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Industry-wide Efforts in Circumventing the Scourge of Bagworm Infestation in Malaysia - What Have Gone Wrong and What Should be Done?

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Bagworms have been infesting oil palm ever since the commercial planting which started more than a century ago. It was previously reported as occasional pests of other crops and ornamental trees. In the early years of commercial oil palm planting, reports of damaging incidence of bagworms, or any other leaf-eating caterpillars were almost negligible. Serious outbreaks of the bagworms began mainly in late 1950s and the scourge remains to the present day, despite the many advances in management and control of bagworms which has been developed over the years. Many of the control practices, especially in the use of broad-spectrum insecticides is believed to be the reason for the recurring bagworm outbreak. The application of these insecticides caused a direct impact in reducing the population of natural enemies (parasitoid and predators) of the bagworms, hence potentially increasing the pest numbers to an outbreak level. Bagworms outbreaks can actually be managed through established methods of census and detection, and control as it reaches a certain economic threshold level. The persistent spraying of broad-spectrum insecticides (i.e. cypermethrin), coupled with the lack of awareness on the consequential effects of a disrupted ecosystem, have possibly caused serious bagworm outbreaks currently experienced in this country. The current recommended option to conserve the natural enemies is by using Bacillus thuringiensis *for spraying, or use of acephate, whenever trunk injection is required. Awareness campaign on this issue should therefore be more dynamic, continuous and follow up census should not be neglected. The formation of a task force for bagworm within the endemic regions of infestation is deemed a crucial factor for successful control. Complacency in not conducting regular census and control, lack in the establishment of beneficial plants for the natural enemies and repeated usage of broad-spectrum insecticides are deemed as prerequisites to an outbreak situation which brings serious losses to the oil palm industry.*

Keywords: *Bagworms, outbreaks, insecticides,* Bacillus thuringiensis, *natural enemies.*

Bagworms (Lepidoptera: Psychidae) have been reported as one of the leaf-eating pests in oil palm plantations in Malaysia ever since the commercial planting of oil palm in 1917. It was previously reported as an occasional pest of other crops and ornamental trees. *Metisa plana* was recorded to attack four other families of plant hosts compared to *Pteroma pendula* or *Mahasena corbetti* which were recorded attacking thirteen to fifteen different families of plants besides Palmae (Norman *et al.*, 1994). On Palmae species, bagworms have been reported on coconut, nipah, sago and Areca sp, to name a few. However, being polyphagous, bagworms can also attack shade trees and other crops such as coffee, tea, rubber, tapioca or jambu (*Psidium* sp.)

In the early years of commercial oil palm

planting, reports of damaging incidence of bagworms, or any other leaf-eating caterpillars were very rare (Wood & Norman, 2019). *P. pendula* and *M. corbetti* were reported infesting coconuts and oil palm at low numbers at around 8-10 years of the commercial oil palm planting (Corbett, 1927; Gater, 1925). Serious outbreaks of the bagworms began mainly in late 1950s and still continue to the present day. Chung (2018) exemplified the outbreak of bagworms as a scourge to the oil palm industry, despite the many advances in management and control of bagworms which have been developed over the years.

This paper reviews the industry-wide efforts and the impact in relation to the bagworm infestation and control measures in Malaysia.

BAGWORM INFESTATION IN MALAYSIA AND ITS CONTROL

Possible causes of recurring outbreaks

Serious outbreaks of *M. plana* and *P. pendula* in the late 1950s were controlled mainly with chlorinated hydrocarbon insecticides, such as endrin and dieldrin (Wood & Norman, 2019). Wood (1968; 1971) has conducted detailed studies since early 1960s which indicated that bagworm and nettle caterpillar outbreaks occurred after the applications of these broad-spectrum pesticides, and recurred when the applications were repeated. The application of the broad-spectrum insecticides has a direct impact on the population of natural enemies (parasitoid and predators) of the leaf-eating caterpillars, causing a reduction in natural control and potentially increase the pest numbers to an outbreak level.

There were several studies focusing on the bagworms and its associated natural enemies, mainly conducted in Sabah during the 70s (Sankaran, 1970; Sankaran & Syed, 1972; Syed, 1970; Syed & Shah, 1977) and in Sarawak (Tiong, 1979), which also included nettle caterpillars. Mainly these studies suggested that the indiscriminate use of chemical pesticides may have disrupted the population of natural enemies of the pest, hence triggering massive outbreaks of the pest. The lack of flowering weeds in the estates which had provided nectar as feed for mainly hymenopteran parasitoids, also tends to aggravate the pest problem.

Pesticide application to control bagworm outbreaks

In the 1970s, pesticides were sprayed aerially to control a wide area of bagworm outbreak (Wood, 1973) whilst trunk injection of organophosphates (i.e. monocrotophos and methamidophos) was later developed for a more targeted and selective action on bagworm control (Wood, 1974). With trunk injection, the natural enemies of the bagworms are virtually not affected, hence sustaining its population for a long-term control of the pest. In the late 1980s, aerial spraying was again reported to be conducted widely using helicopters (Nasir & Liau, 1989) in addition to mechanised mist blowers (Ho, 1988), indicating the rapid spread of this pest over a large area which require quick control.

At the same time, there are more awareness to apply pesticides selectively and safely by trunk injection (Chung, 1988), which also included a root absorption technique (Sinuraya *et al*., 1989), practiced in Sumatra. However, this technique was considered labour intensive and much slower compared to trunk injection. In general, the application of systemic pesticides would not affect the population of natural enemies in the environment, however, there may be some

sublethal effects towards the developing parasitoids within the bagworms which had consumed the systemic pesticides applied through trunk injection (Basri *et al*., 1990).

Alternative hosts besides oil palm

As mentioned earlier, bagworms have many other hosts besides oil palm and they tend to be highly polyphagous. This suggests the possible reason of why bagworm outbreaks often recur even when aerial spraying has been successfully conducted. There are many alternative host plants and also weeds which could possibly act as a source of infestation. These weeds flourish just underneath the oil palm and therefore postulating a high chance that during outbreak situations, the larvae fall onto these weeds and remain there as a subset of the existing bagworm population. Control measures conducted on the palm is thus restricted strictly to the population on the palms; whereas the population beneath the palms were often neglected or remained unnoticed. Lim and Lim (2007) have listed several weed species that may possibly act as alternative hostplants to *Mahasena corbetti* in Sabah. These include *Cyperus iria*, *Dacrydium* sp., *Desmodium* sp., *Macaranga* sp., *Melastoma malabrathricum*, *Mikania cordata*, *Nephrolepis biserrata*, *Panicum* spp. and *Stylosanthes* spp. There are also possibilities that ferns on the trunk of palms serve as a temporary refuge when larvae fall from the oil palm fronds during high density outbreak situations. Aerial spraying may kill off the actively feeding caterpillars on the upper epidermis of the leaflets, while those feeding at the bottom surface of the leaflets (close to pupation) may escape the control operation and therefore continue to develop to the next generation.

Determination of microbes and parasitoids affecting bagworms

In the 1990s research into identification of suitable microbes for the control of bagworms escalated. These include potentials of baculoviruses (Siti Ramlah *et al.*, 1996; Siti Ramlah, 1993), *Bacillus thuringiensis* (*Bt*) (Basri *et al.*, 1994; 1996), fungi (Siti Ramlah, 1993; Ramle, 1993) and the identification of insect parasitoids in Peninsular Malaysia (Norman *et al.*, 1996) which confirmed the various species reported earlier in Sabah (Sankaran, 1970; Sankaran & Syed, 1972; Syed & Shah, 1977). The identification of the three common species of bagworms was confirmed taxonomically and details of other bagworms affecting oil palm and other palmae species were also provided (Norman *et al.,* 1994). The life cycle and feeding behaviour of *Metisa plana*, which is the most prevalent among the three species, was studied in more detail (Basri & Kevan, 1995) and the field impact of its natural enemies was also assessed (Basri *et al.*, 1995). The range of hymenopterous parasitoids affecting both *M. plana* and *Mahasena corbetti* was also documented (Norman *et al.,* 1996).

Exploring cost effective chemicals and control measures

In search of effective and selective chemicals for controlling bagworms, a screening trial was again conducted (Chung & Narendran, 1996). In their study, it was reported that cypermethrin was the cheapest chemical to use at that time (at RM13.50/ha), compared to *Bt* (RM18.45/ha) (*Table 1*). Trichlorfon (RM54/ha) was considered to be the most expensive, albeit being recommended earlier on for its stomach poisoning properties which benefit the natural

TABLE 1
COST COMPARISON OF DIFFERENT ACTIVE INGREDIENTS FOR BAGWORM CONTROL

Active ingredient(ai)	*Class of pesticide*	*Method of application*	*Volume/Ha*	*Average cost /palm(RM)*	*Total cost/ha(RM)*
Acephate 75%	III	TI	1.48 L	±2.00	±296
Monocrotophos 50%	1a	TI	1.48 L	±2.50	±370
Methamidophos 50%	1b	TI	1.48 L	±2.50	±370
Cypermethrin 20%	II	GS	0.5 L	±0.30	±45
Bacillus thuringiensis (Bt)	IV	Aerial / GS	1L/ha	±0.40	±60
Flubendiamide 20%	IV	Aerial / GS	100 g	±0.43	±64
Chloratraniliprole 35%	III	GS	29g	±0.35	±52

Note: TI = trunk injection GS = ground spraying

enemies of the pest. However, there was also a mindshift to exploit environmentally friendly pesticides (i.e. *Bt*) and provide more conducive environments for the insect natural enemies (parasitoids and predators) for the long-term control of bagworms. Basri *et al.* (1999) suggested several suitable beneficial plants which possess the inter flower nectaries which provide food sources for the hymenopterous parasitoids. These species were made known to industry for field adoption and implementation.

Entering the new millennium, the potent cry gene in *Bt* specific for the bagworms was discovered (Siti Ramlah, 2000), which prompted the formulation of a *Bt* product which was further improved compared to the commercial formulations (Siti Ramlah *et al.*, 2005). The fungus, *Beauveria* sp., although showed potential for bagworm control, required a better formulation to be effective in the field (Siti Ramlah, 1993; Ramle, 1993).

In addition to application of biopesticides (i.e. *Bt*), pheromone trapping of the male adults of the bagworm *Metisa plana* was further evaluated using live receptive females as baits (Norman & Othman, 2006). At the pupal stages, control measures using insecticides should be delayed until the next generation of larvae emerge. Pheromone trapping can then be initiated when the female bagworm adult is receptive, and when adult male moths actively emerged to mate with the receptive female bagworm. Mass trapping the adult moth has somewhat disrupted the mating activities of the bagworm, thereby reducing the number of mated females in the field, hence lowering population of its next generation (Norman *et al.*, 2010). The pheromone of *Metisa plana* is considered to be highly novel, and until now, there is no perfect identification of the correct isomers to be viably synthesised for it to be fully attractive in the field as the natural pheromone.

The technique of trunk injection of systemic chemicals was refined and revisited (Yap, 2000) and another screening of chemicals for trunk injection (Lai & Tey, 2009) was evaluated, indicating more awareness on the ill effects of spraying broad-spectrum chemicals to the environment. A survey on the adoption of current technologies for the control of insect pests has also confirmed the shift of the planters into adopting more biocontrol methods besides the application of chemicals (Norman & Basri, 2007). Trunk injection is mainly done to control infestations on tall trees where spraying cannot

be conducted. The labour costs is considered to be quite high when compared to ground spraying but is comparable to drone spraying (*Table 2*).

However, Hasber *et al.* (2015) again recommended the use of trichlorfon, cypermethrin and lambda-cyhalothrin to control *M. plana* infestation in oil palm. They also suggested that although *Bt* provided the most cost-effective control, it seems to be not adequately effective against *M. plana* in a single treatment. Follow-up treatments were often undertaken to reduce the larval population below the economic threshold level (ETL). Cypermethrin EC appeared to be the cheapest chemical insecticide, followed by lambda-cyhalothrin and cypermethrin EW. *Bt* and trichlorfon were ranked as the least cost effective to control *M. plana*. Chung and Narendran (1996) and Chua *et al.* (2012) had also previously reported cypermethrin as the most cost-effective treatment against bagworm infestation. Similarly, cypermethrin is still the cheapest chemical until now (*Table 1*).

Chua *et al.* (2012) also screened several alternative chemicals for bagworms, and showed that the lowest LC_{50} (0.25ppm) was found with chlorantraniliprole and trichlorfon, followed by thiamethoxam with 0.70 ppm, indoxacarb with 0.72 ppm, cypermethrin with 0.90 ppm, and for monocrotophos with 15.03 ppm. The speed of action (LT50) of these insecticides showed trichlorfon was fastest (12.66) followed by chlorantraniliprole (17.04) and cypermethrin (28.63). Despite chlorantraniliprole surfacing as the best alternative to trichlorfon, as fast acting and safer to the natural enemies, the use of cypermethrin is considered cost effective, likely due to it being the cheapest chemical in the market (*Table 1*). This might also be the reason why most plantations in Malaysia had persisted on the use of cypermethrin for bagworm control, not realising the important fact that it is concurrently eliminating the population of natural enemies in the control area.

IPM programme on bagworm

Bagworm infestations and outbreaks have occurred in Malaysia for over five decades (Cheong & Tey, 2011). This remains as a chronic problem, despite the fact that effective control measures are available. In 2013, bagworm infestation was an important issue that affected the yield of oil palm due to procrastinated control, especially among smallholders (Tey & Cheong, 2013). Based on

TABLE 2
LABOUR COST OF DIFFERENT PESTICIDE APPLICATION TECHNIQUES

Type of application	*Labour cost /ha*	*Area coverage/labour/day*
Aerial spray (aircraft)	RM 40	*600-800
Drone spray	RM 150	*8 - 10
Knapsack sprayer	RM 60	2.5 - 4
Power sprayer	RM 80	2 - 3
Tractor turbomiser / mistblower	RM 24-40	12 - 20
Trunk injection	RM148	3.5 (by team of 2, ±500 palm/day)

*Area coverage depends on weather, distance from airstrip to target area spray and topography

the historical records of bagworm infestation in Malaysia as reported by Ho *et al*. (2011), over 63 955 ha of oil palm in 69 estates in Peninsular Malaysia indicated that *M. plana* and *P. pendula* were the primary pests (Ho *et al*., 2011). The Integrated Pest Management (IPM) is the best strategy for controlling bagworm outbreaks in oil palm cultivated areas (Siti Ramlah *et al*., 2013; Mohamed Mazmira *et al*., 2010; Mohd Najib *et al*., 2013). One of the main components of IPM is the application of *Bt* which is not affecting the non-target organisms including the oil palm pollinating weevil, *Elaeidobius kamerunicus* (Najib *et al*., 2012). *Bt* as an environmental-friendly microbial insecticide is generally not toxic to freshwater fish (Najib *et al*., 2014), human, domestic animals and vertebrates (Najib *et al*., 2015). The crystalline protein inclusions produced by *Bt* during sporulation are responsible for the insecticidal actions (Nester *et al.*, 2002) and the proteins are highly specific against certain insects' orders (Hofte & Whitely, 1989). The Malaysian Palm Oil Board (MPOB) has since then developed a local *Bt*-based biopesticides product.

Further work on biocontrol agents and its field implementations were rapidly conducted from 2010 onwards. These works include several field applications of the *Bt* formulation (Siti Ramlah *et al.*, 2009; Mohamed Mazmira *et al.*, 2010) and concurrently evaluating the effects of *Bt* to non-target organism (Mohd Najib *et al.,* 2009; 2011; 2012). In a laboratory evaluation it was confirmed that both *B. thuringiensis* Berliner subspecies kurstaki and aizawai are potent against the bagworm, *M. plana* (Tan *et al.*, 2008). The interaction of natural enemies with the bagworm was also monitored (Norman & Basri, 2010; Norman & Othman, 2016) and the evaluation of beneficial plants with the natural enemies in the field (Nor Sarashimatun *et al*., 2011; Yusdayati *et al.*, 2014), which also confirmed previous works conducted by Basri *et al.* (1999) and Ho *et al.* (2003). These studies showed that natural enemies play a complementary role towards an ecological balance in maintaining low populations of bagworms below its threshold levels. More information was gathered on lesser known predators like the chequered beetle (*Callimerus arcufer*) (Coleoptera: Cleridae) which had shown potential to control the bagworm pupal stages (Cheong & Tey, 2011). Other predatory species like *Platynopus melacanthus* and *Cantheconidea furcellata* (Hemiptera: Pentatomidae) and assassin bugs, *Sycanus dichotomus* and *Cosmolestes picticeps* (Hemiptera: Reduviidae) also possess the predatory ability towards the bagworm (Azlina & Tey, 2011; Siti Nurulhidayah *et al.*, 2011). The most potential predators for *M. plana* are *C. furcellata, P. melacanthus* and *S. dichotomus* (Azlina & Tey, 2011) *C. picticeps,* however, were shown to be a less specific predator and often exhibited cannibalism to its own population which may impede the role as an efficient biocontrol agent for bagworms (Azlina & Tey, 2011).

The extent of bagworm outbreaks between 1986-2000 over an area of close to 64 000 ha was documented by Ho *et al.* (2011). It showed a predominant infestation of *Metisa plana* and *Pteroma pendula* in several states along the west coast of Peninsula, particularly in estates under one prominent plantation agency in Malaysia. An increasing trend of infested areas above the economic threshold level (ETL) was indicated, from 843 ha in the year 1986 up to 7 811 ha in 2000, which was an increase of eight folds (Ho *et al*., 2011). It was also reported that based on their study, the bagworm infestation was 3.9 per cent of the area per

year, compared to the previous survey of Basri *et al.* (1988) which reported of only 1.1 per cent of the area per year. The attributes of causing the increase could be of the widespread use of broad-spectrum chemicals.

Similar trends of infestations and outbreaks were recorded in earlier surveys by Basri *et al.* (1988) and Norman and Basri (2007). There are possibilities that these areas possess certain microclimates (temperature and rainfall patterns) which are conducive for bagworm infestation and prone to outbreak. It was shown that bagworms developed faster in higher temperatures (Yusof *et al.,* 2013), which implied the capability of bagworms to increase in numbers in certain parts of Malaysia especially during the dry periods, creating an outbreak.

The aerial spray with *Bt* covered 28 354.53 ha of bagworm infested area in Peninsular Malaysia covering North (Penang and Perak), South (Johor), Middle (Selangor and Negeri Sembilan and East (Pahang). With proper strategy and the correct timing, bagworm outbreak areas have been successfully reduced to 7 585.98 ha (*Table 3*). Until October 2018, the total reduction of area infestation recorded after the aerial spray with *Bt* had achieved more than 70 per cent.

The importance of census of bagworm

The proper census methods for the bagworms was established in the 70s (Syed & Speldewinde, 1974). There are other reports that indicate census is an important prerequisite to bagworm management (Chung & Sim, 1991). Once a bagworm infestation is detected, the area needs to be monitored and census obtained every 3 months, even though if the bagworm population is below the economic threshold level (ETL). This is to ensure that the bagworm population remains below the ETL and should there be an increase in the population, control should be conducted immediately, depending on the vulnerable

TABLE 3
INFESTATION AREA OF BAGWORM AT SMALLHOLDINGS IN PENINSULA MALAYSIA UNTIL OCTOBER 2018. (BASED ON MPOB ADVISORY VISITS)

Area	*Infected area (ha) sprayed with Bt*		*Area still infected after spray*		*Area under control (below ETL level)*		*% Reduction in area of outbreak (%)*
	No. of locations	*Infestation area (ha)*	*No. of locations*	*Infested area (ha)*	*No. of locations*	*Infestation area (ha)*	
North (S. Prai and Perak)	27	7 910.59	16	5 296.35	11	2 614.24	33.05
South (Johor)	48	19 910.43	13	1 907.26	35	18 003.17	90.42
Middle and east (Selangor and N. Sembilan)	17	533.51	9	382.37	8	151.14	28.33
East (Pahang)							
							Average =
Total area (ha)		28 354.53		7 585.98		20 768.55	73.25

Note: *ETL: Economic threshold level of 10 live larvae per frond

stages of the bagworm. The importance of census is documented in the SOP Guidelines for bagworm control (MPOB, 2016). The infested area / planting block should be mapped out and the area indicated using the current GPS methods for easy monitoring and follow up actions.

Gazzeting of bagworm as a dangerous pest

Bagworm was declared as a dangerous pest on 15 of November 2013 under the Malaysia Act 167, Plant Quarantine Act 1976. Under this Act, planters who failed to control the bagworm infestation after receiving the notice will be fined not more than RM 10 000 or could be jailed for 2 years. Guidelines for a standard operating procedure for bagworm management and control was published in 2016 (MPOB, 2016). With this gazzete, MPOB, together with the Department of Agriculture (DOA) have been conducting advisory visits to many estates and smallholdings around Perak, Selangor and Johor to check on their status of bagworm infestation, control records etc. Some of the independent estates were observed to be controlling with broad spectrum chemicals (i.e. cypermethrin) and were advised to change to *Bt* or other more selective and target specific pesticides (i.e. chlorantrinilaprole) or apply permit to the DOA to conduct trunk injection (i.e. monocrotophos and methamidophos). Acephate, which is a safer alternative and can be used for trunk injection is also being used by many plantation agencies. A better formulation in the form of Acephate SG will be imported soon for use by the plantation industry.

MPOB has now formed a Steering Committee (SC) and Technical Committee (TC) on bagworm control, especially in Perak and Johor and this is expected to serve as a platform to exchange ideas on how to control and manage the bagworm problem more effectively. Members are requested to share their experiences and hence become the role models for other members to emulate and follow. A map showing the location of the infestation and outbreak areas (with bagworm numbers exceeding the ETL) are being shown at each meeting to chart out progress in control. Infested areas are colour coded (i.e. red - outbreak / >ETL, >50 larvae / frond, yellow - >ETL, 10-50 larvae / frond, blue - <ETL, <10 larvae/frond and green - no infestation) (*Figure 1*). The root cause of the problem can be identified much more easily when all parties sit together, discuss and monitor the progress of control over time. It is hoped that with the formation of these committees, members are more committed to control the bagworms and rescue the industry from becoming scourged by the bagworms again.

CONCLUSION

Bagworms have been infesting oil palms in Malaysia ever since the establishment of commercial plantation which started more than a century ago. Bagworm outbreaks can be managed through established methods of census and detection, and control as it reaches a certain economic threshold level.

Several things might have possibly gone wrong over the years that had possibly created conducive environment towards favouring bagworm outbreaks. These could include indiscriminate use of broad-spectrum chemicals, which kills many insects associated with bagworm; lack of establishment of the beneficial plants which form the natural habitat and providing these natural enemies with food and shelter; lack of bagworm census being conducted whenever the pest population is

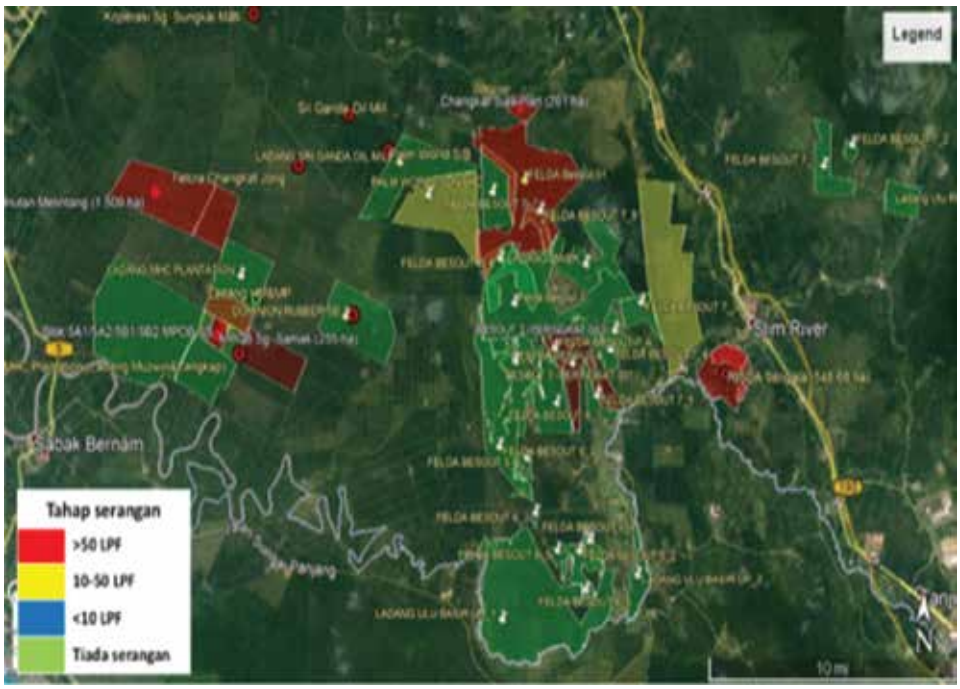

Figure 1 Map showing the bagworm infestation areas in Perak.
Note: The colour codes are according to the severity of the infestation. (Red: >50LPF – more than 50 larvae per frond; Yellow:10-50-LPF – 10 to 50 larvae per frond; Blue: <10LPF – less than 10 larvae per frond; Green: No infestation)

endemic and lacking knowledge on the threshold levels and life cycle of the pest.

It is therefore suggested that the awareness campaign on the bagworms should be more proactive, dynamic, continuous and shall never be neglected. Census should be done in relevant intervals according to schedule and control initiated immediately once the pest exceeds the threshold. The beneficial plants should be planted on a wider scale, for the establishment of natural enemies. Usage of broad-spectrum chemicals should now be replaced with more selective ones which help to avoid killing the non-target insects. These are the prerequisites to prevent the manifestation of a bagworm outbreak which brings about serious losses to the oil palm industry.

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