Intensive IPM for Management of Oil Palm Pests

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ABSTRACT

Oil palm is an important crop to Malaysia because of its huge hectarage (3.3 million hectares) and because of its significant contribution to the foreign exchange earning to the country. However, localized losses attributable to a number of pests can be substantial if high pest populations or outbreaks occur persistently. Intensive integrated pest management (IPM) of various key pests has always formed an integral part of oil palm husbandry.

This paper reviews the current IPM practices of key pests, viz., bagworm, nettle caterpillars, bunch moth, rhinoceros beetles, rodents and the basal stem rot. With the exception of basal stem rot, the use of economic threshold levels are essential in deciding whether chemical intervention is required. Chemicals are therefore used judiciously. The idea of planting beneficial plants such as Cassia cobanensis *and* Crotalaria usaramoensis *to sustain natural enemies are well received by planters and is actively being implemented.*

The change in a number of agronomic practices (e.g. zero burning and empty fruit bunch mulching), coupled with massive replanting programmes has led to a population explosion of Oryctes rhinoceros. *Prophylactic treatment with synthetic pyrethroids is essential. Biological control organisms, viz.* Metarhizium *and virus are being evaluated and for the former, plans are being made for mass production. For the latter, three strains of* Oryctes rhinoceros *virus have been established, one of which falls into the virulent group.*

Of four types of Ganoderma *identified, only one species (*G. boninense*) is the most aggressive, while the other three are not so harmful to oil palm. Various methods of control, viz., cultural, chemical, biological are discussed.*

Research and development to develop barn owl for rat control and to have it accepted as technically feasible and commercially viable, has taken 20 years! The owls are now widespread in the Peninsula, and they have also been successfully introduced into Sabah. Pending further approval, a pilot scale trial will also be made for Sarawak.

ABSTRAK

Sawit merupakan tanaman utama di Malaysia kerana penanamannya yang meluas (3.3 juta hektar), di samping menyumbangkan pertukaran wang asing yang bererti kepada negara. Walau bagaimanapun, kerugian hasil yang ketara akibat masalah perosak akan terjadi jika berlaku kerebakan populasi atau populasi tersebut dibiarkan meningkat secara berterusan. Pengurusan perosak bersepadu (IPM) secara intensif ke atas beberapa perosak utama sawit telah diamalkan dalam pengurusan tanaman ini.

Kertas ini menilai semula amalan IPM masakini ke atas perosak utama seperti ulat bungkus, beluncas, ulat tandan, kumbang badak, tikus dan penyakit reput pangkal batang. Kecuali reput pangkal batang, penggunaaan paras ambang ekonomik adalah penting untuk menentukan sama ada rawatan kimia diperlukan. Dengan cara ini, bahan kimia dapat digunakan dengan lebih bijaksana. Idea menanam tanaman berfaedah seperti Cassia cobanensis *dan* Crotalaria usaramoensis *bagi meningkatkan populasi musuh semulajadi telah mendapat sambutan dan sedang diterapkan secara aktif oleh peladang sawit.*

Perubahan amalan agronomi (contohnya pembakaran sifar dan sungkupan tandan buah kosong), diikuti dengan

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peningkatan program penanaman semula dibuktikan telah menimbulkan peningkatan populasi kubang badak. Tindakan profilaktif bersama dengan piretroid sintetik adalah perlu bagi mengawal keadaan ini. Penyelidikan mengenai organisma kawalan biologi seperti Metarhizium *dan virus serta rancangan bagi meningkatkan pengeluaran* Metarhizium *sedang giat dijalankan. Tiga strain virus kumbang badak telah diperkenalkan di mana salah satu daripadanya merupakan kumpulan virulen.*

Daripada empat spesies Ganoderma *yang dikenalpasti, hanya satu spesies* (G. boninense) *adalah paling agresif, sementara tiga spesies yang lain tidak ketara merosakkan sawit. Beberapa kaedah kawalan penyakit seperti amalan budayatani bahan kimia dan biologikal dibincangkan dalam kertas ini.*

Penyelidikan dan pembangunan telah dijalankan selama 20 tahun untuk membuktikan keberkesanan burung hantu sebagai agen kawalan tikus. Teknologi ini telah pun dipraktikkan secara komersil. Sekarang burung hantu telah tersebar meluas di Semenanjung dan juga telah berjaya diperkenalkan di Sabah. Sementara itu, percubaan perintis akan dijalankan di Sarawak.

INTRODUCTION

Oil palm pests can be classified into insects, diseases and vertebrates. The main insect pests consist of leaf defoliators, bagworms and nettle caterpillars; the crown attacker, rhinoceros beetle; and bunch moth. The main disease affecting the oil palm plantation in Malaysia is *Ganoderma* while others are of lesser significance as they can easily be managed. The vertebrate pests include rodents, wild boar, porcupines and elephants. However, for vertebrates, this paper will emphasize the biological control of rats with the barn owl, *Tyto alba*.

ECONOMIC IMPORTANCE OF OIL PALM PESTS

Losses attributable to oil palm pests can be substantial if pest damage is allowed to occur without any natural or artificial intervention. To date, data on the relationship between pest damage and yield reduction are still limited to a few pests such as bagworms and rodents.

Liau (1987) reported that a severe defoliation by *Mahasena corbetti* resulted in crop losses in excess of 40%-50% in the two subsequent years. In a later study, Basri (1993) found that a light defoliation (estimated at 3.2%) did not affect the yield but a moderate defoliation (estimated at 10%-13%) by *Metisa plana* resulted in a crop loss of 33%-40%. Thus, bagworm defoliation should be prevented from reaching a moderate level as it will result in economic loss.

Rhinoceros beetle attacks are normally serious during the immature phase of the crop. The damaged palms have an extended immaturity period (Liau and Ahmad, 1991). Therefore, the initial yield can be severely reduced after a serious attack. Field experiments conducted by Liau and Ahmad (1991) revealed an average 25% yield loss in the first two years of production.

Rats are also important pests of oil palm because at high population, they could cause a crop loss of 240 kg oil ha^{-1} yr^{-1} (Wood and Liau, 1978). At a palm oil price of RM 1200 t^{-1}, such loss is equivalent to RM 288 ha^{-1} yr^{-1}.

The above examples illustrate that pests in oil palm plantations need to be managed judiciously to avoid substantial crop losses.

DEVELOPMENTS ON IPM FOR OIL PALM PESTS

It is generally accepted amongst crop protectionists that pest control should not rely only one technique for any specific pests. In the past, complete reliance on chemical approach has often led to the development of other more persistent problems such as resistance of pests to treatment, build-up of chemical residues in environment, elevation of insects from secondary to primary pests and the disruption of populations of natural enemies. As such, an understanding of pest population dynamics and adoption of IPM are somewhat essential and rather inevitable for the management of oil palm pests.

The first inclination towards IPM was made in 1971 by Wood, B J who suggested the use of selective insecticides for bagworm control in the hope of conserving the natural enemies of the pest. This is essentially an integrated control approach, where chemical control is integrated into natural biological control as defined by Stern *et al*. (1959).

IPM has a much broader meaning and this

can best be summarized by FAO definition which states 'IPM is defined as a pest management system that, in the context of the associated environment and population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest populations at levels below those causing economic injury'. Thus in IPM, the focus should not be on a single approach and the strategy is not total eradication. Wood (1988), listed 17 principles of IPM for pests of plantation crops.

Basri (1995) discussed the technique of applying IPM specifically for bagworm, the approach of which is also applicable to other pests. There is a need to know the relationship between pest numbers and damage or injury, and subsequently between damage and crop loss. From these relationships, as well as the prices of economic product (that is palm oil), it would be possible to determine the economic injury and economic threshold level. Basri (1993) has reported some development along this direction for the bagworm *M. plana*.

Two core elements of IPM are sampling and economic threshold. The first element would indicate the population size which will help in deciding whether a control action is necessary based on whether the threshold has been exceeded or not. Basri and Norman (2000) have compiled a list of thresholds for the various pests of oil palm, most of which have been subjectively set by various researchers based on their field experience *(Table 1)*. To an extent, these thresholds have been found useful in implementing IPM in oil palm plantations.

As mentioned earlier, the aim of IPM is not total eradication of the pest but to keep the pest population below the level causing economic injury. Nevertheless, there is an exception. The economic threshold concept is not quite applicable to the basal stem rot disease (*Ganoderma*) of oil palm, primarily because the disease inoculum in the soil is relatively long lasting and it can spread. Unlike the insect pest, the inoculum level remains unchanged or tends to increase over time. As such, the strategy would be to eradicate the disease. This strategy offers a great challenge to plant pathologists.

TABLE 1. ECONOMIC THRESHOLDS OF IMPORTANT PESTS OF OIL PALMS

Common name	Scientific name	Economic threshold	References
Bagworm	*Metisa plana*	10 larvae/frond	Wood (1971)
	Pteroma pendula	30-60 larvae/frond	IRHO (1991)
	Metisa plana	8-47 larvae/frond	basri (1993)
	Mahasena corbetti	5 larvae/frond	Wood (1971)
Nettle caterpillars	*Darna trima*	10 larvae/frond	Wood (1971)
		30-609 larvae/frond	IRHO (1991)
	Setora nitens	5-10 larvae/frond	IRHO (1991)
	Darna diducta	10-20 larvae/frond	IRHO (1991)
	Setothosea asigna	5 larvae/frond	Hoong and Hoh (1992)
Rhinoceros beetles	*Oryctes rhinoceros*	10% palms with damage	Wood (1968b)
		3-5 adults/ha	IRHO (1991)
Bunch moths	*Tirathaba rufivena*	30% of the palms with at lease one bunch >50% attacked in young plantings and 60% in older plantings	IRHO (1991)
Cockchafers	*Adoretus*	5-10 adults/palm	IRHO (1991)
	Apogonia	10-20 adults/palm	IRHO (1991)
Rats	*Rattus* spp.	<20% bait acceptance	Wood (1968a)
		20% bunches with damage	Cheong, S P (per. comm.)

Source: after Basri and Norman (2000).

Various control approaches have been developed for various pests of oil palm and these are discussed in the ensuing sections. Further deliberation on this subject has been reported by Chung *et al.* (1995) and Ho and Teh (1997).

BAGWORM

Bagworms are the caterpillars, or larvae, of moths of the family Psychidae. Seven species are found in association with oil palm: *Metisa plana*, *Mahasena corbetti*, *Pteroma pendula*, *Brachycytarus griseus*, *Manatha albipes*, *Amatissa* sp. and *Cryptothelea cardiophaga* (Norman *et al.*, 1995; Sankaran, 1970). The most common species of bagworms are *M. plana*, *P. pendula* and *M. corbetti*. One distinguishing feature of the bagworms is that they build and live in a portable silk case (or bag) to which are attached fragments of leaves and stalks of flowers of the host plant, along with other detritus (Norman *et al.*, 1995). Another distinguishing feature of the bagworm is that the female adult of many species has reduced appendages and is flightless. The male is winged and it searches for females which secrete pheromones to attract the male.

Biological Control

Parasitoids. Parasitoids have been shown to suppress the population of *M. plana* (Basri *et al.*, 1995). As such, they have a potential for the biological control of this pest. Environmental manipulation would be appropriate for the control of this pest because this attempts to modify the environment to make it more conducive for the survival and growth of its natural enemies. The idea is to promote the activities and survival of natural enemies already present in the environment. Out of nine beneficial plants evaluated in the laboratory as hosts for various parasitoids, the most promising plants were *Cassia cobanensis*, followed by *Crotalaria usaramoensis* and *Euphorbia heterophylla* (Basri *et al.*, 1999). Hence, the establishment of these plants would be advantageous because they provide nectar for the parasitoids. Current field studies in Lower Perak confirmed that parasitoids were highly attracted to *C. cobanensis* and levels of parasitisms have increased. This approach ought to be adopted alongside other control techniques.

Bacillus thuringiensis. It was not until recently that a more potent strain (*aizawai*) was found effective against both *M. corbetti* and *M. plana* (Basri *et al.*, 1996). It was also established that *aizawai* is nine times more effective against *M. corbetti* than *M. plana*. The difference could be accounted for by the gut pH; the gut pH of the latter (pH=6) is more acidic than that of the former (pH=9). An acidic condition renders the crystal protein relatively stable. In contrast, in an alkaline midgut, the crystal protein undergoes proteolysis, releasing the active toxin which destroys the gut epithelial cells. It was also found that an emulsifiable suspension of *B. thuringiensis kurstaki* is also more effective against *M. corbetti* than *M. plana*. Chung and Narendran (1996) supported this finding.

More recent study indicated that two *B.t.* gene products were effective for *M. plana* (Siti Ramlah, 2000). These products need to be further exploited for use by the industry.

Beauveria bassiana. A strain of *Beauveria bassiana* has been isolated from a population *of M. plana* and its pathogenicity to bagworm has been established (Siti Ramlah *et al.*, 1993; Ramle *et al.*, 1995). Using three additional strains from other sources, their effectiveness against *M. plana* and against the pollinator, *Elaeidobius kamerunicus*, were assessed. All the strains were highly effective against *M. plana* but only one was not harmful to the pollinator. Further efforts will be towards mass production and field release in bagworm infested areas.

Virus. Viruses, in particular baculoviruses, have potential for pest control but they have not been exploited much for bagworm. However, from a collection and examination of 60 000 larvae of *M. plana*, only nucleo-polyhedrosis virus (NPV) was found. Further, the degree of infection was only tertiary, meaning that they did not successfully infect their host (Siti Ramlah *et al.*, 1996), and as such has little potential for field control.

Chemical Control

Bagworms can be controlled by spraying (Wood and Nesbit, 1969; Mackenzie, 1977) or trunk injection of insecticides (Chung, 1989). Tricholorfon is suitable and effective for spraying (Wood, 1976; Chung, 1989). However, it is important to ensure that the spraying is done at the beginning of a generation, that is, as soon as the eggs hatch. This is because the younger larvae are more susceptible to chemicals than the older ones. The correct timing is therefore of utmost importance for effective control. There have been some reports of poor performance of trichlorfon and the incidences are likely to be associated with improper timing of control.

Further, appropriate spraying equipment need to be selected to suit the frond canopy and height of the palm.

RHINOCEROS BEETLES

In Malaysia, the rhinoceros beetle attacks coconut and another 31 genera of palms (Cumber, 1957). The zero burning method of replanting is practiced because of a greater awareness for the environment and the need to comply to Environment and Quality Act 1974. This method involves shredding the oil palm trunk with an excavator and subsequently stacking in the interrows to rot *in situ* (Mohd Hashim *et al.,* 1993). This practice led to an abundance of decaying materials suitable for the beetles to breed. Another replanting method, called underplanting, involves planting of young palms underneath old palms which are due for felling. This method is unsuitable because the eventually dead standing old trunks harboured the largest number of rhinoceros beetle larvae (about 40 000 ha^{-1}) compared to felled and shredded trunks (Samsudin *et al.*, 1993). Underplanting should therefore never be practised.

The life cycle of the rhinoceros beetle varies according to its habitat and environmental conditions (Catley, 1969; Bedford, 1980). Catley (1969) demonstrated that with ample food, the third instar takes three to four months. However, the duration of all the larval stages can be shortened from six to five months with a superior diet (Schipper, 1976). Similarly, Wood (1968) found that the larvae required five to seven months to mature in oil palm trunk but only four to five months in a habitat of cowdung and sawdust. The temperatures suitable for larval development is 27°C-29°C, with relative humidities ranging from 85%-95% (Bedford, 1980). In the field, *Oryctes* prefers to breed in semi-decayed trunk chips. Moisture content of the trunk played a significant role in determining successful development of the beetles. Establishing the ground cover to avoid infestation of the pest has been confirmed (Norman *et al.*, 1999b).

Chemical Control

Among the earlier chemicals recommended in Malaysia for the control of *Oryctes* were organochlorines such as gamma BHC and dieldrin (Wood, 1968; Mariau and Calvez, 1973). Because of the high toxicity and persistence of organochlorines, a granular formulation of carbofuran was recommended by Toh and Brown (1978) at four to six weeks intervals as a prophylactic control measure against the adult beetles.

Chung *et al.* (1991) evaluated lambda-cyhalothrin, cypermethrin, fenvalerate, monocrotophos and chlorpyrifos in both nursery and field trials. All chemicals had significantly reduced *Oryctes* damage after 11 weeks. Similarly, in immature oil palm, the most effective chemical for reducing damage was lambda-cyhalothrin (Chung *et al.*,1991). In a similar trial, Ho (1996) demonstrated that lower rates for cypermethrin and lambda-cyhalothrin can be applied to control *Oryctes*. Carbofuran however, seems no longer effective at high pest population levels (Ho, 1996).

Besides agrochemicals, naphthalene balls have been used as a repellent, applied fortnightly to the frond axils (Gurmit, 1987). Control was claimed to be more than 95% (Gurmit, 1987). However, at high pest population densities, Chung *et al.* (1991) and Ho (1996) both reported poor control by this method.

Microbial Control

Natural infection of *O. rhinoceros* by *Metarhizium anisopliae* has been reported since 1912 at Western Samoa. Because of its ability to infect a wide range of insect pests, ease of production on simple substrates, easy storage and longer persistence of conidia in soil (Goettel, 1992), *M. anisopliae* has been used to control *O. rhinoceros*. A laboratory bioassay showed that *Oryctes* larvae were more susceptible to the long spored than short spored isolate of *M. anisopliae* (Ramle *et al.,* 1999). The long spored isolates caused 100% mortality and 75% mycosis within 12 days of treatment. The times required to kill 50% of *Oryctes* larvae (LT_{50}), ranged from 8.9 and 9.1 days.

A field trial was conducted using a single application of wet and dried inoculum (Ramle *et al.*, 1999). In the field, the greatest effect of *Metarhizium* was on the third instar larvae (L3), especially three months after application. At this stage, application of both wet and dried inoculum at the highest rates reduced the population significantly. Application of *Metarhizium* in wet and dried inoculums was equally effective in controlling *O. rhinoceros*. Each inoculum has its own advantages and disadvantages. Wet inoculum is easily prepared in water available in the field or from other sources such as rivers and ex-tin mining pools.

Tests showed that water from all these sources can be used to prepare wet inoculum, but the inoculum had to be applied immediately before the spore viability declined. Spores from fresh inoculum can possibly infect *Oryctes* larvae as soon as they are deposited in the breeding sites. The presence of water can facilitate deeper conidial distribution in soils and decayed oil palm tissues. This will increase the exposure of *Oryctes* larvae to *Metarhizium*. Furthermore, spores that distributed deep in the breeding materials are less exposed to abiotic factors such as low humidity, high temperature and ultraviolet radiation which reduce their viability (Zimmermann, 1982; Walstad *et al.*, 1970; Moore *et al.*, 1993).

Due to the substantial quantity of maize required to produce dry *Metarhizium* inoculum, wet inoculum may be preferable as less maize is required. Based on a production rate of 4.4 x 10^{10} conidia 200 g^{-1} of autoclaved maize, wet inoculum requires only 1.4 kg maize ha^{-1} (estimated area of chipped oil palm trunks is 600 m^2), while dried inoculum requires 180 kg. At a maize price RM 1.00 kg^{-1}, the cost of application based on maize alone is RM 1.40 for wet inoculum versus RM 180.00 for dried inoculum. However, the main advantage of using dried inoculum is that it can be stored at room temperature for several months before use.

In collaboration with AgResearch of New Zealand, efforts are also being made to explore the use of *Oryctes rhinoceros* virus, using molecular techniques, for the bio-control of the rhinoceros beetles. The use of two primers and PCR technique revealed that the virus is widespread. RAPD analysis revealed the presence of three strains. From laboratory bioassays, the most potent strain has been identified. This will be followed by a field trial. A system of using the virus will be subsequently developed for use by the industry.

Trapping

Early efforts at trapping *Oryctes* in Malaysia included the use of split log and coconut log traps (Wood, 1968; Turner,1973). These traps required ethyl chrysantemumate – as an attractant (Hoyt, 1963; Barber *et al.*, 1971). However, the *Oryctes* aggregation pheromone, ethyl-4-methyloctanoate, has been confirmed to be 10 times more effective than ethyl chrysanthemumate (Hallet *et al.*, 1995).

The *Oryctes* aggregation pheromone is a useful tool for monitoring and also for mass trapping. The present recommendation for mass trapping is to place 1 trap 2 ha^{-1} (Chung, 1997). At the commercial price of RM 25 (US$ 7) per sachet, the savings of using the pheromone compared to carbofuran is about RM 46 ha^{-1} yr^{-1} (US$ 12 ha^{-1} yr^{-1}) (Chung, 1997).

By using pheromone traps, a medium to low *Oryctes* population (less than five individuals per square metres) can be quickly reduced in an area (Norman *et al.*, 1999a). In another experiment, it was observed that more beetles were captured in the traps which were not regularly emptied, suggesting the captured beetles enhance trapping by releasing chemical cues (Norman, unpublished data). High captures of female beetles at fringes of the replanting block suggest migration of females into new areas, possibly in search of breeding sites (Norman *et al.*, 1999a). In one area in Sepang, Selangor, beetles immigrated to breed at the onset of replanting (Norman *et al.*, 1999a). Trapping can therefore be initiated early at the borders (*e.g.* within mature oil palm or coconut), before replanting is conducted, to reduce immigration of beetles. The number of adult females trapped were related to the number of second instar larvae in the decomposing heaps after 40-60 days of the trapping (Norman *et al.*, 1999a). This also suggests that trapping can be used as a monitoring tool for estimating population density in the heaps, provided the substrate and environmental conditions are similar.

NETTLE CATERPILLARS

The nettle caterpillars are regarded as a group of sluggish moving caterpillars with stinging spines that can cause nettle rash on the human skin. The colour of the caterpillars are specific for each species (Wood, 1968).

There are many types of nettle caterpillars that have been reported in Malaysia, the most common being *Darna trima*, *Setora nitens*, *Setothosea asigna* and *Darna diducta*, and the less common being, *Thosea vestusa*, *Thosea bisura*, *Susica pallida*, *Birthamula chara* (Norman and Basri, 1992). The duration of the life cycle of the various types of nettle caterpillars tended to differ from one species to another, ranging from 42 days in *S.nitens* to 138 days in *Thosea asigna* (Hartley, 1979; Tiong 1977). In implementing IPM control strategies, knowledge on the biology and behaviour are important so as to ensure the effectiveness of the approach. All ages of palms appeared susceptible to nettle caterpillar attack (Norman and Basri

1992; Basri *et al.*, 1988).

Chemical Control

Past records indicate that nettle caterpillars can be effectively controlled with various chemical insecticides. These include monocrotophos, dicrotophos, phosmamidon, leptophos, quinalphos, endosulphan, aminocarb and acephate (Tiong, 1977; Prathapan and Badsun, 1979). Systemic insecticides can be used for trunk injection whereas others can be applied through spraying. In the past, trichlorfon has been used for the control of nettle caterpillars (Wood, 1968), but later it was reported that the effectiveness of trichlorfon had not been satisfactory (Wood, 1976). The nettle caterpillars are also well under natural control because of the numerous natural enemies associated with nettle caterpillars such as ichneumonids, braconids, tachinids, reduuvids and a pentatomid (Wood, 1976; Norman *et al.*, 1998). Tiong (1977) reported ground cover establishment could lead to a reduction in the population of nettle caterpillars by increasing the population of the natural enemies.

Present records have produced a conflicting picture on the effectiveness of the trunk injected chemicals, monocrotophos and methamidophos, for the control *D. trima*. In Sandakan, the application of monocrotophos (at 6 g a.i./palm) was effective to control an outbreak (Simon Siburat, per. comm.). However, in Tawau, it was found that the same level of treatment produced hardly any control on the pest and for satisfactory control a much higher dosage is required (48 g a.i./palm) (Ban-Na, A, per. comm.). This might suggest that the population has developed tolerance to the chemical or the chemical has failed to get translocated upwards to the foliage.

Microbial Control

Microbial pathogens have also been considered for the control of nettle caterpillars and these include *Bacillus thuringiensis*, *Cordycep* sp. nr. *militaris* and RNA virus. Some field trials have reported success in the use of *B. thuringiensis* against *S. nitens, D. trima* and *Setothosea asigna* (Wood *et al.*, 1977). A recent laboratory bioassay of *B. thuringiensis* against *D. trima* from Tawau showed that two commercial products of *B. thuringiensis* (*aizawai* and *kurstaki* ES) were effective against this pest (90% mortality within seven days) (Basri, unpublished).

Besides *B. thuringiensis*, virus of *D. trima* and the fungus of *Thosea asigna* have been found effective for field control. There is also a possibility of amplifying *Cordyceps* in artificial culture for use as a biocide against nettle caterpillars (Papierok *et al.*, 1993). Basri (1995) reported that viruses from *M. corbetti* and *D. trima* have also been found to infect *Spodoptera litura*, suggesting the availability of alternate host. These results suggest that there is potential for the mass production of entomopathogens.

BUNCH MOTH

The bunch moth, *Titrathaba mundella* is also known as the 'inflorescence moth' or 'fruit moth'. It usually attacks newly planted areas where the bunches are not harvested (Wood, 1976).

Life Cycle

The life cycle of the bunch moth is about one month (Wood and Ng, 1974; Chan, 1973; Hartley, 1979). The eggs are found in over ripe rotten bunches or in bunches or inflorescences which have fallen to the ground. The damage is caused by holes made by the caterpillars. Damaged fruits fall to the ground prematurely or develop without kernels. The caterpillars also cause damage by feeding on the outer layer of ripening fruits. Generally, bunch moth caterpillars are capable of damaging the female inflorescences up to the stage of ripening.

Chemical Control

From field trials carried out in the early 1970s, endosulfan was established as the most effective chemical for bunch moth control (Wood and Ng, 1974). However, in the late 1980s, bunch moth became a chronic problem in an estate in Lower Perak despite the use of endosulfan. Consequently, a field study was made in the area, evaluating the effects of endosulfan, diflubenzuron, cyfluthrin and *B. thuringiensis* (Basri *et al.*, 1991). From the study, *B. thuringiensis* was found to be the most effective for both reducing the pest population and damage to the bunches. Subsequently, *B. thuringiensis* has been used on a commercial scale and the problem has been completely overcome.

RODENTS

The use of rodenticide baits has been the most widely used approach of rat control (Wood, 1969;

Wood and Liau, 1978) and the cost was estimated at between RM 10 and RM 22 ha^{-1} yr^{-1} (Basri and Halim, 1985). In an effort to reduce the use of chemicals, the potential of the barn owl, *Tyto alba* has been evaluated over the last 20 years. Lenton (1980) showed that the diet of the barn owls was highly specific to rats. This hypothesis was taken a step further in the field, where nest boxes were erected and the effectiveness of barn owl was demonstrated (Smal, 1989; Duckett and Karuppiah, 1989). The effectiveness of the owls was lately confirmed on a commercial scale by two major plantations in the Peninsular (Ho, C T and Chung, G F, per. comm.) and a plantation in Sabah (Hoong, 2000). Our recommendation is to erect nest boxes at a density of 1 in 10 ha.

OIL PALM DISEASES

From seed germination to field planting, the oil palm is prone to attack by various disease organisms, the most common being fungi. Nevertheless, those diseases affecting seeds and nursery seedlings are, in most cases, under control and do not pose a serious threat to the industry. However, field diseases can threaten the development of the crop. These diseases are currently region specific and confined to certain oil palm growing areas of the world. In Africa, vascular or *Fusarium* wilt is the most serious disease whereas in Southeast Asia, basal stem rot caused by *Ganoderma* can be very devastating. Sudden wilt and red ring diseases are confined to Latin America and, if left unchecked, can severely limit development of the oil palm in this part of the world. Some disorders, such as bud and spear rot are of uncertain causes and the pathogenicity has yet to be conclusively proven.

Basal stem rot (BSR) caused by various species of *Ganoderma* is the major disease of oil palm in Malaysia and Indonesia. In Malaysia, BSR is especially severe on palms planted on coastal marine clays which had previously supported coconut. The fungus, being saprophytic to coconut, remains in the stumps and trunks of coconut left in the soil and infects the oil palm on replanting. Although in earlier years, the fungus was reported to cause severe damage only on oil palm older than ten years, the incidence is on the increase in younger palms. Evidence is also accumulating on incidences of *Ganoderma* on peat and inland soils (Ariffin *et al.*, 1989; Rao, 1990; Benjamin and Chee, 1995).

Infected debris serves as the major inoculum focus for new infection. Therefore, clean clearing of the former stand is recommended to reduce the incidence of *Ganoderma* in oil palm replanting (Turner, 1965). This involves complete removal of the trunks, stumps, boles and major root masses in the bole region. Although costly, the recommendation is widely adopted in most oil palm plantations with a serious history of BSR. However, the present experience is that even clean clearing is not entirely satisfactory in reducing the disease incidence. Despite adoption of this technique, the BSR incidence remains high on sites with a bad history of the disease (Gurmit, 1991).

A number of species of *Ganoderma* have been implicated as the causal organisms for BSR of oil palm. They include *G. lucidum, G. boninense, G. chalceum, G. miniatocinctum, G. pseudoferreum, G. tornatum, G. cochlear, G. colossus, G. fornicatum, G. laccatum, G. pediforme, G. tropicum, G. xylonoides* and *G. zonatum* (Turner, 1981). Studies by Ho and Nawawi (1985) on the fruiting bodies of *Ganoderma* collected from diseased oil palm from a few locations in Peninsular Malaysia established that they were all *G. boninense*. In Nigeria, *G. zonatum* was reported to be associated with *Ganoderma* trunk rot, a disease widespread among wild palms in the groves of West Africa (Oruade-Dimaro *et al.*, 1994). More recently, Idris (1999) classified *Ganoderma* of oil palm in Malaysia into types A, B1, B2 and C, where type A (*G. boninense*) is aggresive, type B1 (*G. zonatum*) and B2 (*G. miniatocinctum*) are less aggressive, and type C (*G. tornatum*) is non-pathogenic.

Infection of young field palms leads to a one sided yellowing of the lower fronds. The foliage is pale green and growth is retarded. As the disease progresses, the fronds start to desiccate beginning with the oldest and moving to the youngest. Eventually, the palm dies. In most cases, *Ganoderma* fructifications do not appear if palms less than two years old are infected. However, *Ganoderma* can be cultured from the infected roots or stems.

In older palms, the symptoms of infection are a pale green appearance of the canopy compared to the healthy neighbours, multiple unopened spears and desiccation of the older fronds. The desiccated fronds break at the petiole and hang down skirting the trunk. Necrosis of the stem base is common and *Ganoderma* fructifications begin to appear, initially as small white buttons but later developing into the typical bracket-shaped sporophores.

Control of BSR

Chemical control of infected field palms using systemic fungicides, mainly those in the triazole group, was then initiated in attempt to save standing infected palms (Khairuddin, 1990; Chung, 1990; Gurmit, 1991; Ariffin and Idris, 1997). Success elsewhere in eradicating decay fungi of tree crops using chemicals normally used for soil fumigation prompted a similar approach to controlling BSR (Ariffin and Idris, 1991; 1993). Dazomet, which releases the fumigant methylisothiocyanate, was shown to move within the stem tissue of oil palm and could subsequently inhibit the growth of *G. boninense*. Nevertheless, despite the promise of triazoles and fumigants, the results of field trials have been inconclusive (George *et al.*, 1996) and unable to demonstrate the viability of using chemicals to treat infected palms. For a long term control strategy, the factors that predispose palms to attack by BSR pathogen need to be elucidated. Circumstantial evidence has shown that techniques of replanting that allow leftover of massive amount of inoculum would ultimately lead to a high BSR incidence (Turner, 1981; Gurmit, 1991; Ariffin *et al.*, 1993; Khairuddin, 1993). The high incidence of BSR in second and third generation palm, despite the adoption of clean clearing technique, begs for a plausible explanation. It must be realized that clean clearing was initially advocated based on the finding that a massive amount of inoculum of at least 734 cm^3, is required to initiate infection (Turner, 1981). However, suspected roles played by these roots in disease outbreak only began to be realized with the successful artificial inoculation of nursery seedlings. The fact that seedlings can be readily infected using pure culture inoculum only slightly bigger than the average oil palm primary root (Ariffin *et al.*, 1995), suggests that under favourable conditions, the leftover infected roots can be infective. These findings suggest that leftover root fragments can play a very important role in the outbreak of BSR despite clean clearing during replanting of second and third generation palm. That the root fragments left *in situ* still have enough inoculum potential to cause disease is reflected in their ability to produce fruiting bodies of *G. boninense* which are sometimes seen on their cut ends.

A cultural control technique which involves surgery followed by soil mounding around the base of diseased palms appeared promising in prolonging the life of infected palms (Lim *et al.*, 1993; Hassan and Turner, 1994).

Little work has been done on biological control of BSR disease. The possibility of control of *Ganoderma* in existing stand should be approached through manipulation of biological agents. Several promising antagonists, mainly *Trichoderma* (Shukla and Uniyal, 1989; PORIM, 1991; Wijesekera *et al.*, 1996), *Aspergillus* (Shukla and Uniyal, 1989) and *Penicillium* (Dharmaputra *et al.*, 1989) have been isolated and their mechanisms of antagonism against *Ganoderma* in culture have been reported. The effectiveness of antagonists in soil can be enhanced under field conditions by fumigation and fertilizer application (Varghese *et al.*, 1975), but there are no reports of effective biological control in infected oil palm. Mass production of these antagonists, especially *Trichoderma* on agriculture oil palm waste such as palm oil mill effluent and empty fruit bunch (Gurmit, 1991) is possible and this preparation could be used for application around roots of infected oil palms.

CONCLUSION

The above review indicates that many control techniques have been developed for various pests. However, for the purpose of decision making, the sampling of population is essential to determine the level of pest abundance and the stages present. Without this information, the implementation of IPM could not be done in a judicious manner.

This review also reveals that R&D is still required for many areas in order to refine the IPM practices. These areas which include determining the relationship between *Oryctes* beetle numbers and damage, and determining an effective biocontrol agent for *Ganoderma* need to be further explored.

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