



UNIVERSITI PUTRA MALAYSIA

***LIFE TABLE, INFESTATION AND INTERACTION OF PAPAYA
MEALYBUG *Paracoccus marginatus* WILLIAMS & GRANARA
DE WILLINK (PSEUDOCOCCIDAE: HEMIPTERA)
AND ITS PARASITIDS***

MUHAMMAD ISHAQUE MASTOI

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By

MUHAMMAD ISHAQUE MASTOI

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfillment of the Requirement for the Degree of Doctor of Philosophy**

December 2014

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DEDICATION

I wish to dedicate this work to my family, parents and friends for their patience and support during my study period at Malaysia.



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Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Doctor of Philosophy

LIFE TABLE, INFESTATION AND INTERACTION OF PAPAYA MEALYBUG *Paracoccus marginatus* WILLIAMS & GRANARA DE WILLINK (PSEUDOCOCCIDAE: HEMIPTERA) AND ITS PARASITOIDS

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December 2014

Chairman: Associate Professor Nur Azura Binti Adam, PhD

Faculty: Agriculture

The papaya mealybug, *Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Pseudococcidae) is a serious pest of papaya. This exotic pest cause a serious problem if, indigenous natural enemies are not available. This pest was never studied in Malaysia although severe infestation of this unidentified mealybug was reported by papaya farmers. This study therefore, was initiated to investigate the life table of papaya mealybug, *Paracoccus marginatus* (Hemiptera: Pseudococcidae), its infestation and interaction with natural enemies. Life table study of *P. marginatus* was initiated on four cohorts, each consisting of 137, 120, 102 and 100 eggs. Age-specific survival life table indicated that 64.27% *P. marginatus* eggs successfully reached to adults with a sex ratio of 1.09:1 (Female: Male). The pattern of survivorship curves (l_x) falls in type III indicating highest mortality in offsprings. The highest mortality was recorded in first instar nymphs (20.09%) with k-value of 0.097. Age-specific fecundity (m_x) of *P. marginatus* showed earliest egg laying on day 25 and continued till death of female. The last female died on day 47. The female laid on average 275.91 ± 8.10 eggs. The maximum (74.90%) eggs laid were during 27th to 33rd day. The intrinsic rate of natural increase (r_m) of *P. marginatus* was 0.12 per female per day and the daily finite rate of increase (λ) was 1.13 female offsprings per female per day with mean generation time (T_c) of 30.72 days. The net reproductive rate (R_0) was 43.36 female offsprings per female. Doubling time was recorded as only 5.65 days. Survey for infestation of *P. marginatus* was done in two states, namely Negeri Sembilan and Selangor, to confirm the pest status in Peninsular Malaysia. A total of ten locations were surveyed for the infestation. All aerial plant parts of the papaya plants including leaves, fruits and stem were observed because pest attacks only aerial plant parts except roots. Results indicate that the pest infestation was observed in both states. This pest was also found infesting seven other host plants (Hibiscus, Cassava, Plumeria, Roselle, Eggplant, Jatropha and Broad beans). During observation, two predators, *Apertochrysa* sp. and *Cryptolaemus montrouzieri* and, one primary parasitoid, *Acerophagus papayae* and three secondary parasitoids viz. *Chartocerus* sp., *Marietta leopardina* and *Cheiloneurus* sp. were found on *P. marginatus*. Out of 7965 mummies of *P.*

marginatus collected, *A. papayae* showed higher (95.22%) population frequency. However, secondary parasitoids remained lower than 5%. The study on weekly population fluctuation of *P. marginatus* and its natural enemies on papaya in five locations within vicinity of Universiti Putra Malaysia showed the highest mean *P. marginatus* population (7.02 per 25 cm² leaf area) in Sri Serdang. The maximum population of *P. marginatus* was found on the basal part of papaya leaf compared to middle and apical leaf parts. The population of *Apertochrysa* sp. on papaya was comparatively higher (0.48 per 25 cm² leaf area) in Ladang-2. The population of *C. montrouzieri* ranged between 0.33 to 0.54 per 25 cm² leaf area. The *A. papayae* population was higher (1.36 to 2.00 per 25 cm² leaf area) at Faculty of Agriculture (old), Ladang-2, Bukit Expo and Sri Serdang. The population of *P. marginatus* remained higher in the month of August, thereafter, declined due to appearance of natural enemies. Similarly, the population of predators (*Apertochrysa* sp. and *C. montrouzieri*) and parasitoid (*A. papayae*) was high during August and declining in the following months. Among the weather parameters, only temperature showed significant effect on the population fluctuation of *P. marginatus*, whereas significant effect of two predators, *C. montrouzieri* and *Apertochrysa* sp. and a parasitoid, *A. papayae* was observed on the *P. marginatus* population. Studies on *A. papayae* was conducted on different host stages of *P. marginatus* viz. second instar male, second instar female, third instar female and adult female in choice and no-choice situations. All the treatments were replicated ten times. The highest percent parasitism was recorded in second instar female (59±5.66%) in no choice situation. However, in choice situation no specific trend of parasitism was found. In choice and no choice situations, the male-biased sex ratio was observed in second instar male *P. marginatus* and the female-biased sex ratios in all female stages of *P. marginatus* with longer developmental time in females. Interestingly, *A. papayae* showed gregarious behavior in adult female *P. marginatus* while solitary in rest of instars in both choice and no choice experiments.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falasafah

**JADUAL HAYAT, SERANGAN DAN INTERAKSI KOYA BUAH BETIK
Paracoccus marginatus Williams & Granara de Willink (PSEUDOCOCCIDAE:
HEMIPTERA) DAN PARASITOIDNYA**

Oleh

MUHAMMAD ISHAQUE MASTOI

Disember 2014

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Fakulti: Pertanian

Koya betik, *Paracoccus marginatus* Williams dan Granara de Willink (Hemiptera: Pseudococcidae) adalah serangga perosak yang amat serius bagi buah betik. Serangga perosak eksotik ini boleh mendatangkan masalah yang serius jika, musuh semula jadinya tiada. Serangga perosak ini tidak pernah dikaji sebelum ini di Malaysia walaupun serangan teruk koya yang tidak dapat dikenalpasti ini telah dilaporkan oleh peladang-peladang betik. Oleh yang demikian, penyelidikan ini telah dijalankan untuk mengkaji jadual hayat koya betik, *Paracoccus marginatus* (Hemiptera: Pseudococcidae), serangannya dan interaksi dengan musuh semula jadi. Kajian jadual hayat *P. marginatus* telah dimulakan dengan empat kohort yang masing-masing terdiri daripada 137, 120, 102 dan 100 biji telur. Jadual hayat kemandirian spesifik umur menunjukkan bahawa 64.27% *P. marginatus* telur berjaya mencapai ke tahap dewasa dengan nisbah jantina 1.09:1 (Betina: Jantan). Corak lengkung kemandirian (l_x) tergolong di dalam jenis ke-III menunjukkan kadar kematian tertinggi tertinggi adalah pada peringkat anak. Kadar kematian tertinggi telah dicatatkan pada peringkat instar nimfa pertama (20.09%) dengan nilai- k 0.097. Fekunditi umur spesifik (m_x) *P. marginatus* menunjukkan telur terawal dihasilkan pada hari ke-25 dan berterusan sehingga kematian individu betina. Individu betina terakhir mati pada hari ke-47. Betina secara puratanya menghasilkan telur sebanyak 275.91 ± 49.3 biji. Kadar tertinggi penghasilan telur (74.9%) adalah pada hari ke-27 hingga hari ke-33. Kadar pertambahan semula jadi intrinsik (r_m) *P. marginatus* adalah sebanyak 0.12 bagi setiap betina setiap hari dan kadar peningkatan harian finit (λ) adalah 1.13 anak betina bagi setiap betina dewasa untuk setiap hari dan masa generasi purata (T_c) ialah 30.72 hari. Kadar pembiakan bersih (R_0) adalah 43.36 anak betina kepada setiap betina dewasa. Masa gandaan dua telah dicatatkan hanya selama 5.65 hari. Tinjauan serangan *P. marginatus* telah dijalankan di dua buah negeri iaitu Negeri Sembilan dan Selangor bagi memastikan status perosak ini di Semenanjung Malaysia. Sebanyak 10 lokasi telah dibuat tinjauan serangan. Semua bahagian aerial pokok betik iaitu daun, buah dan batang telah diperhatikan kerana perosak menyerang hanya pada bahagian aerial sahaja kecuali akar. Hasil menunjukkan serangan terjadi di kedua-dua negeri. Serangga perosak ini juga telah dijumpai telah menyerang tujuh jenis tumbuhan utama yang lain iaitu (Bunga Raya,

Ubi Kayu, Plumeria, Roselle, Terung, Jatropha dan Kacang). Semasa kajian, dua pemangsa, *Apertochrysa* sp. dan *Cryptolaemus montrouzieri*, satu parasitoid primer, *Acerophagus papayae* dan tiga parasitoid sekunder iaitu *Chartocerus* sp., *Marietta leopardina* dan *Cheiloneurus* sp. telah ditemui menyerang *P. marginatus*. Daripada 7965 mumia *P. marginatus* yang dikumpulkan, *A. papayae* mempunyai kadar populasi tertinggi (95.2%). Walau bagaimanapun, populasi parasitoid sekunder kekal rendah di bawah 5%. Kajian ke atas fluktuasi populasi mingguan *P. marginatus* dan musuh semula jadinya pada betik di lima buah lokasi di sekitar kawasan Universiti Putra Malaysia menunjukkan mean populasi *P. marginatus* tertinggi secara bererti (7.02 setiap 25 cm² keluasan daun) di Sri Serdang. Kadar maksimum populasi *P. marginatus* adalah di bahagian basal daun betik berbanding bahagian tengah dan hujung daun. Populasi *Apertochrysa* sp. adalah lebih tinggi (0.48 setiap 25 cm² keluasan daun) di Ladang-2. Populasi *C. montrouzieri* adalah di antara 0.33 ke 0.54 setiap 25 cm² keluasan daun. Populasi *A. papayae* adalah lebih tinggi (1.36 ke 2.00 setiap 25 cm² keluasan daun) di Fakulti Pertanian (lama), Ladang-2, Bukit Ekspo dan Sri Serdang. Populasi *P. marginatus* kekal lebih tinggi di sepanjang bulan Ogos, selepas itu, merosot disebabkan kehadiran musuh-musuh semula jadi. Demikian juga dengan populasi pemangsa-pemangsa (*Apertochrysa* sp. dan *C. montrouzieri*) dan parasitoid (*A. papayae*) tinggi pada bulan Ogos dan menurun pada bulan-bulan berikutnya. Antara parameter cuaca, hanya suhu menunjukkan kesan yang signifikan pada turun naik populasi *P. marginatus*, manakala kesan yang ketara dua pemangsa, *C. montrouzieri* dan *Apertochrysa* sp. dan parasitoid, *A. papayae* diperhatikan ke atas populasi *P. marginatus*. Kajian terhadap *A. papayae* telah dijalankan pada peringkat hayat *P. marginatus* yang berbeza iaitu instar kedua jantan, instar kedua betina, instar ketiga betina dan betina dewasa bagi ujikaji pilihan dan tanpa pilihan dengan sepuluh replikasi. Setiap rawatan mempunyai 10 replikasi. Peratus parasitisma tertinggi telah direkodkan pada instar kedua betina (59±5.66%) dalam ujikaji tanpa pilihan. Walaubagaimanapun ujikaji dengan pilihan, tiada trend parasitisma yang tertentu. Di dalam keadaan yang mempunyai pilihan dan tiada pilihan, kecenderungan nisbah jantan dapat dilihat di dalam instar kedua jantan dan nisbah kecenderungan betina di dalam semua peringkat betina dengan masa perkembangan betina yang lebih lama. *A. papayae* menunjukkan kelakuan gregarius pada peringkat betina dewasa manakala kelakuan solitari pada peringkat instar dalam ujikaji pilihan dan tanpa-pilihan.

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I certify that a Thesis Examination Committee has met on 19 December 2014 to conduct the final examination of Muhammad Ishaque Mastoi on his thesis entitled "Life Table, Infestation and Interaction of Papaya Mealybug *Paracoccus marginatus* Williams & Granara de Willink (Pseudococcidae: Hemiptera) and its Parasitoids " in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Papaya, *Carica papaya* L. is native to tropical America but now it is considered as one of the most important fruit throughout the tropical and subtropical regions of the world. It is rapidly becoming an important fruit internationally, as fresh and processed products (Da Silva *et al.*, 2007). Papaya, known as 'betik' in Malaysia, is a small holder's crop being cultivated on an area of about 2681 hectares with total fruit production of 44,928 metric tonnes in 2011. Malaysia ranked as third major papaya fruit exporting country after Mexico and Belize in 2010. Large amount of Malaysian papaya (57.45%) was exported to international markets with total export value of 9.17 million US\$ (FAOSTAT, 2013).

Papaya production has many constraints; and among them papaya mealybug, *Paracoccus marginatus* is considered as serious horticultural pest when introduced in to new locations without its endemic natural enemies (Miller *et al.*, 2005; Pena *et al.*, 2005). The pest is invasive and polyphagous in nature. First invasion of *P. marginatus* was reported in Asia (Bogor University Indonesia and Tamil Nadu Agricultural University, India) in 2008. Later on, the pest invasion was recorded from many Asian, African and Gulf countries (Muniappan *et al.*, 2009; Muniappan *et al.*, 2008). In Malaysia, the initial infestation of papaya plants with *P. marginatus* was recorded on 10th February 2009 from Universiti Putra Malaysia campus (Personal observation). This pest is native of Mexico and/or Central America and it never caused serious problems in its native region most probably because of the availability of its endemic natural enemies. The most serious outbreaks occur when *P. marginatus* accidentally introduced into new countries without their natural enemies (Muniappan *et al.*, 2012).

Generally, mealybugs are difficult to control chemically due to their thick waxy secretion covering on the body; and their ability to hide in the damaged buds and leaves without being exposed to the insecticide. The adult mealybugs are more difficult to control through repeated applications of chemicals because of too much wax compared to nymphs (Chong, 2005). The indiscriminate use of chemicals develop insecticide resistance as well as non-target effects on natural enemies can make chemical control a less feasible option for the long-term control of *P. marginatus* (Walker *et al.*, 2003). Through unsuccessful chemical measures practiced over many years in several countries, biological control was identified as a preferred alternative to manage *P. marginatus* population. The United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS) initiated a classical biological control program for *P. marginatus* using several natural enemies in 1999. Five solitary endoparasitic wasps, i.e. *Acerophagus papayae*, *Anagyrus loeckii*, *Anagyrus californicus*, *Pseudophycus* sp. and *Pseudleptomastix mexicana* (Hymenoptera: Encyrtidae) were identified parasitizing *P. marginatus* in Mexico. Among them three parasitoids i.e. *A. papayae*, *A. loeckii*

and *P. mexicana* were collected, mass reared in Puerto Rico as potential biological control agents and released in *P. marginatus* infested areas in the Caribbean, the US, Pacific islands, India and Sri Lanka and better results for *P. marginatus* management were noticed (Galanihe *et al.*, 2010; Meyerdirk *et al.*, 2004; Muniappan *et al.*, 2006; Shylesha *et al.*, 2010).

Accidental introduction of *P. marginatus* in Malaysia could pose a serious economic threat to Malaysian agricultural industry as it attack fruits, vegetables and ornamental plants unless certain integrated tactics are implemented. However, an understanding of the biology of the pest is vitally important for the effective control.

1.2 Problem statement

Four major outbreaks of mealybugs causing alarming damage to economically important field, fruit, vegetable and ornamental crops as a result of accidental introductions has been reported. *P. marginatus* is one of them which became a serious pest of papaya when introduced into the Caribbean, the United States and the Pacific islands. Recently it is recorded infesting papaya and many other horticultural plants in Asia including Indonesia, India, Sri Lanka and Malaysia. The pest is polyphagous in nature infesting more than 220 plant species and is difficult to manage with pesticides because the insect body is covered with white waxy secretions. Keeping in view of the economic importance of the pest, it was pertinent to initiate some key studies on status and potential of pest and available natural enemies in new environment. These studies will help the researchers, extension officers and farmers to understand the biology and manage this introduced pest in new locations.

1.3 Objectives of the study

1. To construct life table and demographic parameters of papaya mealybug, *P. marginatus*
2. To explore the infestation of papaya mealybug, *P. marginatus* and its natural enemies
3. To determine population fluctuation of papaya mealybug, *P. marginatus* and its natural enemies
4. To determine parasitism, sex ratio, developmental time and gregarious behaviour of *Acerophagus papayae* on *P. marginatus*

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