reduction in two years due to moderate defoliation (10 - 13%) caused by *Metisa plana* Walker (Lepidoptera: Psychidae). Bagworm is referred to as a larva which hides in a built protective bag like a cocoon. Numerous bagworm species commonly found in Malaysia are based on cocoon size and shape identified in the field. The shapes and sizes of cocoons have variation from a narrow hose to an expansive sac (Cheong and Tey, 2012). Wood (1968) has reported that three major species of bagworms in South-east Asia caused oil palm damage namely, *Metisa plana* Walker, *Pteroma pendula* Joannis and *Mahasena corbetti* Tams. These three psyched species have commonly reached outbreak status (Wood, 1968; Basri *et al.*, 1988; Hoong and Ho, 1992). Several studies have reported that *Metisa plana* is a significantly key pest of oil palm plantations in Malaysia. Basri *et. al.* (1988) reported that the study in 1929 has identified *Metisa plana* as the first among other pests. Meanwhile, Wood and Nesbit (1969) has reported the most common incidence of bagworm attack in Eastern Sabah was *Mahasena corbetti*. Moreover, Norman and Basri (2007) reported that the infestation of *Metisa plana* was identified as the most widely affecting oil palm in Peninsular Malaysia. Ho *et al.* (2011) has analysed the historical records of bagworms infestation in Peninsular Malaysia. The analysis showed that the total 69 estates in Peninsular Malaysia about 63 955 ha were attacked by *Metisa plana* and *Pretoma pendula* as a primary pest. The oil palm was damaged due to the bagworms feed behaviour, specifically on the leaflets. Besides, it is using small pieces of leaflets and small twigs embedded by tough silk as the materials to build the caterpillar casing as a cocoon to develop the larvae into pupae and later adults (Barlow, 1982).

Norman and Basri (2007) have revealed the bagworm outbreak, mainly of *Metisa plana* and *Pretoma pendula* incidence, occurred about 16% of the total area of 1.9 hectares throughout Malaysia in 2000 to 2005. Meanwhile, approximately 32,475 ha estate and 5100 smallholder land in central Johor was infected by bagworms (Mazmira *et al.*, 2015). Earlier, Wood *et al.* (1973) reported that a damage of 50% will cause the oil palm yield decline to 43%. The study by Cheong *et al.* (2010) has reported the biological control agents such as predators, parasitoids and pathogens significantly associated with the bagworm mortality about 37%, 35.9% and 27.2% respectively with naturally controlling bagworm populations in oil palm plantations. According to Hajek (2004) and Norris *et al.* (2003), biocontrol is an eco-friendly and sustainable mechanism to reduce pest population by using natural enemies when the number of pests is below economic level. In addition, Sethi and Gupta (2013) have mentioned that the biological control application in agriculture relies on natural agents rather than chemicals.

Integrated pest management (IPM) is the best mechanism to control the outbreaks of bagworm population in oil plantations (Ramlah *et al.*, 2013; Mohd Mazmira *et al.*, 2010; Najib *et al.*, 2013). According to Wood and Norman (2019), further study on the relationship between current regular treatments and continuing infestation have to be done. These reviews focus on the importance of various mechanisms of bagworm controls and recognising the possible ecological factors in pest control. The application of selective biopesticides, chemicals, mass-trapping by pheromone to complement on-going biological agents contributed to the developing science that became known as integrated pest management (IPM). There has been a gradual increase in bagworm infestation widespread and intensive in many places since 1990. The need of pesticide application besides the existence of biological control in the affected areas without much appreciation of selectivity. In many years, extensive research work has been conducted wherever the existence of bagworm infestation has been outstanding. The continuity of study would improve the current knowledge of bagworm control for minimizing the threats of outbreaks and crop losses. The review finding summarized the application of biopesticides as well as chemicals to control the outbreaks; usage of mass-trapping by pheromone attractant in sticky traps has been discussed as an alternative for continuous male bagworm moth trapping in the field and the establishment of beneficial plants for natural pest control such as predators and parasitoids due to the existence of nectar producing flowers.

Biopesticides

Biopesticides are derived from microbes and plants are known as biological natural agents. The application of biopesticides can target the specific pests and save the environment from any chemical pollution. Application of *Bacillus thuringiensis* (Bt) is nor affecting the non-target organisms including the oil palm pollination weevil, *Elaeidobius kamerunicus* (Najib *et al.*, 2015). Furthermore, Najib *et al.* (2014) reported that Bt is an environmentally friendly microbial insecticide that is not toxic to freshwater fish, human, domestic animals and vertebrates (Najib *et al.*, 2015). Bt has produced crystalline protein inclusion during sporulations as it has become insecticidal actions against bagworms (Nester *et al.*, 2002). In addition, the proteins are highly specific against certain insect orders (Hofte and Whitely, 1989). Mazmira *et al.* (2011) has reported that bagworm has been controlled effectively in several oil palm plantations in Malaysia using *Bacillus thuringiensis* (Bt) via aerial spraying. According to Basri (1993) and Chong *et al.* (2010) that the reduction of bagworm population was not only caused by Bt product application but also the biotic and abiotic factors have the important roles in reducing the population and regulating the larval community.

In addition, Hasber *et al.* (2015) reported that single treatment using bioinsecticide (Btk) have controlled *Metisa plana* larvae satisfactorily compared to the synthetic insecticides such as trichlorfon, cypermethrin and lambda-cyhalothrin. However, the application of Btk was not efficient to reduce the larval population below ETL when the population of *Metisa plana* larvae was high-density (>50 larvae/frond). It was suggested that regular application of Btk is recommended to reduce the population below ETL. According to Tan *et al.* (2008), application of Btk with concentration between 20 to 100 ppm under laboratory conditions resulted in 70% - 100% of larval mortalities. Meanwhile, Kok *et al.* (2012) found that Btk 324 ppm in laboratory conditions was the slowest-acting insecticides to control *Metisa plana*. Hasber *et al.* (2015) suggested that further studies needed to optimise the application Bt conditions for effective control of bagworm larvae in oil palm plantations.

Chemicals

Malaysian Agriculture Digest (2013) has reported that the usage of agrichemicals in Malaysia in 2005 was RM 328 million. Meanwhile in 2012 the increment figure of agrichemical usage to RM 563 million was reported. The usage of pesticides in Malaysia showed a similar trend where there was a significant increase of about 28% since 2008. Application of chemical control, methamidophos through trunk injection and cypermethrin through spraying to infected oil palm by bagworms have shown positive results where live larval numbers fell below the threshold level of 10 LPF (Norman and Basri, 2010). In young oil palm, a knapsack sprayer is used to control identified bagworm population (Basri *et al.*, 1988; Sudarsono *et al.*, 2011) Based on reports by Yap (2000) the bagworm outbreaks have suppressed and maintained the infestation below the action threshold by using chemical control. According to Salim *et al.* (2015) that the fastest acting of chemical insecticides can be seen 30 days after a single application of chemical insecticides where the larval population dropped below economic threshold level (ETL).

Soil chemical drenching with organophosphate insecticides trichlorfon and chlorpyrifos and the pyrethroid insecticides cypermethrin and lambda-cyhalothrin have been used to control the bagworms population (Basri *et al.*, 1988; Chung, 1988; Yap, 2005). Rhainds *et al.* (2009) found that chlorantraniliprole showed the effective control of bagworm populations where the chemical had a residual effect for 10-day thus providing effective control to protect oil palm over the sustained period of bagworms. Chemical controls are the main mechanism in most oil palm plantations to control the outbreaks of bagworms (Hasber, 2010). Based on further study, Hasber *et al.* (2015) reported the application of synthetic insecticides such as trichlorfon, cypermethrin and lambda-cyhalothrin in oil palm has effectively controlled the population of bagworms after 30 DAT.

Ground spraying was done in the field with a single round of treatment and reduced the bagworm populations below the ETL at 30 DAT (<5 larvae/frond). These findings were consistent with Chung (1998) who reported the efficiency of trichlorfon and cypermethrin have reduced the bagworm population below the ETL at 30 DAT. The similar findings also discovered by Syed and Salleh (1991) that the application of trichlorfon was very effective to control larvae of *Metisa plana* with a dosage at 1 kg (95%) per hectare in a single treatment. Similarly, Kok *et al.* (2012) demonstrated pesticides application under laboratory conditions control against bagworms. The application of trichlorfon (1900.0 ppm), chlorantraniliprole (50.0) and cypermethrin (75.0 ppm) showed effective control of bagworms and it is a potential for *Metisa plana* management.

Trunk injection (TI) has been chosen as a treatment to control bagworm population since the mid-1970s. (Khoo *et al.*, 1983). The correct chemical application time is extremely important for effectiveness of treatment. After full emergence of larva is the right time for optimum chemical application. The chemical residue remains in leaves for certain periods have killed the subsequent pest generations (Wood, 1976; Wood, 1988). Reliable census would determine the correct time for chemical treatment thus achieving good results in bagworms population control (Chung and Sim, 1993). Wood (1987) reported that there is no significant damage against oil palm due to drilling the holes in the palm trunk. In addition, pesticides residues have not remained in the edible products (Yap, 2005).

Mass Trapping by Pheromone

Mass trapping using pheromone-baited has been achieved to directly control the insect pest (Smit *et al.*, 2001; Alpizar *et al.*, 2002; Norman and Othman, 2006; Norman *et al.*, 2010). However, the effectiveness of pheromone traps is influenced by several factors such as distance of insects to trap (Byers, 1999), the trap design (Valles *et al.*, 1991) and pheromone plume characteristics (Ali Niazee, 1983). In addition, Witzgall *et al.* (2010) have reported that trap maintenance, cropping system, residue management and environmental conditions were postulated to have affected pheromone efficacy. The usage of pheromone traps is cost-effective compared to mating disruption due to a smaller number of pheromones required as well as crop contamination (Witzgall *et al.*, 2010).

The application of live virgin females' bagworms (*Metisa plana*) as pheromones to trap the male bagworms (Norman and Othman, 2006; Normal *et al.*, 2008; Norman *et al.*, 2010). Norman *et al.* (2010) found that the synthetic female sex pheromone has a potential to be developed as for mass trapping of male bagworms. In addition, Norman *et al.* (2010) reported that the number of live larvae per frond reduced based on the number of female bags with eggs in the trapping plot thus reducing the frond damage.

Further studies by Norman *et al.* (2012) resulted in the confirmation that chances of successfully mating was reduced by trapping the male moth. It was reported that the percentage of female bags with eggs in the trapping plot was about 20% lower than the control plot hence lowering the population of the subsequent bagworm's generation.

BIOLOGICAL AGENTS

Enhancing the biocontrol agent management in oil palm plantations is an important approach to reducing pest populations. The losses of biodiversity in a wide range of organisms as well as biocontrol agents due to the conversion of natural habitat to oil palm plantations (Bernes *et al.*, 2014; Fitsherbert *et al.*, 2008). As suggested by Gray and Lewis (2014) the landscape heterogeneity in oil palm plantations is a potential mechanism to diversify the biodiversity especially the population of native biocontrol agents through the protection of riparian buffers. This is supported by Foster *et al.* (2011) and Koh *et al.* (2009) that protection of natural habitat surrounding the oil palm plantations can promote the predation rates as a biological agent. Maintaining diverse habitats inside and surrounding oil palm plantations support the movement of predatory insects and the potential for predators to control crop pests bridging biodiversity conservation and function (Lucey *et al.*, 2014; Senior *et al.*, 2013; Tscharnke *et al.*, 2007). In addition, planting and maintaining flowering plants in oil palm plantations is necessary to improve the ability of natural enemies to control pest populations as part of integrated management programs (Mathew *et al.*, 2007). Kamarudin and Wahid (2010) have reported that planting *Cassia cobanensis* within the vicinity of oil palm plantations can promote bagworms' parasitoids.

Parasitoids

Parasitoids are known to be the extremely effective natural enemies in controlling pest populations on farms (Hawkins *et al.*, 1997). Parasitoids can be described as living things or organisms that live in or inside the host organism and eventually kill the host. In other terms, parasitoids are parasitic insects that grow from larvae found on or in an individual host of eggs laid either in or near the host (Cheong and Tey, 2013). Since 1967, there have been several parasitoids that were identified that are parasitoids against *M. plana* and *P. pendula (*Brian and Norman, 2019*)*. According to Wood (1968), he described and first described some of the parasitoids including Dolichogenidea (Apanteles) metesae. As stated from Brian and Norman (2019), around 10% of all insect species labeled as parasitoids found in the Order Hymenoptera are one of many insect parasitoids with several Diptera (flies) mainly from individual species of larger size as shown in **Table 1**.

There are two types of parasitoids which are primary parasitoids and secondary parasitoids or other names referred to as hyperparasitoids. According to Basri *et al.* (1995), study from PORIM Kluang, Johor, revealed that the primary parasitoid contains six species and secondary or hyperparasitoid is another six species as shown in **Table 1**. This study was supported (Basri and Kevan, 1995; Norman and Basri, 2010; Jamian, 2017) where the records showed hemipteran species attacked bagworms along with six primary parasitoids and predators against *M. plana*. Hyperparasitoids were attacking other parasitoids that are related to bagworms as a family of Hymenoptera is commonly found for the main oil palm bagworms. This shows that the hymenopteran family may function as primary or secondary parasitoids (Brian and Kamarudin, 2019), of which several of the highly ordinary are the family Eulophidae, Eurytomidae, and Ceraphronidae. Further research from the field collection is from Tiong (1979), Basri *et al.* (1995), Teh (1996), and a comprehensive account by Norman *et al.* (1996). Coincidentally, the life cycles of pests and parasitoids can be associated, or pests can be changed by parasitoids to accommodate their growth (Debach, 1974; Debach and Rosen, 1991).

A major parasitoid in oil palm plantations in Peninsular Malaysia, *D. metesae* were found to attack another species of bagworm, *Pteroma pendula*, (Norman *et al.*, 1998; Cheong *et al.*, 2010; Mahadi *et al.*, 2012; Halim M. *et al.*, 2018). Prior studies from Hanysyam *et al.*, (2013) identified that parasitoids of the family Ichneumonidae (*G. bunoh* and *B. oxymora*) which are closely associated, act as main parasitoids, also has a large and high presence in oil palm plantations attacked by bagworms. There is another species from the family Chalcididae (*B. carinata*) which is the main parasitoid has also been identified as one of the most plentiful hymenopteran parasitoids of bagworms in Peninsular Malaysia (Yusdayati *et al.*, 2014; Halim M. *et al.*, 2018). Among the control effects performed by primary parasitoids where this species will interfere with or slow down the formation of natural balance (Brian and Kamarudin, 2019). This indicates the specific importance of these species in regulating the population of pests.

Table 1: Classification of parasitoid against bagworms in oil palm plantation from 1970 to 2002

Types of Parasitoid	Super Family	Family	Species	Bagworms
Primary	Hymenoptera	Braconidae	*Dolicogenidea (Apanteles) metesae, Aulosaphes psychidivorus*	*Metisa plana*
		Ichneumonidae	*Goryphus bunoh, G. inferus, Fislistina* sp., *B. oxymora*	
		Chalcididae	*Brachymeria* spp., *B. carinata*	
		Eulophidae	*Tetrastichus* sp., *Pediobius* sp.	
		Elasmidae	*Elasmus* sp.	
		Braconidae	*D. metesae, A. psychidivorus*	*Pteroma pendula*
		Chalcididae	*Brachymeria* spp.	
Secondary (Hyperparasitoid)	Hymenoptera	Eulophidae	*Pediobius* sp., *P. imbreus*	*Mahasena corbetti*
		Ichneumonidae	*Ecthromorpha agrestoria, G. bunoh*	
	Diptera	Tachinidae	*Eozenillia equatoralis, Palexorista solennis, Thrycolida psychidarum, Exorista quadrimaculata*	

Source: Basri & Norman (1995); Norman *et al.*, (1998); Cheong *et al.*, (2010); Mahadi *et al.*, (2012); Hanysyam *et al.*, (2013); Yusdayati *et al.*, (2014); Halim M. *et al.*, (2018); Brian & Norman (2019).

Predators

In Malaysia, bagworms are one of the common and severe pests of oil palm (Basri *et al*., 1988). Pests on crops can be handled through two main methods through chemical input with the use of pesticides or biocontrol (Wood, 2004). Controlling this pest by using chemicals continuously will affect the natural enemies of pests and indirectly to beneficial insects such as oil palm insect pollinators. Thus, successful integrated pest management requires biological control that has been the core of the program (Zulkefli *et al.*, 2004). Jamian *et al.* (2017) states that an alternative to chemical dependence in agricultural systems using predatory insects has proven to be an effective biological control agent. Predatory insects are species that live freely by catching and eating bagworms in general, where most frequent are the bugs and beetles (Brian & Norman, 2019). According to Cheong and Tey (2013), whether larvae or nymphs, it takes several to many individuals to reach maturity indicating predatory insects differ from parasitoids. The predators are generalist feeders (wide host range) and will build up when an outbreak is already occurring.

Table 2: Natural predator associated with a population of bagworms.

Types of Insects	Super Family	Family	Species	Mode of Attack
Bugs	Hemiptera	Reduviidae	*Sycanus dichotomus*	Sharp proboscis found in these predatory insects can penetrate and suck body fluids with reduviid which is incredibly capable for eating bagworms.
			Cosmolestes picticeps	
		Pentatomidae	*Cantheconidia furcellata*	
			Platynopus melacanthus	
Beetle	Coleoptera	Cleridae	*Callimerus arcufer*	Grubs reside in the bagworm cocoon and feed the insides. Control at pupal stages

Source: Jamian *et al.*, (2010); Cheong and Tey, (2011); Jamian (2017); Norman *et. al.*, (2019); Brian & Norman (2019); Ahmad *et al*., (2020).

Predatory species from Hemipterans are an important group of predators found in oil palm plantations (De Chenon *et al.*, 1989), which are *Cantheconidea furcellata* and *Platynopus melacanthus* (Pentatomidae) as well as killer bugs, *Sycanus dichotomus* and *Cosmolestes picticeps* (Reduviidae) have predatory abilities against worm caterpillars (Azlina, 2011; Siti Nurulhidayah *et al.*, 2011, Norman *et al*., 2019). Prior studies (Schaefer and Ahmad, 1987; Zulkefli *et al.*, 2004; Siti Nurulhidayah and Norman, 2016; Jamian *et al.*, 2017; Siti Nurulhidayah *et al.*, 2020), had proven that applicable biological control for nymphs and larvae of insect pests are Reduviid predators. However, previous study from Azlina (2011) has shown that *C. picticeps* often show cannibalism to their own population where it can thwart its role as an efficient biocontrol agent for bagworms causing it to become a less specific predator. Other predator agents such as species from Coleoptera that is chequered beetle *Callimerus arcufer* (Cleridae) have shown the ability to control the stages of bagworms even though this species is less well known (Cheong and Tey, 2011). Among the species, the most common Reduviid bug that feeds on nettle caterpillars such as *Darna sp.* and *Setothosea assigna* is *Sycanus dichotomus* Stal. (Singh, 1992; De Chenon *et al.*, 2017); and bagworms such as *M. plana* and *P. pendula* (Jamian *et al.*, 2010; Norman *et al.*, 2017; Siti Nurulhidayah *et al.*, 2020). The study from De Chenon *et al.* (1989) showed the effective way of *S. dichotomus* as a biocontrol agent for *M. plana.* Overall, *C. furcellata*, *P. melacanthus* and *S. dichotomus* are the most potential predators to control *M. plana* (Azlina, 2011; Jamian *et al.*, 2017).

Beneficial Plants

The basis of the success of biological pest control programs is observed from the capability of assassin insects targeted to find their prey effectively to survive in the environment. The development of beneficial plants from ground vegetation flowers was an important element to ensure accomplishment in implementation of Integrated Pest Management (IPM) towards bagworms. Various types of plants have been correlated with the stimulation of the activity from natural enemies for the biological control of bagworms (Nor Sarashimatun *et al.*, 2011). The performance of insect predators can be improved by introducing flowering plants that are usually grown on the edge of oil palm plantations (Jamian, 2017). Thus, there is some previous research done on the suitability of numerous species of flowers that can be planted in the oil palm environment to support natural enemies.

Plant species would produce nectar and flowers that consist of an open structure allowing easy access to the pollen. The vital role of parasitoids in regulating the number of bagworms reported by Basri *et al.* (1995), its population depends on the availability of sanctuary and food resources, such as nectar supplied by plants is advantageous in the oil palm ecosystem, while Basri *et al.* (1999) declared that these plants was discovered to extend the life of adult parasitoids. Jamian and Nur Azura (2018) report that the combination of flowering plants (*T. subulata*) and its prey (*M. plana*) will maintain the longevity and fertility of predatory insects. Longevity and fertility of predatory insects can be maintained by a combination of flowering plants (*T. subulata*) and its prey (*M. plana*) (Jamian and Nur Azura, 2018). However, the observations from Syed and Shah (1977), Brian and Norman (2019) show that shortage of food and shelter for adult parasitoids due to the devastation of soil vegetation can be the cause of leaf-eating caterpillar outbreaks. Norman and Basri 2010 reported that four species of plants are beneficial for bagworms and leaf eating insects which are *Cassia cobanensis*, *Asystasia gangetica*, *Crotalaria usaramoensis* and *Euphorbia heterophylla*. Meanwhile, *Cassia cobanensis*, *Asystasia gangetica*, *Euphorbia heterophylla* and *Turnera subulata* are four species of nectar-producing plants that beneficial to the biocontrol agent of bagworms (Basri *et al.*, 2001; Ho *et al.*, 2003; Norman *et al.*, 2019).

The occurrence of *P. pendula* in oil palm cultivation has been assessed by the presence of parasitoids on *C. cobanensis* (Norman and Othman, 2016). Insect predatory activity is seen to be more noticeable on ferns meanwhile parasitoids prefer to live on plants that have nectar sources which are *C. cobanensis* and *Asystasia gangetica* (Norman *et al.*, 2019). Basri *et al.* (1999) and Yusdayati *et al.* (2014) suggested that *Turnera spp.* better preferred than *C. cobanensis*, due to *Turnera spp*. flowering is continuous, whereas *C. cobanensis* flowers seasonally, once in a year that might require replanting if its growth is inhibited during the dry season. Factors of difficulty in establishing and having a short life cycle, *E. heterophylla* is not recommended for cultivation (Ho *et al.*, 2003)

Basri *et al.* (1999) reported *C. cobanensis*, *Crotalaria usaramoensis*, *Asystasia gangetica* and *Euphorbia heterophylla* are flowering plants containing nectar consisting of sucrose, fructose and glucose. While nectar whose composition includes sugar, protein, phenolic, hydrogen peroxide and aromatic compounds produced from *Mucuna sempervirens* flowers (Liu *et al.*, 2012). Carboxylic acids, lipids and other organic compounds are also found in flower nectar that could attract predatory insects due to volatile compounds from host plants (Baker and Baker, 1975; Buchmann and Buchmann, 1981). A comprehensive experiment was conducted by Ho *et al.* (2003) to evaluate the effectiveness of various types of beneficial plants and the results show three plant species namely *T. subulata*, *A. leptopus* and *C. cobanensis* become the most effective to attract natural enemies. Schlindwein and Medeiros (2006) have reported that Turnera subulata flowers can attract 28 species of insects. The results of previous studies from Jamian *et al.* (2020) showed that a strong attraction to beneficial plant for *T. subulata* against tested predators due to allelochemistry when released into the environment where these findings are in line with Yusdayati (2008), who reported that *Turnera sp.*, *A. leptopus* and *C. cobanensis* were preferred by natural enemy. Thus, these observations show the importance of cultivating beneficial crops such as *C. cobanensis* around oil palm plantations to maintain natural enemy populations for long-term bagworm control.

CONCLUSION

The sustainability of bagworm infestation outbreaks control measures has been investigated intensively in Malaysia. It is important to integrate various mechanisms in bagworm population control measures based on the current knowledge and operational practices. The prominent plantation companies have the research unit to study threats and opportunities regarding the issues of bagworm infestation in oil palm estate. Beside that, the researchers of government agencies and higher institutions have the same interest to collaborate for the sustainability of bagworm control measures needs and opportunities for field experimentation and knowledgeable investigation. Integrated pest management (IPM) is widely recognised and accepted in implementation of bagworms control in oil palm plantation. It is suggested that establishment of biological control would ensure the existence of biological agents to continuously control the population of bagworms as it is still under EDL. However, the incidence of bagworms more than EDL should be controlled with chemical application since the biological agents have been shown to be inefficient in controlling the bagworms population. The integration of several approaches and mechanisms such as biopesticides, chemicals and mass-trapping by pheromone are applicable whenever the infestation of bagworm exceeds the threshold level of 10 LPF. It is to be a complement for the establishment of biological controls agents as a preventive measure by attracting the parasitoids and predators. The predators and parasitoids are the natural agents to control the bagworm population in the estate. The potential of treatment application would reduce the incidence of bagworms attack as to increase oil palm yield in plantations. Continuous monitoring of pest incidence through census programs to detect the early stage of infestation for immediate actions.

Overall, the sustainability of bagworm control should be continuously investigated through intensive field work study. This is important to be referenced in estate operational activities especially for pest and disease management. The precise methods, sufficient knowledge and technical support will contribute to the optimum of oil palm plantations management. This review paper has highlighted the possible approach of sustainable control of bagworm in oil palm plantations. The findings of the paper have summarized from related literature specifically about the recommended measures for both chemical and biological controls in pest infestation controls. This is significant input to the practitioner in industry for the alternative solution in improving sustainability of bagworm control in oil palm plantations.

REFERENCES

Ahmad, S. N., Masri, M. M. M., & Kamarudin, N. (2020). Assessment on voracity and predation by predator, Sycanus dichotomus stal. (Hemiptera: Reduviidae) to oil palm bagworm, Pteroma pendula. Journal of Oil Palm Research. https://doi.org/10.21894/jopr.2020.0040

Ali Niazee, M. T. (1983). Monitoring the filbert worm, Melissopus latiferre (Lepidoptera: Olethreutidae), with sex attractant traps: effect of trap design and placement on moth catches. Environmental Entomology 12: 141-146.

Ashraf, M., Zulkifli, R., Sanusi, R., Tohiran, K. A., Terhem, R., Moslim, R., Norhisham, A. R., Ashton-Butt, A., & Azhar, B., (2018). Alley-cropping systems can boost arthropod biodiversity and ecosystem functions in oil palm plantations. Agric. Ecosyst. Environ. 260, 19–26.

Azlina, Z. (2011). Killing efficiency of selected insect predator species against bagworm, Metisa plana. Proc. of the PIPOC 2011 International Palm Oil Congress - Palm Oil: Fortifying and Energizing the World: Module 1 - Agriculture, Biotechnology and Sustainability Conference. MPOB, Bangi. p. 46-49.

Baker, H. G., & Baker, I. (1975). Studies of nectar constitution and pollinator plant co-evolution. Animal and Plant Co-evolution (Gilbert, L E and Raven, P H eds.). University of Texas Press, Austin, Texas, USA. p. 100-140.

Bale, J. S., Van Lenteren, J. C., & Bigler, F. (2008). Biological control and sustainable food production. In Philosophical Transactions of the Royal Society B: Biological Sciences. https://doi.org/10.1098/rstb.2007.2182

Basri, M. W., Hassan, A. II., & Masijan, Z. (1988). Bagworms (Lepidoptera: Psychidae) of oil palm in Malaysia. PORIM Occasional Paper. Palm Oil Research Institute of Malaysia. No. 23. 37 pp

Basri, M. W.; Hassan, A. H., & Zulkefli, M. (1988). Bagworms (Lepidoptera: Psychidae) of oil palm in Malaysia. PORIM Occasional Paper No. 23: 37 pp.

Basri, M. W., Abdul Halim, H., & Zulkipli, M. (1988). Bagworms (Lepidoptera: Psychidae) of oil palms in Malaysia. PORIM occasional paper, 23. Bangi, Malaysia: Malaysian Palm Oil Board (MPOB); pp. 1–23.

Basri, M. W. (1993). Life History, Ecology and Economic Impact of the Bagworm, Metisa plana Walker (Lepidoptera: Phychidae), on the Oil Palm, Elaeis guineensis Jacquin (Palmae). Ph.D thesis, University of Guelp, Ontario, Canada.

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., & Kevan, P. G. (1995). Life history and feeding behaviour of the oil palm bagworm, Metisa plana Walker (Lepidoptera: Psychidae). Elaeis, 7(1):18-35.

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

Basri, M. W.; Siburat, S.; Ravigedari, S., & Othman, A. (1999). Beneficial plants for the natural enemies of the bagworm in oil palm plantations. Proc. Of the 1999 PORIM International Palm Oil Congress: Emerging Technologies and Opportunities in the Next Millennium. PORIM, Bangi. p. 165-179.

Basri, M. W.; Norman, K., & Othman, A. (2001). Field impact of beneficial plants on the parasitism levels of the bagworm, Metisa plana (Lepidoptera: Psychidae). Proc. of the PIPOC 2001 International Palm Oil Congress - Cutting-edge Technologies for Sustained Competitiveness: Module 1 - Agriculture, Biotechnology and Sustainability Conference (unedited). MPOB, Bangi. p. 441-445.

Barlow, H. S. (1982). An Introduction to the Moths of South East Asia. Art Printing Works Sdn Bhd. Kuala Lumpur, pp: 305

Barnes, A. D., Jochum, M., Mumme, S., Haneda, N. F., Farajallah, A., Widarto, T. H., & Brose, U. (2014). Consequences of tropical land use for multitrophic biodiversity and ecosystem functioning. Nat. Commun. 5, 5351. doi:http://dx.doi.org/ 10.1038/ncomms6351.

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

Byers, J. A. (1999). Effects of attraction radius and flight paths on catch of scolytid beetles dispersing outward through rings of pheromone traps. Journal of Chemical Ecology 19: 1905-1916.

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

Cheong, Y. L., & Tey, C. C. (2011). Checkered beetle, Callimerus arcufer (Coleoptera: Cleridae) and its preparation activity on a bagworms, Metisa plana and Pteroma pendula. Proc. of the PIPOC 2011 International Palm Oil Congress - Palm Oil: Fortifying and Energizing the World: Module 1 - Agriculture, Biotechnology and Sustainability Conference. MPOB, Bangi. p. 50-53.

Cheong, Y. L., & Tey, C. C. (2012). Understanding pest biology and behaviour for effective control of oil palm bagworm. The Planter, 88: 699-715.

Cheong, Y. L., & Tey, C. C. (2013). Environmental Factors which Influence Bagworm Outbreak. Proceeding of Sustainable Management of Pests and Diseases in Oil Palm – The Way Forward. Proceedings of 5th MPOB-IOPRI International Seminar 2013.

Chung, G. F. (1998). Strategies and methods for management of leaf eating caterpillars of oil palm. The Planter. 1998;74(871):531–558.

Corley, R. H. V., & Tinker, P. B. (2003). The Oil Palm, Fourth edition. Blackwell Science, Oxford.

DeBach, P., & Gordh, G. (1974). A new species of Aphytis that attacks important armored scale insects. Entomophaga. https://doi.org/10.1007/BF02371051

De Chenon, R. D.; Sipayung, A., & Sudharto, P. S. (1989). The importance of natural enemies on leaf-eating caterpillars in oil palm plantations in Sumatra, Indonesia – Uses and possibilities. Proc. of the PORIM International Palm Oil Development Conference. PORIM, Bangi. p. 245-262.

Feintrenie, L., Schwarze, S., & Levang, P. (2010). Are local people conservationists? Analysis of transition dynamics from agroforests to monoculture plantations in Indonesia. Ecol. Soc. 15, 37. 23, 538–545.

Fitzherbert, E., Struebig, M., Morel, A., Danielsen, F., Bruhl, C., Donald, P., & Phalan, B. (2008). How will oil palm expansion affect biodiversity? Trends Ecol. Evol. 23, 538–545. doi:http://dx.doi.org/10.1016/j.tree.2008.06.012.

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, P., Khen, C. V., & Yusah, K. M. (2011). Establishing the evidence base for maintaining biodiversity and ecosystem function in the oil palm landscapes of South East Asia. Philos. Trans. R. Soc. B Biol. Sci. 366, 3277– 3291. doi:http://dx.doi.org/10.1098/rstb.2011.0041.

Gazhali, A., Asmah, S., Syafiq, M., Yahya, M. S., Aziz, N., Peng, T., Norhisham, A. R., Puan, C. L., Turner, E. C., & Azhar, B. (2016). Effects of monoculture and polyculture farming in oil palm smallholdings on terrestrial arthropod diversity. J. Asia-Pacif. Entomol. 19, 415–421.

Gray, C. L., & Lewis, O. T. (2014). Do riparian forest fragments provide ecosystem services or disservices in surrounding oil palm plantations? Basic Appl. Ecol. 15, 693– 700. doi:http://dx.doi.org/10.1016/j.baae.2014.09.009.

Greathead, D. J. (1992). P. Debach, & D. Rosen,. (1991). (second edition) Biological control by natural enemiesCambridge University Press, Cambridge, UK xiv + 440 pages ISBN 0-521-39191-1 Price: £37 50/$44 50 (hardback). Journal of Tropical Ecology. https://doi.org/10.1017/s0266467400006374

Hajek, A. E. (2004). Natural Enemies: An Introduction to Biological Control. Cambridge University Press.

Halim, M., Aman-Zuki, A., Syed Ahmad, S. Z., Mohammad Din, A. M., Abdul Rahim, A., Mohd Masri, M. M., Badrul, B. M., & Yaakop, S. (2018). Exploring the abundance and DNA barcode information of eight parasitoid wasps species (Hymenoptera), the natural enemies of the important pest of oil palm, bagworm, Metisa plana (Lepidoptera: Psychidae) toward the biocontrol approach and it's application in Malaysia. Journal of Asia-Pacific Entomology, 21(4), 1359–1365. https://doi.org/10.1016/j.aspen.2018.10.012

Hanysyam, M., Fauziah, I., Siti Khairiyah, M. H., Fairuz, K., Mohd Rasdi, Z., Nurul Zfarina, M. Z., Ismail, R., & Norazliza, R. (2013). Assessment on the Diversity of parasitoids of bagworms (Lepidoptera: Psychidae) in FELDA Gunung Besout 6, Sungkai, Perak. In: In IEEE Symposium on Humanities, Science and Engineering Research (SHUSER).

Hasber, S. (2010). Evaluation of Several Chemical Control Approaches against Bagworm, Metisa plana Walker (Lepidoptera: Psychidae) in Felda Oil Palm Plantations. M.Sc. thesis, Universiti Sains Malaysia, Pulau Pinang, Malaysia.

Hasber, S.; Che Salmah, M. R.; Abu Hassan, A., & Salman, A. A. (2015). Efficacy of insecticide and bioinsecticide ground sprays to control Metisa plana Walker (Lepidoptera: Psychidae) in oil palm plantations, Malaysia. Tropical Life Science Research,26(2): 73-83.

Hawkins, B. A. (1994). Pattern and process in host-parasitoid interactions. Pattern and Process in Host-Parasitoid Interactions. https://doi.org/10.2307/3495912

Ho, C. T.; Khoo, K. C.; Yusof, I., & Dzolkifli, O. (2003). Comparative studies on the use of beneficial plants for natural suppression of bagworm infestation in oil palm. Proc. of the 2003 PIPOC International Palm Oil Congress – Palm Oil, the Power-House for the Global Oil & Fats Economy: Module 1 - Agriculture, Biotechnology and Sustainability Conference (Unedited). MPOB, Bangi. p. 372-424.

Hofte, H., & Whitely, H. R. (1989). Insecticidal crystal proteins of Bacillus thuringiensis. Microbial Reviews, 53: 242-255.

Hoong, H. W., & Hoh, C. K. Y. (1992). Major pests of oil palm and their occurrence in Sabah. The Planter, 68(793): 193-210.

Jamian, S.; Muhammad, R.; Norman, K., & Idris, A. B. (2010). Feeding behaviour and predatory efficiency of assassin bug, Sycanus dichotomus Stal. on oil palm bagworm, Metisa plana Walker. Malaysian Applied Biology, 39(2): 51-55.

Jamian, S. (2017). Role of Beneficial Plants in Improving Performance of Predators of Oil Palm Bagworm. 76.

Jamian, S.; Norhisham, A.; Ghazali, A.; Zakaria, A., & Azhar, B. (2017). Impacts of 2 species of predatory Reduviidae on bagworms in oil palm plantations. Insect Science, 24(2): 285-294.

Jamian, S., & Nur Azura, A. (2018). The performance of predatory insect, Sycanus dichotomus Stal. (Hemiptera: Reduviidae) on combination of plant host and prey. Serangga: 23(2): 56-64.

Jamian, S., Adam, N. A., Noor, H. M., Zulperi, D., Asib, N., Muhamad, R., Mokhtar, A. S., As'Wad Abdul Wahab, M., Azhar, B., Sidi, M., & Maamor, A. (2020). The effect of plant volatiles on plant preference by the predatory insect, sycanus dichotomus stal. (Hemiptera: Reduviidae) in oil palm plantation. Journal of Oil Palm Research, 32(3), 471–479. https://doi.org/10.21894/jopr.2020.0053

Kamarudin, N., Wahid, M. B. (2010). Interactions of the bagworm, Pteroma pendula (Lepidoptera: Psychidae), and its natural enemies in an oil palm plantation in Perak. J. Oil Palm Res. 22, 758–764.

Kamarudin, N., Seman, I. A., & Masri, M. M. M. (2019). Prospects in sustainable control of oil palm pests and diseases through the enhancement of ecosystem services - The way forward. Journal of Oil Palm Research. https://doi.org/10.21894/jopr.2019.0030.

Kruess, A., & Tscharntke, T. (1994). Habitat fragmentation, species loss, and biological control. Science. https://doi.org/10.1126/science.264.5165.1581

Koh, L. P. (2008). Birds defend oil palms from herbivorous insects. Ecol. Appl. 18, 821–825. doi:http://dx.doi.org/10.1890/07-1650.1.

Koh, L. P., Levang, P., & Ghazoul, J. (2009). Designer landscapes for sustainable biofuels. Trends Ecol. Evol. 24, 431–438. doi:http://dx.doi.org/10.1016/j.tree.2009.03.012.

Kok, C. C., Eng, O. K., Razak, A. R., Arshad, A. M., & Marcon, P. G. (2012). Susceptibility of bagworm Metisa plana (Lepidoptera: Psychidae) to chlorantraniliprole. Pertanika Journal of Tropical Agriculture Science. 2012;35(1):149–163.

Kok, C. C., Eng, O. K., Razak, A. R., Arshad, A. M., & Marcon, P. G. (2012). Susceptibility of bagworm Metisa plana (Lepidoptera: Psychidae) to chlorantraniliprole. Pertanika Journal of Tropical Agriculture Science 35(1): 149–163.

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

Lucey, J. M., Tawatao, N., Senior, M. J. M., Chey, V. K., Benedick, S., Hamer, K. C., Woodcock, P., Newton, R. J., Bottrell, S. H., & Hill, J. K. (2014). Tropical forest fragments contribute to species richness in adjacent oil palm plantations. Biol. Conserv. 169, 268–276. doi:http://dx.doi.org/10.1016/j.biocon.2013.11.014.

Mahadi, N. A., Muhamad, R., & Adam, N. A. (2012). Relationship between bagworm Pteroma pendula Joannis (Lepidoptera: Psychidae) populations, parasitoids, and weather parameters in oil palm plantation. J. Agric. Sci. 4 (12), 13.

MALAYSIAN AGRICULTURAL DIGEST. (2013). Chapter 16: Agricultural chemicals. Malaysian Agricultural Digest. p. 155-163.

Mathews, J., Yong, K. K., & Nurulnahar, B. E. (2007). Preliminary investigation on biodiversity and its ecosystem in oil palm plantation. Proc. PIPOC 2007 Int. Palm Oil Cong. Agricult. Biotechnol. Sustain. 2, 1112–1159.

Mazmira, M. M. M.; Najib, M. A.; Norhazwani, K.; Norman, K., & Siti Ramlah, A. A. (2015). Implementing an Integrated Pest Management (IPM) program for bagworm control in oil palm smallholdings in Johor. Proc. of the PIPOC 2015 International Palm Oil Congress – Oil Palm: Powering the World, Sustaining the Future: Module 1– Agriculture,Biotechnology and Sustainability Conference. MPOB, Bangi. p. 43-55.

Mohd Mazmira, M. M.; Ramlah, A. A. S.; Najib, M. A.; Norman, K.; Kushairi, A. D., & Basri, M. W. (2010). Integrated Pest Management (IPM) of bagworms in Southern Perak via aerial spraying of Bacillus thuringiensis (Bt). Oil Palm Bulletin No. 63: 24-33.

Mohamed Mazmira, M. M., Siti Ramlah, A. A., Mohd. Najib, A., Norman, K., Ahmad Kushairi, D. & Mohd. Basri, W. (2011). Integrated pest management (IPM) of bagworms in Southern Perak via aerial spraying of Bacillus thuringiensis (Bt). Oil Palm Bulletin 63: 24-33.

Murphy, D. J. (2009). Oil palm: future prospects for yield and quality improvements. Lipid Technol. 21, 257–260. doi:http://dx.doi.org/10.1002/lite.200900067.

Nester, E. W.; Thomashow, L. S.; Metz, M., & Gordom, M. (2002). 100 Years of Bacillus thuringiensis: A Critical Scientific Assessment. Ithaca, New York. p. 22.

Nor Sarashimatun, S., Teh, C. L., & Tey, C. C. (2011). Evaluation of beneficial plants as hosts for natural enemies of oil palm bagworms. Proceedings of the PIPOC 2011 International Palm Oil Congress, November 2011, 36–40. https://doi.org/10.13140/RG.2.2.29862.57926

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.

Norman, K.; Walker, A. K.; Mohd Basri, W.; Lasalle, J., & Polaszek, A. (1996). Hymenopterous parasitoids of the bagworm, Metisa plana and Mahasena corbetti on oil palm in Peninsular Malaysia (1996). Bulletin of Entomological Research, 86: 423-439.

Norman, K., Mohd Basri, W., & Zulkefli, M. (1998). Handbook of Common Parasitoids and Predators Associated with Bagworms and Nettle Caterpillars in Oil Palm Plantations. Institut Penyelidikan Minyak Kelapa Sawit Malaysia (PORIM). pp. 29.

Norman, K., & Othman, A. (2006). Potentials of Using the Pheromone Trap for Monitoringand Controlling the Bagworm, Metisa plana Walk (Lepidoptera: Psychidae) in a Smallholder Plantation. Journal of Asia Pacific Entomology 9(3): 281-285.

Norman, K., & Basri, M. W. (2007). Status of common oil palm insect pests in relation to technology adoption. The Planter, 83(975): 371-385.

Norman, K., & 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., Siti Nurulhidayah, A., & Basri, M. W. (2010). Pheromone mass trapping bagworm moths (Metisa plana, Lepidoptera: Psychidae) for its control in mature oil palms in Perak, Malaysia. Journal of Asia-Pacific Entomology 13: 101-106.

Norman, K., & Othman, A. (2016). Diversity and activity of insect natural enemies of the bagworm (Lepidoptera: Psychidae) within an oil palm plantation in Perak, Malaysia. J. Oil Palm Res. Vol. 28(3): 296-307.

Najib, M. A.; Ramlah, A. A. S.; Mohd Mazmira, M. M., & Zaini, M. A. (2012). Effect of Bt products, Lepcon-1, Bafog-1 (S) and Ecobac-1 (EC), against the oil palm pollinating weevil, Elaeidobius kamerunicus, and beneficial insects associated with Cassia cobanensis. J. Oil Palm Res. Vol. 24: 1442-1447.

Najib, M. A.; Ramlah, A. A. S.; Mohd Mazmira, M. M., & Basri, M. W. (2013). Efficacy of Bafog-1 (s),formulated local Bacillus thuringiensis for controlling bagworm, Pteroma pendula (Lepidoptera :Psychidae). J. Oil Palm Res. Vol. 25(2): 228-234.

Najib, M. A.; Ramlah, A. A. S.; Mohd Mazmira, M. M., & Noorazah, Z. (2014). Lepcon-1, Bafog-1 (S) and Ecobac-1 (EC), Bacillus thuringiensis based-products are not toxic against the freshwater fish, Tilapia nilotica. J. Oil Palm Res. Vol. 26(4): 317-320.

Najib, M. A.; Ramlah, A. A. S.; Mohd Mazmira, M. M., & Zaini, M. A. (2015). Effect of Bacillus thuringiensis based-products on rats. J. Oil Palm Res. Vol. 27(1): 30-38.

Ramlah, A. A. S.; Najib, M. A.; Mohd Mazmira, M. M. M.; Tajuddin, N. A.; Keni, M. F. & Norman, K. (2013). Microbial control for pests and diseases and its challenges. Proc. of the PIPOC 2013 International Palm Oil Congres - Agriculture, Biotechnology & Sustainability Conference. p. 67.

Rhainds, M., & Sadof, C. (2009). Control of bagworms (Lepidoptera: Psychidae) using contact and soil-applied systemic insecticides. Journal of Economic Entomology. 2009;102(3):1164–1169.

Rizali, A., Karindah, S., Himawan, T., Meiadi, M. L. T., Rahardjo, B. T., Nurindah, & Sahari, B. (2019). Parasitoid wasp communities on oil palm plantation: Effects of natural habitat existence are obscured by lepidopteran abundance. Journal of Asia-Pacific Entomology. https://doi.org/10.1016/j.aspen.2019.07.012

Schaefer, C. W., & Ahmad, I. (1987). Parasites and predators of Pyrrhocoroidea (Hemiptera) and possible control of cotton stainers by Phonoctonus spp. (Hemiptera: Reduviidae). Entomophaga, 32: 269-275.

Sclindwein, C., & 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.

Senior, M. J. M., Hamer, K. C., Bottrell, S., Edwards, D. P., Fayle, T. M., Lucey, J. M., Mayhew, P. J., Newton, R., Peh, K. S. -H., Sheldon, F. H., Stewart, C., Styring, A. R., Thom, M. D. F., Woodcock, P., & Hill, J. K. (2013). Trait-dependent declines of species following conversion of rain forest to oil palm plantations. Biodivers. Conserv. 22, 253–268. doi:http://dx.doi.org/10.1007/s10531-012-0419-7.

Sethi, S., & Gupta, S. (2013). Impact of pesticides and biopesticides on soil microbial biomass carbon. J. Environmental Research and Technology, 3(2): 326-330.

Siti Nurulhidayah; A., Norman K., & Zulkefli M. (2011). Mixed preys as food sources for mass rearing the bagworm predator, Sycanus dichotomus. MPOB Information Series. No. 486: 4 pp.

Siti Nurulhidayah, A., & Norman, K. (2016). Growth and longevity of the insect predator, Sycanus dichotomus Stal. (Hemiptera: Reduviidae) fed on live insect larvae. J. Oil Palm Res. Vol. 28(4): 471-478.

Smit, N. E. J. M., Downham, M. C. A., Laboke, P. O., Hall, D. R. & Odongo, B. (2001). Mass trapping male Cylas spp. with sex pheromones: a potential IPM component in sweetpotato production in Uganda. Crop Protection 20: 643-651.

Sudarsono, H., Purnomo, P., Hariri, A. M. (2011). Population assessment and appropriate spraying technique to control the bagworm (Metisa plana Walker) in North Sumatra and Lampung. AGRIVITA Journal of Agricultural Science. 2011;33(2):188–198.

Syed, R. A. & Shah, S. (1977). Some important aspects of insect pest management in oil palm estates in Sabah, Malaysia. International Developments in Oil Palm (Earp, D A and Newall, W eds.). Incorporated Society of Planters, Kuala Lumpur. p. 577-590.

Tan, S. Y., Ibrahim, Y., & Omar, D. (2008). Efficacy of Bacillus thuringiensis berliner Subspecies kurstaki and aizawai against the Bagworm, Metisa Plana Walker on oil palm. Journal of Bioscience 19(1): 103–114.

Teh, C. L. (1996). Integrated pest management of leaf- eating caterpillars of oil palms in Sabah. The Planter, 72(844): 395-405.

Tiong, R. H. C. (1979). Some predators and parasites of Mahasena corbetti (Tams) and Thosea asigna (Moore) in Sarawak. The Planter, 55(639): 279-289.

Tscharntke, T., Bommarco, R., Clough, Y., Crist, T. O., Kleijn, D. R. T. A., Tylianakis, J. M., Van Nouhuys, S., & Vidal, S. (2007). Conservation biological control and enemy diversity on a landscape scale. Biol. Control 43, 294–309. doi:http://dx.doi.org/ 10.1016/j.biocontrol.2007.08.006.

Valles, S. M., Capinera, J. L., & Teal, P. E. A. (1991). Evaluation of pheromone trap design, height and efficiency for capture a male *Diaphania nitidalis* (Lepidoptera: Pyralidae) in a field cage. *Environmental Entomology*, 20: 1274-1278.

With, K. A., Pavuk, D. M., Worchuck, J. L., Oates, R. K., & Fisher, J. L. (2002). Threshold Effects of Landscape Structure on Biological Control in Agroecosystems. Ecological Applications. https://doi.org/10.2307/3061136

Witzgall, P., Philipp, K., & Alan, C. (2010). Sex pheromones and their impact on pest management. *J. Chem. Ecol.* DOI 10.1007/s10886-009-9737-y

Wood, B. J. (1968). Pest of Oil Palms in Malaysia and their Control. Inc in Eastem Sabah. The Planter, 45: 285-299.

Wood, B. J., & Nesbit, D. P. (1969). Caterpillar outbreak on oil palmsts of tropical perennial crops in Malaysia. In: Huffaker, C.B. (Ed.), Biol. Control. Plenum Press, New York, pp. 422–457.

Wood, B. J. (1971). Development of integrated control programs for pesorporated Society of Planters, Kuala Lumpur. 204 pp.

Wood, B. J. (2002). Pest control in Malaysia's perennial crops: a half century perspective tracking the pathway to integrated pest management. Integr. Pest Manag. Rev. 7, 173–190.

Wood, B. J. (2004). Pest Control in Malaysia's Perennial Crops: A Half Century Perspective Tracking the Pathway to Integrated Pest Management. Integrated Pest Management Reviews. https://doi.org/10.1023/b:ipmr.0000027501.91697.49

Wood, B. J., & Kamarudin, N. (2019). A review of developments in integrated pest management (ipm) of bagworm (lepidoptera: Psychidae) infestation in oil palms in Malaysia. In Journal of Oil Palm Research. https://doi.org/10.21894/jopr.2019.0047

Yap, T. H. (2005). A review on the management of Lepidoptera leaf-eaters in oil palm: Practical implementation of integrated pest management strategies. The Planter.;81(954):569–586.

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. Master thesis. Universiti Sains Malaysia. p. 157.

Yusdayati, R., Che, S., Abu, H. A., & Noor, H. H. (2014). Diversity and distribution of natural enemies (predators and parasitoids) of bagworms (Lepidoptera: Psychidae) on selected host plants in an oil palm plantation. Planter 90 (1055), 91–101.

Zulkefli, M.; Norman, K., & Basri, M. W. (2004). Life cycle of Sycanus dichotomus (Hemiptera: Pentatomidae) – A common predator of bagworm in oil palm. J. Oil Palm Res. Vol. 16(2): 50-56.