UNIVERSITI PUTRA MALAYSIA

PERSISTENCE OF SELECTED PYRETHROIDS IN THE COCOA ECOSYSTEM AND ITS TOXICITY ON THE BLACK COCOA ANT, DOLICHODERUS THORAOCUS SMITH (HYMENOPTERA: FORMICIDAE)

SULAIMAN GINTING

FP 2001 26

PERSISTENCE OF SELECTED PYRETHROIDS IN THE COCOA ECOSYSTEM AND ITS TOXICITY ON THE BLACK COCOA ANT, *DOLICHODERUS THORACICUS* SMITH (HYMENOPTERA: FORMICIDAE)

SULAIMAN GINTING

MASTER OF AGRICULTURAL SCIENCE
UNIVERSITI PUTRA MALAYSIA
2001

PERSISTENCE OF SELECTED PYRETHROIDS IN THE COCOA ECOSYSTEM AND ITS TOXICITY ON THE BLACK COCOA ANT, *DOLICHODERUS THORACICUS* SMITH (HYMENOPTERA: FORMICIDAE)

By

SULAIMAN GINTING

Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of Agricultural Science in the Faculty of Agriculture Universiti Putra Malaysia

February 2001

Abstract of thesis submitted to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Agricultural Science

PERSISTENCE OF SELECTED PYRETHROIDS IN THE COCOA ECOSYSTEM AND ITS TOXICITY ON THE BLACK COCOA ANT, *DOLICHODERUS THORACICUS* SMITH (HYMENOPTERA: FORMICIDAE)

By

SULAIMAN GINTING

February 2001

Supervisor : Prof. Dr. Khoo Khay Chong

Faculty : Agriculture

The persistence of pyrethroids in the cocoa ecosystem and its toxicity on the black cocoa ant *Dolichoderus thoracicus* Smith (Hymenoptera: Formicidae) were studied in a series of experiments using chemical assay through gas chromatography and biological assay using *D. thoracicus* workers. Samples of soil were taken from an estate in Sabah from plots that had been subjected to different regimes of pyrethroid application labelled low, moderate and frequent, and compared with soil taken from an area with no history of pyrethroid usage (control). Both the chemical and biological assays showed that the pyrethroids were present in larger amounts and caused higher mortality in the order: frequent >moderate> low >control.

The role of light on the degradation of cypermethrin on leaf litter and in soil was examined. Samples of leaf litter treated with 0.011% cypermethrin solution were exposed to various light intensities and then chemically and biologically assayed at various times after treatment. At the end of the experiment, under light intensities of 200, 2000, 4000, 6000 and 8000 Lx the degradations rates of cypermethrin residue were 16, 42, 55, 67 and 87% respectively; the mortality rates of *D. thoracicus* were 89, 68, 47, 32 and 12% respectively. A similar experiment was carried out using 500 g soil treated with 125 ml of 0.011% cypermethrin solution. The degradation rates at the end of the experiment at light intensities of 200, 2000, 4000, 6000 and 8000 Lx were 13, 16, 22, 35 and 43% respectively; the mortality rates of *D. thoracicus* were 99, 96, 85, 69 and 18% respectively. Light therefore plays an important role in the degradation of cypermethrin and the degradation was influenced by intensity and time of exposure.

The possibility that the pyrethroid residues could be reduced through the use of the common soil amendment, ground magnesium lime (GML) was investigated through laboratory and field experiments. In the laboratory experiment, 500 g samples of soil were treated with 125 ml of 0.011% cypermethrin solution and then followed with GML at dosages of 0, 2.5, 5, 7.5 g per sample. At the end of the experiment, the degradation rates were 12, 18, 20 and 32% respectively, while the mortality rates of *D. thoracicus* were 100, 100, 91 and 82% respectively. In the field experiment, microplots (50 x 50 cm) were demarcated in a cocoa field and treated with 20 ml of

0.011% cypermethrin solution. The plots were then treated with GML at various dosages of 0, 50, 100 and 200 g per microplot. At the end of the experiment, the degradation rates were 18, 25, 58 and 89% respectively, while the mortality rates of *D. thoracicus* were 84, 68, 6 and 1% respectively. Thus GML accelerated the degradation of cypermethrin in the soil and the degradation was influenced by the dosage of GML and time of exposure.

The studies show that pyrethroids can persist in the cocoa ecosystem for a long time and affect establishment of *D. thoracicus* for biological control. Amount of pyrethroids in the soil was related to the poor availability of light that is important in degradation of pyrethroids in the cocoa ecosystem. Although degradation of pyrethroids in the soil can be accelerated by applying GML, the persistence of these insecticides would have a severe effect on the fauna in the cocoa ecosystem. This is an important consideration when deciding on the use of pyrethroids for cocoa pest control.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains Pertanian

KEKEKALAN PIRETROID TERPILIH DALAM EKOSISTEM KOKO DAN TOKSISITINYA KE ATAS SEMUT HITAM KOKO, *DOLICHODERUS THORACICUS* SMITH (HYMENOPTERA: FORMICIDAE)

Oleh

SULAIMAN GINTING

Februari 2001

Penasihat : Prof. Dr. Khoo Khay Chong

Fakulti : Pertanian

Kekekalan piretroid di dalam ekosistem koko dan toksisitinya ke atas semut hitam koko *Dolichoderus thoracicus* Smith (Hymenoptera: Formicidae) telah dikaji melalui beberapa siri ujikaji menggunakan asai kimia melalui kaedah kromatografi gas dan kaedah asai biologi ke atas semut pekerja *D. thoracicus*. Sampel-sampel tanah yang telah diperolehi dari estet koko di Sabah dari plot yang telah terdedah pada aplikasi berbagai regim piretroid yang dilabelkan sebagai rendah, sederhana dan kerap telah dibandingkan dengan tanah yang diambil dari kawasan yang tiada sejarah penggunaan piretroid (kawalan). Kedua-dua ujian kimia dan asai biologi menunjukkan pyrethroid tersedia ada dengan banyaknya dan menyebabkan kematian

yang tinggi mengikut aturan penggunaan kerap > sederhana > rendah > kawalan.

Peranan cahaya terhadap penguraian sipermetrin pada serasah daun dan tanah telah diselidiki. Sampel serasah daun yang telah dirawat dengan 0.011% larutan sipermetrin telah didedahkan kepada berbagai peringkat keamatan cahaya dan kemudian dilakukan asai kimia dan biologi pada beberapa peringkat masa lepas rawatan. Pada penghujung ujikaji, pendedahan di bawah keamatan cahaya 200, 2000, 4000, 6000 dan 8000 Lx kadar penguraian masing-masing adalah 16, 42, 55, 67 dan 87%; kadar kematian *D. thoracicus* masing-masing adalah 89, 68, 47, 32 dan 12%. Ujikaji yang seumpamanya telah dijalankan menggunakan 500 g tanah yang dirawat dengan 125 ml larutan 0.011% sipermetrin. Kadar penguraian pada penghujung ujikaji di bawah pengamatan cahaya 200, 2000, 4000, 6000 dan 8000 Lx ialah masing-masing 13, 16, 22, 35 dan 43%; kadar kematian *D. thoracicus* masing-masing ialah 99, 96, 85, 69 dan 18%. Dengan ini cahaya terbukti memainkan peranan penting dalam penguraian sipermetrin dan kadar penguraian telah dipengaruhi oleh keamatan cahaya dan tempoh pendedahan.

Kemungkinan bahawa residu piretroid boleh dikurangkan melalui pembaikan tanah secara pengapuran kapur magnesium (GML) telah dikajiselidiki menerusi ujikaji di makmal dan lapangan. Dalam ujikaji di makmal, sample 500 g tanah telah dirawat dengan 125 ml larutan 0.011% sipermetrin dan kemudian diikuti dengan GML pada kadar 0, 2.5, 5 dan 7.5

g bagi setiap sampel. Pada penghujung ujikaji, kadar penguraian masing-masing ialah 12, 18, 20 dan 32%, manakala kadar kematian *D. thoracicus* masing-masing ialah 100, 100, 91 dan 82%. Dalam ujikaji di lapangan, mikroplot (50 x 50 cm) telah ditentukan dan dirawat dengan 20 ml larutan 0.011% sipermetrin. Setiap plot kemudiannya dirawat dengan GML mengikut kadar yang berlainan dari 0, 50, 100 dan 200 g bagi setiap mikroplot. Pada penghujung ujikaji, didapati kadar penguraian masing-masing adalah 18, 25, 58 dan 89%, manakala kematian *D. thoracicus* pula masing-masing ialah 84, 68, 6 dan 1 %. Oleh itu, GML telah mempercepatkan penguraian sipermetrin di dalam tanah dan penguraian ini dipengaruhi oleh kadar penggunaan GML dan masa pendedahan.

Kajian menunjukkan bahawa piretroid dapat kekal di dalam ekosistem koko untuk suatu jangka masa yang lama dan memberi kesan kepada pertapakan *D. thoracicus* untuk kawalan biologi. Amaun piretroid di dalam tanah berhubungkait dengan kurangnya kedapatan cahaya yang memainkan peranan penting di dalam penguraian piretroid dalam ekosistem koko. Sungguhpun penguraian piretroid dapat dipercepatkan dengan aplikasi GML, kekekalan racun serangga ini akan mengakibatkan kesan merbahaya ke atas fauna di dalam ekosistem koko. Ini adalah suatu pertimbangan yang penting dalam memutuskan penggunaan piretroid untuk kawalan perosak koko.

ACKNOWLEDGMENTS

I would like to express my sincere gratitude to the numerous people who have been invaluable to me during my study. The first on the list is Prof. Dr. Khoo Khay Chong, the Chairman of my Supervisory Committee, for his valuable guidance, ideas and for his constructive suggestions as well as time spent for the supervision of the research work. I credit him as the best supervisor a student could ask for.

I am grateful to Assoc. Prof. Dr. Dzolkhifli Omar and Assoc. Prof. Dr. Yusof Ibrahim, the members of my supervisory committee, for their support, suggestions and guidance. I thank the staff of the Plant Protection Department for providing logistical support.

This study was partially financed by the American Cocoa Research Institute and is gratefully acknowledged.

I am indebted to my fellow graduate students and to the Indonesian Student Association for their co-operation and a very nice friendship during the study.

Finally, my deepest appreciation goes to my father, H. Mustafa Majnu MSc., PhD., my mother, Hj. Nurlela Sitepu, and my brothers and sisters for the enormous amount of love, support and sacrifice that they have given.

Above all, my praise to Almighty God, Allah SWT., for all His blessing on me and my family.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATE

CHAPTER I

INTRODUCTION

Cocoa, *Theobroma cacao* Linnaeus, is an important crop for both Indonesia and Malaysia. Indonesia is presently the third largest exporter of cocoa beans in the world while Malaysia is the seventh (ICCO, 1999).

The presence of pests on cocoa has a serious effect on cocoa production. In Southeast Asia many insect pests have been reported on cocoa (Conway, 1971; Wardojo, 1992), however, only two seriously affect production. The two key pests are the cocoa pod borer, *Conopomorpha cramerella* Snellen, and the mirid, *Helopeltis theivora* Waterhouse (Lim *et al.*, 1982; Khoo, 1987). These two pests can cause persistent yield reduction in cocoa if left unmanaged. Due to the damage they cause, many areas have been abandoned both in Indonesia and Malaysia (Lim, 1992; Wardojo, 1992; Lockwood *et al.*, 1994).

Although there are many methods to control these pests, the chemical approach is the most commonly practised both in smallholdings and estates (Khoo, 1987; Lee and Sidhu, 1994). Many insecticides can be used to control these pests, but in practice, pyrethroid insecticides are the most commonly applied (Ho, 1987; Lim, 1992).

Pyrethroids are broad-spectrum and non-systemic insecticides, which are effective following contact and ingestion and are highly toxic at low dosages (Elliot, 1989; Hirano, 1989).

A possible disadvantage of the later generation of pyrethroids which also could be their advantage is that they are highly persistent in the soil. Used as termiticides or as soil insecticides, they are known to retain their toxic and repellent effects for several years (Harris *et al.*, 1981; Cheng, 1984; Su and Scheffrahn, 1990; Sornuwart *et al.*, 1996).

Studies have shown that when a foliar insecticide is applied to control insect pests, more than 99% will miss the target species (Pimentel *et al*, 1980; Pimentel, 1992). The missed proportion will ultimately enter the environment and affect the non-target components of the ecosystem such as the organisms that live on or in the soil.

Consequently, when pyrethroids are applied to control insect pests of cocoa, a large proportion will contaminate the cocoa leaf litter and the soil. Hill (1985) and Inglesfield (1989) concluded that the pyrethroid residues on the soil surface also affect the non-target organisms including the beneficial insects such as natural enemies.

Consumers, especially in developed countries, have voiced concern over the excessive use of pesticides in cocoa production. In order to minimize the use of pesticides both for ecological and commercial reasons, there is a need to develop of an alternative to chemical spraying. This is an incentive for the development of biological control programmes in cocoa.

Beside chemical control, it is believed that biological control can also be used against insect pests of cocoa. Wood and Chung (1992) have recorded several of the biological control agents that can be used in Southeast Asia. However, many of them have been reported to be unsuccessful (Ooi, 1992).

The black cocoa ant, *Dolichoderus thoracicus* (Plate 1) is a promising biological control agent against several pests of cocoa. The ant is reported to be effective in reducing cocoa losses due to *H. theivora* (Khoo and Chung, 1989; Way and Khoo, 1989) and *C. cramerella* (See and Khoo, 1996; Liew *et al.*, 1999). In addition, *D. thoracicus* is also associated with the reduction of losses due to rodent and black pod damage (Khoo and Ho, 1992; Khoo, 1997).

Although *D. thoracicus* has been successfully established on many occasions, attempts to do so in Sabah, Malaysia have not been successful (Khoo, *pers.comm.*). The probable cause has been narrowed down to the frequent and prolonged use of pyrethroids in that state. The residual effect

Plate 1. *Dolichoderus thoracicus* workers on cocoa pod