UNIVERSITI PUTRA MALAYSIA

RELATIONSHIP BETWEEN THE BLACK COCOA ANT, DOLICHODERUS THORACICUS SMITH (HYMENOPTERA: FORMICIDAE) AND THE COCOA POD BORER, CONOPOMORPHA CRAMERELLA SNELLEN(LEPIDOPTERA: GRACILLARIIDAE) IN A COCOA-COCONUT ECOSYSTEM

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By

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Thesis Submitted in Fulfilment of the Requirements for the Degree of Master of Agricultural Science in the Faculty of Agriculture, Universiti Pertanian Malaysia

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by

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MARCH 1996

Chairman: Dr. Khoo Khay Chong

Faculty: Agriculture

The relationship between the black cocoa ant *Dolichoderus thoracicus* Smith (Hymenoptera: Formicidae) and the cocoa pod borer *Conopomorpha cramerella* Snellen (Lepidoptera: Gracillariidae) was studied in a cocoa-coconut field. *D. thoracicus* was present in moderate to high abundance in the field at the beginning of the experiments. In one treatment, the *D. thoracicus* population was depressed with insecticides (ant-scarce plots) and was augmented in the other treatment by the provision of artificial nests and dried leaf shelters (ant-abundant plots). The percentage of *C. cramerella* infestation in ant-abundant plots was generally less than 50% while the reverse was true in ant-scarce plots. Even though there was no significant difference in the percentage of pods which were infested and extractable as well as partially extractable, the percentage of unextractable pods in ant-abundant plots was significantly lower than in ant-scarce plots, indicating that *D. thoracicus* reduced the severity of *C. cramerella* infestation. This difference was evident throughout the trial. Mammalian damage was also more pronounced in ant-scarce plots. In a survey of the relationship between *D. thoracicus* pod abundance and *C. cramerella* infestation conducted within and outside the trial area, the two were found to be negatively related. Pods within the trial plots also had less *C. cramerella* damage compared to those outside the trial plots, indicating a possible attrition effect. Pods from which *D. thoracicus* were deliberately excluded also had a higher incidence of infestation compared to pods on which *D. thoracicus* was enhanced. Moderate *D. thoracicus* abundance on pods was sufficient to prevent *C. cramerella* infestation. The mechanism of control was probably deterrence of *C. cramerella* oviposition. This study shows that encouraging *D. thoracicus* is beneficial to cocoa as it reduces the damage of two major pests, *C. cramerella* and mammals.

Abstrak Tesis Yang Dikemukakan kepada Senat Universiti Pertanian Malaysia Sebagai Memenuhi Syarat Keperluan Untuk Ijazah Master Sains Pertanian

PERHUBUNGAN SEMUT HITAM, *DOLICHODERUS THORACICUS* SMITH (HYMENOPTERA: FORMICIDAE) DENGAN PENGOREK BUAH KOKO, *CONOPOMORPHA CRAMERELLA* SNELLEN (LEPIDOPTERA: GRACILLARIIDAE) DALAM EKOSISTEM KOKO-KELAPA

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Perhubungan semut hitam koko *Dolichoderus thoracicus* Smith (Hymenoptera: Formicidae) dengan pengorek buah koko *Conopomorpha cramerella* Snellen (Lepidoptera: Gracillariidae) dikaji di sebuah ladang koko-kelapa. *D. thoracicus* hadir dalam kepadatan yang sederhana ke tinggi pada permulaan kajian. Kepadatan *D. thoracicus* dalam satu rawatan dikurangkan dengan semburan racun serangga (plot kurang-semut) dan peningkatan melalui augmentasi dengan menggunakan sarang buatan dan penutup daun kering dalam rawatan yang lain (plot

banyak-semut). Peratus infestasi *C. cramerella* di dalam plot banyak-semut secara amnya tidak melebihi 50% manakala sebaliknya berlaku di plot kurang-semut. Walaupun tidak terdapat perbezaan yang bererti di antara peratus lenggai yang diserang dan boleh diekstrak serta separa boleh dieskstrak, peratus lenggai yang tidak boleh diekstrak di plot banyak-semut lebih rendah dengan bererti berbanding dengan plot kurang-semut. Ini menunjukkan bahawa *D. thoracicus* mengurangkan keterukan infestasi *C. cramerella*. Perbezaan ini agak ketara pada keseluruhan kajian. Kerosakan oleh mamalia juga didapati lebih serius dalam plot-plot kurang-semut. Dalam survei perhubungan antara kepadatan *D. thoracicus* dengan infestasi *C. cramerella* yang dijalankan di dalam dan di luar kawasan kajian, keduanya didapati mempunyai perhubungan negatif. Lenggai di dalam kawasan kajian kurang dirosakkan oleh *C. cramerella* berbanding dengan yang di luar. Ini menunjukkan kemungkinan berlakunya penyisihan. Lenggai yang mana *D. thoracicus* telah diasingkan dengan sengaja mempunyai kadar infestasi yang lebih tinggi berbanding dengan lenggai di mana *D. thoracicus* dibiarkan. Kepadatan *D. thoracicus* pada tahap sederhana adalah mencukupi untuk mencegah infestasi. Ada kemungkinan mekanisme kawalan ialah penghindaran oviposisi *C. cramerella*. Kajian ini menunjukkan bahawa penggalakan *D. thoracicus* adalah berguna kepada koko kerana ia mengurangkan kerosakan oleh dua perosak utama, *C. cramerella* dan mamalia.

CHAPTER I

INTRODUCTION

The cocoa pod borer, *Conopomorpha cramerella* Snellen (Lepidoptera: Gracillariidae) is the most damaging pest of cocoa in the tropics. It is indigenous to this region, being known to occur on native fruits like rambutan (*Nephelium lappaceum*), kasai (*Pometia pinnata*) and nam-nam (*Cynometra cauliflora*) (Loke et al., 1986; Ooi et al., 1987). The origins of *C. cramerella* on cocoa is vague; the pest is believed to have evolved to feeding on cocoa after the crop was planted on a large scale (Ooi et al., 1987). Since then the devastating effect of *C. cramerella* on cocoa has propelled the pest to its current position as a major agricultural pest in the region. Infestation of cocoa by *C. cramerella* occurs throughout the South-east Asian region, spanning from the Maluku islands in the east to Sumatra in the west and Mindanao in the north. Two of the 3 countries encompassed by this region, Malaysia and Indonesia, are major cocoa growers.

C. cramerella is not a new problem in cocoa, having been recorded as a pest early this century in Northern Sulawesi (Snellen, 1904). Earlier efforts to eradicate the pest were largely unsuccessful; the pest was eliminated in most cases only when cocoa was replaced with other crops. Such was the case in Sulawesi as no satisfactory method of control was available then. Concerted efforts to control *C. cramerella* were renewed when large areas of cocoa in Sabah and Peninsular Malaysia were infested in the early 1980s at the height of the cocoa boom (Ooi et al., 1987; Mumford, 1988).

C. cramerella is so damaging to cocoa primarily because it causes a direct yield loss. Larval feeding in the pod causes beans to stick to each other and the husk, making it difficult to remove the beans (Day, 1985). In a severe infestation, more than 50% of the pods may be unextractable (Lim & Phua, 1986) accounting for corresponding losses in yield. Infestation is also believed to affect bean size and quality (Lim & Phua, 1986). The problem is compounded because the pest tends to spread quickly and reaches serious levels if left unchecked.

Despite the presence of *C. cramerella*, the cocoa industry by and large survived as a certain amount of infestation could be tolerated without noticeable loss in yield as shown in later studies (Day, 1985; Lim & Phua, 1986). Efforts were subsequently directed at reducing the impact of the pest rather than eradicating it.

C. cramerella is still a major challenge to cocoa growers. Control of *C. cramerella* has increased production costs substantially. The high labour needed in current *C. cramerella* control methods has discouraged cocoa planting in Peninsular

Malaysia where labour is scarce and is partially responsible for the waning cocoa industry here (Zam & Ramasamy, 1993).

Current *C. cramerella* control measures centre on the use of pesticides (Mumford, 1988). Spraying has to be carried out regularly and frequently to keep infestation in check. However, the continued use of chemicals to control such a persistent pest is not without its drawbacks. The nature of the pest makes it necessary to carry out spraying thoroughly and frequently (Johney et al., 1986), whereas the labour required to conduct spraying is both costly and scarce. There have also been indications that *C. cramerella* has developed resistance to some pyrethroids. In addition, consumers, especially in developed countries, have voiced concern over the excessive use of pesticides in cocoa production. In order to minimise the use of pesticides both for ecological and commercial reasons, there is a need for the development of an alternative to chemical spraying. This is an incentive for the development of biological control programmes of *C. cramerella*.

Two natural enemies have been tested against *C. cramerella* in the field; the egg parasitoid, *Trichogrammatoidea bactrae fumata* Nagaraja (Hymenoptera: Trichogrammatidae) (Lim, 1983) and a predatory ant, *Dolichoderus thoracicus* Smith (Hymenoptera: Formicidae) (Khoo et al., 1993). *T. bactrae fumata*, while showing good results in reducing *C. cramerella* populations (Lim, 1983), is not self-perpetuating in the field (Lim & Chong, 1987). This means that regular mass releases have to be conducted to replenish field populations (Lim, 1991), which in turn increases cost and makes the method not viable commercially.

The black cocoa ant, *D. thoracicus*, which is indigenous to the region has been found to be effective in reducing cocoa losses due to the mirid, *Helopeltis theivora* Waterhouse in Malaysia (Khoo & Chung, 1989; Way & Khoo, 1989; Khoo & Ho, 1992), and *H. bradyi* Waterhouse and *H. clavifer* Walker in Indonesia (Giesberger, 1983). In addition, *D. thoracicus* is also associated with the reduction of losses due to rodent and black pod damage (Khoo & Ho, 1992). Unlike the homopteran component in some ant-homopteran associations which are detrimental to the host plant (Beattie, 1985), the mealybug tended by *D. thoracicus*, *Cataenococcus hispidus* Morrison (Homoptera: Pseudococcidae), is largely innocuous to cocoa (Khoo & Ho, 1992). The ant can also be manipulated . This has paved the way for the exploitation of the ant-homopteran interaction in cocoa to manage other pests.

Although there have been indications that *D. thoracicus* may have a negative effect on *C. cramerella* (Khoo et al., 1993; Ho, 1994), its usefulness has not yet been properly ascertained. Before *D. thoracicus* can be utilised for *C. cramerella* control, its effect over a longer period of time and larger scale needs to be verified.

relationship between plant, pest and natural enemy with weather, and the mechanisms involved in the control were also be studied. In the following chapters, the experiments conducted to study specific objectives are described. In Chapter III, experiments carried out to determine the ecological relationship between *D. thoracicus* and *C. cramerella* are detailed. Chapter IV deals with the effect of *D. thoracicus* pod abundance on *C. cramerella* control. Finally in Chapter V, the effect of *D. thoracicus* establishment on *C. cramerella* infestation is given.

CHAPTER II

LITERATURE REVIEW

Ants in Biological Control

One of the earliest records of biological control in agriculture was the utilisation of *Oecophylla* sp. for the control of mandarin orange pests (Huang & Yang (1987) as quoted in Way & Khoo, 1992). Since then, many other species of ants have been identified as being potentially useful in pest management. Predaceous ants are especially useful as biological control agents (Way & Khoo, 1992) and may constitute a major component of natural control in annual (Risch & Carroll, 1982; Godfrey et al., 1989; Lee et al., 1990; Perfecto, 1991; Perfecto & Sediles, 1992; Sturm et al., 1990) and perennial ecosystems (Stapley, 1980; Tryon, 1986; Way et al., 1989; Jaffe et al., 1990; Lohr, 1992; Paulson & Akre, 1992). Ant species most useful in biological control are those which utilise many different sources of food (Way & Khoo, 1992). These ants would not need to depend on the density of a single prey species or food source to thrive in high numbers (Risch & Carroll, 1982) as would most parasitoids (Parker, 1969) and would therefore be more stable even though a food source may fluctuate (Risch & Carroll, 1982). However, the use of ants in pest management is limited compared to the use of parasitoids. This is due mainly to beneficial effects often being accompanied by non-desirable effects.

Predatory ants known to protect trees against herbivores will usually also cause some damage to plants or irritate workers (Way & Khoo, 1992). Many predatory species useful for biological control also tend honeydew-producing homopterans which may be detrimental to plants (Adlung, 1966; Finnegan, 1971; Beattie, 1985; Delabie, 1990; Samways, 1990). Ants, especially tent-building species are also responsible for encouraging black pod disease (Evans, 1973; McGregor & Moxon, 1985; Delabie, 1990). The aggressiveness of ants often deter more than herbivores. Beneficial organisms like parasitoids of herbivorous insects are often deterred or preyed on as well (Adlung, 1966; Fritz, 1983). Direct damage to trees through herbivory has also been recorded (Delabie, 1990; Banks et al., 1991). In addition, ants are usually an irritant to workers on account of their painful bites and stings and may be considered pests because of that (Delabie, 1990; Way & Khoo, 1989; Way & Khoo, 1991).

Effect of Ant Abundance on Control Effectiveness

Abundance is an attribute which characterises ants and makes them useful as biological control agents (Way & Khoo, 1992). Ant colonies may range from small dispersed colonies numbering a few scores (Wilson & Regnier, 1971) to huge dense colonies covering many hectares (Haines & Haines, 1978; Higashi & Yamanchi, 1979). Ant species with the propensity to maintain high nest populations are considered more valuable in pest control (Finnegan, 1971). Ants are not only able to achieve large populations, they are also stable at such densities (Way & Khoo, 1992). Their complex colony structures with precise division of labour enable them to dominate large areas of a habitat and exploit its resources optimally (Holldobler & Wilson, 1977a; Holldobler, 1983). Therefore the larger a colony is, the larger the area it is able to forage (Finnegan, 1971).

The efficiency with which ants limit pest populations is often related to their abundance. Better control is usually achieved when ant abundance in a habitat or crop is high (Way et al., 1989; Way & Khoo, 1989; Way & Khoo, 1991; Lohr, 1992; Way et al., 1992) because their territory is more thoroughly foraged. Species thought to be useful in biological control are also usually dominant species which are the most numerically superior species in their territory (Leston, 1973; Taylor, 1977).

Ants in the Cocoa Ecosystem

Ants are found in high abundance and diversity in tropical habitats. In the cocoa ecosystem, they constitute a major part of the fauna (Entwistle, 1972). Ants play a mixed role in cocoa ecosystems, being responsible for transmitting diseases (Evans, 1973; Taylor, 1977; Delabie, 1990), and encouraging pests like aphids and mealybugs (Taylor, 1977; Wood & Lass, 1985) but also conferring protection against some pests (Leston, 1973; Taylor, 1977; Geisberger, 1983; Fataye et al., 1989; Way & Khoo, 1989; Way & Khoo, 1991; Khoo & Ho, 1992; Majer & Delabie, 1993). Certain species of ants have been identified to be beneficial to cocoa, the most important being *Oecophylla smaragdina* Fabricius (Stapley, 1980; Way & Khoo, 1989; Way & Khoo, 1991), *O. longinoda* Latreille (Fataye et al., 1989) and *Dolichoderus thoracicus* Smith (Geisberger, 1983; Khoo & Chung, 1989; Way & Khoo, 1989; Way & Khoo, 1991; Khoo & Ho, 1992).

D. thoracicus

Dolichoderus thoracicus belongs to the Dolichoderinae family. The members of this more advanced family do not possess a sting but have anal glands which produce volatile alarm and defence secretions (Cavill & Robertson, 1965). Other members of the Dolichoderinae family like *Iridomyrmex* spp. are relatively more well-studied than *Dolichoderus* spp. Our knowledge of *D. thoracicus* habits and behaviour are based on the works of a few researchers mainly Khoo & Chung (1989), Ho (1991) and Way & Khoo (1991). Most of the research centred on the study and manipulation of *D. thoracicus* for the control of the cocoa mirid, *Helopeltis theivora*. Little is known about *D. thoracicus* population dynamics as no work has been conducted in this area. Findings about the mutualistic relationship with mealybugs, nesting habits and potential abundance of *D. thoracicus* are summarised as follows.

Mutualistic Relationship with *C. hispidus*

D. thoracicus is a homopteran tending species, utilising the honeydew produced by homopterans for food (Khoo & Chung, 1989). On cocoa, *D. thoracicus* is known to tend several species of homopterans; *C. hispidus* (Ang, 1988; Khoo & Chung, 1989), *Planococcus lilacinus* Cockerell (Roepke, 1916; Khoo & Chung, 1989), *Pseudococcus elisae* Borkhsenius and *Maconellicoccus hirsutus* Green (Khoo & Chung, 1989). Among the species, *C. hispidus* is the most widely distributed and abundant (Khoo & Chung, 1989). It has therefore been regularly established artificially to enhance *D. thoracicus* abundance (Ang, 1988).

C. hispidus is an especially important source of food for *D. thoracicus* (Khoo & Chung, 1989), being known to provide sole sustenance to *D. thoracicus* for up to two months without any noticeable damage to *D. thoracicus* colonies (Ho, 1991). *D. thoracicus* colonies on cocoa trees seem to be limited to pods where *C. hispidus* is present (Way & Khoo, 1991). *D. thoracicus* is usually absent from trees without large or medium sized pods on which *C. hispidus* colonies can be established.

Conversely, *C. hispidus* is dependent on *D. thoracicus* for its survival. *C. hispidus* colonies in the absence of *D. thoracicus* are quickly decimated by rain and predators (Ang, 1988). Although *C. hispidus* may be found in profusion on cocoa pods when *D. thoracicus* abundance is high, it is largely innocuous (Khoo & Ho, 1992). *C. hispidus* in very large numbers may cause pod chlorosis and stunting of cherelles (Khoo & Chung, 1989). However, no decrease in yield was recorded in areas where both *D. thoracicus* and *C. hispidus* were established in high numbers (Khoo & Ho, 1992).

Nesting Habits

D. thoracicus is known to be non-selective in its choice of nesting sites (Khoo & Chung, 1989; Way & Khoo, 1991). Nests have been found both on the ground and on trees as long as the space is dark and dry (Khoo & Chung, 1989). On the ground, nests usually occur in thick leaf litter or among fallen coconut fronds. In mixed cocoa-coconut stands, *D. thoracicus* is found nesting mostly on coconut palms. Large stable colonies are usually established on coconut spadices (Way & Khoo, 1991). *D. thoracicus* will nest in any suitable sites on cocoa trees although colonies found on cocoa trees are usually small and unstable. These nests are normally constructed between the crevices of leaves pressed together or against branches. *D. thoracicus* generally traverse between trees aerially, using overlapping branches and leaves as bridges between trees.

Abundance

D. thoracicus has the potential to achieve high densities over a large area (Way & Khoo, 1991). However in certain habitats as in mixed cocoa-coconut gardens, it also exists in small, separate colonies. *D. thoracicus* abundance on cocoa trees is constrained by suitable nesting sites. The natural abundance of *D. thoracicus* is therefore not high unless artificial nests are placed on the trees (Giesberger, 1983; Khoo & Chung, 1989). *D. thoracicus* abundance is generally confined to areas intercropped with coconut due to the natural nesting sites provided by coconut spadices and old fronds on the ground. In areas interplanted with gliricidia only, *D. thoracicus* does not normally achieve high abundance.