TAXONOMY AND BIOLOGY OF WHITEFLY (*Aleurodicus dispersus*) INFESTING GUAVA PLANT

WONG YEE TING

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IJAZAH: BACHELOR OF AGRICULTURAL SCIENCE WITH HONOURS (CROP PRODUCTION)

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1. Dr. Suzan Benedick
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ABSTRACT

A field experiment was conducted in guava farm at Faculty of Sustainable Agriculture, Sandakan, Sabah to study the taxonomy and biology of whitefly infesting guava plant in the guava farm. The objectives of the study were to identify and to construct dichotomous keys of whitefly species, to investigate the biology and behavior of whitefly on guava plant, and to identify possible indigenous natural enemy of whitefly that will be useful for biological control. This study was conducted for three months from September to November 2015. The whitefly was collected by using leaf sampling. All stages of whitefly life cycle from eggs, pupae and adults were sampled and identified by examining live specimens by using stereomicroscope and electronic compound microscope. The slide-mounted pupae were prepared by using temporary slide preparation method. Only one species of whitefly, *Aleurodicus dispersus* Rusell was found in the studied area. The most important *A. dispersus* identification characteristics includes egg deposition pattern, presence of compound pores on pupa, presence of claw at each thoracic legs, length of lingula at vasiform orifice, presence of two pairs of setae at apex, form of wax secretion, adult wing structure, pupae and adults eyes structure, body structure at pupae and adults stage. The mean life cycle of *A. dispersus* (from eggs stage to pupae stage) was 37.07 days. The mean duration of the eggs stage, first instar stage, second instar stage, third instar stage and pupae were 7.63 ± 0.38 days, 6.53 ± 1.22 days, 6.43 ± 1.63 days, 6.8 ± 2.86 days, and 9.67 ± 4.37 days respectively. *Eretmocerus mundus* was found to be a potential beneficial parasitoid in controlling infestation of *A. dispersus.*

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TAKSONOMI DAN BIOLOGI LALAT PUTIH (*Aleurodicus dispersus*) YANG MENYERANG POKOK JAMBU BATU

ABSTRAK

Eksperimen lapangan telah dijalankan di ladang jambu batu di Fakulti Pertanian Lestari, Sandakan, Sabah untuk mengkaji taksonomi dan biologi lalat putih yang menyerang pokok jambu batu di ladang jambu. Objektif kajian ini adalah untuk mengenalpasti dan membina kekunci dikotomi spesies lalat putih, untuk menyiasat biologi dan tingkah laku lalat putih terhadap pokok jambu batu, dan untuk mengenal pasti musuh semula jadi asli lalat putih berpotensi yang boleh digunakan untuk kawalan biologi. Kajian ini telah dijalankan selama tiga bulan dari September hingga November 2015. Lalat putih ini telah dikumpulkan dengan menggunakan pensampelan daun. Semua peringkat kitaran hidup lalat putih dari telur, pupa dan dewasa telah disampel dan dikenalpasti dengan memeriksa spesimen hidup menggunakan stereomikroskop dan mikroskop elektronik. Slaid yang dipasang pupa telah disediakan dengan menggunakan kaedah penyediaan slaid sementara. Hanya satu spesies lalat putih, *Aleurodicus dispersus* Rusell ditemui di kawasan yang dikaji. Ciri-ciri pengenalan *A. dispersus* yang paling penting termasuklah corak pemendapan telur, kehadiran liang kompaun pada pupa, kehadiran cakar pada setiap kaki toraks, panjang lingula di vasiform orifis, kehadiran dua pasang setae di puncak, bentuk rembesan lilin, struktur sayap dewasa , struktur mata peringkat pupa dan dewasa, struktur badan peringkat pupa dan dewasa. Purata kitaran hidup *A. dispersus* (dari peringkat telur ke peringkat pupae) adalah 37.07 hari. Purata tempoh peringkat telur, peringkat instar pertama, peringkat instar kedua, peringkat instar ketiga dan pupae adalah masing-masing pada 7.63±0.38 hari, 6.53±1.22 hari, 6.43±1.63 hari, 6.8±2.86 hari, dan 9.67±4.37 hari. *Eretmocerus Mundus* didapati sebagai parasitoid berfaedah berpotensi untuk mengawal serangan *A. dispersus*.

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LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

%	Percentage
°C	Degree celcius
cm	Centimetre
EPPO	European and Mediterranean Plant Protection Organization
FAO	Food and Agriculture Organization of the United Nations
FSA	Faculty of Sustainable Agriculture
ha	Hectare
IUCN	International Union for Conservation of Nature
ISSG	Invasive Species Specialist Group
kg	Kilogram
MOA	Ministry of Agriculture
RM	Ringgit Malaysia

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CHAPTER 1

INTRODUCTION

1.1 Background

The whitefly (Hemiptera: Aleyrodidae) has long been known as potentially detrimental pest in agricultural crops and ornamental plant industry in many parts of the world. Whitefly which belongs to family Aleyrodidae has been recorded to infest a wide range of crops in the Philippines in 2000, Indonesia in 1981, El Salvador in 1961, Mexico in 1962, Brazil in 1968, Turkey in 1974, Israel in 1976, Thailand in 1978, Arizona in 1981 and California in 1986 (Mohd. Rasdi, 2005). The economic damages brought by whitefly are direct feeding damage on plant sap, indirect damage by forming honeydew to support sooty mold growth on plant leaf and being a vector of over 100 plant viruses in the genera Begomovirus (Geminiviridae), Crinivirus (Closteroviridae) and Carlavirus or Ipomovirus (Potyviridae) (Brown and Nelson, 1986; Duffus, 1996; McAuslane, 2009; Jones, 2003). Mosaic, leaf curl, and yellowing types are whitefly-transmitted diseases which are recognized on symptoms of New World begomoviruses, Old World begomoviruses, and Criniviruses, respectively (Suresh *et al.*, 2013). Hence, it is important to understand the ecology of whitefly as understanding the ecology of whitefly *Bemisia tabaci* is the key to understand its role in the epidemiology of the plant viruses it transmits thus essential for study (Legg, 1994).

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The distribution of the whitefly has spread to over 500 plant species from Asia, Africa, America, Europe, Russia, Australia and Pacific Islands confirming its polyphagous nature (Greathead, 1986). For example, a wide range of crops was attacked by this pest in the Philippines such as Cucurbitaceae [cucumber (*Cucumis sativus* L.), melon (*Cucumis melo* L.), and squash (*Cucurbita muschata* Duch)], Leguminosae (mungbean and string beans), Caricaceae [papaya (*Carica papaya* L.)], Musaceae [banana (*Musa* spp.)], Solanaceae [brinjal (*Solanum melongena*), chilli (*Capsicum annuum*), tomato (*Lycopersicon esculentum*)], Euphorbiaceae (*Euphorbia pulcherrima*, an ornamentals), and fruit trees such as guava (*Psidium guajava*) (Nicolas, 2000). The origin of whitefly has not been confirmed but possibly native to India or the Middle East and was transmitted through imported ornamentals (Brown *et al.*, 1995; Perring, 2001).

As a consequence, sweet potato whitefly, *B. tabaci*, is included in a list of 100 of the "worst" invasive species in the Global Invasive Species Database managed by the IUCN Invasive Species Specialist Group (ISSG). *B. tabaci* is declared in EPPO Plant Quarantine Act 1997 Section 10 to be List A pests (Appendix A1 and A3). *B. tabaci* has been reported from all continents except Antarctica with over 900 host plants and transmission of 111 plant virus species (ISSG, 2005). In Malaysia, the whiteflies complex that include the sweet potato whitefly (*B. tabaci*) commonly found in the lowlands, the greenhouse whitefly (*Trialeurodes vaporariorum*) commonly found in the highlands and the spiraling whitefly (*Aleurodicus dispersus*) commonly found on ornamentals and fruit crops, are listed as invasive alien species (Yahaya and Sivapragasam, n.d.). In Malaysia, the entry and spread of alien invasive species are prohibited and monitored by the Department of Agriculture under the Malaysian Plant Quarantine Act 1976 (Appendix A1) and the Plant Quarantine Regulation 1981. However, there is very little does known on whitefly quarantine status in Sabah therefore understand its ecology and behaviour may provide useful baseline data for such purposes.

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In Malaysia, not many information on whitefly has been published and more study on this pest is needed. This study is focused on guava as this crop is recently being seriously attacked by whiteflies and diseases vectored by them. Guava (*P. guajava*) is one of the host plant of whitefly *A. dispersus* as its host range increases day by day in distribution to other part of the world (Banjo *et al.*, 2003). A loss of 80 % in fruit yield has been recorded in guava attacked by the pest in four continuous months in Taiwan (Wen *et al.*, 1995). Besides, guava in Malaysia is generally cultivated for local market and export business to Singapore and Brunei Darussalam. Therefore, the spread of whitefly this invasive species should be strictly prohibited under Plant Quarantine Regulation 1981 with strong understanding on the ecology of whitefly.

1.2 Justification

The research was carried out to identify whitefly species on guava planted in a guava farm at Faculty of Sustainable Agriculture, Sandakan, Sabah and construct dichotomous keys on the identified whitefly species. Until now, there is lack of study done on biological aspects and behaviour of whitefly on guava. Hence, the research was conducted to study the biological aspects and behavior of whitefly on guava which will support the pest management and crop improvement strategies in future. It would hopefully provide baseline information to growers, researchers, and students and could be used as reference for further research. In addition, this would also provide an avenue for collaboration with the Department of Agriculture (DOA) and other research institutions to initiate better understanding on whitefly ecology and systematics.

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1.3 Objectives

Objectives of the research are:

1. To identify whitefly species on guava and construct dichotomous keys by life stages of the identified species.
2. To investigate the biology and behavior of whitefly on guava.
3. To identify possible indigenous natural enemy of whitefly that will be useful for biological control.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Guava

Guava, *Psidium guajava* L. (family Myrtaceae) is originated from area between Peru and Mexico. Its domestication spread to tropical and sub-tropical countries. Guava farming had been commercialized in Malaysia in the mid-80s. Perak, Johor and Melaka were the main production areas that had been producing fresh guava. The average production of guava for seeded guava variety and seedless guava variety was 17,664 kg/ha and 15,970 kg/ha respectively with the average profit per year of RM 7,109 and RM 10,568.

The hectareage of guava farming in 2006 was 1,992 ha with average yield 16.8 t/ha and production value was about RM 33.6 million (Anon, 2006). From 1993 until 2000, there was high guava production in Johor (Engku Elini and Raziah, 2008). However, its production decreased by over 50 % in 2000 as compared to 1993. After 2000, Perak has become the highest guava producing area in Peninsular Malaysia. In Malaysia, guava is generally cultivated for local market and export business. The main importers of fresh guava and dried guava from Malaysia are Singapore and Brunei Darussalam. Statistics showed that Singapore was the main importer of guava from Malaysia with import value of RM2.5 million in 2006, comprising 90% of total export of guava.Guava grows well in tropical climate with annual temperature 27-30 °C and annual rain fall 2000 mm. The fruiting season of guava in Malaysia is all around the year. However, there are two main fruiting season which is after drought season (January-March and June-July).

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2.2 Distribution of Whitefly

Whiteflies (Hemiptera: Aleyrodidae), have long been recognized as a vital group of agricultural insect pests that has polyphagous nature and cause economic damage to more than 600 plant species with 500 plant species from Asia, Africa, America, Europe, Russia, Australia and the Pacific Islands (Greathead, 1986; Khalid *et al.*, 2013). However, only a few species are of economic importance among family Aleyrodidae (Bogran and Heinz, 2012).

Since first record as cotton pest in Greece from 1889, whitefly *B. tabaci* (Gennadius) has been reported as major cotton pest in cotton producing western countries such as Middle East, Europe, North and Central America (Mound and Halsey, 1978; Lopez-Avilla, 1986; McKenzie *et al.*, 1986; Annonymous, 1989; Cock, 1993). In addition, *B. tabaci* has also been reported as a serious tobacco pest of tobacco crops in tropical and subtropical areas including Africa, Asia, Central America, South America, and the West Indies (Mau and Kessing, 2007).

All whitefly species are phytophagous and some transmit viruses to infest plant species previously unaffected by whitefly-transmitted viruses (Byrne *et al.*, 1990). Whitefly-transmitted viruses have also been recorded in the United States in the late 1800's (McAuslane, 1995). Before 1986, whitefly was only as occasional pest of cultivated crops. However, according to McAuslane (1995), in 1986, whitefly became extreme economic pest in Florida with expansion of new uninfected host plant and by 1991 had spread throughout the United States where it caused economic loss of 500 million USD. The whiteflies are now globally distributed and found on all continents except Antartica (Oliveira *et al.*, 2000). Cereals were the only major food crops that had remained free from whitefly pests in Central America, however, a new whitefly species, *Aleurocybotus occiduus* was found to become serious pest in rice and sorghum fields in N.W. El Salvador and maize in the Americas (Tropical Whitefly IPM Project, 2004).

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In Malaysia, two species of whiteflies were recently found in vegetables which were sweet potato whitefly, *B. tabaci* (Gennadius) in the lowlands and greenhouse whitefly, *T. vaporariorum* (Westwood) in the highlands. The reason for the infestation of this invasive species was probably through importation of ornamentals planting materials from Europe (Syed *et al.*, 2000). According to EPPO Global Database (2014) (Appendix A2), the spiraling whitefly, *A. dispersus* (Rusell) is endemic and have widespread distribution on several ornamental and fruit crops in Malaysia. The places that have been infested by whitefly are shown in Figure 2.1 and 2.2.

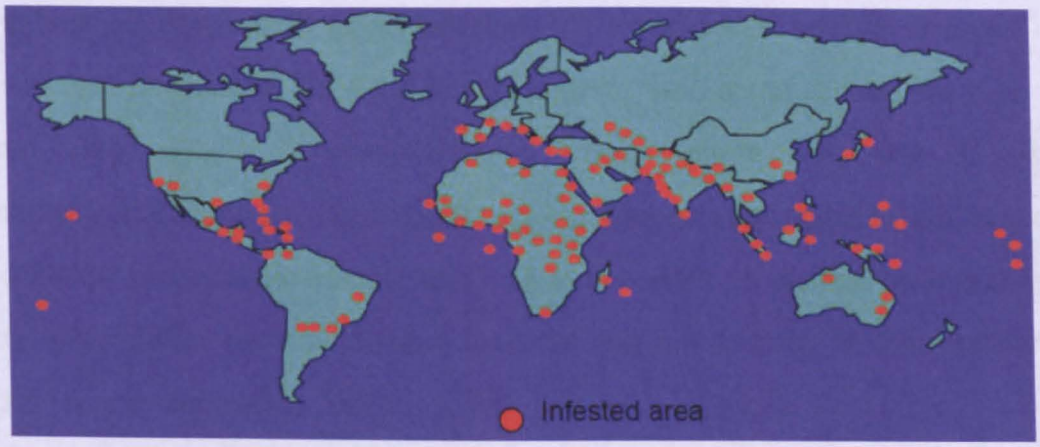

Figure 2.1 The worldwide areas infested by whitefly
Source: http://www.tropicalwhiteflyipmproject.cgiar.org/wf/project.structure

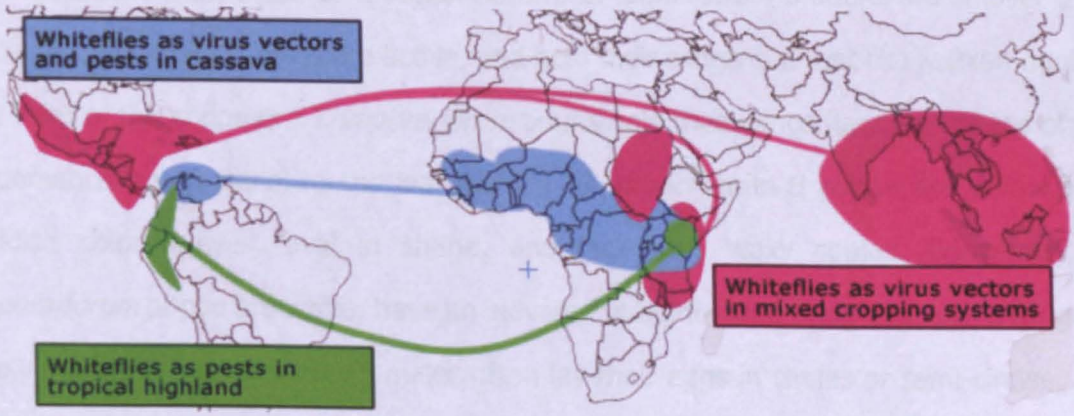

Figure 2.2 Whiteflies as pests in tropical highlands
Source: http://www.tropicalwhiteflyipmproject.cgiar.org/wf/project.structure

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2.3 Taxonomy of Whitefly

Whitefly belongs to the family Aleyrodidae of the order Hemiptera. The family Aleyrodidae is composed of tiny insects which obtained the common name "whiteflies" because the wings and bodies of the adults are covered with a fine, powdery or flour like white wax (Hodges and Evans, 2005). Most of whitefly taxonomy is based on pupae characters, but exceptions do exist (Hodges and Evans, 2005). Genera and species are commonly separated according to the structure of the fourth nymphal instar, so-called "pupal case" (Mound and Halsey, 1978). The whitefly adult can be differentiated based on the position in which its wings are held over the body. Tent-like position which is close to the body is shown in *B. tabaci* whereas, the more loosely position is found in *T. vaporariorum* (McAuslane, 1995). Apart from white wax, some species are dark with colored wing patterns. All developmental stages secrete wax, and in nymphs (immatures), the appearance of accumulated wax filaments and plates is used in species identification (Bogran and Heinz, 2012). It is important to distinguish the different species of whiteflies because damage potential and susceptibility to control differs by species (Bogran and Heinz, 2012).

Adults and pupae of *B. tabaci* strain B (*Bemisia argentifolii*) are readily distinguishable from those of *T. vaporariorum*. *B. tabaci* strain B adults are smaller than adult *T. vaporariorum*, are more active, and hold their wings in a tent like fashion against the sides of the abdomen. *T. vaporariorum* adults hold their wings flat over the top of the abdomen almost parallel to the leaf surface. *B. tabaci* strain B pupae are yellow with reddish colored eyes, oval in shape, and lack long waxy spines. Conversely, *T. vaporariorum* pupae are white, have an elevated straight-sided body wall with a fringe of waxy spines. *T. vaporariorum* females often lay their eggs in circles or semi-circles, and as the eggs mature they turn from white to dark purple in color. *B. tabaci* strain B females lay their eggs haphazardly over the underside of the leaf (occasionally females will lay eggs in circles). As eggs mature they turn from white to amber.

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2.4 Common Species of Whitefly in the World

Four worldwide common species of whitefly are mainly greenhouse whitefly (*T. vaporariorum*), silverleaf whitefly (*B. argentifolii*), sweet potato whitefly (*B. tabaci*), and bandedwinged whitefly (*Trialeurodes abutilonea*). Three species of whitefly are commonly found in Malaysia. They are spiralling whitefly (*A. dispersus*), sweet potato whitefly (*B. tabaci*), and greenhouse whitefly (*T. vaporariorum*) (Syed Abdul Rahman *et al.*, 2000).

2.4.1 Sweet Potato Whitefly

Sweet Potato Whitefly (*B. tabaci*) is also known as the tobacco, cotton, and sweet potato whitefly. This species is commonly known worldwide as sweet potato whitefly. It feeds on the leaves of sweet potato plants producing the characteristics of silvering symptoms. It is a notifiable pest and is an effective vector of over 60 viruses from several groups particularly geminiviruses (McAuslane, 1995). The adult of this species is small with about 0.9 to 1.2 mm in length. The size of an egg is 0.2 mm, which darkens at the apex just before hatching. The first instar or crawler stage (0.2 - 0.3 mm) settles down on the undersides of leaves. The last instar is often referred to as a pupa with its size ranging from 0.7 to 0.8 mm and having distinct eye spots. The duration of life cycle from egg to adult is about 18 days under warm temperatures, but may take as long as two months under cool conditions (Drees, 2000).

2.4.2 Silverleaf Whitefly

Sliverleaf whitefly (*B. argentifolii*) is a new strain of *B. tabaci* that spreads in most parts of the world. Its common name is the silverleaf whitefly, because of its unique ability to induced silverleaf disorder in squash. Bellows *et al.* (1994) described this strain as a new species, *B. argentifolii* which is morphological similar to *B. tabaci*. Adults are 0.8-1.2 mm

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long with white wings (without markings) and pale yellow bodies. The wings are held in a rooflike position (about a 45-degree angle) over their bodies, whereas other whiteflies typically hold the wings nearly flat when at rest. As a result, the silverleaf whitefly appears more slender than other common whiteflies. Eggs are oblong, smooth and yellow to amber brown and are laid randomly on the underside of leaves. Nymphs are greenish-yellow, oval and flat. Late third and fourth instars develop distinctive eye spots and are often referred to as red-eyed nymphs. Silverleaf whitefly pupae are oval, flattened (with tapering sides) and lack the marginal fringe of wax filaments common to other whiteflies. Their hosts include more than 500 species representing 74 plant families.

Morphological evidence indicates that there are distinct differences in fourth instar (pupal cases) thoracic tracheal fold widths between silverleaf whitefly and sweetpotato whitefly (Bellows *et al.*, 1994). The silverleaf whitefly has tracheal folds that are half the width of sweetpotato whitefly tracheal folds (14 to 29 micrometers). Another morphological difference is the absence of submarginal seta ASMS4 in silverleaf whitefly pupal cases. Submarginal seta ASMS4 is present on sweetpotato whitefly pupal cases. This morphological evidence supports the idea that the silverleaf whitefly and the sweetpotato whitefly are different species.

2.4.3 Greenhouse Whitefly

Greenhouse whitefly is an occasional pest, especially in greenhouses (Bogran and Heinz, 2012). According to Bogran and Heinz, adults are about the same size as the silverleaf whitefly (0.9-1.1 mm). Bogran and Heinz stated that the wings of greenhouse whitefly are held nearly parallel to the leaf and cover the abdomen when at rest. Bogran and Heinz also stated that eggs of greenhouse whitefly are occasionally laid in circular patterns on plants with smooth leaves. Eggs are oblong, smooth and are initially yellow but darken before hatching. According to Bogran and Heinz, pupae are oval, slightly

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raised (with vertical sides) and have a fringe of wax filaments along the perimeter of their upper surface. Relatively large wax filaments project from their bodies; the number and length of these filaments varies with the host plant. Their hosts include more than 200 plant species (Bogran and Heinz, 2012).

2.4.4 Spiralling Whitefly

Aleurodicus dispersus (Russel, 1965) otherwise known as spiralling whitefly is a small (1 - 2 mm long) insect as other whiteflies (Avidov and Harpaz, 1969) with a characteristic spiralling pattern of oviposition on the underside of leaves (Russel,1965). Spiralling whitefly is a polyphagous whitefly species of tropical or neotropical origin (Russell, 1965; Martin, 1987). Spiralling whitefly (*A. dispersus*) is a major pest devouring agricultural crops as it spreads with extraordinary speed across the tropics. Altogether, A. dispersus has been reported on more than 27 plant families, 38 genera with over 100 species including citrus and ornamental plants (Russell, 1965; Cherry, 1980). Spiralling whiteflies are small insect which feed on plants by sucking plant juices from the phloem through a slender stylet as other whiteflies do (Muniyappa, 1980). The pest has six life stages on all host plants (Banjo and Banjo, 2003) which are the egg, first, second and third nymphal stages, the fourth nymphal stage also known as the pupa and the adult. These natural enemies include *Nephaspis amnicola* Wingo (Coccinellidae) and *Encarsia haitiensis* Dozier (Aphinilidae) (*Khoo et al.*, 1991).

2.4.5 Other Whitefly Species

The citrus blackfly is a sporadic pest of ornamental plants and a potentially serious pest of citrus, especially in South Texas (Bogran and Heinz, 2012). Both nymphs and adults are easily distinguished from other whitefly species by their dark color (Bogran and Heinz, 2012). According to Bogran and Heinz, adult citrus blackflies are 1.3-1.6 mm long with slate-blue wings and red abdomens. Bogran and Heinz stated that citrus whiteflies are

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an occasional pest of citrus in southern Texas but may also attack ornamental plants and trees such as Boston ivy, chinaberry, laurel cherry, crepe myrtle, English ivy, gardenia, green ash, jasmine, osage orange, prickly ash, trumpet vine, water oak, persimmon and wild olive.

Giant whitefly adults are about three times larger than other common whiteflies (Bogran and Heinz, 2012). Wings overlap when at rest and are mottled with grey markings. According to Bogran and Heinz, common hosts of giant whitefly include bamboo, begonia, bird of paradise, citrus, geranium, hibiscus, ivy, jasmine, morning glory, lantana, passion flower, philodendron and pittosporium.

2.5 Biology of Whitefly

Whiteflies are small insects (1 to 3 mm) (Bogran and Heinz, 2012). Adults have four broad wings of approximately the same size (Bogran and Heinz, 2012). The adult is the most mobile stage and is responsible for colonizing the host plant. Adult whiteflies have the ability to both walk and fly, and females lay eggs either singly in a haphazard manner or in spirals or circles on the undersides of leaves (Hoddle, 2013). The eggs with smooth or sculptured (honeycombed) surface almost invariably are attached to the underside of leaves by means of a short or long stalk (Hodges and Evans, 2005). The eggs hatch into mobile first instars called crawlers, which search and find a suitable feeding site (Bogran and Heinz, 2012). They then insert their mouthparts and remain in one place for the rest of their immature stages (Bogran and Heinz, 2012).

Most whitefly species are arrhenotokous, and females are produced from fertilized eggs (Hoddle, 2013). Hoddel stated that males are haploid and eclose from unfertilized eggs. According to Hoddle, the ratio of male and female whiteflies in a population changes over time and is affected by both temperature and male longevity. Males tend to live for shorter periods and populations appear female biased as a result.

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