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Towards the development of an integrated pest management system of *Helopeltis* in Malaysia

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Key words: *Helopeltis*, Integrated Pest Management (IPM), cultural control, chemical control, biological control, ants, early warning system

Abstrak

Helopeltis ialah perosak koko yang penting di Malaysia. Oleh itu pengurusannya sangatlah penting untuk mendapatkan hasil koko yang menguntungkan. Memandangkan koko ialah tanaman baru di Malaysia penyelidikan dalam pengurusan *Helopeltis* masih berkurangan. Kebanyakan pendekatan pengurusan perosak ini berpandukan pengalaman di Afrika Barat, kerana banyak penyelidikan telah dijalankan di negara tersebut. Namun demikian, cara pengurusannya masih berasaskan kimia, yang menjadi pendekatan utama dalam pengurusan *Helopeltis* di Malaysia. Perkembangan kawalan kimia dibincangkan.

Perkara-perkara utama dalam pengawalan biologi dan kultur juga dibincangkan. Kecetekan kefahaman terhadap prinsip-prinsip yang merangkumi kaedah kawalan tersebut menyebabkan kaedah ini jarang digunakan dalam pengurusan *Helopeltis*. Namun demikian, peranan utama semut dalam mengurangkan serangan *Helopeltis*, terutamanya dalam ekosistem koko dan kelapa patut diambil kira dalam menggubal sistem pengurusan perosak bersepadu (PPB) untuk *Helopeltis* tidak kira sama ada untuk kawasan pekebun kecil ataupun ladang besar.

Sebagai matlamat utama untuk mengurangkan penggunaan racun kimia, pengawasan populasi *Helopeltis* dan kefahaman terhadap ekologinya telah menjadi penting dalam pelaksanaan PPB. Penggunaan sistem amaran awal adalah salah satu cara untuk mencapai matlamat PPB dan seterusnya mempertingkatkan hasil koko.

Abstract

Helopeltis is a major insect pest of cocoa in Malaysia. Hence its management is of prime importance to ensure profitable yield. Cocoa is a relatively new crop in Malaysia and research on the management of *Helopeltis* is relatively scanty. As such, management approaches are largely based on West African experiences where considerable research has been carried out. However, this management approach is largely based on chemicals, which remain the first line of defence in existing *Helopeltis* management strategies in Malaysia. The development of chemical control of *Helopeltis* is discussed.

The salient features of biological and cultural control are also examined. A lack of understanding of the principles involved has resulted in minor use

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of them in *Helopeltis* management. Nevertheless, the significant role of ants in limiting *Helopeltis* attack, especially under the cocoa and coconut ecosystem, is worth considering in the development of an integrated pest management (IPM) system regardless of the size of cocoa areas.

With the ultimate aim of reducing chemical usage monitoring of the *Helopeltis* populations and the understanding of their ecology have become important in the implementation of IPM. The use of an early warning system is one of the means by which the objectives of IPM may be achieved with subsequent improvement in cocoa yield.

Introduction

Mirids are serious pests of cocoa. They are widespread throughout the cocoa growing areas of the world, and about 40 species in the subfamily Bryocorinae (the tribe Monaloniini and Odoniellini) are known to attack cocoa (Entwistle 1972). The tribe Monaloniini is the most widespread with the genus *Monalonion* exclusively feeding on cocoa in the neotropics. The species of *Helopeltis* are more important in the Old World cocoa growing areas. Attacks by members of Odoniellini occur mainly in the Ethiopian region, Sabah and Papua New Guinea. *Sahlbergella singularis* (Hagl.) and *Distantiella theobroma* (Dist.) constitute the two most damaging species of this tribe and are distributed mainly in West African cocoa areas (Entwistle 1972).

In Peninsular Malaysia, *Helopeltis theobromae* Mill. continues to be the greatest concern of cocoa growers. It was first reported attacking cocoa at the Federal Agriculture Experiment Station, Serdang in 1939 (Miller 1941). On the other hand, *H. clavifer* (Walk.) and *Platyngomiriodes apiformis* Ghauri are the two important mirid species in Sabah with the former first discovered in 1957 and the latter in 1962 (Conway 1971; Pang 1981). However, mirid problems in Sabah are currently of secondary importance with the discovery of the cocoa pod borer, *Conopomorpha cramerella* (Snell.), in late 1980. Other mirid species present in this region are *H. antonii* Sign. and *H. theivora* Waterh. in Indonesia (Giesberger 1983) and *H. bakeri* Popp. and *H. collaris* Stal. in the Philippines (Entwistle 1972).

The biology of *H. theobromae* has been described by Miller (1941), Tan (1974a) and Azhar (1986). No detailed biological studies on *H. clavifer* are known but a description of the life history of *P. apiformis* was given by Pang (1981). Mirids are polyphagous, and *H. theobromae*, in addition to cocoa, also attack seven alternate host plants (Ahmad and Ho 1980). Smith (1978) reported 25 alternate hosts of *H. clavifer* in Papua New Guinea but no report of alternate hosts for *P. apiformis* has been recorded.

Damage is primarily due to the feeding of adults and nymphs on green pods and young shoots or unhardened stems. *Platyngomiroides apiformis* also attacks the chupon and fan branches as well (Conway 1971; Pang 1981). Feeding by these mirids results in the development of circular lesions on pods and lenticular lesions on unhardened stems. Attacks on young cherelles may lead to cherelle wilt and complete loss of the crop may result if the infestation is severe. Infestation by these mirids may also lead to subsequent attack by fungal pathogens. Correct crop loss assessment attributable to *Helopeltis* has never been reported in Malaysia perhaps because of the confounding nature of contributory factors. However, a 25% decrease in yield due to mirid infestations was reported in Ghana (Stapley and Hammond 1959).

The recognition of the effect of mirid infestation on cocoa in Malaysia has led to the institution of various control measures against this pest soon after they were discovered attacking cocoa (Miller 1941; Conway 1971). Since mirids are more important in Peninsular Malaysia than in Sabah, this review will emphasize the management of *H. theobromae*, although reference to other mirid species will also be made where appropriate.

Various management approaches to *Helopeltis* have been described and reviewed by a number of authors (see e.g., Miller 1941; Conway 1971; Tan 1974b; Mainstone 1978; Azhar and Jamaludin 1981; Azhar 1984, 1985, 1986). However, chemical control was and still is the most widely adopted approach by many cocoa growers. The extensive use of chemicals for the management of *Helopeltis* is due to several reasons. Among them are quick action, easily available and implemented and inefficient natural control factors (Azhar 1985). In this review, it is therefore appropriate to lead the discussion with chemical control followed by other control measures and eventually a discussion of the implementation of an Integrated Pest Management (IPM) programme.

Chemical control

Cocoa planting in Malaysia which began in the early sixties, is relatively new when compared to West Africa. Research on the management of *Helopeltis* is relatively scanty and many of the chemicals used were adopted from trial results in West Africa.

Historical view

In West Africa, numerous control measures with special emphasis on chemicals were tried against the cocoa mirids since when they were recognized as pests in 1910 (Dundgeon 1910; Nichol and Taylor 1954). Spraying of trees with chemicals such as kerosene/soap emulsion, nicotine sulfate, and tar and petroleum distillate were tried with partial success (Entwistle 1966). The subsequent use of DDT, after World War II, by painting branch unions or jorquettes and other mirids resting places provided better control (Collingwood 1971). The use of HCH evolved after the chemical was proved to be more successful than DDT in controlling cocoa mirids (Stapley and Hammond 1959). The effectiveness of HCH was attributed to its fumigative effect (Raw 1959). Since then, the use of this insecticide has become widespread throughout the West African cocoa growing areas as well as other parts of the world (Entwistle 1972; Omole and Ojo 1981). However, the widespread use of this chlorinated hydrocarbon insecticide against cocoa mirids has resulted in the localized development of resistant strains (Dunn 1963; Entwistle 1964). The phenomenon of insecticide resistance has necessitated continuous screening of insecticides for control of cocoa mirids in West Africa (Prins 1965; Laryea 1967; Johnson et al. 1970; Collingwood and Marchart 1971; Marchart 1971a, 1971b; Nwana et al. 1979; Omole and Ojo 1981; Owusu-Manu 1985).

The first attempt to control *Helopeltis* was probably in Sri Lanka in 1907 where the spraying of sulfur and Macdonaghue's mixture proved a failure (Entwistle 1966). In Java, early attempts of insecticidal control of cocoa mirids were made using the natural insecticide, derris and lead arsenate, but with little success (Giesberger 1983). DDT was later used to control *Helopeltis* in Java (Entwistle 1972).

The earliest report on the use of insecticides in Peninsular Malaysia to control *H. theobromae* was made by Miller (1941). He demonstrated that dusting with pyrethrum-lime at weekly intervals was effective in controlling the pest. Lever (1949) found that three dustings of 0.5% DDT applied every 10 days could check the damage caused by

H. cinchonae Mann. and *H. bradyi* Waterh. which were attacking the shoots of tea bushes in the Cameron Highlands. The earliest report on the use of insecticide to control cocoa mirids in Sabah was in 1959 when HCH dust was applied to the young growing points of cocoa trees (Conway 1971). Further reports on the development of insecticide usage against cocoa mirids in Sabah did not appear until the seventies.

Current situation

Insecticides Spurred by the significant results of mirid control in West Africa using HCH, this chemical was and is still widely used by many cocoa growers in Peninsular Malaysia. However, because of the reported development of mirid resistant strains and the suspected tainting effect through extensive use of HCH, alternatives to HCH were sought. The Department of Agriculture recommended the use of other chemicals including dieldrin and trichlorphon for *Helopeltis* control (Anon. 1977). However, dieldrin is no longer recommended because of its high mammalian toxicity. Other insecticides such as chlorpyrifos and methamidophos, though not officially recommended, were also used by a number of cocoa growers (Azhar 1985). Screening efforts by Jamaludin (1981) and Lee et al. (1986) further added to the list of suitable insecticides for *Helopeltis* control and include the carbamate and synthetic pyrethroid groups. A list of insecticides currently recommended for used against *Helopeltis* in Peninsular Malaysia is given in *Table 1*.

Table 1. Some of the commonly used insecticides in *Helopeltis* control

Common names	Group
Gamma–HCH (lindane)	organochlorine
Propoxer	carbamate
Dioxacarb	carbamate
Cypermethrin	pyrethroid
Alphamethrin	pyrethroid
Deltamethrin	pyrethroid

Application methods Various insecticidal application methods are employed, some of which were reviewed by Khoo et al. 1983. Growers may use methods ranging from dusting, spraying and fogging depending on the severity and distribution pattern of the infestation, the phenology of cocoa crops and the economic constraints.

Dusting with *gamma*-HCH dust has been recommended in the past in Peninsular Malaysia (Anon. 1977) but the method is now obsolete. The method was also recommended for mirid control in Papua New Guinea (Smith 1979).

Spraying is the most widely practised method of applying insecticides against cocoa mirids and the operation may be carried out using manual knapsack sprayers or portable motorized mist blowers. The manual knapsack sprayers are suitable where cocoa trees are not too tall whereas mist blowers are more suitable for taller trees in order to reach pods in the upper canopy (Taylor et al. 1982). The manual knapsack sprayers are more popular among smallholders because of the small acreage and their limited resources while many plantations use the motorized mist blowers as well as manual knapsack sprayers. Comparatively, the motorized mist blower has a higher working rate than the manual knapsack sprayer (Taylor et al. 1982). A worker can cover only 2–3 ha/day using the knapsack sprayer compared to the 5–6 ha/day using the motorized mist blower. At the same time, the manual knapsack sprayer is a high volume application method compared to the motorized mist blower which is low to medium volume. Hence, larger amounts of insecticides are applied per unit area using the former sprayer.

Fogging is commonly used when greater coverage of insecticide is required and labour is limited. The operation may be carried out using portable pulsejet foggers when the infestation is not widespread or tractor-drawn pulsejet foggers when larger outbreaks occur (Taylor et al. 1982). However, fogging is suitable for use with insecticides having a fairly high degree of thermostability and only on mature cocoa with a closed canopy. The use of insecticides having fumigative effect is an added advantage.

Localized treatment of infestation is encouraged because of the heterogenous distribution pattern of *Helopeltis* in the field (Conway 1971; Tan 1974a; Wills 1986). In this situation, knapsack sprayers and mist blowers are commonly used. Taylor et al. (1982) reported that portable pulsejet foggers may also be useful for spot treatment, as the application cost is only one-fourth of that of knapsack sprayers or mist blowers. During outbreak situations, the larger pulsejet foggers could provide more rapid coverage and better bioefficacy than knapsacks or mist blowers. When fogging equipment is not available, spraying with chemicals having a strong fumigative effect at every second or more row of cocoa trees may be practised. This method has been practised in Papua New Guinea (Smith 1981).

Interval and timing of application *Helopeltis* population build-up occurs at different times of the year with the trend being dictated by the availability of food, breeding sites, and weather (Tan 1974a; Azhar et al. 1983; Azhar 1986). Since the population increases when pod numbers are high and after the onset of the rainy season, control of the pest may be achieved through application of insecticides during the period of increasing pod numbers and ascending rainfall (Tan 1974a; Azhar 1986) or during the preceding dry season (Azhar 1986). Dry season spraying has been recommended in Nigeria and has been found to delay and reduce the build-up of mirid populations (Youdeowei 1970). As the objective of a spraying programme is essentially to protect the developing young cherelles, such a programme that coincide with this particular period is appropriate. In any case, each spraying programme would essentially consist of two spray applications about 18–27 days apart (Azhar 1986; Wills 1986), with the later application aimed at destroying individuals that emerged from eggs that were protected during the earlier spray (Entwistle 1972; Azhar 1986).

Proper application timing during the day is another factor that determines the effectiveness of the spraying programme. Based on a study of the daily activity pattern of *H. theobromae*, Azhar (1986) suggested that spraying or fogging is more desirable in the early morning or early evening as more individuals are exposed during these periods. However, other factors such as practicality and weather conditions may influence appropriate timing. Taylor et al. (1982) reported that the effectiveness of fogging was enhanced when applied during 1930–2230 h as the rise of fog was suppressed by temperature inversion conditions during these hours.

Cultural control

Some cultural practices in cocoa production have become established that they may not be considered a part of the total pest management package. These include such practices as the management of shade level, pruning and the planting of resistant varieties.

Management of shade level

The role of shade in the management of *Helopeltis* is debatable. To date, no quantitative studies have been made to ascertain the role of shade in the management of *Helopeltis* in Malaysia except for isolated observational reports. *Helopeltis* is a shade-loving insect, that prefers areas with well-developed closed canopies which afford protection from the sun, heavy rain, and strong wind; or areas with high humidity (Miller 1941; Azhar and Jamaludin 1981). Smith (1979), in his review on the interrelationship between shade types and pest problems in Papua New Guinea, stated that mirid population can be damaging under a nil or short shade regime but less troublesome under the taller shade types. In West Africa, mirid infestation can be particularly damaging where there are gaps or breaks in the shade tree canopy or where overhead shade is sparse (Williams 1953; Entwistle 1972).

In Malaysia, however, no obvious relationship could be established between shade types and *Helopeltis* attack as infestations occur regardless of whether cocoa is planted under coconut or *Gliricidia*. Nevertheless, the incidence of *Helopeltis* attack was observed to be less in cocoa planted under taller shade regime (such as under tall coconut of more than 40 years old) than those planted under shorter shade regime (such as under dwarf and semi-dwarf coconuts or under heavy shade of *Gliricidia)*. This phenomenon could possibly be due to the more exposed environment under tall shade regime leading to less moisture retention capacity, greater exposure to sunlight and better aeration as compared to the low and heavy shade of cocoa monoculture under dwarf and semi-dwarf or *Gliricidia* shade. Under the latter conditions, the greater intensity of the green house effect tends to provide a relatively warm and moist atmosphere suitable for *Helopeltis* to flourish. Conversely, Lim (1978) observed that removal of shade in a monoculture cocoa in Sabah led to an increase incidence of infestation by mirids and other insect pests. Accordingly, no recommended general policy on the management of *Helopeltis* through shade manipulation could be established.

Resistant clones

Research effort on this aspect of pest management of *Helopeltis* in Malaysia is scanty. The reasons for the lack of studies could be due to the perennial nature of cocoa and the heterogenous infestation of *Helopeltis* in the field. Currently, there are no recommended clones which are less susceptible to *Helopeltis* but research is in progress to indentify clones which are less susceptible to this pest through visual assessment (Azhar 1984). Elsewhere, limited amounts of research on the susceptibility of clonal cocoa to mirids have been reported in Ghana (Posnette 1943), Cameroon and Ivory Coast (Decazy and Lotode 1975; Decazy and Coulibaly 1981) and Papua New Guinea (Smith and Moles 1981).

Hand collection and scorching

This method of *Helopeltis* control has been practised since the beginning of this century in Indonesia (Giesberger 1983). Hand collection of both adults and nymphs is made using a split bamboo stick, with one end dipped into some sticky fluid. Zehntner (1903) emphasized that the operation should be carried out when *Helopeltis* populations are low to prevent a rapid increase in the next generation. Especially in the larger plantation sector in Malaysia, this method of *Helopeltis* management is unrealistic because of time and labour costs. However, it may be useful to smallholders.

Because manual collection is time and labour intensive, scorching of *Helopeltis* on mature pods with fire was recommended in Indonesia particularly during the high population period (Giesberger 1983). However, this method was not popular and was discarded shortly. In Malaysia, scorching has never been recommended at all because it is impractical.

Biological control

Parasites and predators

Little is known of the biological control of *Helopeltis* by parasites and predators. Up to the present no parasite has ever been recorded attacking *H. theobromae* although three species of egg parasites, namely *Anagyrus* sp. (Hymenoptera: Mymaridae), *Erythmelus helopeltis* Gahan (Hymenoptera: Mymaridae) and *Telenomus* sp. (Hymenoptera: Scelionidae), have been reported to attack *H. cinchonae* on tea in Cameron Highlands (Ahmad and Ho 1980). In Java a braconid parasite, *Leiphron helopeltidis* Ferr., with its hyperparasite, *Stictopisthus javensis* Ferr., was recovered from *H. antonii* nymphs (Giesberger 1983). Attempts at releasing the parasite *L. helopeltidis* were made in Indonesia but were discontinued due to its ineffectiveness. An egg parasite, *Telenomus* sp. (Hymenoptera: Scelionidae), and a nymphal parasite, *Euphorus helopeltidis* (Hymenoptera: Braconidae), have been recorded attacking *S. singularis* and *D. theobromae* in West African cocoa with an average parasitism of 25% and 12% in Ghana and Nigeria respectively (Entwistle 1972).

The nymphs of *Helopeltis* spp. in Indonesia have also been reported to be attacked by two species of mermithid nematodes, *Hexamermis microamphidis* Steiner and *Agamermis paradecaudata* Steiner, with parasitization ranging from 5–10% (Giesberger 1983). Pathogenic fungi such as *Beauvaria, Hirsutella* and *Aspergillus* were occasionally recorded parasitizing cocoa mirids in West Africa (Collingwood 1971).

Many predators have been observed to have the potential of attacking *Helopeltis* in the field. A species of reduviid. *Cosmolestis picticeps* Stal., has frequently been encountered but its importance is not known (Azhar 1985). This species together with the others, *Sycanus leucomesus* Walk., *Isyndus heros* F., *Euagoras plagiatus* Burm., and *Rhinocoris marginellus* Thunbg. have been mass-bred and released in Cameron Highlands for the control of *Helopeltis* on tea (Corbet and Pagden 1941). However, the result of the release is not known. Conway (1971) also reported the presence of three of these reduviid species in Sabah but did not describe their significance. Spiders were also observed to attack both adults and nymphs of *Helopeltis* in the field (Azhar 1985).

Ants

Ants are the most abundant insect in the cocoa ecosystem. The dominant species are generally distributed in a mosaic pattern as a result of intense interspecific competition and the influence of light and shade regimes (Leston 1971, 1973a, 1973b; Room 1971; Majer 1972, 1976a, 1976b; Bigger 1981; Jackson 1984). Their role as a control agent of insect pests has been reviewed by Clausen (1940) and Room (1973). The use of ants as a biological control agent against cocoa mirids was realized in the early part of this century when cocoa growers in Indonesia deliberately introduced the indigenous black ant, *Dolichoderus bituberculatus* Mayr into the cocoa fields to control *Helopeltis* (Giesberger 1983). Perhaps the most extensive investigations on the ecology and role of ants in limiting cocoa mirids have been carried out in West Africa (see e.g., Leston 1971, 1973a, 1973b; Collingwood 1971; Room 1971; Majer 1972, 1976a, 1976b; Taylor 1977, 1978; Jackson 1984). Control of cocoa pests by ants have also been developed in Papua New Guinea (Room 1973; Smith 1981). In Malaysia, the importance of ants in controlling *Helopeltis* was mentioned by Conway (1971) and Mainstone (1978) who referred to the successful Indonesian example. Azhar (1985) reported the ant species composition and briefly discussed their roles in the cocoa ecosystem.

In West Africa, although numerous

Table 2. Ant species (Hymenoptera: Formicidae) collected from cocoa growing areas in Peninsular Malaysia (After Azhar 1985)

Dolichoderus thoracicus Smith	*Iridomyrmex* sp.
Dolichoderus sp. (*thoracicus* – gp.)	*Paratrexhina longicornis* (Latr.)
Crematogaster (Acrocoelia) sp.	*Paratrexhina* sp.
Crematogaster sp.	*Odontoponera transversa* (Smith)
Meranoplus sp.	*Bothroponera tridentata* (Smith)
Tetraponera rufonigra (Jerdon)	*Brachyponera* sp.
Tetraponera sp.	*Hypoponera* sp.
Anoplolepis longipes (Jerdon)	*Anochaetus* sp.
Odontomachus simillimus Smith	*Cerapachys* sp.
Odontomachus rixosus Smith	*Pachycondyla* sp.
Odontomachus haematodes L.	*Leptogenys* sp.
Diacamma regosum (Le Guillon)	*Pheidologenton* sp.
Technomyrmex albipes (Smith)	*Polyrhachis leavissima* Smith
Oecophylla smaragdina (Fab.)	*Polyrhachis tibialis* Smith
Solenopsis geminata F.	*Polyrhachis thrinax* Roger
Pheidole sp.	*Polyrhachis hector* Smith
Camponotus (Tanaemyrmex) inconspicous Mayr	*Polyrhachis bicolor* Smith
Camponotus gigas	*Polyrhachis divesr* Smith
Camponotus sp.	*Polyrhachis* sp.
Myopopone castanea (Smith)	*Monomorium* sp.
Tetramorium pacificus Mayr	*Trachymesopus* sp.

ant species are known in the cocoa ecosystem, only a few are dominant and are noted for their important role in limiting mirid attacks. Among the 52 species listed by Majer (1976) species in the genera *Oecophylla, Crematogaster* and *Macromischoides* are the most common. Although earlier evidence is somewhat conflicting (Williams 1954), the presence or absence of the cocoa mirid *D. theobroma* are known to be largely influenced by the presence and absence of one of these dominant ants (Majer 1972). Both *Oecophylla* and *Macromischoides* prey on *D. theobroma* and *S. singularis* and exclude *Crematogaster* but neither have been reported to tend mealybugs (Leston 1973a). These two species together have been reported to confer adequate protection on 65% of mature and healthy trees (Leston 1973b) although Collingwood (1971) provided a more conservative figure of only 15.2%. Attempts at artificially spreading *Oecophylla* in Ghana has not been successful. Collingwood and Marchart (1971) attributed the failure to the relative stable colonies of the *Oecophylla* which forage mainly on litter. Although the important South American ant species *Wassmannia auropunctata* Roger has been reported to give good control of cocoa mirids, the ants failed to spread outside the area of original introduction (Mire 1970).

Successful control of *Helopeltis* has been reported in Java by introducing *D. biturberculatus* into cocoa plantations provisioned with artificial nests of dried banana and cocoa leaves (Giesberger 1983). The success of this control depends entirely on the availability of the mealybug, *Planococcus lilacinus* (Cockl.), which provide the ants with honey-dew. It has been demonstrated that *Helopeltis* populations were controlled for over 40 years by maintaining large populations of ants and mealybugs. Van der Goot (1917) reported that increased mortality was observed in mealybugs unattended by the black ants as opposed to those tended by ants. Currently, in Indonesia biological control by using ants has stopped.

In Malaysia, Azhar (1985) listed 43 species of ants collected from the cocoa ecosystem *(Table 2)*. Only a few were

Table 3. Potential ant species as biological control agents of *Helopeltis*

Species	Subfamily
Dolichoderus thoracicus	Dolichoderinae
Oecophylla smaragdina	Formicinae
Anaplolepis longipes	Formicinae
Crematogaster spp.	Myrmicinae

observed to have potential in controlling *Helopeltis (Table 3)*. Among these species only *Dolichoderus thoracicus* Smith seemed to be effective against *Helopeltis*. This species is predominantly found in the cocoa-coconut ecosystem where it forms nests mainly in the coconut crown (Azhar and Musa 1988). It sometimes build temporary nests in the cocoa canopy or in the dried leaf litter on the ground and often with a trail leading to the main nest. The beneficial effect of this species is due to its mutualistic relationship with a few species of mealybugs (e.g. *Cataenococcus hispidus* (Morr.), *P. lilacinus* and *P. pacificus* Cox) which infest mainly cocoa pods and young shoots. The maintenance of large populations of these ants, which are mainly arboreal, in the cocoa plantations may be achieved by providing additional migrating alleys from their nests in the cocoa canopies using materials such as fallen coconut fronds. Proper shade level such as the complete canopy of cocoa trees should be maintained to ensure the build-up of mealybug colonies as they thrive in well-shaded fields. Although the mealybug populations may occasionally get excessively high, the populations would normally decline as a result of dispersal and mortality inflicted by various natural enemies (Azhar 1985). The use of the black ant-mealybug association to control *Helopeltis* is only feasible where cocoa is interplanted under coconut. It may not be feasible in monoculture situations because black ants do not thrive well probably due to the lack of nesting places. In addition, competition pressures impose by other ant species may affect the black ant in this ecosystem.

Other ant species that seem to provide some *Helopeltis* control are *Oecophylla smaragdina* Fab., *Anoplolepis longipes* Jerd. and *Crematogaster* spp. *Oecophylla smaragdina* does not spread very fast and they seem to acquire their food items on the ground. The problem with using *A. longipes* to control *Helopeltis* is its superior competitive effect that may drive other ant species out of the cocoa field, and its sporadic behaviour in visiting the mealybugs. *Crematogaster* spp. mostly forage or tend mealybugs inside their galleries on the branch and, therefore, any intruder on the pods may be ignored. The association of mealybugs with other ant species such as *Meranoplus* sp. may be accidental and therefore render little or no effect in deterring *Helopeltis* attack.

Use of pheromone

The presence of an attractant pheromone in *H. clavifer* has been reported by Smith (1977) in Papua New Guinea. In Malaysia, caged virgin females of *H. theobromae* has been observed to attract adult males in the fields indicating the presence of sex attractant (Azhar 1982, unpublished data). Although there were no further investigations on this aspect there are certainly prospects of incorporating pheromones in the *Helopeltis* management programme in Malaysia, especially as a useful monitoring tool.

The integrated pest management system

The evolution of pest management strategies for *Helopeltis* in Malaysia has centred entirely on the use of chemicals. However, over reliance on chemicals has been shown to be environmentally and economically unsound (Conway 1969; Azhar 1985). Unexpected problems such as outbreaks of secondary pests may appear following unjustified chemical applications. Although insecticide resistant strains of *H. theobromae* have not been detected in Malaysia (Dzolkhifli et al. 1986) its eventual development may lead to a situation of 'pesticide treadmill' (van den Bosch 1975). There is no denying that chemicals have an important role in the management of *Helopeltis* but they have to be harmoniously incorporated into an integrated pest management (IPM) system to ensure maximum economic benefits with minimal costs incurred. IPM is a dynamic system and may be adjusted according to variations in cocoa cultural practices or to incorporate any new information gathered periodically from field research. In Malaysia, cocoa is either planted as a smallholder's crop of minimal acreage or as a plantation crop with areas of more than 100 ha. In addition, cocoa may be planted either as an intercrop under coconut or as a monoculture under *Gliricidia* shade. Each of these planting systems certainly influences the management strategies of *Helopeltis* as the environmental variables within each system will differentially affect the ecology and behaviour of *Helopeltis*. However, the following underlying elements of IPM as listed by Flint and van den Bosch (1982) do not vary:

- Decision maker, in this case either the owner or the manager
- Knowledge or information about the pest
- Sampling or monitoring
- Decision making criteria
- Management tactics

Detailed elaboration of these elements were given by Flint and van den Bosch (1982) and Smith (1983). Examples of successful implementation of IPM against *Helopeltis* are provided by the system of mirid control practised in the Lubolela plantation in the Congo Republic (Entwistle 1972), Pabatu Estate in North Sumatra, Indonesia (Youdeowei and Toxopeus 1983) and Dunlop Sagil Estate, Johore (Wills 1986).

Implementation of the IPM programme

The IPM system can be implemented by both estates and smallholdings. However, the smallholders may not have as elaborate a system as the estates since their resources are rather limited. The key to the development of this approach is monitoring with the ultimate objective of reducing the amount of chemical usage. Blanket spraying is common among smallholders regardless of pest status. This is because smallholders are normally ignorant or have little information about the pest. At the same time the small area of the holding may be completely infested necessitating blanket spraying. However, the management system may be improved if the grower carries out regular monitoring to ensure that chemical application is applied at the correct time to achieve increased effectiveness and reduce the frequency of chemical application. Weather pattern and cropping phenology should also be considered in deciding chemical application. It has been found in various studies (Tan 1974a; Azhar 1986; Wills 1986) that the best time to apply chemicals is when there is maximum build-up of *Helopeltis* which coincide with ascending rainfall and increasing pod numbers. Spot treatment of only the infested trees could spare some of the beneficial insects available within the holding. Although this approach is slightly laborious it may be compensated by the small size of the holding. The availability of black ants, especially under the cocoa-coconut ecosystem, further necessitates spot treatment. Nevertheless,the effectiveness of this management system may not be lasting due to the immigration of breeding adults from the surrounding, unmanaged holdings. As such, the institution of a regional approach to *Helopeltis* management is often necessary to achieve persistent effectiveness which is economically and environmentally justifiable. This requires cooperative efforts from all growers within the region.

In the estate sector, pest management system is often better implemented than in the smallholder sector. Here, pest and disease situations are routinely monitored and infestations are promptly treated. The treatment methods, whether fogging, spot treatment or blanket spraying depend on the severity of infestation. Since monitoring is mainly on the basis of detecting the presence or absence of damage, the detection of damage is occasionally late leading to heavy chemical application to suppress the high population causing the damage. As such, the system is also inefficient in terms of cost-effectiveness. This leads to the development of a management using the Early Warning System (EWS) or Early Response System (ERS).

Early warning system

This approach was initiated and practised in a North Sumatran cocoa estate (Wignyosoemarto and Soebiyakto 1980; Youdeowei and Toxopeus 1983). The use of this system in Malaysia is as recent as 1986 when Wills reported the adoption of this system at the Dunlop Sagil Estate, Johore. Basically, the objective of this approach is to reduce the amount of chemicals used without reducing its effectiveness. In this system the areas of infestation or aggregation of *Helopeltis* are located and treated in the early stages of population build-up limiting the outbreak. The development of this system takes into consideration various factors involving the biology of *Helopeltis*, such as the rapid build-up of its population (Youdeowei and Toxopeus 1983), its aggregation behaviour (Wills 1986) and the condition of the cocoa canopy (Youdeowei and Toxopeus 1983). Azhar (1986) also suggested the incorporation of the cropping cycle or pod numbers and weather patterns, especially rainfall, as well as consideration on the existing status of the naturally occurring biological control agents, such as ants, in this system.

The organization of this pest management system has been outlined by (Wignyosoemarto and Soebiyakto 1980; Youdeowei and Anwar (1983) and Wills (1986). Generally, the total cocoa area is divided into sections or blocks of proportionate size which are then subdivided into plots of 5 ha *(Figure 1)*. Monitoring is carried out within subplots consisting of an appropriate number of cocoa trees to allow for satisfactory identification of aggregations as used by Wills (1986). A subplot consists of a group of four trees distributed evenly at 5.5 groups per hectare. Wills (1986) carried out monitoring at 18 days interval as the life cycle of *Helopeltis* from egg to adult is about 21 days. He also secured the actual number of *Helopeltis* at a hand height using a scoring system of 1 to 5; a score of 1 indicates one insect, 2 indicates two, and so on but a score of 5 indicates that five or more than five insects have been recorded. He advocated immediate chemical treatment only to subplots and adjacent plots with a score of 3 to 5. However, he did not take into consideration the presence of ants (such as their distribution) as a natural control

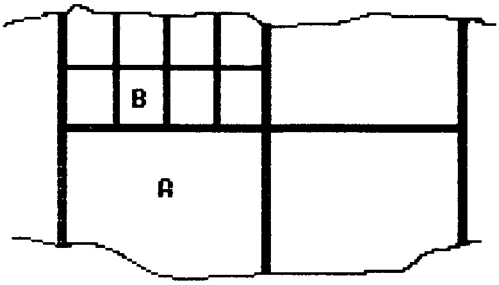

Figure 1. Implementation procedures of EWS. Demarcation of the area into main plots of 5 ha each (A) and establishment of subplot (B) where sampling will be carried out on predetermined number of trees

agent in the cocoa field although they are known to provide some control of *Helopeltis* in the field (Azhar 1985).

The use of this system has been demonstrated to reduce the amount of insecticide and labour required in addition to a reduction in yield loss due to *Helopeltis* (Youdeowei and Toxopeus 1983; Wills 1986). Wills (1986) indicated that only 5% of the total area at each inspection round required treatment. In North Sumatra, Youdeowei and Toxopeus (1983) reported the use of chemicals was reduced by 50% through the implementation of this system. As a result of the reduction in insecticide usage through spot treatment, the ecology of the ecosystem is maintained and the natural enemies spared. In addition, the establishment of this system allows for the monitoring of other aspects of cocoa growing such as diseases and crop level. As problems are uncovered appropriate remedies can be immediately implemented.

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